Annex D

Monitoring Plans for the Lake Okeechobee Watershed Restoration Project

Adaptive Management and Monitoring Plan

Water Quality Monitoring Plan

Hydrometeorological Monitoring Plan

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Table of Contents

D MONITORING PLANS D-1
PART 1: ADAPTIVE MANAGEMENT AND MONITORING PLAN D-3
D.1 Introduction to the LOWRP Adaptive Management and Monitoring Plan D-5
D.1.1 Structure of the LOWRP AMMP D-6
D.1.2 LOWRP Adaptive Management Plan Background D-6
D.1.3 How the LOWRP Adaptive Management and Monitoring Plan was Developed: Identification, Screening, and Prioritization of LOWRP Uncertainties D-9
D.1.4 LOWRP Adaptive Management Uncertainties, Strategies, and Management Options D-12
D.1.5 LOWRP Monitoring Plan D-49
D.1.6 Implementation of LOWRP Adaptive Management D-61
D.1.7 LOWRP Adaptive Management Plan Cost Estimate D-67
D.1.8 LOWRP Screened Uncertainties D-74
D.1.9 Adaptive Management Plan References D-79
PART 2: WATER QUALITY MONITORING PLAN D-83
D.2 Introduction to the LOWRP Water Quality Monitoring Plan D-85
D.2.1 Project Description D-85
D.2.2 Water Quality Monitoring Objectives D-86
D.2.3 Surface Water and Groundwater Quality Monitoring D-87
PART 3: HYDROMETEOROLOGICAL MONITORING PLAN D-91
D.3 Hydrometeorological Monitoring D-93
D.3.1 Data Quality Objectives D-93
D.3.2 Rationale for Indicator Selection D-96
D.3.3 Sampling Frequency and Duration D-96
D.3.4 Assessment Process and Decision Criteria (Triggers and Thresholds) D-96
D.3.5 Documentation D-98
D.3.6 Quality Assurance and Quality Control D-99
D.3.7 Data Analyses and Records Management D-99
D.3.8 Adaptive Management Considerations D-99

List of Tables

Table D-1. LOWRP AM strategies: template and definitions. D-7
Table D-2. Lake stage management option matrix. D-18
Table D-3. ASR recovery efficiency management option matrix. D-21
Table D-4. Estuaries oyster and SAV management option matrix. D-27
Table D-5. Estuaries substrate management option matrix. D-30
Table D-6. ASR – methyl mercury (MeHg) management option matrix. D-33
Table D-7. ASR fish entrainment management option matrix. D-37
Table D-8. Invasive species management option matrix. D-41
Table D-9. Wetland vegetation management option matrix. D-45
Table D-10. Water supply management option matrix. D-48
Table D-11. LOWRP AM monitoring cross-walked with other monitoring programs. D-51
Table D-12. LOWRP project-specific monitoring cross-walked with other monitoring programs. D-57
Table D-13. Adaptive management and monitoring cost estimate. D-69
Table D-14. Total cost estimate for AM, project-level, water quality, hydrometeorological, Biological Opinion, and regulatory monitoring. D-74
Table D-15. Uncertainties screened from the AM Plan. D-75
Table D-16. Monitoring gages at existing structures in the LOWRP. D-94
Table D-17. LOWRP minimal gaging needs. D-94

List of Figures

Figure D-1. Adaptive management strategies and project implementation diagram. D-63
Figure D-2. LOWRP footprint map. D-86
Figure D-3. ASR well locations. D-88
Figure D-4. WAF with proposed structures. D-95

D MONITORING PLANS

This annex contains 3 monitoring plans:

1. Adaptive Management and Monitoring Plan
2. Water Quality Monitoring Plan
3. Hydro meteorological Monitoring Plan

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PART 1: ADAPTIVE MANAGEMENT AND MONITORING PLAN

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D.1 Introduction to the LOWRP Adaptive Management and Monitoring Plan

The primary objective of the LOWRP Adaptive Management and Monitoring Plan (AMMP) is to identify the monitoring necessary to inform decision-makers, LOWRP partner agencies, and the public on achieving restoration success, as well as address uncertainties related to project performance that can be addressed with efficiently structured approaches. The AMMP follows the CERP Guidance Memorandum 56 on the Integration of Adaptive Management into Program and Project Management. The monitoring plan specifies what monitoring is necessary to measure and detect the benefits of capturing, storing, and redistributing water entering the north part of Lake Okeechobee to improve lake stage levels for both environmental restoration and water supply purposes; improving discharges to the Caloosahatchee and St. Lucie estuaries; restoring wetland habitats; and reestablishing connections among natural areas that have become spatially and/or hydrologically fragmented. This monitoring will be leveraged as much as possible to contribute to LOWRP AM. LOWRP's planning process and TSP were based on extensive existing scientific knowledge of Lake Okeechobee, the Lake Okeechobee watershed, and the St. Lucie and Caloosahatchee estuaries; understanding of the problems and opportunities; and the evaluation of alternatives and estimation of the potential project restoration performance. While the LOWRP PIR is based on a wealth of knowledge, the AM plan is provided to help address uncertainty that exists as in every natural resource management and restoration effort.

While the ecological monitoring focuses on LOWRP's success at meeting project objectives (per WRDA 2007 guidance), the AM monitoring focuses on addressing project uncertainties (per WRDA 2007 Section 2039 guidance; USACE 2009) that may be more specific in their location and/or scale than the overall project objectives. Because most of the ecological monitoring helps address project uncertainties as well as document project success, the ecological monitoring plan and AM plan have been combined in this document. The AM monitoring focuses on addressing project uncertainties that might not already be covered by the ecological monitoring. The AMMP will monitor ecosystem responses to changes in lake stage, created wetlands, and discharges into the estuaries that are expected to provide ecological conditions suitable for expanded and intensified plant and wildlife utilization through improvements. Monitoring described in the plan will address specific AM questions to determine the need for project adjustments that would improve ecosystem restoration performance. The AMMP will also contain the monitoring and associated costs required under the U.S. Fish and Wildlife Service's Biological Opinion (BO) and other agency permits that are needed to protect and conserve natural resources. The Biological Opinion and associated monitoring information for LOWRP will be found in **Annex A**, Fish and Wildlife Coordination Act and Endangered Species Act Compliance. Cost estimates for monitoring associated with the BO, including a project-wide contingency cost, will be included in **Section 6** and **Annex D** of the final PIR/EIS.

The AMMP will be closely coordinated with the CERP RECOVER Monitoring and Assessment Plan (MAP) to ensure that measures and targets selected by the project team are consistent with system-wide measures and leverage existing monitoring to avoid duplication of efforts. Furthermore, the AMMP will ensure temporal and spatial coverage of monitoring parameters that are appropriate to detect changes at the project level. The AMMP will fill gaps in the MAP monitoring parameters to address LOWRP-specific

needs by adding additional project-level parameters not included in the MAP. Thus, the LOWRP AMMP will cover LOWRP regions within Lake Okeechobee and the northern estuaries with greater spatial and temporal resolution to detect ecological changes resulting from project-level implementation in order to evaluate project success.

D.1.1 Structure of the LOWRP AMMP

The LOWRP AMMP is organized by project objective. For each LOWRP project objective, monitoring parameters have been identified to measure progress toward success of meeting the objective. Uncertainties for each objective were identified through a robust process described below in **Section D.3**. The AMMP provides a screened and prioritized summary of specific uncertainties that can be addressed with efficiently structured approaches. The AMMP describes the approaches (called strategies) and suggests management options to adjust project implementation for future consideration if needed. The AM plan is a culmination of input from well-developed USACE planning procedures, extensive scientific and local knowledge developed over decades of experience, and input from the LOWRP PDT during planning and the LOWRP Value Engineering and Cost Risk Analysis workshop. **Table D-1** summarizes the (1) AM uncertainties, (2) monitoring attributes, (3) monitoring methodology and frequency, (4) monitoring cost estimates, (5) LOWRP monitoring locations, (6) Current MAP monitoring component, (7) Current monitoring by other agencies/universities and (8) Performance Measures and ecological indicators. The AMMP's main goal is to detect the expected improvements from LOWRP features and operations as well as specify strategies, timing, and appropriate monitoring to address LOWRP uncertainties.

D.1.2 LOWRP Adaptive Management Plan Background

LOWRP's planning and tentatively selected plan were based extensively on scientific knowledge of the Everglades ecosystem, Lake Okeechobee, and associated estuaries from understanding the problems and opportunities to evaluating alternatives and estimating potential project restoration performance (Davis and Ogden 1994; Department of Defense 2003; RECOVER 2004; Ogden 2005; RECOVER 2009; McVoy, et al. 2011; and RECOVER 2011a; LOWRP PIR Appendix H) and USACE and CERP guidance. However, uncertainty exists in every natural resource management and restoration effort due to the fact that many processes in the ecosystem are not linear; they work synergistically together; and they will unfold in a future climate that is likely different than the one used to formulate the LOWRP plan. The LOWRP Adaptive Management Plan will address the key uncertainties identified during LOWRP's planning that relate to achieving restoration success and making adjustments in LOWRP if determined to be necessary to improve performance.

Table D-1. LOWRP AM strategies: template and definitions.

LOWRP AM Uncertainty and ID#. *The uncertainty is a question faced during planning or implementation regarding the best restoration actions to achieve desired goals and objectives within constraints, which cannot be fully answered with available data or modeling. Uncertainties were screened and prioritized to determine which to include in the AM Plan.*

LOWRP Objective or Constraint: *Uncertainties needed to be related to LOWRP objectives or constraints, among other criteria, to be included in the AM Plan. This rule helped to focus the scope of the AM Plan.*
Region(s). *Area of LOWRP footprint to which the uncertainty and strategy pertain.*
Associated LOWRP features: *Structures or measures to which the uncertainty and strategy pertain.*
Driver or uncertainty type: *Unlike most AM Plans, not all LOWRP AM uncertainties and strategies are ecological. Types such as Engineering and Operations are identified.*

What is expected to be learned by addressing this uncertainty, i.e., how will LOWRP benefit from addressing this uncertainty? *Why the uncertainty needs to be addressed in LOWRP.*

Expectations or hypotheses to be tested to address the uncertainty, and attribute(s) that will be measured to test each. *A scientific approach begins with a well-informed, pointed, detailed statement that will be tested. For the purposes of LOWRP's AM Plan the statement can be referred to as an expectation or hypothesis. Approaching uncertainties scientifically is efficient because it is targeted; a properly identified hypothesis statement is the most important step to lead to effective, efficient methodology to address an uncertainty. It leads to proper identification of what to measure, how, how often, how to analyze, etc.*

More Information on attributes to be measured:

- **What is expected to be learned by measuring this attribute, i.e., *how will LOWRP benefit from knowledge gained about this attribute?***
- **What is the time frame in which changes to this attribute are expected to be measurable?**
- **Is this attribute complemented by other monitoring programs within and/or outside of LOWRP? If so, provide reference to other monitoring. Note the monitoring paid for by others in the LOWRP AM budget spreadsheet.**
- **When during LOWRP's life cycle should this monitoring begin and end?**

Methodology for testing each expectation or hypothesis (including frequency of monitoring) and for reporting: *More information on what to measure, how, how often, how to analyze, and when and how to report results. PLEASE NOTE: the LOWRP AM Plan varies in the level of methodology detail provided; in several cases the details will be formed during LOWRP's detailed design phase. In ALL cases, methodology will be reviewed, updated and adjusted if needed by agency subject experts, before initiation, to best meet the intent of the AM Plan.*

Triggers/thresholds that indicate good LOWRP performance or need for adaptive management action. *Triggers or thresholds are a point, range, or limit that signifies when restoration performance is veering away from expectations and is trending toward an unintended outcome. Triggers/thresholds should be described per attribute to be monitored because each should result in an outcome that informs management decisions.*

Management options that may be chosen based on test results. *Management Options are provided in case a performance trigger or threshold is crossed, which would indicate that LOWRP performance needs to be adjusted. The Management Options are suggested paths forward and adjustments that can be made to keep LOWRP progressing toward objectives and within constraints. The Management Options are summarized in 11x17 pull-out tables after each region's strategies.*

Congress understood that there were uncertainties in the Comprehensive Everglades Restoration Plan and therefore required CERP to include AM for its individual projects (WRDA 2000). The 2003 programmatic regulations (Pro Regs) outlined an AM program that would provide the tools needed to gather new information from the RECOVER monitoring and assessment plan (MAP- RECOVER 2009) and incorporate new information so that CERP could be adjusted to ensure restoration success. The National Research Council's Committee on the Independent Scientific Review of Everglades Restoration Progress (CISRERP) endorsed the CERP AM program (NRC 2007) and concluded that "uncertainties remain about the degree to which a resilient, self-sustaining ecosystem can be restored under the dramatically changed environment of South Florida" (NRC 2008). The CISRERP noted that AM is essential for "…designing management strategies for dealing with complex ecosystem projects for which probable ecosystem responses are poorly known and hence, difficult to predict" (NRC 2007). The CISRERP further reinforced its view regarding the inclusion of AM in CERP project planning and implementation by stating that, "Given the enormous scope and complexity of the restoration effort, the success of the CERP depends on strategic, high-quality, responsive, and sustained science and an effective adaptive management framework" (NRC 2010).

Per the 2003 Pro Regs, CERP produced guidance for project teams to develop AM plans and integrate AM activities into all phases of a project lifecycle, e.g., planning, design, construction, and operations (USACE and SFWMD, 2011; RECOVER, 2011b). These are appropriate to the large scale and complexity of CERP and its projects, with its changing context of new non-CERP water infrastructure projects, and the shifting nature of its ecosystems. The intent of the detailed guidance is to improve restoration performance and reduce costs by increasing certainty throughout project implementation. The CERP guidance is consistent with the Everglades AM WRDA 2000 authorization and follows the more general 2009 AM guidance from USACE Headquarters on implementing Section 2039 of WRDA 2007.

In summary, there is extensive knowledge about Lake Okeechobee but there are still uncertainties that were evident during project planning that need to be addressed. Rather than delaying planning for the sake of further data collection or model development, the AM plan provides a mechanism to systematically address uncertainties during LOWRP's implementation in order to confirm that project performance is on the right trajectory, to detect early if an adjustment is needed, and to provide sound data to inform operations and implement decisions. The AM plan identifies which areas to monitor to detect performance, and options for adjusting LOWRP, if needed, to remain on track with performance expectations, as well as suggesting future CERP options to meet overall CERP restoration goals.

Definitions that will help the reader in understanding the LOWRP Adaptive Management Plan include the following terms below. The concepts and definitions are described in more detail in CGM 56 (2010) and in the CERP Adaptive Management Integration Guide (RECOVER 2011b).

- **Adaptive Management** – A scientific process for continually improving management policies and practices by learning from their outcomes; Adaptive Management links science to decision making to improve restoration performance, efficiency, and probability of success. In the context of Lake Okeechobee watershed and estuary restoration, AM is a structured approach for addressing uncertainties by implementing one project component or operational criteria for best project designs and operations to achieve restoration goals and objectives, linking science to decision making, and adjusting implementation, as necessary, to improve the probability of restoration success.

- **Uncertainty** – A question faced during planning or implementation regarding the best actions to achieve desired goals and objectives within constraints, which cannot be fully answered with available data or modeling.
- **Management Options** – Potential structural, non-structural, and/or operational alternatives to be undertaken to improve restoration performance. Adaptive management plans contain potential management actions "options" to improve performance in meeting project/program goals and objectives.
- **Strategies** – A plan to address one or more uncertainties identified in the AM plan. The AM strategies fit into the following approaches:
  - *Active Adaptive Management* – Multiple pilot projects or design tests are implemented to determine the most efficient and effective way to achieve desired goals and objectives. Each design or operational action is monitored, assessed, and results are used to inform implementation of the best design for a project component or operations. Pilot projects or design tests are usually conducted during implementing the full project component that they are intended to inform.
  - *Passive Adaptive Management* – All of the LOWRP AM plan strategies are considered passive AM approaches. One project component or set of operational criteria is implemented to test its ability to achieve desired goals and objectives. Results are monitored, assessed, and communicated to the appropriate participating agencies to determine how best to adjust project component designs, operations, LOWRP contingency options, or inform future CERP projects.

Adaptive management activities will be implemented during the coming phases of LOWRP, and the AM plan will be updated accordingly. At such time, more baseline data and lessons learned will be available from other monitoring programs and restoration projects. Given the new knowledge and answers to key questions, the AM options proposed in this plan may need refinement. Therefore, items included in this plan are not guaranteed to be funded as-is, but will be considered again when LOWRP is closer to being implemented and as appropriate, and funding decisions will be made commensurate with available funding at that time.

D.1.3 How the LOWRP Adaptive Management and Monitoring Plan was Developed: Identification, Screening, and Prioritization of LOWRP Uncertainties

The LOWRP Adaptive Management plan development consisted of the following activities, consistent with the USACE planning guidance and CERP AM guidance:

- PDT and stakeholder involvement.
- Identification and prioritization of key LOWRP AM uncertainties, also referred to simply as "uncertainties" throughout this AM Plan (**subsection D.1.4**) related to achieving LOWRP goals and objectives and avoiding constraints (**Section 1** of PIR).
- Development of AM strategies to address the uncertainties during LOWRP design, construction, and operations that consider existing Everglades conceptual ecological models, hypotheses, performance measures, and monitoring (**subsection D.1.4**).
- Identification of monitoring thresholds and/or triggers and associated management options to adjust, if necessary, based on feedback from assessments (**subsection D.1.4**).
- Development of an AM implementation process to carryout AM activities during design, construction, operations related to baseline and post-project construction monitoring, tests,

analyses, and the process for communicating scientific findings to decision-makers, restoration partners, and the public (**subsection D.1.6**).

The identification of LOWRP uncertainties to be considered for inclusion in the LOWRP Adaptive Management Plan began with input from the LOWRP PDT and RECOVER. The outcome of this early effort, along with uncertainties identified through a multi-agency PDT process, produced a large list of LOWRP-related uncertainties to be considered for inclusion in the LOWRP Adaptive Management Plan.

The large list of uncertainties was screened using the following criteria:

1. Must be directly related to LOWRP goals, objectives, or 'constraints'. The constraints included but were not limited to the legal/USACE definition of constraints; they also included important considerations identified during LOWRP PDT and planning discussions.
2. Must be at project-scale. Although LOWRP is large, it is not system-wide scale. System-wide uncertainties were routed to appropriate groups.
3. Must have AM options (i.e., ability to be addressed during implementation, improved by adjusting LOWRP). In some cases, additional ability to address the uncertainty with a future increment of restoration was noted as a "future opportunity", but this feature was not sufficient in itself to pass this LOWRP AM criteria.
4. Must be an uncertainty. It should not include items that are already known. For example, the question should not ask "What are the effects of reduced fresh water discharges on oysters in the St. Lucie estuary?" which is known. Instead ask, "Will LOWRP's improvements to salinity regimes be sufficient for recruitment of new oyster populations, or will supplemental habitat enhancement be required?"
5. The uncertainty needs at least one attribute that is measurable that will provide information to resolve the uncertainty (i.e, the attribute must be a trait able to change in the timeframe of the AM plan, and one that is distinct from the 'background noise' of natural variability). Long-term changes need a faster responding surrogate-measure for the AM plan.

After a short-list of screened uncertainties was identified, the following criteria were used to prioritize them:

Risk: What is the risk (high, medium, low) of not meeting LOWRP restoration goals if this uncertainty is not addressed?

- Low risk means that even if the uncertainty is not addressed, it does not pose much risk to achieving LOWRP goals and objectives.
- Medium risk means that if the uncertainty is not addressed it may or may not affect achievement of a goal/objective.
- High risk means that without addressing this uncertainty, there is a high risk to not achieving LOWRP goals and objectives.

Knowledge: What is the level of (high, medium, low) understanding of this uncertainty (i.e., how much is known about this uncertainty)?

- Low understanding means little is known about the question/issue or how to address it.
- Medium understanding means some information is known in some geographical areas, but not all.
- High understanding means much is known about addressing this question in multiple geographical areas.

Relevance to Adaptive Management for LOWRP: What is the level of confidence (high, medium, low) that anything could be done to address the uncertainty? The team's preliminary identification of management options helped to determine this.

- Low confidence means that even if this uncertainty is addressed, LOWRP or operations will not be able to be modified given the results of LOWRP implementation.
- Medium confidence means if this question is addressed, a connection to future CERP project implementation is established/documented but future adjustments to the LOWRP may or may not be limited, especially if indicator response is longer than 10 years and is more relevant to RECOVER system-wide monitoring.
- High confidence means if this question is addressed, LOWRP design, implementation, and/or operations can be modified to improve restoration results.

The identification, screening, and prioritization process resulted in a final prioritized list of uncertainties. This list was used to develop strategies, management options, and costs in order to develop the Adaptive Management Plan.

The AMMP provides a screened and prioritized summary of specific uncertainties that can be addressed with efficiently structured strategies. The AMMP describes the called strategies and suggests management options for future consideration if needed. The AM plan is a culmination of input from well-developed USACE planning procedures, extensive scientific and local knowledge developed over decades of experience, and input from the LOWRP Eco Subteam during planning.

The screened uncertainties were then considered by six management action subteams that provided strategies and options for addressing them. Per CERP's AM guidance, the management options included in this AM plan can be described as the following:

1. Informing LOWRP Implementation - results of monitoring a project component may inform design, construction, and/or operation of subsequent project components,
2. Informing Project Operations - results inform project operations and/or system operating manuals,
3. LOWRP Adaptive Management Contingency Options - monitoring results may suggest a need to implement additional restoration actions, called management options, pending all required and applicable coordination, policies, and permitting.

The strategies and management options comprise the bulk of this AMMP. Adaptive management activities will be implemented during the coming phases of LOWRP, and the AMMP will be updated accordingly. At such time, more baseline data and lessons learned will be available from other monitoring programs and restoration projects. Given the new knowledge and answers to key questions, the AM strategies and options proposed in this AMMP may need refinement. Therefore, items included in this plan are not guaranteed to be funded as-is, but will be considered again when LOWRP is closer to being implemented and as appropriate, and funding decisions will be made commensurate with available funding at that time.

It should be noted that cost estimates in this plan were provided using the best available information at the time of writing and will be updated for the final PIR and EIS. Therefore, several detailed estimates provided in this AM and monitoring plan may be lower than the amounts shown in the cost summary tables that include the contingency (**Table 6-9** in **Section 6**, and **subsection D.1.7**). The contingency percentage was based on a project-wide analysis and therefore it should not be assumed that the additional contingency amounts shown in the summary cost tables will be available specifically to fund monitoring.

D.1.4 LOWRP Adaptive Management Uncertainties, Strategies, and Management Options

The LOWRP uncertainties in this section consist of prioritized needs and opportunities to learn in order to make scientifically sound recommendations to refine LOWRP design, construction, and operations; the strategies and management options provided to address each uncertainty are intended to guide LOWRP performance in the face of inevitable uncertainties, with existing knowledge and knowledge that will be gained through monitoring and assessment. The strategies are focused on LOWRP to maximize 'return on investment' for resources invested in pursuing the AM activities. As with the other monitoring plans in Annex D, the monitoring proposed in the AM strategies was guided in part by two objectives: to be complete from a LOWRP perspective by providing the monitoring required to address LOWRP-specific uncertainties; and to integrate with other Lake Okeechobee watershed and estuary monitoring to take advantage of existing monitoring efforts, knowledge, and information and thereby leverage dollars committed and spent elsewhere to avoid redundancies and ensure cost-effectiveness. *Where possible, the LOWRP AM strategies rely on existing monitoring resources such as physical instrumentation, stations, locations, servicing, and analysis efforts funded by RECOVER, CERP sponsors, and partner agencies. Therefore, the monitoring requirements described here are limited to the additional, marginal increase in monitoring resources and analysis efforts needed to address LOWRP-specific AM questions.* This point is discussed in the LOWRP Adaptive Management Implementation section of this plan, and **Table D-11** is provided to show leveraged monitoring. In addition, it should be noted that the timing of the strategies is staggered throughout the design and implementation of LOWRP. Please see Section 1.5 Implementation of LOWRP Adaptive Management and the associated Figures and Tables for more detail on the estimated start- and stop-times for each AM strategy.

The uncertainties, their strategies, and management options are organized in this plan by the following categories: Lake Okeechobee, Aquifer Storage and Recovery (ASR), estuaries, invasive species, water supply, and wetlands.

The uncertainties, their identification numbers (ID#), and the LOWRP project objective and/or constraint are listed here for reference. The project objectives and constraints are described in detail in LOWRP PIR Section 1 (Introduction). A list of uncertainties that were screened out is provided in the final section of this AM plan (**Table D-15**) to show the array of ideas that were considered and brief notes from the screening process. As the LOWRP Project Team learns from LOWRP implementation, the list of LOWRP AM uncertainties will be updated to identify which have been addressed and where the risks to achieving LOWRP restoration success have been lowered.

The remainder of this section of the AMMP provides strategies for addressing the following screened uncertainties.

Note: The uncertainty ID numbers below refer to the ID numbers assigned to each uncertainty during AM screening, and therefore may not appear sequential because those that did not pass screening are

no longer included. The ID numbers were maintained for organizational purposes; future refinements of the LOWRP AM Plan may include re-numbering of the uncertainties.

Lake Okeechobee

- Will adjustments in lake stages result in increases in ecological indicator abundances that will be above the projected range of their PM scores? (ID#25; LOWRP Objective 1)
- When storage is built and lake stages are better maintained, will ecological indicator species' abundance in the lake increase, or will consideration of supplemental habitat enhancements be warranted? (ID#26; LOWRP Objective 1)

Aquifer Storage and Recovery (ASR)

- Will ASRs exacerbate methyl mercury concentrations in surface waters that receive ASR releases, which would impact the habitats being restored in LOWRP? (ID#2; LOWRP Objective 2/3)
- Will project operations result in significant fish entrainment / impingement, reducing ecological function of the aquatic habitats that LOWRP will restore? (ID#3; LOWRP Objective 3)
- Will ASRs deliver the recovery efficiency we are expecting in order to achieve the hydrologic restoration objectives of the project? (ID#5; LOWRP Objective 1/2)

Estuaries

- When discharges from LO are reduced and salinity regimes improved, will species' abundance and diversity in the estuaries increase, or will consideration of supplemental habitat enhancements be warranted? (ID#12; LOWRP Objective 2)
- Will augmentation of substrate be needed if desired salinities are achieved and recruitment is still not at expected levels? (ID#12; LOWRP Objective 2)
- Will there be displacement / limitation of spat / SAV in the St. Lucie Estuary as a result of the project? (ID#16; LOWRP Objective 2)
- Will there be displacement / limitation of spat / SAV in the Caloosahatchee Estuary as a result of the project? (ID#16; LOWRP Objective 2)
- Will anticipated salinity improvements result in natural recruitment / reestablishment of SAV? (ID#40; LOWRP Objective 2)

Invasive Species

- How will new hydrologic regimes affect the occurrence of invasive species in restored wetlands? (ID#17; LOWRP Objective 3)
- If algal blooms occur in the wetland attenuation feature (WAF), how will they be managed? (ID#36; LOWRP Objective 3)

Water Supply

- Will there be sufficient water availability to maintain LO ecology during a drought? (ID#41; LOWRP Objective 4)

Wetlands

- When wetlands are restored, will wetland vegetation return or will consideration of supplemental habitat enhancements be warranted? (ID#46; LOWRP Objective 3)

Adaptive management strategies are provided in this section to describe and address each LOWRP AM uncertainty and inform LOWRP implementation based on the body of existing scientific knowledge of Lake Okeechobee watershed restoration. This section comprises the bulk of the LOWRP Adaptive Management Plan. It provides 1-2 page strategy descriptions for each uncertainty (sometimes combined, where appropriate) and summary tables of suggested management actions to improve restoration performance, as illustrated in **Table D-1.** The strategy write-ups include information on drivers of the uncertainty, restoration targets and LOWRP targets for particular attributes of the ecosystem associated with the uncertainty (such as a key species or ecological features), how these attributes will be monitored to track progress toward the targets, the timeframe in which changes in these attributes will be measurable, and identification of a trigger or threshold that would give early warning that LOWRP performance is veering from restoration expectations. *The "timeframe in which changes will be measurable" does not imply that changes will be complete in that timeframe; rather, the timeframes provide an estimate of time needed to begin to be able to distinguish LOWRP effects. For practicality, the LOWRP AM Plan screening criteria included the need to have attributes measurable within the time of the AM Plan, which in some cases necessitated a 'proxy' attribute to be measured that would represent expected changes on a longer time scale. In addition, the triggers and thresholds were identified with the best available information, but the AM team recognizes that they should be updated to keep current with best available science*. Second, following the strategies, tables of suggested management options are provided, called management option matrices (MOM). These provide suggestions of paths forward and adjustments that can be made in order to keep LOWRP progressing toward the targets, based on specific decision-criteria, e.g., a trigger or threshold is crossed (reflecting unintended effects related to a constraint) or is not crossed (reflecting lack of restoration progress towards restoration goals and objectives). The purpose of the two formats is to provide A) background and detail of each strategy in the 1-2 page write-ups and B) a table reference summary and crosswalk that relates monitoring to specific decision-criteria and potential actions for multiple strategies in a specific area. The detailed write-up descriptions are referred to as the "strategies" and the summary tables are referred to as MOMs (**Table D-1**). The strategies and MOMs provide synopses of the best available information, which in some cases is sparse and will need to be developed further as LOWRP moves toward implementation and the AM plan is updated based on new information gained about the best project design and operations to achieve restoration goals.

Adaptive management activities will be implemented during the coming phases of LOWRP, and the Adaptive Management Plan will be updated accordingly. At such time, more baseline data and lessons learned will be available from other monitoring programs and restoration projects. Given the new knowledge and answers to key questions the AM options proposed in this plan may need refinement. Therefore, items included in this plan are not guaranteed to be funded as-is, but will be considered again when LOWRP is closer to being implemented and as appropriate, and funding decisions will be made commensurate with available funding at that time.The LOWRP AM uncertainties and the strategies to address them are provided in the format shown in **Table D-1**. The uncertainties and strategies are presented by project objective, and each objective's set is followed by an 11x17 pull-out table of suggested management options that can support LOWRP and potentially CERP refinement (Management Option Matrices, or MOMs). The Management Option Matrix (MOM) shown in Table D-2, and those throughout the AM plan, help link monitoring identified in specific AM strategies to decision criteria and suggested management options to consider for adjusting LOWRP if monitoring reveals performance issues related to LOWRP operations. The "timeframe to detect changes…" does not imply that changes will be complete in that timeframe; rather, they provide an estimate of time needed to begin to be able to distinguish effects of LOWRP. These time frames are indications of response speeds, not limits on how long the monitoring will be conducted.

D.1.4.1 LOWRP Objective 1 - Lake Okeechobee Strategies and Management Options

Objective 1 of LOWRP is to improve quantity, timing, and distribution of flows into Lake Okeechobee to maintain ecologically desired lake stage ranges more often. The following AM strategies were developed to address the uncertainties about maintaining the ecologically desired lake stage ranges. From the AM uncertainties, a monitoring plan is presented in **subsections D.1.5.1** and D.1.5.2 that documents the ecological monitoring and AM monitoring required to measure success of the project in reaching the goals of Objective 1.

D.1.4.1.1 Lake Okeechobee Ecological Indicators: Fish and Wildlife Communities

LOWRP is expected to benefit floral and faunal communities on Lake Okeechobee by improving the quantity, timing, and distribution of flows into the lake, resulting in more ecologically desired lake stages. These expectations are based on known or assumed relationships of certain indicators and species to lake stage, based on varying periods of record. For many of the datasets, the period of record is marked by extreme weather events, including multiple hurricanes and record low lake levels, most of which occurred within 1-2 years of each other. Such events likely mitigated the effects of one another, and recent stable climatic periods (2012-2015) where extreme drought and floods were absent, resulted in an improvement in emergent and submerged aquatic vegetation, water quality, and fish communities (RECOVER 2014; SFWMD, 2015).. Therefore, while there is ample evidence regarding effects of extreme lake stages, there is more uncertainty regarding effects of stabilized water levels as predicted to occur with LOWRP. How the indicators and faunal communities respond will depend on the extent of stabilization that occurs from the additional water storage constructed in the Lake Okeechobee watershed.

The LOWRP AM strategy described here focuses on continuing long-term monitoring programs and updating analyses to improve LOWRP's ability to achieve benefits in the lake ecosystem, concurrent with project objectives. This topic is included in the Adaptive Management Plan because of its level of uncertainty and risk to LOWRP outcomes, its ability to be addressed through management options, and to ensure that it remains part of LOWRP discussions as lessons are learned throughout the implementation of the project.

LOWRP AM Uncertainty #25 and 26: Will ecological indicator abundances stay within the range of their performance measure scores after lake stages change? Will fish and wildlife communities benefit from changes in lake stage or will additional habitat management be needed?

Objective or Constraint: These uncertainties are related to the objective of improving the quantity, timing and distribution of flows into Lake Okeechobee to maintain ecologically desired lake stage ranges (Objective 1).

Region(s): Lake Okeechobee and the majority of watershed which is north of the lake.

Associated project features: WAF and ASR wells

Driver or uncertainty type: Ecological

What is expected to be learned by addressing this uncertainty (i.e., how will LOWRP benefit from addressing this uncertainty)? Little new monitoring is proposed in this AM strategy, other than annual aerial (or satellite) imagery collection and classification for the littoral marsh. However, continuation of many ongoing monitoring efforts conducted by various entities and updating analyses will be key to

addressing these uncertainties. Most of the specified ecological indicators are monitored by SFWMD (including classifying littoral aerial imagery, when available), while various faunal groups are monitored by USACE and FFWCC. Thus far, these projects have provided fairly strong evidence for lake stage targets, but need to be collected across a wider variety of climate conditions to verify assumptions and refine predicted relationships. Specifically, the monitoring of the indicators and fauna need to assess what effects subtle increases in extreme high lake stages and decreases in lower lake stages, or stabilization of water levels overall may have on Lake Okeechobee's resources. Increasing the frequency and reliability of aerial imagery collection and classification will vastly improve our ability to detect change on a lake-wide scale, and be critical to discerning project-related effects from climate or other variability.

Expectations and hypotheses to be tested to address uncertainty, and attribute(s) that will be measured to test each. The expectation to be tested is that maintaining lake stages within ecologically desired ranges (12.0 – 15.5 feet NGVD) more frequently will offset impacts from very minor increases in the frequency of extreme high (>17.0 feet NGVD) lake stages. Additionally, the expectation that reducing the frequency of stages at the high end of the ecologically beneficial range (15.0 – 15.5 feet NGVD) will offset reductions in the frequency of stages at the low end of the beneficial range (12.0 – 13.0 feet NGVD) and lower (<12.0 feet NGVD) will be tested.

The attributes to be measured are representative of ecological conditions on the lake, and how they respond will be a direct measurement of LOWRP's impact to the system. Many of them will be monitored in the nearshore region, which is the area where changes in lake stages have the most immediate impact. These include submerged and emergent aquatic vegetation (SAV and EAV), cyanobacteria, periphyton, phytoplankton, and bluegill and redear sunfish creel data. Wading birds, snail kites, and vegetation composition/distribution will be monitored throughout the marsh, while fish communities will be assessed in the nearshore and pelagic zones.

All the attributes respond relatively quickly to hydrological changes or the indirect effects of stage variations on water quality parameters. While the initial responses could be detected within a year, correlating those responses to project implementation would likely take several years and cover a variety of climate conditions. Monitoring should be implemented concurrent with project implementation and continue through extreme dry and wet conditions (5-10 years) to fully evaluate responses.

Methodology for testing each expectation or hypothesis. Little new monitoring is proposed to address these uncertainties, other than classifying annual imagery (aerial or satellite) for the littoral marsh. Classification is proposed to be done by SFWMD staff, while imagery collection would be funded through LOWRP. All the monitoring proposed relies on existing long-term datasets and on maintaining or expanding monitoring programs that are currently running. LOWRP-specific analyses would be needed to determine how project operations affect various ecological indicators, these are currently being done by agencies, but if that monitoring is discontinued, LOWRP would need to cover the monitoring.

Most of the methodologies for the proposed monitoring can be found in existing sources. For the ecological indicators, see CERP's documentation sheet for Lake Okeechobee Ecological Indicator Score (http://www.saj.usace.army.mil/Portals/44/docs/Environmental/RECOVER/Lake_Okeechobee_Ecological_Indicator_Score_Performance_Measure_Final_102016.pdf?ver=2016-10-26-131319-687). For SAV and EAV mapping procedures, wading bird foraging surveys, and fish monitoring see the Lake Okeechobee chapter of many South Florida Ecosystem Reports (SFER) (e.g., Zhang and Welch 2018). For information on wading bird nesting colonies, see the annual South Florida Wading Bird Report (SFWBR) (e.g., Cook and Baranski 2016),

and for snail kites, see annual demographic reports from University of Florida's snail kite monitoring program (Fletcher et al. 2015).

How results will be reported, and the triggers/thresholds that indicate good CERP performance or need for AM action:

The results for many of the monitoring activities, regardless of whether there was a significant relationship with LOWRP operations, are reported on annually in the SFER. Exceptions are the epipelon, epiphytes, and panfish, which will only be reported with other indicators as specified below. Wading bird nesting is reported in the annual SFWBR, and snail kite nesting in the annual demographic reports from the University of Florida (e.g., Fletcher et al. 2015).

For Uncertainty #25, related to the ecological indicators and their performance measure scores, those will be evaluated separately on an annual basis in the SFER. For example, the abundances and/or trends of the indicators will be compared to their corresponding scores and/or trends to determine whether lake stage and abundance relationships are accurate.

For individual triggers/thresholds that would indicate a need for action, see **Table D-2**.

Management options that may be chosen to reduce the impacts of invasive species.

For all of the monitored groups, one AM option would be to manipulate operations to affect lake stages so that they better align with needs of the specific flora or fauna. For example, if operations appear to be having detrimental impacts to a particular group due to high recession rates or high lake stages, reducing those stressors through operations might be feasible.

There are also various habitat management actions that could be implemented to reach target vegetation compositions or to improve habitat for specific wildlife, like fish, wading birds, snail kites, etc. For example, spraying cattail or torpedograss, implementing prescribed burns, or both. Further, for harvested species like sportfish, regulations for harvest could be revisited as well. Other options are provided in **Table D-2**

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Table D-2. Lake stage management option matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
#25 Will ecological indicators respond to lake stage changes as their PM scores suggest? (i.e., are the PM scores indicative of ecological responses?)	1 year	Ecological Indicators (EI) - *Chara*, cyanobacteria, epipelon, epiphyte, PanFish (bluegill and redear sunfish). Areal coverage of vascular SAV, total nearshore SAV, and 9 EAV spp. groups in littoral zone	Abundances of EI, as well as acreage of total SAV in nearshore and 9 EAV spp. in littoral zone Annual: *Chara*, vascular SAV, nearshore SAV, cyanos, littoral EAV Twice annually: epipelon and epiphytes, PanFish creel data	Adjust increased lake stage duration triggers to maximize storage in project features to increase storage during dry times or reduce any unforeseen impacts from slightly longer high stage durations. Reduction below the annual combined score (8 pts) for ecological indicators. Reduction of coverage (35k acres) for the nearshore SAV and below the combined score (4 pts) for select littoral zone species groups: bulrush, sawgrass, beakrush/spikerush, cattail, willow, floating leaf, torpedograss, other invasive exotics, and woody vegetation.	Adjust water level operations as appropriate for the ecological indicators, included but not limited to, recessions, low water, reduced highs, etc. Additional habitat management operations, e.g., exotic/nuisance vegetation removal, muck removal, prescribed burning, plantings, etc. Additional nutrient reductions in inflow and/or in-lake nutrient levels to reduce negative impacts to target attributes, e.g., sediment capping or dredging, STAs, etc. Implement additional fish monitoring or analyses, adjust fishery regulations, stocking program, etc.

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
#26 Will fish and wildlife communities benefit from project's effect on lake stages or will additional habitat management be needed?	1 year	Current annually monitored species: Wading birds, snail kites, fish	Annual wading bird abundance and nesting effort/success; snail kite nesting effort/success; fish composition/catch rate/age distribution	Substantial reductions in abundance/composition/catch rates/age distributions, etc. of listed attributes: Annual wading bird abundance reduction 50% and reduction in nesting effort/ success 50%. Annual snail kite reduction below 3-year moving avg in nesting effort/success. Annual fish composition/catch rate /age distribution reductions %.	Adjust water level operations as appropriate for the listed attributes, included but not limited to, recessions, low water, reduced highs, etc. Additional habitat and/or species management operations, e.g., exotic/nuisance removal, muck removal, prescribed burning, plantings, harvest regulations, etc. Implement additional faunal monitoring or analyses. Implement additional fish monitoring or analyses, adjust fishery regulations, stocking program, etc.

*Time frame could be shorter or longer, depending upon prevailing weather patterns.

D.1.4.1.2 ASR – Recovery Efficiency Strategy

ASR facilities are expected to have a recovery efficiency of 70% over the long-term. A persistent, significantly low recovery (<30%) would reduce the likelihood of meeting project storage benefits. This AM objective is to identify when, and if, recovery efficiency falls to unacceptable levels and how to remediate this potential.

LOWRP AM Uncertainty #5: Will ASRs be able to deliver the recovery efficiency we are expecting?

Objective or Constraint: Objectives 1 and 2 (meeting project storage target).

Region(s): Surface waters of LOWRP ASR operations

Associated project features: Wetland Attenuation Feature and ASR Wells

Driver or uncertainty type: Operational and Ecological

What is expected to be learned by addressing this uncertainty, i.e., how will LOWRP benefit from addressing this uncertainty? This will improve the understanding and predictability of long-term ASR operations to provide necessary water storage for maximum project benefits.

Expectations and hypotheses to be tested to address uncertainty, and attribute(s) that will be measured to test each. The expectation is that recovery efficiencies do not decrease significantly over time. Monitoring would begin with the onset of ASR operations and likely continue for the project lifespan.

Methodology for testing each expectation or hypothesis. Volume of water pumped into the aquifer versus the volumes recovered of acceptable quality; measured daily, compiled and reported annually.

Triggers/thresholds that indicate good project performance or need for AM action: In accordance with FDEP Permit (TBD, as appropriate) and a level of recovery that stays above 30% and does not drop significantly over the project's lifetime (**Table D-3**).

Management options that may be chosen to improve recovery efficiencies of ASR. 1) Back-plugging individual wells to draw from higher quality portions of the aquifers (well testing/assessment would be needed to do this); 2) concentrating well clusters in areas that have the highest quality or best aquifer attributes, and reducing the numbers of wells in poor producing areas (this option would best be served by constructing well clusters in a multi-phased approach, so that subsequent wells can be sited in the most optimal locations); 3) at the Hillsboro ASR system, allow the well to recover "passively," using only the natural, artesian pressure of the Floridan aquifer (instead of actively pumping the ASR well). Substantially higher recovery efficiency has been observed elsewhere as a result of this method, which takes advantage of the buoyancy stratification within the aquifer as fresh water is stored within a saline zone. This is an example of how recovery efficiency can be modified through operational tweaks.

Table D-3. ASR recovery efficiency management option matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
#5 Will ASRs be able to deliver the recovery efficiency we are expecting?	Months to years of operations	Volume pumped down vs volumes recovered. The specific conductance value in recovered water must not exceed 1,275 µS/cm	Volumes of water, measured daily, compiled monthly	A persistent, significantly low recovery (<30%)	Would first need to understand why recovery efficiency reduced over time, and then evaluate the following: 1) Back-plugging individual wells, to draw from fresher portions of the aquifers (well testing/assessment would be needed to do this); 2) Concentrating well clusters in areas that have the highest quality or best aquifer attributes, and reducing the numbers of wells in poor producing areas (this option would best be served by constructing well clusters in a multi-phased approach, so that subsequent wells can be sited in the most optimal locations); 3) We have recently completed a test cycle at the Hillsboro ASR system, where we allowed the well to recover "passively", using only the natural, artesian pressure of the UFA (instead of actively pumping the ASR well during recovery). We observed substantially higher recovery efficiency as a result of this method, which takes advantage of the buoyancy stratification that takes place within the aquifer as fresh water is stored within a saline zone. This is an example of how recovery efficiency can be modified through operational tweaks. Note: a certain amount of "aquifer conditioning" needs to take place as an ASR system is operated. In order to achieve high recovery efficiencies, the saline water that is within the storage zone needs to be displaced away from the ASR well, and a freshwater "target storage volume" (the bubble) needs to be established within the aquifer. In order to accomplish this, the initial recharge volumes/durations should be large, and the recovery volumes should purposefully be limited, so that the freshwater bubble is created within the storage zone.

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
					It is instructive to remind folks that “recovery efficiency” is a transient number – that is only used to measure the early performance of an ASR system - which is why it takes months or years of operation to truly realize the full potential of an ASR facility.

D.1.4.2 Objective 2 - Estuaries Strategies and Management Options

Objective 2 of LOWRP is to improve estuary discharges from Lake Okeechobee to improve the salinity regime and the quality of oyster, SAV, and other estuarine community habitats in the northern estuaries. The following AM strategies were developed to address the uncertainties about improving estuary discharges from Lake Okeechobee. From the AM uncertainties, a monitoring plan is presented in **Section D.5.1** and **D.5.2** that documents the ecological monitoring and AM monitoring required to measure success of the project in reaching the goals of Objective 2.

D.1.4.2.1 Estuaries – Submerged Aquatic Vegetation (SAV) Strategy

Within and between years, there will be seasonal and inter-annual conditions which may, in the short term, dampen the ability to detect changes to SAV between these short-term environmental conditions and restoration. Inherent uncertainties for SAV include species-specific salinity regimes, and some measurable parameters may be limited by species (e.g., productivity measurements for only *Vallisneria americana* and *Thalassia testudinum* due to blade size and width). The decision criteria and management action options consider both whether the intended changes in salinity timing are met, and what other actions may be required if salinity conditions are met but effects to SAV cause decline or no change, in which case mediation by changing other environmental conditions may be required (e.g., introduction of suitable substrate).

LOWRP AM Uncertainty #12 – <u>Submerged Aquatic Vegetation</u> – When discharges from Lake Okeechobee are altered, and salinity regimes for SAV are improved, what changes to SAV abundance, extent, and species composition/diversity will occur in the estuaries? Further, will natural recruitment of SAV occur, or will other management actions/options be necessary? (Driver or uncertainty type: Ecological)

LOWRP Objective or Constraint: Objective 2 0 - Restore and/or maintain estuarine communities (oysters, fish, seagrass).

Region(s): St. Lucie Estuary (SLE) & Caloosahatchee River and Estuary (CRE).

Associated LOWRP features: Wetland Attenuation Feature and ASR wells

What is expected to be learned by addressing this uncertainty, i.e., how will LOWRP benefit from addressing this uncertainty?

Submerged aquatic vegetation (SAV) plays a critical role in influencing the population, community, and ecosystem dynamics of estuarine environments. Altered hydrologic activity (e.g., restorative freshwater flows) may influence the abundance and distribution of SAV including estuarine seagrasses, and have marked positive effects on SAV with a lower salinity tolerance. However, if target freshwater flows are not achieved, there may be neutral or deleterious effects to SAV distribution, abundance, and productivity. Elucidating how restoration performance may influence SAV in the northern estuaries is imperative so that AM actions can be undertaken, ensuring restoration success.

Schedule and methodology for monitoring SAV:

RECOVER SAV monitoring for the northern estuaries was updated in Spring 2018 and is currently under review by the RECOVER REC for approval pending edits to the monitoring SOP document. The new

protocol, the Northern Everglades Northern Estuaries SAV Ecosystem Assessment (NESEA), applies a nested, three-tiered hierarchical approach to address multiple scales of SAV monitoring in the northern estuaries region, namely: 1) landscape, 2) patch, and 3) shoot-level scales. The tiers are summarized as:

- **Tier 1** - Landscape scale from which information on system-wide, long-term trends is attained. Currently, SFWMD has historical and current aerial mapping data for the east coast, which occurs every two years, flown most recently in spring 2017 through current collaboration with SJRWMD and FDEP. Flights and photographs for the next set of maps were completed in May of 2017 and final maps completed in May 2018.
- **Tier 2** - Patch-scale measures which examine segments (or basins) of the system to determine segment-specific trends in ecological conditions at the species-specific level. This sampling will take place at the end of the dry and end of the wet season.
- **Tier 3** – Fixed-point sampling by which statistically significant differences in specific plant responses to environmental stressors at a shoot-scale range are measured. Metrics such as biomass and shoot density are attained at this level. This sampling will occur every other month from April through November.

Triggers/thresholds that indicate good LOWRP performance or need for AM action, and subsequent management options:

To assess the LOWRP performance or whether there is a need for AM action as it pertains to SAV, decision criteria to trigger management action needs to be developed for each of the estuaries based on the best available science and known seagrass ecology and population dynamics. No framework exists for identifying ecological feedback mechanisms influencing seagrass ecosystems (Maxwell et al. 2016); and therefore, following the optimization of freshwater flows to obtain salinity in location in which SAV is or should be present, if seagrasses are unable to disperse, recruit, or grow in the expected or desired capacity, other management options may be necessary, including:

- Removal of fine-sediment (i.e., muck) that may accumulate, so SAV can expand and grow.
- Assessing water quality to ensure that abiotic conditions are suitable for SAV growth.
- SAV restoration in areas in which SAV should be present or is present but at low densities.
- Implementing structures such as breakwaters or sediment traps to reduce possible sedimentation issues and/or shear stress on SAV.

D.1.4.2.2 Estuaries – Oyster Strategy

Within and between years there will be seasonal and inter-annual conditions which may, in the short term, dampen the ability to detect changes to oysters between these short-term environmental conditions and restoration. Inherent uncertainties for oysters, restoration activities which meet the salinity envelopes and timing may be limited if there is also substrate or spat limitation. The decision criteria and management action options consider both whether the intended changes in salinity timing are met, and what other actions may be required if salinity conditions are met, but effects to oysters cause decline or no change without also mediating other environmental conditions (i.e., substrate limitation; spat limitation).

LOWRP AM Uncertainty #16 – <u>Oysters</u> – When discharges from Lake Okeechobee are altered, and salinity regimes for oysters are improved, what changes to oyster abundance, density, and extent will occur in the estuaries? Further, will natural recruitment of oyster spat occur, or will supplemental

habitat enhancements (i.e., substrate) be required, or other management actions/options be necessary?

Driver or uncertainty type: Ecological

LOWRP Objective or Constraint: Objective 2 - Restore and/or maintain estuarine communities (oysters, fish, seagrass).

Region(s): St. Lucie Estuary (SLE) & Caloosahatchee River and Estuary (CRE).

Associated LOWRP features: Wetland Attenuation Feature and ASR wells

What is expected to be learned by addressing this uncertainty, i.e., how will LOWRP benefit from addressing this uncertainty?

Oyster communities in coastal estuaries have respective salinity envelope requirements to persist within a system. However, the timing and duration of altered freshwater flows due to restoration activities will affect the desired areal extent and abundance of oysters if restoration performance is not met. In addition, substrate and spat limitation may further impede restoration performance despite meeting suitable salinity envelopes. By addressing these uncertainties in the LOWRP monitoring plan, performance goals and subsequent AM actions are developed to ensure restoration success moving forward.

Schedule and methodology for monitoring oysters:

- Growth
- Disease prevalence
- Predation
- Recruitment
- Reproductive Development
- Density; and live/dead counts (twice per year)
- Mapping (last conducted in 2010/2011; mapping contract for SLE and CRE scheduled for 2018).

Within and between years there will be seasonal and inter-annual conditions which may, in the short term, dampen the ability to detect changes to oysters between short-term environmental conditions post-restoration; therefore, mapping should occur pre-restoration, and then again five years after restoration implementation, and once every five years after to track long-term change and inform AM.

Triggers/thresholds that indicate good LOWRP performance or need for AM action, and subsequent management options:

To assess the LOWRP performance or whether there is a need for AM action as it pertains to oysters, decision criteria to trigger management action needs to be developed for each of the estuaries based on the best available science and known oyster ecology and population dynamics (**Table D-4**).

- Identifying triggers for AM is complicated in the northern estuaries, especially the SLE and CRE, by occasional (or seasonal), extended periods of freshwater inputs following high rainfall or tropical storm events. For example, since 2005, five major, estuary-wide die-offs in the SLE have been observed including late 2017 following Hurricane Irma, following approximately 45-60 days of flows resulting in salinities of < 5, and often paired with temperatures > 25°C (M. Parker, pers. comm.). Generally, within 4-8 months oysters return, which is attributed to persistent seed

sources in the southern Indian River Lagoon (outside of the SLE proper); these larval oysters are transported through tidal forces from the mouth of the estuary/IRL, and repopulate dead shell material (M. Parker, pers. comm.). AM management triggers may be developed for the estuaries following this dynamic, whereby a given amount of time for oyster recruitment is used as a threshold. This will vary by estuary, and by location in the estuary. This also emphasizes the importance of remnant oysters in these highly urbanized systems.

- Within the northern estuaries, loss of oysters is typically a result of altered salinity regime, and other ecological effects associated with salinity and temperature interactions leading to increased predation and disease. In other estuaries (e.g., Gulf of Mexico), oyster harvest is an additional factor needing consideration for management due to the removal of shell material (Soniat et al. 2012). While loss in shell material may be a factor of sedimentation/burial rather than harvest in the northern estuaries, substrate enhancements may be required. An updated map of oysters and oyster shell in the SLE and CRE is contracted by RECOVER for FY18, and will provide a baseline for LOWRP substrate availability, as well as estimates of live/dead oyster resources if present.
- For substrate-limitation, cultch or travertine tiles may be added. For spat limitation, several options exist, including adding spat to the water column, transplanting mature oysters, or deploying seeded (with spat) cultch or travertine tiles.

Table D-4. Estuaries oyster and SAV management option matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
#12 and 16	SAV: 5 years Oysters: 5 years (acres of live oysters)	SAV Oysters	SAV Monitoring: **Tier 1** - Landscape scale – aerial mapping every 2 years **Tier 2** - Patch-scale – species-specific cover and abundance at the end of the dry and end of the wet season. **Tier 3** – Fixed-point sampling – cover, abundance, shoot density, canopy height, above and below ground biomass - sampling occurs every other month from April through November + Oyster Monitoring: Monthly at 18 existing RECOVER sites Growth Disease Predation Reproductive Development Recruitment Density; and Live and Dead counts (twice per year – spring and fall)	SAV: TBD Oysters: TBD	SAV: Optimize flows to get the correct salinity in the correct locations Substrate issues – muck removal Assess water quality Seagrass plantings Oysters: Change operations to increase or decrease flows if salinity envelope is not correct Add cultch If spat is a limiting factor, add mature oysters to existing beds or add spat or seeded cultch to water column, add travertine tiles
#12 and 16		Substrate type	Benthic map at 2 years and then every 10 years after		

D.1.4.2.3 Estuaries – Substrate Strategy

Provided that restoration activities meet intended changes to timing in salinity, SAV and oysters may otherwise be limited by the available substrate. Specifically, areas susceptible to fine sediment entrainment (e.g., muck) can limit productivity or result in sedimentation. For oysters, in areas of good water quality and sediment, spat may be unable to locate suitable substrate on which to settle. Benthic mapping will identify changes to substrate and benthic conditions following restoration and whether additional management actions are required to create suitable conditions for SAV and oysters.

LOWRP AM Uncertainty #23. As we change salinity ranges and locations, do we have the proper substrate for the new salinity?

Driver or uncertainty type: Ecological

LOWRP Objective or Constraint: Objective 2 - *Restore and/or maintain estuarine communities (oysters, fish, seagrass)*.

Region(s): Caloosahatchee River Estuary and St. Lucie Estuary

Associated LOWRP features: Wetland Attenuation Feature and ASR Wells

What is expected to be learned by addressing this uncertainty (i.e., how will LOWRP benefit from addressing this uncertainty)?

Both oyster and seagrass communities in coastal estuaries have substrate requirements to persist and recruit in a system. By restoring the salinity regime in the system through restoration activities these communities will shift. Shifting of these communities will require the appropriate substrate for recruitment in restoration areas in addition to the alteration of salinity regimes. This subject was included in the Adaptive Management Plan due to its level of uncertainty, uncertainty of project outcomes and the ability to address undesired outcomes through AM options.

Expectations or hypotheses to be tested to address the uncertainty, and attribute(s) that will be measured to test each:

A change in the volume, timing, and duration of freshwater flows are expected to shift oysters and seagrasses in the estuaries. This is dependent on the availability of the appropriate substrate for each of these communities existing in these areas following two years of restoration activities. Restoration activities may suspend and redistribute fine-grained sediments and possibly muck in the water column, which may affect the distribution of oysters and SAV. This redistribution can result in covering of hard bottom surface needed for oyster reef growth. Successful restoration of SAV will aid in sequestration of sediments from the water column, providing smaller grained substrate which is beneficial for rhizome growth in sandy sediments.

Methodology for testing each expectation or hypothesis (including frequency of monitoring) and for reporting:

Two years following the initiation of restoration, benthic mapping will be conducted to determine if the appropriate substrate exists for these communities. Following this initial mapping there will be additional mapping every 10 years.

Triggers/thresholds that indicate good LOWRP performance or need for AM action, and subsequent management options:

If the substrate within the estuaries is not appropriate for the species expected to be found in the area (i.e., hard bottom substrate such as rock and preferably oyster cultch (shell) for oysters; medium to small grained sediment for seagrass) or if muck starts to dominate areas which can be enhanced by appropriate substrates for either oysters or SAV, the following actions may be applied to provide the appropriate substrate (**Table D-5**):

- Adding cultch may be necessary for oyster recruitment and growth if existing hard bottom substrate is not present. Addition of cultch will replace or add to the available hard bottom substrate needed for oyster communities.
- Removing or capping fine sediments may be needed. Fine sediments that are suspended in the water column reduce the amount of light available to seagrasses and cover hardbottom substrate needed by oysters. By removing or capping fine sediment these communities will be aided by reducing the burying of hard bottom substrate and increasing light availability.
- Sediment traps may need to be installed to reduce sediment runoff into the system.
- Installation of breakwaters could assist in protecting areas from shear stress and/or promote sediment accumulation.

Table D-5. Estuaries substrate management option matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
#23	2 years	Substrate type	Benthic map at 2 years and then every 10 years after	If substrate is not appropriate for the species expected to be found in the area (hard sediment/crunched shell for oysters or medium to small grained sediment for seagrass) If muck is present in the area neither oysters nor will SAV be able to expand into the area.	Substrate remediation: Adding cultch Removing or capping fine sediments Sediment traps Install breakwaters to protect areas from shear stress and/or sediment accumulation

D.1.4.2.4 ASR – Mercury Methylation Strategy

The operation of ASR facilities in the LOWRP has the potential to recover groundwater having higher sulfate concentrations, and thus increase sulfate concentrations in receiving surface waters. This is particularly important for recovered water from the Avon Park Permeable Zone, which generally shows higher sulfate concentrations compared to that of the UFA in the project area. It is hypothesized that increased sulfate concentration in surface water can stimulate sulfate-reducing bacteria in sediments, and thus enhance mercury methylation in sediments downstream of the ASR discharge structures.

The preliminary operational strategy for ASR systems co-located at the WAF will be to recharge from, and recover into the impoundment. This will reduce the risk of introducing water having elevated sulfate concentrations directly into the Kissimmee River and Lake Okeechobee. Recovered water from the ASR systems will mix with surface water in the WAF, and then be conveyed into the Kissimmee River through gated culverts. This mode of operations will reduce the number of discharge points into the Kissimmee River.

The preliminary operational strategy for ASR systems located in the watershed will rely on surface water dilution to manage release of recovered water into the receiving water body. Currently, there is no State or Federal surface water quality criterion for sulfate. However, ASR recovered water having elevated sulfate concentrations also will have elevated chloride and specific conductance concentrations. When recovered water quality equals the surface water criterion for chloride (250 mg/L) and/or specific conductance (1,275 µS/cm), recovery will cease. Therefore, sulfate loading of surface water bodies adjacent to watershed ASR systems will be limited by chloride and specific conductance criteria. The LOWRP AM strategy described here focuses on monitoring and addressing the risks of sulfate loading from ASR operations; and, if the risk is significant, monitoring for increased methyl mercury concentration in vertebrates (most likely freshwater fish) collected near the site.

LOWRP AM Uncertainty #2: Will ASR operations exacerbate mercury methylation in downstream sediments?

Objective or Constraint: Constraint (of not worsening the existing mercury methylation issue).

Region(s): Surface waters downstream of LOWRP ASR discharges where those discharges comprise a significant proportion of surface water flow. This condition occurs primarily at watershed ASR systems.

Associated project features: Watershed ASR systems.

Driver or uncertainty type: Ecological and Operational

What is expected to be learned by addressing this uncertainty (i.e., how will LOWRP benefit from addressing this uncertainty)? This will improve the understanding and predictability of ASR operations' risk to exacerbating the mercury methylation issue.

Expectations and hypotheses to be tested to address uncertainty, and attributes that will be measured to test each: The expectation is that ASR operations will not cause a measurable increase in sulfate concentrations downstream. Typically, surface water concentrations of selected constituents are required by NPDES permit in downstream waters. Sulfate along with other constituents will be measured as required to define how recovered water mixes with surface water in the receiving water body. Monitoring

of sulfate (and other water quality parameters) in groundwater and surface water would start with the onset of ASR operations and will continue until, at least, the risk is quantified. Subsequent monitoring will continue for the life of ASR system operation as required by UIC and NPDES operational permits. A numerical relationship will be defined between sulfate and chloride or specific conductance concentrations in recovered waters at representative ASR systems so that specific conductance (measured frequently) can serve as an indicator of potential discharges having elevated sulfate. There may be other complementary monitoring for sulfate conducted by the State in Lake Okeechobee or other downstream surface water bodies, which may provide for a long-term pre-discharge record, but these data may not be of sufficient frequency for future AM guidance. There is also a fish tissue mercury monitoring program in place, in which Lake Okeechobee is sampled once every seven years (see MOM below for more details).

Methodology for testing each expectation or hypothesis. Sulfate concentration shall be measured in accordance with requirements defined in all relevant FDEP Permits (e.g., UIC, CERPRA, NPDES) in recovered water at the ASR wellheads, in WAF surface water, and in adjacent water bodies at watershed ASR systems. .

If increased mercury methylation is quantified in sediments of the WAF or in sediments adjacent to watershed ASR systems, methyl-mercury measurements in fish tissue is merited, annually or biannually. Alternatively, the frequency could be based on the triggers used in the CERPRA permit for the Kissimmee River ASR Pilot Project shown below in **Table D-6** (see footnote*). Methyl mercury analyses in fish tissue, if required, will be consistent with CGM-42 protocol.

Triggers/thresholds that indicate good project performance or need for AM action: No significant increase in sulfate concentrations in surface water within the WAF or at watershed ASR systems, or in methyl mercury concentrations in sediments or fish tissue, attributable to LOWRP operations.

Management options that may be chosen to reduce the impacts of sulfate in ASR discharges. Blend recovered water at ASR systems with surface water within the WAF, or reduce discharge volumes (**Table D-6**).

Table D-6. ASR – methyl mercury (MeHg) management option matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
#2 Will ASR recovered water increase methyl mercury methylation in downstream sediments?	1 to 3 years of operation	Increased sulfate concentrations in WAF surface water or at downstream receiving water bodies; and increase in methyl mercury concentration in downstream sediments	Sulfate in ASR recovered water discharged into the WAF, or in adjacent flowing surface water body. Sulfate plumes in receiving water, if they exist, should be delineated if required by NPDES permitting. For frequency of MeHg fish tissue monitoring: One approach is to monitor MeHg in fish tissue in the WAF, which would more closely related ASR discharge effects on impounded fish. Additional fish tissue analyses from downstream areas annually or biannually	Elevated concentrations of sulfate in the discharge with sufficient volume to potentially affect mercury methylation in downstream sediments. If mercury methylation increases, a more stringent fish consumption health advisory compared with current advisories (see table below for 8 fish species).	Blend ASR recovered water with surface water in the WAF or flowing receiving water to dilute sulfate concentrations to surface water quality at the respective site. Quantify the relationship between sulfate concentration and chloride and/or specific conductance in recovered water at representative ASR systems so sulfate loading in the receiving water can be predicted. Generally, FWC collects the fish, DEP analyzes fish, and DOH issues advisory. FWC samples Lake Okeechobee once every seven years. Therefore, if sulfate levels indicate an increased risk of me-Hg bioaccumulation, additional samples would be needed (likely annually until the risk is characterized). Annual collection of largemouth bass (N=5) per site (4 quadrants). Cost is ~$20,000/year

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
			(depending on amount of ASR discharge and any sulfate monitoring or modeling). Alternatively, the frequency could be based on the triggers used in the CERPRA permit for the Kissimmee River ASR Pilot Project shown below.*		

* CERPRA permit for the Kissimmee River ASR Pilot Project required the following during the recovery phase:

- Initially, sulfate monitoring frequency was weekly at the discharge point and monthly at the monitoring wells.
- After several cycle tests, the CERPRA permit was modified to allow sulfate monitoring to be conducted biweekly for 2 months and then monthly at both the discharge point and at the monitoring wells.
- Initially, total mercury (THg) and methyl mercury (MeHg) monitoring frequency of surface water samples was weekly at the discharge point and monthly at upstream and downstream locations.
- After several cycle tests, the CERPRA permit was modified to allow THg and MeHg monitoring of surface water samples to be conducted monthly at the discharge point.
- THg monitoring in mosquitofish would be triggered if either of the following occurred:
    - MeHg concentrations at the downstream site were significantly greater than MeHg concentrations at the upstream site.
    - THg or MeHg concentrations at the ASR well during recovery were significantly greater than THg or MeHg concentrations at the upstream site.

D.1.4.2.5 ASR – Recovery Efficiency Strategy

Recovery efficiency is defined as the volume of water recovered that does not exceed the primary drinking water standard for chloride (250 mg/L), as a percentage of volume recharged. ASR facilities are expected to have a recovery efficiency of 70% over the long-term. A persistent, significantly low recovery (<30%) will reduce the likelihood of meeting project storage benefits. This AM objective is to identify when, and if, recovery efficiency falls to unacceptable levels and how to remediate this potential. LOWRP AM Uncertainty #5 also relates to Objective #1; therefore was detailed previously in **Section D.1.4.1.2** and **Table D-3.**

D.1.4.3 Objective 3 – Wetland/Wildlife/Habitat Strategies and Management Options

Objective 3 of LOWRP is to increase the spatial extent and functionality of aquatic and wildlife habitat within Lake Okeechobee and the surrounding watershed. The following AM strategies were developed to address the uncertainties about conserving and restoring biota and habitat in and around Lake Okeechobee. From the AM uncertainties, a monitoring plan is presented in **Section D.5.1** and **D.5.2** that documents the ecological monitoring and AM monitoring required to measure success of the project in reaching the goals of Objective 3.

D.1.4.3.1 ASR - Fish Entrainment Strategy

The lower Kissimmee River is a nursery area for black crappie and threadfin shad, both important to commercial and recreational fisheries. The Kissimmee River ASR system incorporated a wedge-wire screen (1 mm slot size) to eliminate fish entrainment at the intake structure. A limited sampling effort still showed entrainment of larval fishes and numerous aquatic invertebrates. The strategy to minimize larval fish entrainment at impoundment-assisted ASR systems will be to recharge from, and recover to the impoundment. This AM objective is to minimize the magnitude of larval fish entrainment at ASR intake structures. Additional design refinements will be incorporated at WAF intake pumps. Currently, the abundance of fish or aquatic invertebrates at risk in the surface water is not known. Therefore, a risk characterization study based on sampling could be useful prior to implementing alternative strategies to reduce entrainment. The Kissimmee River ASR system currently is inactive, so no monitoring is performed. Recommend reinstating larval fish monitoring at the intake structure when KRASR operations are initiated prior to construction of new ASR facilities.

LOWRP AM Uncertainty #3: Will project operations (i.e., WAF pumps or ASR pumps) result in significant occurrences of fish entrainment / impingement?

Objective or Constraint: Constraint (of not adversely affecting the local fisheries).

Region(s): Surface waters with LOWRP ASR and/or WAF pumps, especially the Kissimmee River, Indian Prairie Canal, and Lake Okeechobee.

Associated project features: Wetland Attenuation Feature, ASR intake structures and/or wetland restoration site pumps

Driver or uncertainty type: Ecological and Operational

What is expected to be learned by addressing this uncertainty (i.e., how will LOWRP benefit from addressing this uncertainty)? This will improve the understanding and predictability of the effects of pumping operations on fishery spawning areas.

Expectations and hypotheses to be tested to address uncertainty, and attribute(s) that will be measured to test each. Operations of LOWRP pumps for WAFs or at ASR system intakes located in the watershed will not appreciably reduce the number of larval fishes in the Kissimmee River or other similar nursery areas. These fisheries are important to the local economy and as such, should not be diminished. The impacts to the fisheries could be identified immediately by sampling the pump intake water for evidence of entrained organisms; therefore, sampling should begin as soon as operations start and end when the risk is characterized and remediated, if necessary.

Methodology for testing each expectation or hypothesis. Intake water should be sampled when recharge occurs during the spawning seasons (January to June), and during the time of day when fish larvae are most likely to be entrained. A sampling protocol will be defined during the intake design phase.

Triggers/thresholds that indicate good project performance or need for AM action: Significant numbers of larval fish entrainment during the monitoring period may trigger AM (**Table D-7**).

Management options that may be chosen based on test results. Implement new intake screening techniques (smaller pore size or larger screen area), siting locations of intakes away from resource (either spatially or temporally – [no intakes on lower C-38]). -Operate ASR systems at the WAF conjunctively (recharging from and recovering to the WAF) to minimize impacts to Kissimmee River fisheries. Run the pumps when fish are not spawning, or adjust operations to minimize impacts to larval fish.

Table D-7. ASR fish entrainment management option matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
#3 Will project operations (i.e., WAF pumps or ASR intake pumps) result in significant occurrences of fish entrainment?	Days to weeks of operations	Number of fish and aquatic invertebrates entrained	Number of entrained aquatic organisms associated with ASR intakes or WAF pump operations until the risk is quantified, then frequency may be reduced. Sampling is not needed if pumps are not operating (i.e., during storage and recovery) and assuming no other significant fishery risk is evident (i.e., fish are trapped in the intake even though pumps are not operational).	Unacceptable amount of organisms entrained (TBD)	Implement new intake screening techniques (smaller pore size or larger screen area), re-siting locations of intakes away from resource (either spatially or temporally – [no intakes on C-38]). ASR systems at the WAF conjunctively (recharging and recovering to the WAF) to minimize impacts to Kissimmee River fisheries. Run the pumps when fish are not spawning, or adjust operations to minimize impacts to larval fish Currently, the abundance of fish or aquatic invertebrates at risk in the surface water is not being determined. Therefore, a risk characterization study based on sampling would be useful prior to implementing alternative strategies to reduce entrainment. No monitoring is occurring at the Kissimmee River ASR system (although some very limited sampling occurred previously). Recommend re-instating larval fish monitoring at the Kissimmee ASR system during future operations.

D.1.4.3.2 ASR - Methyl Mercury Strategy

Recovered groundwater can show sulfate concentrations greater than that in surface water and sediments. Increased surface water sulfate concentrations is one of several mechanisms that has been hypothesized to increase the rate of mercury methylation in sediments, possibly leading to methyl mercury bioaccumulation up the food chain. The LOWRP AM strategy described here focuses on monitoring and addressing the threat of additional sulfate from ASR operations; and, if the threat is present, monitoring for increased methyl-mercury bioaccumulation in vertebrates (most likely freshwater fish). LOWRP AM Uncertainty #2 is detailed in **Section D.1.4.2.4** and **Table D-6.**

D.1.4.3.3 Invasive Plant and Animal Species Strategy for Proposed Wetland Restoration Areas

Invasive plant and animal species are important to control if full restoration of wetlands and the WAF are to be achieved. Such species can alter plant community structure, species composition, fire frequency and intensity, habitat quality, compete with and displace native species, threaten endangered species, and alter trophic dynamics and food webs. High profile floral and faunal species (e.g., *Melaleuca*, Brazilian Pepper, Burmese python) and their impacts to the landscape are well documented. However, these species are but a fraction of the invasive and nuisance species in the Lake Okeechobee region. Many of the other species' life histories and responses to disturbance and treatments are important to understand in order to prevent their proliferation in LOWRP implementation. The targeted wetlands areas currently have Bahia grass, Brazilian pepper, and other invasive plant species that need to be eradicated or controlled. Soil and hydrologic disturbances associated with construction of the wetland restoration features, as well as future operation and maintenance of the wetlands, has the potential to allow colonization by invasive species if the species are not controlled. After restoration, invasive or exotic animal species (e.g., hogs, fish [armored catfish, tilapia, or other cichlids], pythons or other herps) may move into these wetlands and disrupt native ecosystems. Uncontrolled proliferation of the species undermines restoration efforts and prevents the LOWRP from achieving restoration objectives.

Under fully restored conditions there would be no (or minimal) unwanted invasive species. The strategy described here focuses on monitoring and addressing the extent of unwanted species, primarily plants. The team recognizes that there will be an Invasive and Nuisance Species Management Plan for LOWRP and control of certain animal species will be governed by that plan.

LOWRP Uncertainty #17. How will new hydrologic regimes affect the occurrence of invasive species in restored wetlands?

Objective or Constraint: LOWRP Objectives #1 and #3

Region(s): Paradise Run and Kissimmee River Central wetland restoration sites.

Associated Project Feature: None specifically; however consideration of hydrologic conditions, as affected by other LOWRP management measures (ASR or WAF), may be needed assuming a connection to the wetland sites. For example, if a wetland site needs to be dried down for invasive species control, it may not be able to receive co-located ASR or WAF flows; therefore, ASR or WAF operations may need tweaking.

Driver or Uncertainty Type: Ecological and Operational

What is expected to be learned by addressing this uncertainty (i.e., how will LOWRP benefit from addressing this uncertainty)? This will improve the understanding and control of invasive species dynamics within these sites and the efficacy of implementing these types of sites elsewhere in the region to achieve habitat restoration.

Expectations or hypotheses to be tested to address uncertainty, and attribute(s) that will be measured to test each. The expectation is that the invasive plants currently on the site will be controlled and that as additional invasives may invade the sites, that the monitoring plan will detect this and control or eradication of invasive species will be implemented. It is also expected that this type of work will be more intensive for the first 5 years of the project until the sites become more ecologically "stabilized". The attributes to be monitored are the location, percentage, and types of invasive species on the site. To this extent, the other anticipated monitoring of wetland vegetation (conducted under Uncertainty #46) should provide the data needed to implement any AM for this uncertainty. In the case of invasive animal species, the vegetative surveys could be designed to detect their presence. We expect that invasive plants will be more problematic and expensive to manage than invasive animal species. Monitoring for invasive species will be covered in the Invasive and Nuisance Species Management Plan for LOWRP (**Annex G**).

What is the time frame in which changes to this attribute are expected to be measureable? Although changes could occur any time, we expect the greatest change and potential need for action to occur within 1 year of acquisition, then within 1–5 years after construction.

When during LOWRP's life cycle should this monitoring begin? After acquisition and within the appropriate season (within 12 months of acquisition).

Methodology for testing each expectation or hypothesis. Assessment of sites via aerial or photographic interpretation in conjunction with ground surveys. Invasive vegetative communities will be mapped to show location and species composition. Post-treatment surveys will report percentage of invasive species controlled or eliminated. For invasive animal species determined to be of significant risk to restoration, standard sampling (and eradication) techniques will be employed (see **Annex G**).

Triggers/thresholds that indicate good project performance or need for AM action: No or minimal unwanted invasive species. In the case of invasive plants, the target is less than 5% coverage (**Table D-8**).

Management options that may be chosen to reduce the impacts of invasive species. Please refer to **Annex G**, the LOWRP INSMP. The efforts of the INSMP and the AM strategy will be coordinated to minimize redundancy. Remediation techniques (flooding, burning, or herbicide) will be appropriate for cost and efficacy. Control techniques for invasive animal species could include trapping or hunting (hogs, pythons), spraying (mosquitos/insects), or electro-fishing/dry-down (fish).

D.1.4.3.4 Algal Bloom Strategy for Proposed WAF

The creation of above ground storage features for surface water in Florida has the potential to create harmful algal blooms (HABs) of cyanobacteria especially if stored water is high in nutrients. The time of year for greatest bloom potential in this area of Florida is May 1 through September 30. HABs in drinking water is a threat to livestock. In Lake Okeechobee or downstream areas, HABs can be a human health threat and cause economic losses to commercial and residential endeavors that are either adjacent to or which rely on water and natural aquatic resources.

LOWRP AM Uncertainty #36. If algal blooms occur in the LOWRP WAF, how will they be managed?

Objective or Constraint: Constraint (of not worsening bloom conditions).

Region(s): Surface waters in the WAF and downstream (Lake Okeechobee and northern estuaries).

Associated project features: WAF and ASR wells

Driver or uncertainty type: Ecological, Operational, Economic, Human Health.

What is expected to be learned by addressing this uncertainty (i.e., how will LOWRP benefit from addressing this uncertainty)? The degree to which HABs in CERP reservoirs/WAFs may contribute to the existing periodic HAB conditions in Lake Okeechobee and downstream.

Expectations and hypotheses to be tested to address uncertainties #36-38 and attribute(s) that will be measured to test each. Our expectation is that HABs are unlikely to occur in the LOWRP WAF throughout much of the year; however, there is a possibility that in some years, environmental conditions may favor HABs. Also, four cycle tests at the Kissimmee River ASR system demonstrated reduction of total phosphorus concentrations from a mean surface water value of 67 ppb (n=54) to less than 15 ppb in recovered water Reduction of total phosphorus in recovered water would reduce the risk of HABs in the receiving waters. In any case, a monitoring plan is needed due the potential risk of severe HABs may cause (as in 2016 and 2017).

What is the time frame in which changes to this attribute are expected to be measurable? May 1st through September 30th if there is water in the WAF.

When during LOWRP's life cycle should this monitoring begin? As soon as the WAF holds water and continue for the life of the project.

Methodology for testing each expectation or hypothesis. HAB protocols currently followed by FDEP, FDOH, and SFWMD will be followed. Monitoring for visual algal blooms will occur throughout the warmer months, but start no later than May 1 and shall continue until at least September 30. If visual observations indicate bloom conditions, water samples will be collected for lab analysis for chlorophyll-*a*, microcystins, anatoxin-a, and possibly other toxins.

How will results, and the triggers/thresholds that indicate good LOWRP performance or need for AM action, be reported? Good performance is defined as no or minimal HAB conditions. The threshold for bloom conditions is a chlorophyll-*a* concentration greater than 40 mg/l, or presence of microcystins or other similar toxins above concentrations deemed problematic by HAB protocols currently followed by FDEP, FDOH, and SFWMD .

Management Options that may be chosen to reduce the impacts of HABs. Options include treatment of surface water before blooms start (add flocculants to reduce nutrients or aeration); adding herbicide to reduce algae; filtering the water prior to discharge; holding the water until the bloom is gone; and route water to agricultural irrigation users if safe (**Table D-8**).

Table D-8. Invasive species management option matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
#17 How will new hydrologic regimes affect the occurrence of invasive species in restored wetlands?	Seasonally to years	Percent of invasive plant coverage, or appearance of new plant or animal invasive species, changes in density of existing invasive species in project footprint	% invasives, species composition; measured annually during appropriate season for spp.	Infestations above 5% for plants; or if there is the presence of damaging (hogs) or dangerous (pythons) animals.	Use standard practices (burning, flooding, herbicides) or novel techniques to control or eradicate invasive plants; also refer to Invasive and Nuisance Species Management Plan. This MOM will be coordinated as much as possible with the INSMP to minimize redundancy. • Adjust LOWRP-related management decisions such as timing of delivering water, or routing water through an area slightly differently than originally specified, in addition to informing the invasive and nuisance species management team actions. • Contribute monitoring data to the refinement of Invasive Risk Assessment Tools used by invasive species management practitioners. During PED, redesign of existing or planned features, as appropriate and feasible, based on lessons learned by ongoing invasive species management efforts in south FL, to make the features less supportive of invasive exotic species proliferation/movement. Note: There is potential overlap with wetland restoration uncertainties, as invasive spp. control is used as a tool to improve success of native plant

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
					communities. During implementation these management actions will be coordinated to complement each other and minimize redundancy.
#36 If algal blooms occur in WAF, how will they be managed?	Seasonally (monthly)	Cell counts or visual presence of HABs	HAB protocols currently followed by FDEP, FDOH, and SFWMD Cell counts of HABs via water samples as needed Currently biovolumes are assessed quarterly	**Visible algae problem, possibly using cell counts over a certain density (if standard is available)** 40 mg/l (ppm) chlorophyll *a* or toxin levels above State recommendations / Tests may include microcystins / cyanobacteria/ anatoxin-a/ and cylindrospermopsin as per HAB protocols currently followed by FDEP, FDOH, and SFWMD	Treat water before blooms start; add herbicide to water; filter water prior to discharge through sand filter; hold water until bloom is gone; route water to ag irrigation users

D.1.4.3.5 Wetlands Strategies and Management Options

Wetland restoration is a LOWRP project management measure and objective designed to improve habitat for fish and wildlife and provide water storage in the Lake Okeechobee watershed. The LOWRP AM strategy described here focuses on monitoring hydrology and vegetation in the restored wetlands and WAF to maximize project benefits and determine when (or if) the restoration trajectory is not being achieved.

LOWRP AM Uncertainty #46: When wetlands are restored, will wetland vegetation return or will consideration of supplemental habitat enhancements be warranted?

Objective or Constraint: This uncertainty is related to LOWRP objective 3 to increase spatial extent and functionality of aquatic and wildlife habitat within Lake Okeechobee and the surrounding watershed.

Region(s): Kissimmee River Center, Paradise Run, and the 1BW WAF

Associated project features: Kissimmee River Center, Paradise Run, and the 1BW WAF.

Driver or uncertainty type: Ecological

What is expected to be learned by addressing this uncertainty, i.e., how will LOWRP benefit from addressing this uncertainty? Addressing this uncertainty will identify the level of effort that may be needed to ensure restoration of native habitat in this area (i.e., documentation of anticipated project benefits). Greater coverage with desirable wetland species will provide more appropriate and productive habitat (greater foraging space, better nesting habitat, etc.) which ties into and enhances the LOWRP goal for increasing the spatial extent and functionality of aquatic and wildlife habitat.

Expectations or hypotheses to be tested to address uncertainty, and attribute(s) that will be measured to test each. Restoring topography and hydrology to former wetland sites is expected to result in the recruitment of wetland vegetative species to complete the restoration of wetland habitat (a project objective). The plan should establish a target to encourage 90% or greater coverage by desirable plant species in both wetland and upland areas. Assuming the appropriate hydrology and topography have been restored, this is further dependent upon the presence of a seed bank within the restored soils as well as limiting (or controlling) coverage of invasive species. Herbaceous wetland systems will respond within one year although may take up to 3-5 years for full development. Forested wetlands would take additional time (as much as 30 years) to determine whether there is appropriate tree growth. Monitoring should be conducted annually for the first 5 years, then at a reduced frequency if restoration trajectory is being met for the life of the project.

Methodology for testing each expectation or hypothesis. One year following wetland creation and construction of the WAF, annual surveys of species composition, diversity, and abundance through either: 1) photo stations and mapping of vegetative communities; or 2) stem counts along transects will be conducted (monitoring method TBD based on cost). Frequent water level monitoring, most likely using SCADA and telemetry, will also occur to determine short vs long hydrology and maximum depths.

How results will be reported, and the triggers/thresholds that indicate good LOWRP performance or need for AM action: Plant species and community specific success criteria should be established based on the anticipated hydrology (i.e., short vs long-hydroperiod). The results will be reported as percent

coverage of desirable vegetation and invasive or non-desirable vegetation. If greater than 10% of the area where hydrology and topography have been restored are colonized with invasive or undesirable species, or if vegetative diversity is lower than expected, management action options will be implemented. Triggers include unexpected low species diversity, vegetation appears to be stressed, or plant diversity differing from the hydrology of the wetland.

Management options that may be chosen to supplement the return of wetland vegetation.

If the vegetation in wetland areas is not appropriate and/or supplemental habitat enhancement is needed the following actions may be applied to provide the appropriate habitat (**Table D-9**):

1) Seeding or planting of desirable plant species may be necessary if the existing seed source is not adequate for anticipated wetland plant generation.
2) Alterations to wetland hydrology to meet a certain wetland community type may be needed. If unable to meet a desired wetland type, a different plant community may need to be chosen.
3) Implement fire management (or other acceptable vegetative control mechanism) to match natural frequency as needed.
4) As identified for the Invasive Species Management (**subsection D.1.4.3.3**), remove undesirable/exotic vegetation (or animal) species to allow natural vegetation to establish and prevent natural vegetation from being out competed. To the extent practicable, exotic vegetation shall be treated with an appropriate systemic herbicide such as an approved brand that may be used near water, or removed using hand-held equipment in a manner that will minimize impacts to the existing native wetland plants and will not cause ruts in the wetland soils which will impede or divert the flow of surface waters.

Cost saving for wetland monitoring may arise by combining water quality sampling occurrences with any overlap with annual plant monitoring events.

Table D-9. Wetland vegetation management option matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
#46 As wetlands are restored, will wetland vegetation return or will consideration of supplemental habitat enhancements be warranted?	1+ years for herbaceous system; and 5+ longer for forested wetlands (to determine if trees are growing appropriately)	Plant species composition, diversity, and relative abundance. Species- and community-specific success criteria may be established; county / NRCS criteria may inform this indicator	Water level (weekly; stage recorder installation needed); Plant health, diversity, and abundance (annually or seasonally as appropriate) photo points, and mapping of diversity.	Is the species diversity as expected (adequate seed bank or do seeds/plants need to be brought in)? Do plants appeared stressed from improper hydrology (can we change hydrology, or should we try for a different plant community)? Is the plant diversity what we'd expect based on the hydrology (or are there improvements needed to the hydrology)?	Plant desirable species; Change hydrology if needed; Implement fire management as necessary; *and as linked to **Invasive Species** Management Option*: Remove undesirable/exotic plant (or animal) species to allow natural vegetation to establish. Because these will be new sites, a monitoring plan is proposed below. Cost may drive the scope of monitoring performed. There may also be opportunities for cost-savings by combining any WQ sampling (yet to be determined) with plant monitoring. Would likely be the local sponsor's responsibility and be similar to that which is currently done for the Kissimmee River Restoration Project or within Lake O littoral zone.

D.1.4.4 Objective 4 – Water Supply Strategies and Management Options

Objective 4 of LOWRP is to increase availability of the water supply to the existing legal water users of Lake Okeechobee. The following AM strategies were developed to address the uncertainties about project performance during droughts. From the AM uncertainties, a monitoring plan is presented in **Section D.1.5.2** that documents the AM monitoring required to measure success of the project in reaching the goals of Objective 4.

D.1.4.4.1 Water Supply in the LOWRP Footprint

The LOWRP AM for water supply focuses on the uncertainty associated with project performance during droughts. The specific concern is whether the actual project performance during challenging drought conditions matches expectations from the project's formulation and modeling phases. If LOWRP's expected ecological benefits are not realized during drought events, AM options exist that can be implemented to improve performance.

LOWRP AM Uncertainty #41: Will there be sufficient water availability to maintain Lake Okeechobee ecology during a drought?

Driver or type: Ecological and operational; balancing multiple objectives (ecological health of Lake Okeechobee and water supply).

This uncertainty is related to two of LOWRP's ecological objectives:

- Improve quantity, timing, and distribution of flows into Lake Okeechobee to maintain ecologically desired lake stage ranges more often (Objective 1).
- Increase the spatial extent and functionality of aquatic and wildlife habitat within Lake Okeechobee and the surrounding watershed (Objective 3).

What is expected to be learned by addressing this uncertainty (i.e., how will LOWRP benefit from addressing this uncertainty)? It is anticipated that addressing this uncertainty will clarify whether LOWRP's storage features are capable of supplying water adequate for maintaining Lake Okeechobee's ecology during droughts. The uncertainty is focused on whether the project features deliver water supply (specifically quantity and timing of deliveries) that match the expectations from plan formulation and modeling simulations. If the project features are found to have lower than expected performance during actual, rather than modeled, drought events, then LOWRP operations can be adaptively managed to improve performance.

Expectations and hypotheses to be tested to address uncertainty, and attribute(s) that will be measured to test each. The expectation to be tested is that actual project performance during drought events will match performance modeled during plan formulation. No new monitoring is proposed in this AM strategy to improve predictions and risk assessment. Data from existing ecological monitoring (e.g., monitoring associated with the Lake Okeechobee Ecological Indicator Score) and Lake Okeechobee stage data will be used for analysis.

Methodology for testing each expectation or hypothesis. This uncertainty is focused on performance during droughts. Given that the timing and severity of droughts in the project areas is unpredictable, the uncertainty cannot be tested until one or more droughts of significant severity is experienced. An

additional constraint is that the project's storage (i.e., WAF storage and ASR storage) will require a start-up period of approximately three years to reach full capacity and allow full assessment of the project's performance. During and after a drought event, the project's performance will be assessed by comparing the calculated Lake Okeechobee Ecological Indicator Score with the indicator score calculated during plan formulation and modeling. If the comparison shows that the indicator score is lower than expected for a drought of similar characteristics, then AM management actions should be considered.

How results will be reported, and the triggers/thresholds that indicate good LOWRP performance or need for AM action: During and after a significant drought event, staff will compare expected versus actual performance. A post-drought summary report will be created, and based on performance results, either verify good performance or recommend AM management options to address any shortcomings. Lessons learned will be provided as feedback to the next stages of CERP design, construction, and implementation.

Management action options that may be chosen include (**Table D-10**):

- Adjust operations of WAF and ASR system (changing timing and rate of releases/recovery).
- Consider operations to recover more water from ASR wells that are in "fresh" aquifers (e.g., aquifers with specific conductance < 1275 µmhos/cm) to maximize recovery efficiency/rate.

Table D-10. Water supply management option matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
#41 Will there be sufficient water availability to maintain Lake Okeechobee ecology during a drought?	Minimum of 3 years. Three years from project start-up to reach full storage, plus an additional period of time to experience one or more drought events.	Lake Okeechobee Ecological Indicator Score	Monthly average Lake Okeechobee stage	Conduct performance review post drought event. Did LOWRP storage features significantly deviate from expected performance based on LOWRP modeling? Was the actual annual Lake Okeechobee Ecological Indicator Score computed after a drought event significantly lower than the annual score computed after a similar modeled drought? Use “drought performance curve” to verify drought is within envelope of POR used for modeling.	1.) Adjust operations of WAF and ASR system (changing timing and rate of releases/recovery). 2.) Consider operations to recover more water from ASR wells that are in “fresh” aquifers (i.e., aquifers with specific conductance < 1275 micromhos/cm) to maximize recovery efficiency/rate.

D.1.5 LOWRP Monitoring Plan

The primary objective of the LOWRP AMMP is to identify the monitoring necessary to inform decision-makers, LOWRP partner agencies, and the public on achieving restoration success, as well as address uncertainties that can be addressed with efficiently structured approaches. The monitoring plan specifies what monitoring is necessary to measure and detect the benefits of capturing, storing, and redistributing water entering the north part of Lake Okeechobee to improve lake stage levels for both environmental restoration and water supply purposes; improving discharges to the Caloosahatchee and St. Lucie estuaries; restoring wetland habitats; and reestablishing connections among natural areas that have become spatially and/or hydrologically fragmented. This monitoring plan also includes monitoring required to reduce uncertainties and address the prioritized AM uncertainties described in **Section D.4**.

This second objective of the LOWRP AMMP is to contain the monitoring and associated costs required under the U.S. Fish and Wildlife Biological Opinion (BO) and other agency permits that are needed to protect and conserve natural resources. The Biological Opinion and associated monitoring information for LOWRP can be found in **Annex A**, Fish and Wildlife Coordination Act Report and Endangered Species Act Compliance. Cost estimates for monitoring associated with the BO, including a project-wide contingency cost, will be in **Section 6**, **Table 6-9**, and **subsection D.1.7** when completed for the final PIR/EIS.

The LOWRP AMMP will be closely coordinated with the CERP RECOVER Monitoring and Assessment Plan (MAP) to ensure that measures and targets selected by the project teams are consistent with system-wide measures and to avoid duplication of efforts. Furthermore, the LOWRP AMMP will ensure temporal and spatial coverage of monitoring parameters that are appropriate to detect changes at the project level. The AMMP will fill gaps in the MAP monitoring parameters to address LOWRP-specific needs by adding additional project-level parameters not included in the MAP. Thus, the LOWRP AMMP will cover LOWRP regions within the watershed that are not covered in the MAP in order to evaluate project success.

Table D-11 summarizes the AM monitoring and includes (1) uncertainty, (2) monitoring attributes, (3) RECOVER costs, (4) other agency costs, (5) LOWRP costs, and (6) sampling frequency that summarizes the monitoring required to address the uncertainties described in **Section D.1.4**. In **Table D-11**, LOWRP monitoring costs are shown as if all monitoring will take place in one 10-year window. Therefore, LOWRP costs here are a 'worst case', whereas the actual monitoring schedule is expected to be staggered over the LOWRP implementation schedule as shown in **Figure D-1** and would therefore cost the project less per year.

For each LOWRP project objective, monitoring has been identified to measure progress toward success of meeting the objective. **Table D-12** summarizes the project-specific monitoring and includes (1) monitoring attributes, (2) monitoring methodology and frequency, (3) monitoring cost estimates, (4) LOWRP monitoring locations, (5) Current MAP monitoring component (6) Current monitoring by other agencies/universities and (7) Performance Measures and ecological indicators. In **Table D-12**, LOWRP monitoring costs are shown as if all monitoring will take place in one 10-year window. Therefore LOWRP costs are a 'worst case', whereas the actually monitoring schedule is expected to be staggered over the LOWRP implementation schedule as shown in **Figure D-1** and would therefore cost the project less per year.

D.1.5.1 Adaptive Management Monitoring

Table D-11 summarizes the AM monitoring to address the prioritized uncertainties. The AM monitoring also covers some of the project-level monitoring described in **Table D-12** and is noted in where AM monitoring will also be used as project-level monitoring.

Table D-11. LOWRP AM monitoring cross-walked with other monitoring programs.

LOWRP Objective	Category or Specific LOWRP Area	Uncertainty	AM ID# or PM	Attributes to be Monitored	Ongoing RECOVER 1-Yr Cost	Ongoing Other Agency 1-yr Cost	LOWRP 1-yr Cost*	Sampling Frequency	Notes
1	Lake Okeechobee	Will ecological indicators respond to lake stage changes as their PM scores suggest? (i.e., are the PM scores indicative of ecological responses?)	25	Abundances of ecological Indicators : *Chara* – nearshore 1km grid cell centers Cyanobacteria – three pelagic and one nearshore site Epipelon – three nearshore sites Epiphytes – around 20 nearshore sites, depends on amount of SAV Panfish – data collected from fishermen (creel surveys) SAV – nearshore 1km grid cell centers and 4 nearshore transects with 9 or 11 sites	$0	All but panfish: $201,610 (SFWMD) Panfish: $5,280 (FWC) Lake Imagery $75,000 (every 3 years, SFWMD)	$0	Annual summer: *Chara*, vascular SAV, nearshore SAV, cyanobacteria, littoral EAV Twice annually (spring and fall): epipelon and epiphytes Annual winter two-month panfish creel data	
1	Lake Okeechobee	Will fish and wildlife communities benefit from project's effect on lake stages or will additional habitat management be needed?	26	Wading birds, snail kites, fish	Wading bird nesting: $100,000	Snail Kites: $150,000 (USACE regulatory) Wading Bird Foraging: $25,000 (SFWMD) Fish: $25,500 (FWC electrofishing)	$0	Annual: wading bird and snail kite abundance and nesting effort/success, fish composition/catch rate/age distribution	
1/2	ASR	Will ASRs be able to deliver the recovery efficiency we are expecting?	5	Volumes of water recharged and recovered, measured daily, compiled ,monthly		Likely to be additional FDEP permitting costs not captured in this spreadsheet	This is a spreadsheet exercise assuming a regulatory requirement of accurate, continuous recordkeeping (of volume in vs. volume out) to be maintained by the project. So, costs should be minimal. Total $5,000.00 per year	Daily, compiled monthly	The end point of this monitoring is to determine recovery efficiency and track any changes.
2	Estuaries	Oysters When discharges from LO are reduced and salinity regimes improved, will species' abundance and diversity in the estuaries increase, or will consideration of supplemental habitat	12	Monthly at 18 existing RECOVER sites Growth Disease Predation Reproductive Development Recruitment Density; and Live and Dead counts (twice per year – spring and fall)	$55,000	NA	$0	Monthly at existing RECOVER sites	Mapping should be done for IG&T by RECOVER, but if not the project will need to MAP oysters 1x/5yrs. Currently scheduled for mapping SLE and CRE 2018-2019

LOWRP Objective	Category or Specific LOWRP Area	Uncertainty	AM ID# or PM	Attributes to be Monitored	Ongoing RECOVER 1-Yr Cost	Ongoing Other Agency 1-yr Cost	LOWRP 1-yr Cost*	Sampling Frequency	Notes
		enhancements be warranted? Will there be displacement / limitation of spat / SAV in the Caloosahatchee Estuary as a result of the project?							
2	Estuaries	Submerged Aquatic Vegetation When discharges from LO are reduced and salinity regimes improved, will species' abundance and diversity in the estuaries increase, or will consideration of supplemental habitat enhancements be warranted? Will there be displacement / limitation of spat / SAV in the Caloosahatchee Estuary as a result of the project? Will anticipated salinity improvements result in natural recruitment / reestablishment of SAV?	16	Tier 1 - Landscape scale – aerial mapping every 2 years Tier 2 - Patch-scale - species specific cover and abundance at the end of the dry and end of the wet season. Tier 3 – Fixed-point sampling – cover, abundance, shoot density, canopy height, above and below ground biomass - sampling occurs every other month from April through November	$200,000 every 2 years for Tier 1 mapping $105,000 for Tiers 2 and 3	NA	$0	Tier 1 - aerial mapping every 2 years Tier 2 - at the end of the dry and end of the wet season. Tier 3 –every other month from April through November	Mapping should be done for IG&T by RECOVER, but if not the project will need to MAP SAV 1x/3-5yrs.
2	Estuaries	Will augmentation of substrate be needed if desired salinities are achieved and recruitment is still not at expected levels?	23	Substrate Type Benthic map at 2 years and then every 10 years after Benthic maps available from 2011	NA	NA	$75,000	Benthic map at 2 years and then every 10 years after	

LOWRP Objective	Category or Specific LOWRP Area	Uncertainty	AM ID# or PM	Attributes to be Monitored	Ongoing RECOVER 1-Yr Cost	Ongoing Other Agency 1-yr Cost	LOWRP 1-yr Cost*	Sampling Frequency	Notes
2/3	ASR	Will ASRs increase mercury methylation in downstream sediments?	2	Sulfate measured in recovered water at ASR wellheads and at representative surface water locations in the WAF and adjacent surface water bodies at watershed ASR systems Sulfate plumes, if they exist in receiving waters, should be definedif required by NPDES permit <u>Additional Discussion needed</u> for frequency of MeHg fish tissue monitoring. One approach is to monitor MeHg in fish tissue in within the WAF or adjacent to watershed ASR systems Alternatively, the frequency could be based on the triggers used in the CERPRA permit for the Kissimmee River ASR Pilot Project	NA	See Subsection C in "LOWRP 1-yr cost" Column (for MeHg sampling). The FWC, DOH, and FDEP conduct fish tissue monitoring every 7 years on Lake Okeechobee, so we can assume FWC will absorb sampling costs once every 7 years but the project will have to cover the other years. (i.e., $10,000/year)	Total Max if all 3 below are done = $45,200 (would be reduced in out years) A. $800 per WQ sample (9 parameters; see Notes) (Sulfate alone sample =~$500); assuming max of 6 months of recovery discharges= 24 weekly grab samples in year 1. Total annual cost = (24x800) = $19,200 or sulfate alone ~ $12,000. Year 2 could be reduced to $9,600 for bi-weekly or $4,800 for monthly sampling (9 parameters) B. To delineate sulfate plumes would require a mixing model or more intensive discharge sampling downstream at various flow rates. A one-time cost of $10,000 should be sufficient to determine this. C. Total analytical costs associated with methyl mercury fish tissue monitoring = $10,000 maximum for each sampling event per year (5 bass per year per quadrant)	Year 1 Weekly during recovery Year 2+ Biweekly for two months and then monthly	
3	ASR	Will project operations result in significant occurrences of fish entrainment?	3	Number of entrained organisms. Sampling of entrained fish larvae will occur only at representative watershed ASR systems where fisheries resources are well-defined. Fish entrainment studies are not necessary at WAF because all recharge and recovery will occur within the WAF.	NA	NA	Total cost for larval fish sampling (per year) is $7,400 (6,400 for staff time and sampling and $1,000 equipment and reporting). 8 sampling events per year spread out amongst the spawning season to characterize the threat. Each event consists of one day sampling (up to 4 temporal samples, sampled immediately pre- and post-sunset and sunrise) ($400); and one day (8 hours) identification time ($400) to guild (invertebrate order or fish family) (assumes 2hrs processing per each of 4 samples). If any larval fish are entrained, then that indicates a potential problem to be adaptively managed.	8 sampling days per year (based on an anticipated six-month recharge operations coinciding with the 4-5 month fish spawning season). When the risk is quantified, then frequency may be reduced in out years unless threat is mitigated (and sampling can stop).	Cost based on weekly sampling (while pumping during breeding season) but separated into 4 individual grab samples on that day for delineation of daylight vs nighttime entrainment. Maximum of 8 sampling days per year. Staff time cost based on previous uncertainty (i.e., #2) ($400/day), but Day 1 for collection and Day 2 for identification.
3	Invasive Species	How will new hydrologic regimes affect the occurrence of invasive species in restored wetlands?	17	% invasives, species composition	NA	NA, unless FWC wishes to take responsibility for management of exotic invasive species on the site (but this would only be for out-years, after construction is completed)	Total costs for identification of an invasive plant problem would be minimal as activities under Uncertainty #46 will identify if a problem exists. If exotic plants need to be treated on the entire 5,400 acres of wetland sites, then one-time spray	Annually.	This is linked to Uncertainty #46 in that plant identification and mapping will guide the need for Adaptive Management here.

LOWRP Objective	Category or Specific LOWRP Area	Uncertainty	AM ID# or PM	Attributes to be Monitored	Ongoing RECOVER 1-Yr Cost	Ongoing Other Agency 1-yr Cost	LOWRP 1-yr Cost*	Sampling Frequency	Notes
							costs = $175,610. This cost is based on one $80 jug of Round-up Pro Max will treat 2.46 acres.		We received another flat cost estimate of $100 per acre for spraying and $10 per acre for burning (which would be triple the cost in the column to the left)
3	Invasive Species	If algal blooms occur in the WAF, how will they be managed?	36	Cell counts of HABs via water samples as needed per the HAB action protocols.	NA	NA	Total sampling and analytic cost = $8,160. Assumes some regular (weekly) inspection of the facility would be needed during potential "bloom months". (4hr per trip)(16 trips x $200 = $3,200). Analytical costs are $100 per sample for Microcystins, or $200 for Anatoxin-a. Assuming worst-case of 16 samples per year = $4,800 for analytical costs only. Add $10 per sample for equipment (adds $160/yr).	Once per week over the 16 hottest weeks of the year.	Staff cost = $50/hour
3	Wetlands	When wetlands are restored, will wetland vegetation return or will consideration of supplemental habitat enhancements be warranted?	46	Water level (weekly) Plant diversity and abundance (annually)	NA	NA	Water level monitoring could be automated and relatively inexpensive in out-years (i.e., once installed). Installation = $120,000 for 6 recorders. Annual O&M for all = $3,000. Year one cost for hydrologic monitoring = $123,000. Vegetation Monitoring costs will be dependent on the level of effort needed to determine success. UMAMs will be needed to determine pre-restoration conditions, along with annual aerial photo-interpretation with GIS mapping, total Year-1 costs = $14,800; (broken down in Notes column). Out-year costs reduced for aerial photo interpretation.	Water Level Weekly Plant Diversity and Abundance Annually	Assumes 5,400 acres total. Six digital stage recorders (4 in Paradise Run and 2 in Kissimmee Center site). Each cost 20,000 for installation and annually $500 for data collection and O&M. GIS Mapping of Vegetative Groups at 6 locations (4 in Paradise, 2 in Kissimmee) = $3,000. Aerial Photo Interpretation for Vegetation across entire sites once every 5 years = $10,000. UMAMs pre-restoration (annual cost =10 days for 3 staff; = 30 x $60 = $1800 for all acreage. Staff time = $60/hr.
4	Water Supply	Will there be sufficient water availability to maintain LO ecology during a drought?	41	Monthly average Lake Okeechobee stage	No field costs. Staff time for data evaluation.	No field costs. Staff time for data evaluation.	No field costs. Staff time to calculate and report the Lake Okeechobee Ecological Indicator Score during and after a drought event is ~2 hours. Total cost in a drought year = $120.	Stage data is already routinely collected. No additional sampling is required.	

D.1.5.2 LOWRP Project-specific Monitoring

For each LOWRP project objective, monitoring has been identified to measure progress toward success of meeting the objective. **Table D-12** summarizes the (1) monitoring attributes, (2) monitoring methodology and frequency, (3) monitoring cost estimates, (4) LOWPR monitoring locations, (5) Current MAP monitoring component (6) Current monitoring by other agencies/universities, and (7) Performance Measures and ecological indicators. The goal of project-specific monitoring is to detect the expected improvements from LOWRP features and operations.

D.1.5.2.1 Objective 1

Improve quantity, timing, and distribution of flows into Lake Okeechobee to maintain ecologically desired lake stage ranges more often.

This objective has three main components, one is the amount of time Lake Okeechobee remains in the ecologically preferred envelope; another is the amount of time the lake is above the extreme high lake stage and the amount of time the lake is below the extreme low lake stage, and the third is the ecological response to lake hydrology. The nearshore and pelagic regions of Lake Okeechobee are occupied by a number of key ecological communities which can be used to evaluate the environmental health of the lake as a function of their responses to changing hydrologic conditions. For this objective, two attributes will be monitored: a) Lake stage and b) ecological indicators (vascular SAV, *Chara*, panfish, cyanobacteria, epiphyton and epipelon). Lake stage data will be leveraged from existing monitoring networks and the LOWRP Hydrometeorological Monitoring Plan (**Annex D, Part 3**). Ecological indicator data will be leveraged from existing monitoring done by SFWMD, but additional monitoring of panfish will be required for this project. The detailed field methodology to accomplish this objective will be described in more detail once LOWRP is authorized. Additional AM monitoring may be required and is discussed in **Section D.4.1** and **Table D-11**.

D.1.5.2.2 Objective 2

Improve estuary discharges from Lake Okeechobee to improve the salinity regime and the quality of oyster, SAV, and other estuarine community habitats in the northern estuaries.

Using LOWRP planning model output, areas have been identified within the northern estuaries where the most change is expected due to LOWRP. In these areas salinity conditions will improve the habitat for oysters and SAV, which will be the attributes to measure for project success in meeting Objective 2. For this objective, three attributes will be monitored: a) Lake Okeechobee discharges to the Caloosahatchee and St. Lucie Estuaries, b) oyster abundance, health and distribution; and c) SAV shoot count, density and canopy cover. Lake discharge data will be leveraged from existing monitoring networks and the LOWRP Hydrometeorological Monitoring Plan (Annex D, Part 3). The monitoring methodology includes gage data at S-79 and S-80. Oyster and SAV data will be leveraged from the RECOVER MAP. Oyster data will include density, live and dead counts, growth, disease, predation, reproductive development and recruitment. SAV data will include a nested, multi-tiered monitoring approach that looks at regional, patch, and shoot-level responses to environmental change, and include aerial mapping, haphazard sampling within tessellated hexagons, and Braun-Blanquet densities, shoot counts, and biomass metrics as to better understand within-bed productivity, respectively.. The detailed field methodology to accomplish this objective is described in the RECOVER MAP and will be described in more detail once LOWRP is authorized

and the SAV protocol is approved by the RECOVER Executive Committee. Additional AM monitoring may be required and is discussed in **Section D.4.2**.

D.1.5.2.3 Objective 3

Increase the spatial extent and functionality of aquatic and wildlife habitat within Lake Okeechobee and the surrounding watershed.

Increased spatial extent of desirable wetland species will provide more appropriate and productive habitat (greater foraging space, better nesting habitat, etc.) which ties into and enhances the LOWRP goal of increasing the spatial extent and functionality of aquatic and wildlife habitat. This objective has three main components; water level, vegetation change, and biological indicators such as wading birds, aquatic fauna, and fish. The restored wetlands and the WAF are expected to restore wetland hydrology, vegetation, and wildlife. For this objective three attributes will be monitored: a) water levels in the wetlands; b) vegetation; c) wading birds; d) anurans; e) small mammals; and f) fish. Water level data will be leveraged from existing monitoring networks and the LOWRP Hydrometeorological Monitoring Plan (**Annex D, Part 3**). Vegetation data will include percent coverage of native desirable species vs percent coverage of invasive exotic or undesirable species through visual observation of species diversity and coverage in the two wetland restoration sites (Kissimmee River Center and Paradise Run) and in the 1BW WAF. Wading bird data will include total wading bird counts, species richness, species diversity, and nesting success. Anuran data will include species richness, species diversity, species occupancy, and water bodies for breeding. Small mammal data will include species richness, species diversity, and species occupancy. Fish data will include species richness, species diversity, migration/movement and age/size class. Detailed field methodology to accomplish this objective will be described in more detail once LOWRP is authorized. Additional AM monitoring may be required and is discussed in **Section D.4.3** and **Table D-11**Error! Reference source not found..

D.1.5.2.4 Objective 4

Increase availability of the water supply to the existing legal water users of Lake Okeechobee.

Monitoring for this objective is covered in the LOWRP Hydrometeorological Monitoring Plan (**Annex D, Part 3**).

Table D-12. LOWRP project-specific monitoring cross-walked with other monitoring programs.

LOWRP Objective	LOWRP Monitoring Attributes	Monitoring Methodology	Number of Transects / Sampling Points	Monitoring Frequency	Specific LOWRP Monitoring Locations	Estimated Annual Cost	Current Monitoring (Other)	Current Monitoring (RECOVER)	Performance Measures/Ecological Indicators	Monitoring Targets
1 - Improve quantity, timing, and distribution of flows into Lake Okeechobee to maintain ecologically desired lake stage ranges more often.	Abundance of ecological Indicators (*Chara*, cyanobacteria, epipelon, epiphyte, PanFish (bluegills and redear sunfish) and vascular SAV), as well as acreage of total SAV in nearshore and coverage of 9 EAV spp groups in littoral zone	–See Table D-11	See Table D-11	See Table D-11	See Table D-11	$0	See Table D-11	NA	RECOVER Lake Okeechobee Ecological Indicator PMs Lake Stage Envelope PM Extreme High and Extreme Low Lake Stage PMs	The Ecological Indicator PMs target is a cumulative point score of 427 points over the 41 period of record (POR) lake stages The annual summer nearshore SAV target is 50,000 acres. The littoral EAV cumulative target is 28,825 hectares with four of the individual targets including a range that could be smaller and three including a range that could be larger. The annual sentinel sites cumulative target is 850 hectares with the same indicators having either smaller or larger ranges.
2 - Improve estuary discharges from Lake Okeechobee to improve the salinity regime and the quality of oyster, SAV, and other estuarine community habitats in the northern estuaries.	**Oysters** Growth Disease Predation Reproductive Development Recruitment Density; and Live and Dead counts (twice per year – spring and fall)	See Table D-11	See Table D-11	See Table D-11	See Table D-11	**$0**	See Table D-11	Monthly oyster monitoring at 18 sites Growth Disease Predation Reproductive Development Recruitment Density; and Live and Dead counts (twice per year – spring and fall)	RECOVER Northern Estuaries Salinity Envelope PM RECOVER Oyster PM	Maintain a salinity range favorable to fish, oysters and submerged aquatic vegetation (SAV) 834 acres of live oyster habitat in the St. Lucie Estuary 500 acres of live oyster habitat

LOWRP Objective	LOWRP Monitoring Attributes	Monitoring Methodology	Number of Transects / Sampling Points	Monitoring Frequency	Specific LOWRP Monitoring Locations	Estimated Annual Cost	Current Monitoring (Other)	Current Monitoring (RECOVER)	Performance Measures/Ecological Indicators	Monitoring Targets
										in the Caloosahatchee Estuary.
2 -Improve estuary discharges from Lake Okeechobee to improve the salinity regime and the quality of oyster, SAV, and other estuarine community habitats in the northern estuaries.	**Submerged Aquatic Vegetation** Tier 1 - Landscape scale – aerial mapping every 2 years Tier 2 - Patch-scale - species specific cover and abundance at the end of the dry and end of the wet season. Tier 3 – Fixed-point sampling – cover, abundance, shoot density, canopy height, above and below ground biomass - sampling occurs every other month from April through November	See Table D-11	See Table D-11	See Table D-11	See Table D-11	**$0**	See Table D-11	Fixed transects 3x/yr during growing season for monitoring Mapping 1x/3-5 years	RECOVER Northern Estuaries Salinity Envelope PM RECOVER SAV PM	Maintain a salinity range favorable to fish, oysters and submerged aquatic vegetation (SAV) SAV coverage
3 - Increase the spatial extent and functionality of aquatic and wildlife habitat within Lake Okeechobee and the surrounding watershed**.**	Wetland Vegetation % Cover of native desirable species % Cover of invasive exotic or undesirable species	Visual surveys, UMAMs, and Aerial Photo Interpretation for Vegetation across entire sites once every 5 years.	A total of 12 transects in Kissimmee River Center (2 transects), Paradise Run (4 transects) and the WAF (6 transects).	Annually for transects, once every 5 years for photo interpretation and mapping	Kissimmee River Center (covered in AM Monitoring, Table D-11) Paradise Run (covered in AM Monitoring, Table D-11) 1BW WAF	For WAF an additional $14,800 is needed for Year one. Years 2-5 = $6,800 (annualized for 5 year deliverable)	None	None	UMAM Wetland vegetation	100% coverage with desirable wetland species
3 - Increase the spatial extent and functionality of aquatic and wildlife habitat within Lake Okeechobee and the surrounding watershed.	Wading Birds and waterfowl Total wading bird count Species richness Species diversity Nesting success	Visual surveys Aerial surveys, count number of nests per species	Transects in Kissimmee River Center, Paradise Run and the WAF	Bi-annually/Monthly	Kissimmee River Center Paradise Run 1BW WAF	For Kissimmee Center, use existing SFWMD monitoring program for Kissimmee River (minimal cost to add on). For Paradise Run and WAF, expand	None	WAF and Paradise Run could be covered by current RECOVER contract (may require contract mod and small cost increase)	Wading bird usage of the restored site	Increase in the number of nesting birds. Wading bird recruitment and survival of offspring.

LOWRP Objective	LOWRP Monitoring Attributes	Monitoring Methodology	Number of Transects / Sampling Points	Monitoring Frequency	Specific LOWRP Monitoring Locations	Estimated Annual Cost	Current Monitoring (Other)	Current Monitoring (RECOVER)	Performance Measures/Ecological Indicators	Monitoring Targets
						RECOVER contract.				
3 - Increase the spatial extent and functionality of aquatic and wildlife habitat within Lake Okeechobee and the surrounding watershed.	Anurans Species richness Species diversity Species occupancy Water bodies for breeding	Acoustic surveys Transect and pipe surveys Wet season dipnet sampling	Sites in Kissimmee River Center, Paradise Run and the WAF	Bi-annually Wet season breeding surveys	Kissimmee River Center Paradise Run 1BW WAF	$25,000	None	None	Diversity and abundance of anurans	Anuran diversity and recruitment in the project area including reproduction and survivability of offspring
3 - Increase the spatial extent and functionality of aquatic and wildlife habitat within Lake Okeechobee and the surrounding watershed.	Small mammals Species richness Species diversity Species occupancy	Camera tapping	Transects in Kissimmee River Center, Paradise Run and the WAF	Bi-annually	Kissimmee River Center Paradise Run 1BW WAF	$20,000	None	None	Diversity and abundance of small mammals	A diverse mix of small mammal species
3 - Increase the spatial extent and functionality of aquatic and wildlife habitat within Lake Okeechobee and the surrounding watershed.	Fish Species richness Species diversity Migration/movement Age/size class	Seines, dip nets, electroshockers (non-lethal), cast nets	Transects in Kissimmee River Center, Paradise Run and the WAF	Bi-annually (mid and late wet season)	Kissimmee River Center Paradise Run 1BW WAF	$20,000	None	None	Fish species diversity, abundance and seasonal variation.	Fish species diversity, recruitment and movement

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D.1.5.3 Biological Opinion Monitoring and Regulatory Monitoring

The LOWRP AMMP is to contain the monitoring and associated costs required under the U.S. Fish and Wildlife Service Biological Opinion and other agency permits that are needed to protect and conserve natural resources. The LOWRP AMMP will be updated accordingly when the Biological Opinion is received and FDEP and other agency permits are obtained. Additional regulatory monitoring will be added as required.

D.1.6 Implementation of LOWRP Adaptive Management

Adaptive management provides an interdisciplinary, integrated, structured process for lowering risk, increasing certainty and informing decisions. For AM to be successful in ensuring the delivery of intended benefits and avoiding unintended negative impacts of LOWRP, AM activities should continue beyond project planning for the entire project-life cycle from completion of the PIR through all aspects of monitoring, engineering, design, construction, operations, and maintenance components. In addition, mechanisms must be in place to collect, manage, analyze, synthesize, coordinate, and integrate new information into management decisions. Adaptive management implementation can only succeed when decision makers have sufficient funding and staffing resources to implement the AM and monitoring plans. In addition, success requires political and stakeholder support to implement the AM decision methodology and to adjust management decisions based on what is learned.

Per the Programmatic Regulations for the Comprehensive Everglades Restoration Plan (2003), an AM process has been developed for CERP that guides system-wide CERP AM and project-level AM (CGM 56 2010; RECOVER 2011b). This detailed CERP guidance adheres to WRDA 2007 and the WRDA 2007 implementation guidance provided by USACE in 2009 in that it focuses on using monitoring information to inform projects and project components by resolving uncertainties and providing mechanisms to efficiently incorporate new knowledge in project planning, design, and implementation. LOWRP has and will use this framework to implement AM. Doing so will allow LOWRP to both take advantage of and contribute to work being done system-wide and by other projects. Because new information is continually becoming available, the LOWRP AMMP must be recognized as a living document that is improved upon through incorporation of new information. In particular, as each project component is designed and implemented, specific AM strategies and monitoring should be reviewed and adjusted as necessary.

To facilitate implementation of the LOWRP Adaptive Management Plan, RECOVER scientists will coordinate the AM monitoring, analysis, and reporting throughout the life of the project. RECOVER will include expertise from multiple agencies and disciplines, such as, hydrologists, engineers, and water managers; in other words, while RECOVER will be the central organizing entity of the AM monitoring, analysis, reporting, and elevating of options to adjust LOWRP, RECOVER will continually coordinate with others to ensure that a full suite of experts is included. RECOVER scientists will coordinate with project managers to inform possible AM actions as outlined in subsequent sections. LOWRP project funds during PED, construction, and operations and maintenance will support RECOVER's coordination efforts and the AM strategies described in this LOWRP Adaptive Management Plan. LOWRP funds will be used to fund monitoring directly related to LOWRP AM monitoring needs and the funds are not designed to replace RECOVER's system-wide monitoring and science efforts. However, the RECOVER system-wide monitoring information will be used in combination with LOWRP's monitoring to best address key questions about achieving restoration success. The intent is to have complementary efforts that maximize efficiency of monitoring. RECOVER will be responsible for ensuring that the AMMPs are implemented and that the

information is appropriately managed and integrated into the CERP decision process as outlined in the Adaptive Management Integration Guide (RECOVER 2011b).

This section identifies which AM activities will occur during the phases of LOWRP project implementation and how they relate back to the project's AM plan. Unless otherwise noted RECOVER will be engaged in all activities. Adaptive management will be reiterated in the coming phases of LOWRP, and the Adaptive Management Plan will be reviewed and updated. At such time, more baseline data and lessons learned will be available from other monitoring programs and restoration projects. Given the new knowledge, key questions, monitoring thresholds/triggers, and AM options proposed in this plan may need refinement. Therefore, items included in this plan are not guaranteed to be included or funded as-is, but will be refined and considered again prior to LOWRP implementation.

Adaptive management was incorporated during LOWRP's planning with AM experts integrally involved throughout the planning process. All of the items in the CERP "Project Level Adaptive Management Checklist" were considered and/or incorporated during the planning of LOWRP. CEMs were used for the other project areas including Lake Okeechobee, northern estuaries, and the total system (http://141.232.10.32/pm/recover/cems.aspx). A cost effectiveness/incremental cost analysis of the future AM options was not conducted due to time constraints during planning. Adaptive management activities on the checklist that will take place during and after the project's implementation are described here in the Adaptive Management Plan (CERP AM checklist: http://141.232.10.32/pm/program_docs/adaptive_mgmt.aspx#p7HGMpc_1_2). The following subsections identify how AM has been and will be incorporated into each LOWRP project phase: planning, design, construction, and operations and maintenance.

D.1.6.1 How Adaptive Management Activities Were Applied During LOWRP Planning

Concerns and uncertainties were identified in an initial step for LOWRP, discussed throughout the USACE "In Progress Review" meetings, and discussed throughout the interagency and public participation process. During screening of management measures to develop alternative plans, screening criteria included flexibility (the speed, ease, efficiency that a management measure could move water to adjust to changing real-time conditions such as storms or extreme events), robustness (the ability to function effectively in the face of broad-scale, uncertain future conditions such as climate change [NRC 2007]), and future compatibility (the efficiency with which this management measure or configuration would complement future restoration work). Finally, a broadly invited interagency team developed the AM plan to prioritize the remaining uncertainties and describe in the plan how they may be addressed through the life of LOWRP and inform CERP implementation.

Overall, the inclusion of AM principals during this study provided several avenues to address and reduce risks and uncertainties and, during its continued implementation in the following phases of LOWRP, will provide a mechanism to continue LOWRP's achievement of its vision, goals, and objectives and effectively remain within its constraints.

D.1.6.2 How Adaptive Management Activities Will Be Applied during LOWRP Implementation

RECOVER will work with the LOWRP project managers to develop workplans and monitoring scopes of work in coordination with other technical resource providers as needed to provide the budget, schedule, and details to execute the AM strategies identified in the Annex D. At a minimum, one RECOVER scientist should be dedicated to overall all coordination of the LOWRP monitoring and AM efforts. Additional technical expertise should be engaged as needed. AM activities will be implemented in sequence with the

project components being implemented (see **Table D-1**). Workplans will include all necessary activities, resources needed, and schedule for completion so that they can be resourced appropriately and tracked by the project manager for progress and execution as part of the project schedule and implementation plan during design, construction, and operations.

Project components will be implemented in a staggered fashion due to budget (amount of funds available each year), regulatory requirements (permits and compliance monitoring feedback), and LOWRP dependency constraints (state and federal projects required prior to implementation of a specific LOWRP project component). Time needed to conduct certain AM activities and tasks to inform subsequent project component is incorporated in the LOWRP implementation schedule and the Strategies section of the LOWRP Adaptive Management Plan. Each AM strategy workplan will explain the timing needed to observe, understand, and report restoration performance results from any design tests, pilot projects, and/or response to phases of project components or full project components being implemented to inform LOWRP implementation. **Figure D-1** shows that AM can proceed associated with a full project component, phase, or test, with associated monitoring, to inform subsequent restoration actions. Monitoring should be implemented before and after implementation for regulatory compliance, restoration response, and AM purposes, as described in the AM and monitoring plans. The monitoring data assessed after construction, and any other current information, can then be coordinated with appropriate CERP agencies to determine progress or the need for adjustments. Adjustments are implemented as part of the AM strategies or made to the next set of LOWRP project components. The information can also be used to inform future CERP projects.

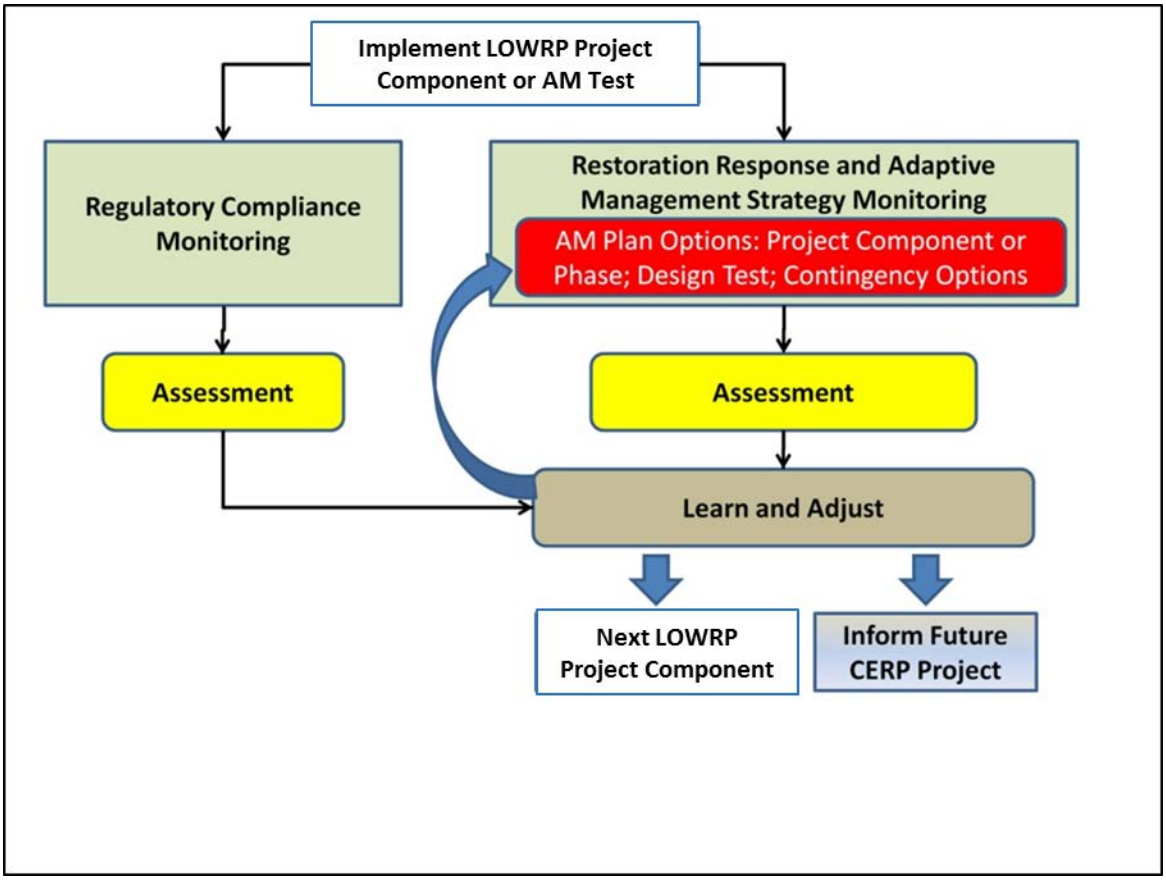

Figure D-1. Adaptive management strategies and project implementation diagram.

Adaptive management during LOWRP's implementation will incorporate learning to reduce uncertainties and associated risk with some of the components, with the intent of achieving cost savings and providing the ability for certain project components to be implemented more efficiently. In order for this learning to occur, AM strategies will need to be implemented in sequence with the project schedule.

D.1.6.3 Design

AM activities will also be executed during the preliminary engineering and design (PED) phase of the project. Adaptive management strategies that may involve pilot projects (ASR), operational tests, and phased implementation and will be discussed during value engineering and detailed design to determine the full scope of each test, project construction phase, and implementation. RECOVER team members tasked with overseeing LOWRP AM will coordinate with the LOWRP engineers and water managers to ensure project designs, tests, and project operations manual allow flexibility for AM implementation, as well as ensure monitoring plan designs, thresholds-triggers, and reporting is consistent with engineering design and water management needs. Adaptive management strategies will also involve updates to monitoring and assessment plans to better develop experimental designs, monitoring locations, and analysis methods, as well as initiate baseline monitoring data. Some AM activities will need to begin early enough to allow development of the monitoring plan design and to implement monitoring contracts to support establishment of a minimal baseline before construction of LOWRP project components is completed.

D.1.6.3.1 Monitoring and Experimental Design

RECOVER, other agency monitoring, and other contracts that are being relied upon to inform the LOWRP implementation as identified in the AMMP will be reviewed to determine if changes in scope and frequency are needed to better capture LOWRP effects. The activities described here fall within the approved LOWRP AM budget. LOWRP specific monitoring identified in the monitoring and AM plan will require scopes of work, schedules, and assessment protocols to be developed and coordinated by RECOVER to determine monitoring location and experimental design details to update the monitoring plan. Data analysis and modeling may be needed to inform the statistical sampling design needed for monitoring to be able to test LOWRP project hypotheses (AM triggers needed for NE SAV and oysters, **D.4.2.1** and **D.4.2.2**). Before and after control designs will be specified in the monitoring plan update, consistent with the parameters identified in each strategy and within the constraints specified by regulatory permits. LOWRP monitoring plan design will use existing data where possible, e.g., RECOVER and other agency monitoring efforts. Adaptive management strategies maybe updated with more detailed decision trees to outline the decision-points associated with triggers/thresholds identified in each strategy. Decision trees will describe who receives reports, who provides guidance on decisions associated with the results, and what potential adjustments might occur. Updated monitoring plans will be coordinated for approval by implementing agencies and concurrence by participating agencies and Tribes.

D.1.6.3.2 Baseline Monitoring

In cases where there is not sufficient pre-project data monitoring, contracts will need to be initiated prior to construction of specific LOWRP components. Final assignment of agency monitoring responsibilities will be made after state and federal regulatory permits are issued for a component. RECOVER, USACE, and SFWMD monitoring points-of-contact will be identified to coordinate and implement monitoring with in-house agency resources or via contracts with CERP partner agencies and/or contracted universities or consultants to most efficiently and effectively execute the monitoring plan designs. Designated contacts

will ensure that results are shared with the partnering agencies and non-governmental stakeholders for the duration of the monitoring plan. In addition, prior to construction of any component and/or test, a baseline monitoring report will be developed by RECOVER and coordinated with the project team and stakeholders, as stated in the PIR monitoring and AM plan. The report results will be presented during annual (or as frequently as needed) State of the LOWRP technical meeting described below in the post construction and operations and maintenance section.

D.1.6.3.3 Pre-construction Engineering and Design

Project component designs will be developed and coordinated with RECOVER to ensure project component designs are consistent with the testing objectives identified in the AM plan strategy. Further data analysis or review of other project design and monitoring information may be required to inform the design of LOWRP project components (e.g., WAF, ASR and wetland restoration project components). In addition, monitoring locations that need to be installed prior to construction for baseline monitoring will be coordinated with the PED team to ensure they are aligned properly. The PED team will share project component plans and specifications with the RECOVER. Monitoring contract schedules will be aligned with project construction schedules and operating protocol as defined in the project component's operational strategy and consistent with the experimental design outlined in the AM plan. RECOVER LOWRP point of contacts will also be responsible for conveying results from annual monitoring reports to the PED team to help determine options for improving project designs., particularly for the blue shanty and seepage management features, but also for additional project components when deemed relevant and necessary.

D.1.6.3.4 Project Operating Manuals

Project operating manuals are developed during design by water managers in coordination with engineers, and hydrologists to specify the operating criteria for each structure. Water managers and engineers will coordinate with RECOVER to understand what hydrologic analysis is needed to inform operational criteria to be used as part of AM tests. In addition, RECOVER will work with water managers, planners, and hydrologists to ensure flexibility is incorporated into the project operational plan to allow for potential needed adjustments in the future consistent with regulatory constraints and NEPA analysis. RECOVER will work with water managers to identify the monitoring information, triggers, and process to be included in the project operating manual that will inform operational adjustments. Project operating manuals should also include the process by which operational changes will be assessed throughout the year to integrate with assessments of monitoring data and report the effects of operational decisions as part of the annual State of the Central Everglades meeting, and/or similar relevant discussions. Draft project operating manuals will be reviewed by the RECOVER LOWRP points of contacts, as well as regulatory agencies, to coordinate with the AM strategies outlined in the PIR monitoring and AM plan and with regulatory permit requirements.

D.1.6.4 Construction

Construction schedules, construction contract language, and implementation progress will be coordinated with RECOVER to ensure that appropriate flexibility is included as needed to be effective in fulfilling the intent of the AM plan. Schedules and implementation should include monitoring and operational tests consistent with the AM strategies described in the AM plan in order to learn from project component implementation. In some cases, when agreed to by the implementing agencies, AM strategies may require adjustment to construction schedules to be able to learn from implementation of one phase

to inform additional phases. This logic will reduce uncertainty and risk, could reduce cost, and will need to be incorporated into the construction schedule and contracting approaches to ensure this flexibility.

D.1.6.5 Post-construction Monitoring and Operations, Maintenance, Repair, Replacement, and Rehabilitation

This subsection discusses how AM will handle post-construction monitoring and OMRR&R.

D.1.6.5.1 Post-construction Monitoring

LOWRP specific project monitoring, RECOVER system-wide monitoring and other agency monitoring will be assessed by RECOVER to determine the restoration performance related to key project components or groups of components. The timing outlined in each strategy will determine when data analysis and reporting should occur based on the temporal and spatial scale of the parameters being assessed. The triggers and thresholds outlined in the management option matrices and AM strategies will guide the frequency of reporting and whom the reports are intended to inform. For example, strategies developed to address higher risk uncertainties may require more frequent reporting to LOWRP implementing agencies and associated regulatory agencies to ensure constraints are addressed. Other strategies will have monitoring implemented after a particular project component is constructed for a specific timeline to report results to inform LOWRP operations or construction of subsequent project components.

D.1.6.5.2 Post-construction Assessment, Reporting, and Linking to Decision-making

LOWRP assessment results will be reported to the implementing agencies and LOWRP partner agencies as part of the RECOVER system-status report, South Florida Environmental report, or more frequently if needed. The process for reporting results to decision-makers is provided in the CERP science feedback to decision-making diagram in the CERP Adaptive Management Integration Guide (Figure 3-9, RECOVER 2011b). The process has changed slightly since publication: 1) Senior-level decision-making/coordination bodies have been renamed from the Joint Project Review Board (JRB) to the Quarterly Executive Team (QET), and the Quality Review Board (QRB) to the Quarterly Agency Team (QAT).

As part of assessing and reporting LOWRP's performance, annual State of the LOWRP meetings will be coordinated by RECOVER to discuss assessment results. These annual meetings will be coordinated with similar meetings specified in other Adaptive Management plans, such as the CEPP AM Plan. Coordination will accomplish seamless information sharing and eliminate redundancy (e.g., the CEPP and LOWRP meetings may be one and the same each year). Scientists, hydrologists, engineers and water managers will present results of structural and operational changes (Drivers) and corresponding hydrological changes (Stressors), ecosystem processes (Effects), and ecological response (Attributes) specific to LOWRP implemented project features, tests, and/or operational changes. The meeting goal will be to understand status and trends and potential causes of performance issues and/or success, as well as discuss the reality of what options (LOWRP and non-LOWRP related) are available to improve performance if needed. The meetings could occur in late summer or early fall after completing a water year (ending April 30). The meetings will be LOWRP performance focused. The meetings will require coordination among RECOVER entities overseeing monitoring (LOWRP funded, RECOVER, and non-agency funded), and trained facilitation is recommended to ensure the technical meeting fulfills the LOWRP assessment reporting goals. RECOVER will work with the South Florida Ecosystem Restoration Task Force's Science Coordination Group to determine if that forum should host the technical meeting to encourage broader non-governmental stakeholder participation.

No later than 1 -2 months after the annual State of the LOWRP meeting, an environmental coordination meeting will be held with managers to discuss any performance issues and to communicate success. This meeting will also be used to agree on the appropriate forum to make decisions about options to adjust LOWRP implementation and operations, if determined to be needed, e.g., DCT, QET, or QAT.

Monitoring results will be reported in the context of the triggers/thresholds identified in the AM strategies (e.g., if performance remains within the triggers/thresholds that are provided to indicate need for adjustments, then the operations may continue or the next project component may be constructed based on the demonstrated results). Constraint triggers/thresholds that are "triggered" will be reported to LOWRP implementing agencies and associated regulatory agencies with suggestions of management options to implement, as stated in the AM plan management options matrices (MOM), to be evaluated by the agencies to decide what action is needed. Results of multiple monitoring trends will be integrated as part of a multiple lines of evidence analysis (Burton, et al. 2002; RECOVER 2006) to inform the potential need for adjusting LOWRP implementation or documenting success.

Suggested options to adjust CERP implementation fall into several categories, listed here by level of effort required to implement:

1. Operational Decisions: Operations decisions are weekly/monthly, but get reported and summarized and reported at annual meetings. Annual meetings also are a forum to discuss potential upcoming operations decisions (e.g., wet vs. dry years going into El Nino or La Nina years);
2. NEPA Covered Options, No Modeling Needed: LOWRP AM plan options that are covered by NEPA and do not require additional modeling or analysis beyond what has been discussed by scientists and managers;
3. NEPA Covered Options, Requires Modeling: LOWRP AM plan options that are covered by NEPA but may require model runs to determine best option;
4. Not NEPA Covered: LOWRP AM options that have not yet undergone sufficient NEPA analysis and therefore require additional environmental review and public comment, and potentially additional modeling.
5. Not Included in LOWRP AM plan: In some cases, the monitoring results may indicate the need for an option not identified in the AM plan or PIR/EIS. This may result in agency-approved temporary adjustment to LOWRP implementation and operations to avoid the constraint while potential project adjustments are further scoped, analyzed, approved, and budgeted for implementation. If additional technical expertise is required in RECOVER, an ad-hoc team could be formed to identify performance issues and options in a post authorization change report or make suggestions for a future CERP project.

The USACE Jacksonville District in consultation with Federal and State resource agencies and the USACE South Atlantic Division (SAD) and the South Florida Water Management District will guide decisions on determining whether restoration success has been achieved or additional operational, structural, or other contingency options identified in the AM plan MOMs need to be implemented.

D.1.7 LOWRP Adaptive Management Plan Cost Estimate

Identification of the LOWRP monitoring contained in Annex D was guided partly by two objectives. First, it must be complete from a LOWRP perspective in that it must provide the monitoring required to address LOWRP-specific needs. Second, it must be integrated with other Everglades monitoring to take advantage

of existing monitoring efforts, knowledge, and information and thereby leverage dollars committed and spent elsewhere to avoid redundancies and insure cost-effectiveness. These two objectives guided development of the AMMP, hydrometeorological monitoring plan, and the water quality monitoring plan. Where possible, LOWRP will rely on existing monitoring resources such as physical instrumentation, stations, locations, servicing, and analysis efforts funded by RECOVER, CERP sponsors, and partner agencies. Therefore, the monitoring described in the LOWRP Adaptive Management and Monitoring plan is limited to the additional, marginal increase in monitoring resources and analysis efforts needed to address LOWRP-specific questions. It is assumed that the monitoring programs will continue for at least the time needed by LOWRP. The cost estimate for the AM monitoring and project-specific monitoring can be found in **Table D-13**. **Table D-14** presents the cost estimate for all parts of the LOWRP AMMP, including AM monitoring, project-level monitoring, water quality monitoring, hydrometeorological monitoring, required USFWS Biological Opinion monitoring, and other required regulatory monitoring.

Table D-13. Adaptive management and monitoring cost estimate.

LOWRP Objective	Category or Specific LOWRP Area	Uncertainty or Project PM	AM ID# or PM	Attributes to be Monitored	Ongoing RECOVER 1-Yr Cost	Ongoing Other Agency 1-Yr Cost	LOWRP 1-yr Cost*
1	**Lake Okeechobee**	Will ecological indicators respond to lake stage changes as their PM scores suggest? (i.e., are the PM scores indicative of ecological responses?)	AM 25	Abundances of ecological Indicators (*Chara*, cyanobacteria, epipelon, epiphyte, PanFish (bluegills and redear sunfish) and vascular SAV), as well as acreage of total SAV in nearshore and coverage of 9 EAV spp groups in littoral zone	$0	$206,890	$0
1	**Lake Okeechobee**	Will fish and wildlife communities benefit from project's effect on lake stages or will additional habitat management be needed?	AM 26	Wading birds, snail kites, fish	$100,000	$200,000	$0
1/2	**ASR**	Will ASRs be able to deliver the recovery efficiency we are expecting?	AM 5	Volumes of water, measured daily, compiled monthly		$0	$100,000
2	**Estuaries**	Oysters - When discharges from LO are reduced and salinity regimes improved, will species' abundance and diversity in the estuaries increase, or will	AM 12	Monthly at 18 existing RECOVER sites • Growth • Disease • Predation • Reproductive Development • Recruitment • Density; and Live and Dead	$55,000	$0	$0

LOWRP Objective	Category or Specific LOWRP Area	Uncertainty or Project PM	AM ID# or PM	Attributes to be Monitored	Ongoing RECOVER 1-Yr Cost	Ongoing Other Agency 1-Yr Cost	LOWRP 1-yr Cost*
		consideration of supplemental habitat enhancements be warranted		counts (twice per year – spring and fall)			
2	**Estuaries**	Submerged Aquatic Vegetation - When discharges from LO are reduced and salinity regimes improved, will species' abundance and diversity in the estuaries increase, or will consideration of supplemental habitat enhancements be warranted?	AM 16	Tier 1 - Landscape scale – aerial mapping every 2 years Tier 2 - Patch-scale - species specific cover and abundance at the end of the dry and end of the wet season. Tier 3 – Fixed-point sampling – cover, abundance, shoot density, canopy height, above and below ground biomass - sampling occurs every other month from April through November	$102,000	$0	$0
2	**Estuaries**	Will augmentation of substrate be needed if desired salinities are achieved and recruitment is still not at expected levels?	AM 23	Substrate Type	$0	$0	$75,000

LOWRP Objective	Category or Specific LOWRP Area	Uncertainty or Project PM	AM ID# or PM	Attributes to be Monitored	Ongoing RECOVER 1-Yr Cost	Ongoing Other Agency 1-Yr Cost	LOWRP 1-yr Cost*
2/3	**ASR**	Will ASRs exacerbate mercury methylation in adjacent sediments?	AM 2	Sulfate measured in recovered water at ASR wellheads and at representative surface water locations in the WAF and adjacent surface water bodies at watershed ASR systems	$0	$0	$45,200
3	**ASR**	Will project operations result in significant occurrences of fish entrainment?	AM 3	Number of entrained organisms. Not needed if intake pumps are not operating (i.e., during storage and recovery) and assuming no other significant fishery risk is evident (i.e., fish are trapped in the intake even though pumps are not operational).	$0	$0	$10,000
3	**Invasive Species**	How will new hydrologic regimes affect the occurrence of invasive species in restored wetlands?	AM 17	% invasives, species composition	$0	$0	$50,000

LOWRP Objective	Category or Specific LOWRP Area	Uncertainty or Project PM	AM ID# or PM	Attributes to be Monitored	Ongoing RECOVER 1-Yr Cost	Ongoing Other Agency 1-Yr Cost	LOWRP 1-yr Cost*
3	**Invasive Species**	If algal blooms occur in the WAF, how will they be managed?	AM 36	Cell counts of HABs via water samples as needed	$0	$0	$10,000
3	**Wetlands**	When wetlands are restored, will wetland vegetation return or will consideration of supplemental habitat enhancements be warranted?	AM 46	Water level and plant diversity and abundance (annually)	$0	$0	$120,000
4	**Water Supply**	Will there be sufficient water availability to maintain LO ecology during a drought?	AM 41	Monthly average Lake Okeechobee stage	$0	$0	$5,000
3	**Wetlands**	Project Performance	PM 1	Wading Birds and waterfowl • Total wading bird count • Species richness • Species diversity • Nesting success	$0	$0	$50,000
3	**Wetlands**	Project Performance	PM 1	Anurans • Species richness • Species diversity • Species occupancy • Water bodies for breeding	$0	$0	$25,000

LOWRP Objective	Category or Specific LOWRP Area	Uncertainty or Project PM	AM ID# or PM	Attributes to be Monitored	Ongoing RECOVER 1-Yr Cost	Ongoing Other Agency 1-Yr Cost	LOWRP 1-yr Cost*
3	**Wetlands**	Project Performance	PM 1	Small mammals • Species richness • Species diversity • Species occupancy	$0	$0	$20,000
3	**Wetlands**	Project Performance	PM 1	Fish • Species richness • Species diversity • Migration/movement • Age/size class	$0	$0	$20,000
Total Annual Adaptive Management and Ecological Monitoring Costs					**$260,000**	**$406,890**	**$530,200**

Table D-14. Total cost estimate for AM, project-level, water quality, hydrometeorological, Biological Opinion, and regulatory monitoring.

	Annual	1-Year	5-Year	50-Year
AMMP	$530,200	$530,200	$2,651,000	$26,510,000
WQ				
Hydro				
BO				
Regulatory				
Total				

D.1.8 LOWRP Screened Uncertainties

Table D-15 lists the uncertainties screened out of the AM plan. Reasons for screening out suggested uncertainties included lack of direct relevance to project objective or constraint, low ratings in the screening criteria (Tier 3) described earlier in this plan, inappropriate scale for LOWRP (system-wide scale questions may be more appropriate to include in the RECOVER System-wide Adaptive Management Plan; very small scale questions may have scored low in the screening criteria), lack of ability to improve LOWRP performance by understanding more about the uncertainty, or simply that the uncertainty was already covered by another that had been suggested (duplicates).

Table D-15. Uncertainties screened from the AM Plan.

Uncertainty ID #	Category	Risk or question or uncertainty	Meeting notes and discussions	Rationale of uncertainty removal
#23, 24	Lake Okeechobee	Are we meeting lake stage envelope with projected frequency?	Not screened out initially, went through the prioritization process.	Tier 3 of prioritization so not carried forward.
#1	ASR	Will temperature of ASR discharge alter fish spawning patterns?	Not screened out initially, went through the prioritization process.	Tier 3 of prioritization so not carried forward.
#4	ASR	Are ASRs having expected effects on groundwater levels?	Not screened out initially, went through the prioritization process.	Tier 3 of prioritization so not carried forward.
#16	Fauna	Will displacement of upland species (T&E and others) from reservoir footprint result in impacts to adjacent landowners?	Not screened out initially, went through the prioritization process.	Tier 3 of prioritization so not carried forward.
#30	Reservoirs	If ideal design is implemented and negative impacts to fish / other spp. occur, are there other options that could be implemented to offset those negative effects?	Not screened out initially, went through the prioritization process.	Tier 3 of prioritization so not carried forward.
#35	Water Quality	Will the project result in mobilization of pollutants (i.e., N, P) from reservoir / wetland sites?	Not screened out initially, went through the prioritization process.	Tier 3 of prioritization so not carried forward.

Uncertainty ID #	Category	Risk or question or uncertainty	Meeting notes and discussions	Rationale of uncertainty removal
42	Water Supply	Will there be unanticipated changes in water levels that impact existing level of service to nearby residential areas?	Not screened out initially, went through the prioritization process.	Tier 3 of prioritization so not carried forward.
6	Climate Change	Will a major storm event overwhelm the flows to reservoirs and discharges to estuaries?	If a severe weather event overwhelms reservoirs, AM strategies may not be feasible / effective, and may be secondary to health and safety concerns.	AM not feasible.
7	Climate Change	Climate change effects on water supply and reservoir operations	Depending on context this may be a program- or system-scale uncertainty; what AM strategies could be implemented to offset climate change at a project level?	System-wide, not project-level AM.
8	Climate Change	Will project changes offset SLR effects? How will it affect what we are trying to do?	Depending on context this may be a program- or system-scale uncertainty; what AM strategies could be implemented to offset climate change at a project level?	System-wide, not project-level AM.
9	Engineering	How will the southern reservoir affect this project?	Effects from outside projects would be addressed under their respective scopes.	Not project-level.
10	Engineering	Reservoir - will there be seepage through the berm of the reservoir?	Strategies to address seepage may not fall under AM Plan; concern to be reported to Engineering team.	Engineering design concern - covered in PED, not AM.
11	Engineering	Reservoir - will there be seepage into the groundwater table?	Strategies to address seepage may not fall under AM Plan; concern to be reported to Engineering team.	Engineering design concern - covered in PED, not AM.

Uncertainty ID #	Category	Risk or question or uncertainty	Meeting notes and discussions	Rationale of uncertainty removal
15	Estuaries	How will Lake O water quality affect our ability to restore the estuaries?	Water quality is not a primary objective of the project.	Not project-level.
27	Land Use	Land use in the watershed outside of the project features.	This may exceed project scale, and would be addressed under NEPA.	Not project-level and project-level uncertainties covered in the PIR/EIS under NEPA.
28	Operations	How will a change in lake regulation schedule affect this project?	This would be addressed during Plan Formulation.	Addressed during plan formulation.
29	Reservoirs	Maintain reservoir levels - drought, dry season, wet season.	Need additional info / specific question; none proposed by team in subsequent discussions.	No specific uncertainty identified.
24	Lake Okeechobee	Extreme high and low - duration and frequency.	Discussed during teleconferences; concept merged with uncertainties 23 and 25.	Merged with Uncertainties #23 and 25.
31	Reservoirs	Will there be recreational access to the reservoirs?	This would be addressed under NEPA.	Not an AM uncertainty - addressed in the PIR/EIS.
32	Reservoirs	Buffer lands around the reservoirs to protect uplands in the area.	This would be addressed during project design.	Not an AM uncertainty - addressed during PED.
33	Reservoirs	Effect of reservoirs on groundwater levels.	There is existing knowledge / modeling for anticipated effects to groundwater levels. Also, how would this be related back to at least one of the stated objectives or constraints?	Not tied directly to a project objective or constraint.
34	Reservoirs/Wetlands/Fauna	Impacts to uplands/wetlands in reservoir footprints.	This would be addressed under NEPA.	Not an AM uncertainty - addressed in the PIR/EIS.

Uncertainty ID #	Category	Risk or question or uncertainty	Meeting notes and discussions	Rationale of uncertainty removal
39	Water Quality	Nutrient inflows into Lake Okeechobee.	Need additional info / specific question; none proposed by team in subsequent discussions.	No specific uncertainty identified and not at a project-level.
43	Wetlands	Ability of engineering the wetlands to provide the hydrology for our endpoint.	Need additional info / specific question; none proposed by team in subsequent discussions.	Not an AM uncertainty - addressed during PED.
44	Wetlands	Impacts of reservoirs on adjacent and nearby wetlands	Need additional info / specific question; none proposed by team in subsequent discussions.	Not an AM uncertainty - addressed in the PIR/EIS.
45	Wetlands	Will there be short-circuiting due to the wetlands?	Need additional info / specific question; none proposed by team in subsequent discussions.	Not an AM uncertainty - addressed in the PIR/EIS.
47	Wetlands/Estuaries/Lake	How do habitat changes unrelated to the project affect restoration?	Outside project scope.	Not in project scope.
48	Wildlife	Will species (T&E) impact our ability to manage the features for the benefit of the project?	This will be addressed under NEPA / ESA section 7 consultation.	Not an AM uncertainty - addressed in the PIR/EIS and under Section 7 ESA consultation.

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PART 2: WATER QUALITY MONITORING PLAN

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D.2 Introduction to the LOWRP Water Quality Monitoring Plan

This document serves as a preliminary reference for monitoring surface and ground water quality for the LOWRP. Monitoring will be conducted to evaluate the LOWRP's performance with regard to restoration goals and regulatory compliance. Specifically, the project is intended to improve the quantity, timing and distribution of water entering Lake Okeechobee; provide for better management of lake water levels; reduce undesirable regulatory releases to the Caloosahatchee and St. Lucie estuaries; improve system-wide operational flexibility; and restore portions of the historic Kissimmee River channel and floodplain. The LOWRP area of focus is the northwestern side of the Lake. The area of the TSP extends east from the C-40 canal to the Kissimmee River and includes the Paradise Run Wetland. See **Figure D-2** for a map of the project. The plan is organized into three geographic areas: Lake Okeechobee Watershed, Lake Okeechobee, and the northern estuaries (Caloosahatchee Estuary and St. Lucie Estuary).

D.2.1 Project Description

The LOWRP project features include the following elements:

1. Wetland Attenuation Feature
    a. The WAF is primarily used for surface water storage to attenuate peak flows into Lake Okeechobee from the Kissimmee River basin.
    b. Secondary Function of the WAF is habitat utilization by maintaining water levels between 0.5 ft. and 3 ft. during non-flow attenuation periods to encourage the growth of wetland vegetation.
2. Aquifer Storage and Recovery Wells
    a. A total of 80 ASR wells are proposed. The wells will utilize the UFA and the APPZ for storage and recovery.
    b. Wetland attenuation ASR wells are used to increase the total storage capacity of the WAF. There are twelve well pairs (25 wells open to the UFA and the APPZ) co-located with the WAF.
    c. Watershed ASR wells**:** The remaining 55 ASR wells are located at sites adjacent to flowing surface water throughout the watershed.
3. Wetland Restoration Sites
    a. A pump station on the C-41A canal downstream of S-84 serves as the water source for Paradise Run wetland rehydration.

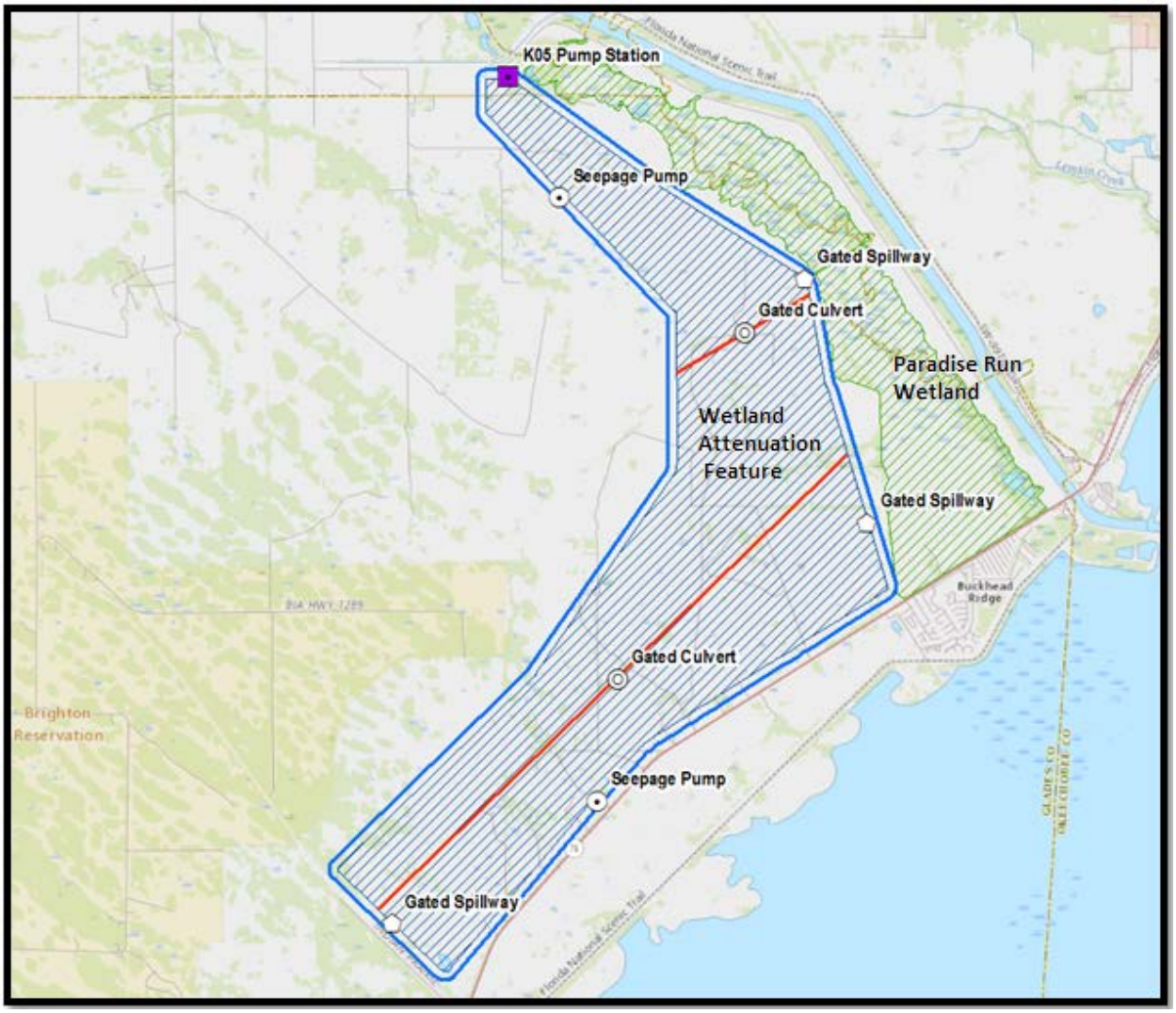

Figure D-2. LOWRP footprint map.

D.2.2 Water Quality Monitoring Objectives

The monitoring stations described in this document are referenced to satisfy requirements of the LOWRP and requirements of (issued or pending) Department of the Army 404 permits and/or State of Florida 373.1502 Comprehensive Everglades Restoration Plan Regulation Act (CERPRA) permits for Start Up and Operational Phase Monitoring. This plan provides a preliminary outline for quantifying the quality of surface water entering and downstream of the project area for a period of ten years. This plan may be updated to meet permit requirements as necessary.

Surface water samples have been collected and analyzed for multiple constituents and at various frequencies within south Florida from stations adjacent to or nearby the targeted project features. These baseline data are compiled in the SFWMD's DBHYDRO database (https://www.sfwmd.gov/science-data/dbhydro) and in the annual South Florida Environmental Report (SFWMD 2018). The U.S. Geological Survey also collect surface water quality data in this region that may be relevant to the project as baseline data. To access relevant data, contact the program manager at the SFWMD.

Historical groundwater quality data also have been collected from wells open to the SAS, the UFA, and the APPZ. These data also appear in DBHYDRO, in the U.S. Geological Survey National Water Information System database, in the CERP technical data reports for the ASR pilot systems, and in technical reports documenting exploratory borehole construction and testing in the FAS.

The water quality data obtained under this program will be used for these purposes:

1. Evaluate water quality status and trends.
2. Assess compliance with federal and state water quality statutes, the EFA, and the applicable Everglades Consent Orders.
3. Guide mid- and long-term resource management decisions as part of the adaptive management plan for the project.

D.2.3 Surface Water and Groundwater Quality Monitoring

The goal of surface water quality monitoring is to ensure that surface water quality will not be negatively impacted by the project. The goal of groundwater quality monitoring is to ensure that aquifers are not negatively impacted by ASR activities, and that recovered water quality from the WAF or ASR systems is in regulatory compliance. The water quality monitoring plan presents a conceptual outline for surface water and groundwater monitoring in relation to the operation of the WAF and ASR and their subsequent discharges into adjacent waterways.

D.2.3.1 Surface Water Monitoring

Surface water on the site will be pumped into the WAF from the Kissimmee River. Flow out of the WAF will pass via a culvert back into the Kissimmee River or into the seepage management canal that surrounds the WAF. Surface water from the WAF will be conveyed to the northern portions of Paradise Run for wetland rehydration via gated spillways. Surface water will be monitored at the intake and outflow structures of the WAF and at culvert discharge structures to Paradise Run. Surface water quality criteria are defined in the Clean Water Act and also Florida Administrative Code (FAC), Chapter 62-302, Surface Water Quality Criteria.

D.2.3.2 Groundwater Quality Monitoring

Groundwater quality at ASR systems is typically monitored during recharge, storage, and recovery phases. The most intensive monitoring periods are during recharge and recovery. Groundwater quality monitoring criteria for ASR systems are defined in the Safe Drinking Water Act and in FAC Chapter 62-528, Underground Injection Control, during recharge and Chapter 62-302, Surface Water Quality Criteria, during recovery. In the project area, 25 ASR wells are located within the footprint of the WAF and 55 ASR wells are located in clusters throughout the watershed.

Figure D-3 presents the conceptual locations of ASR well clusters. This monitoring plan is preliminary because the actual ASR well locations and quantities of wells will be configured based upon the results of exploratory wells. The ASR wells will be arranged in well pairs, to have vertically “stacked” underground storage zones in the upper FAS and the deeper APPZ. In this configuration, efficiencies in ASR facility design and costs will be achieved by co-locating wells.

Note: Red circles denote watershed ASR systems; yellow circles denote WAF ASR systems. ASR system locations are considered preliminary.

Figure D-3. ASR well locations.

When ASR systems are first constructed, there is typically an early period of "cycle" testing, when the wells are tested for pre-determined periods of recharge, storage, and recovery, so that the operational efficiencies of the systems can be assessed and permit compliance can be confirmed. After the cycle testing phase is completed (typically specified within the UIC permit), actual operation of the ASR systems will commence, with recharge, storage, and recovery durations linked to watershed flows and water levels within the project area and operation of the WAF.

During recharge into the ASR wells (both WAF and watershed systems), water quality monitoring is performed to assure that the aquifer and potential underground sources of drinking water are not negatively impacted by operation of the ASR systems. Physical parameters such as flow rates, durations, volumes, water levels, and pressures are measured. Water quality samples are collected and analyzed for ionic and chemical constituents, nutrients, and drinking water standards. Actual sampling locations and frequencies are typically determined during the permitting process.

During recovery, water quality monitoring takes place to assure that surface water quality is not negatively impacted by water discharged from the ASR to the surface. As with during recharge, parameters such as recovered water flow rates, durations, volumes, water levels, and pressures are measured. Water quality samples are collected and analyzed for chemical constituents, nutrients, and applicable surface water standards. Actual sampling locations and frequencies are typically determined during the permitting process. For the WAF wells, water recovered from the ASR wells may be routed back into the WAF storage

volume to optimize operation of the combined system. Water quality monitoring of the discharge from the WAF will take place as described in **subsection D.2.3.1.**

D.2.3.3 Surface and Groundwater Monitoring during ASR Cycle Testing

A preliminary surface water and groundwater monitoring plan for ASR cycle testing will be required for the final PIR. This monitoring plan will be developed in conjunction with the draft Project Operation Manual that also is required for the final PIR.

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PART 3: HYDROMETEOROLOGICAL MONITORING PLAN

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D.3 Hydrometeorological Monitoring

This document serves as a preliminary version of the hydrometeorological monitoring plan. It is conceptual at this point and will be adjusted accordingly as additional analyses of alternatives are performed during optimization of the TSP.

D.3.1 Data Quality Objectives

Developing Data Quality Objectives (DQO) is an integral and important part of a systematic planning process that is designed to ensure that the final results can be used for the purpose for which the data were generated. This systematic planning process for purposes of these discussions on environmental data quality is the quality system that each organization must develop, implement, and evaluate on a continuing basis.

The data will be used to measure project performance and, water quality-related goals and objectives. It will also be used to comply with monitoring requirements of an operational permit. The DQOs to be considered include accuracy, precision, sampling frequency, availability, completeness, reporting frequency, and timeliness. These are addressed in CERP's *Quality Assurance Systems Requirements*, Chapter 6, Table 6.1, dated 7 December 2010. The DQOs are further outlined in **subsection 3.1.1** of this document.

D.3.1.1 Monitoring Data Elements/Indicators/Cost Estimate

Hydrometeorological and hydraulic monitoring data will be collected, at a minimum, at each of the new structures; gate openings at gated structures; ASR wells; and pump stations. **Table D-16** provides a list of existing gages at main structures within the LOWRP project area. Structures proposed in the current TSP are still conceptual and locations will change as the recommended plan is developed. Labels or structural names will be provided after the optimization of the TSP. **Table D-17** describes a preliminary list of minimal gaging needs. This table lists the necessary gaging parameters to be collected as part of LOWRP, which are in addition to current monitoring stations that will be leveraged for LOWRP. The headwater and tailwater stage gages located directly upstream and downstream of the structures, respectively, along with the gate openings, are used in computing flows through structures, as well as assisting in determining the operations. The 15-minute frequency is the USACE required standard for these parameters. Breakpoint data for a pump is collected when changes to the RPMs are made, up to a frequency of 1 minute. The hydrologic and meteorological data collection equipment used for this project would be installed either as part of the construction contract or via a separate contract with construction funding. Hydrometeorological parameters such as surface and ground water stages require accurate estimates of the water elevation height compared to a known reference. All new surface-water and groundwater monitoring installations will be surveyed to a first order accuracy using the nearest geodetic benchmark. Reference elevations will be reported in both the NAVD88 and NGVD29 datums. Several of the structures are located within a close proximity to each other and/or existing gages, and therefore fewer new gages will be needed. See **Figure D-4** for a map of the conceptual structures proposed in the K05 WAF.

The USACE-SAJ receives data from various sensors and data collection platforms to monitor surface water flows and levels. Automated timed processes provide provisional near-real-time data required for water management operations. Additional data are also received through an interagency data exchange program among the SFWMD, the USGS, and ENP.

As the recommended plan is optimized and further developed, estimates and contingencies for hydrometeorological monitoring during OTMP, and OMRR&R will be reported in **Section 6**.

Table D-16. Monitoring gages at existing structures in the LOWRP.

Structure	Gage Parameter	Frequency
S-84	Stage, headwater Stage, tailwater	15-minute 15-minute
S-65E	Stage, headwater Stage, tailwater	15-minute 15-minute
S-77	Stage, headwater Stage, tailwater	15-minute 15-minute
S-78	Stage, headwater Stage, tailwater	15-minute 15-minute
S-79	Stage, headwater Stage, tailwater	15-minute 15-minute
S-308	Stage, headwater Stage, tailwater	15-minute 15-minute
S-80	Stage, headwater Stage, tailwater	15-minute 15-minute

Table D-17. LOWRP minimal gaging needs.

Management Measure	Structure	Number of Structures	Gage Parameter	Frequency
Wetland Attenuation Facility	Inlet Pump Station	1	Pump RPMs	Breakpoint
	Gated Culvert	3	Stage, headwater Stage, tailwater	15-minute 15-minute
	Gated Spillway	2	Stage, headwater Stage, tailwater	15-minute 15-minute
	Seepage Pump	2	Stage, headwater Stage, tailwater	15-minute 15-minute
Wetlands	Inlet Pump Station	1	Pump RPMs	Breakpoint
	Gated Culverts	2	Stage, headwater Stage, tailwater	15-minute 15-minute
	Weir/Levee notch	2	Stage, headwater Stage, tailwater	15-minute 15-minute
Aquifer Storage and Recovery	Well Pairs	40	Water quality	ppb
			Pump RPMs	Breakpoint

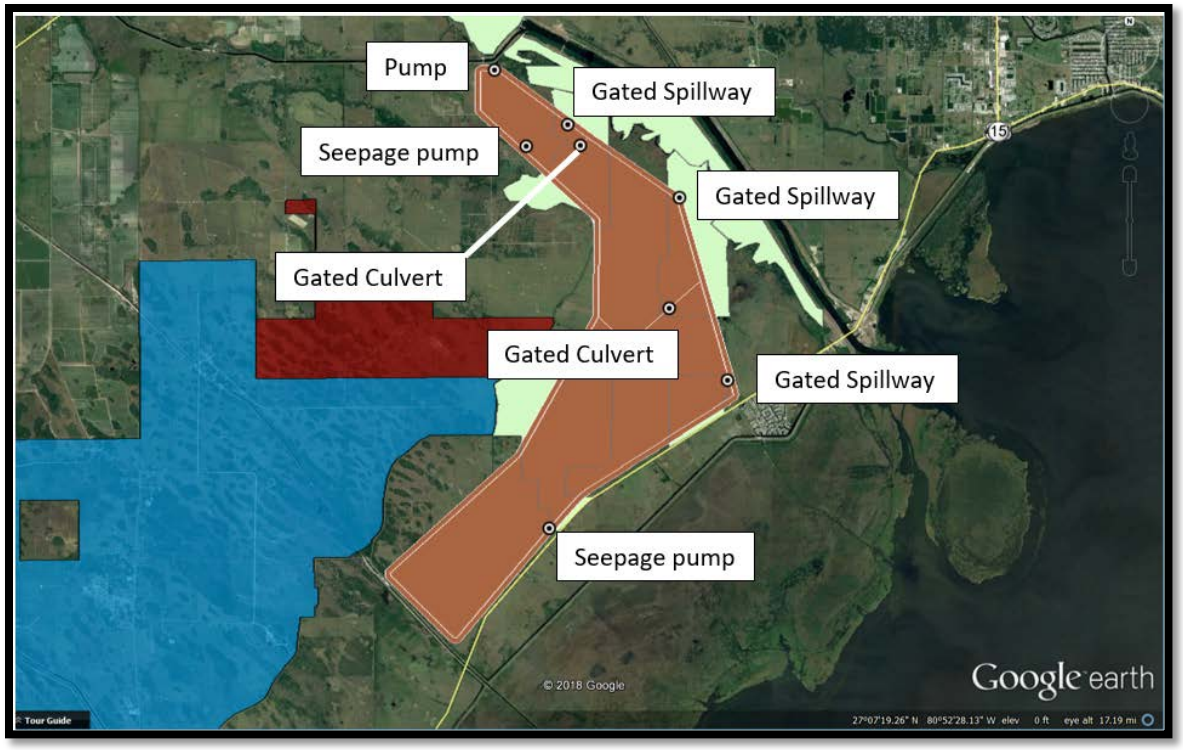

Figure D-4. WAF with proposed structures.

D.3.1.2 Procedures and Methods

Measurements will be recorded in the manner outlined in CERP's *Quality Assurance Systems Requirements*, Chapter 6, Table 6.1, dated 7 December 2010.

To summarize, surface water stages will be measured using an SDI encoder at each monitoring location. The accuracy required is ±0.02 ft. for critical sites and ±0.03 ft. for non-critical sites. The reported resolution will be 0.01 feet and the instrument range will be 0 20 ft. The precision will be ±0.01 ft. The sampling frequency will be 15 minutes, at 0, 15, 30, and 45 minutes past each hour (e.g. at 1500 hrs, 1515 hrs, 1530 hrs, and 1545 hrs).

Groundwater stages will be measured using an SDI encoder at each monitoring location. The accuracy required is ±0.03 ft. The reported resolution will be 0.01 feet and the instrument range will be 0 30 feet. The precision will be ±0.01 ft. The sampling frequency will be 15 minutes.

Rainfall will be measured with an accuracy of ±0.01 inches. The reported resolution will be 0.01 inches and the precision will be ±0.01 inches. The sampling frequency will be 15 minutes.

Gate positions will be measured using gate position indicators with an accuracy of ±0.05 ft., a reported resolution of 0.01 feet, and a gate position range of either 0-75 inches or 0-550 inches. The precision required is ±0.02% full stroke. The reporting frequency will be 15 minutes.

Pump RPMs will be measured with an accuracy of ±25 RPM and a reported resolution of 1 RPM. The pump RPM range will be 0-3,000 RPMs. The reporting frequency will be 1-360 samples per hour.

Computed flows will have an accuracy uncertainty limit of 95% C.I. The accuracy will be ±10% for inland spillways, ±15% for culverts, and ±15% for pumps. The velocity instrumentation will have a precision of ±0.01 ft./second. The reporting frequency will be 15 minutes.

The hydrologic and meteorological data collection instruments utilized for this project will be installed as part of the construction contract or under separate contract. Water stage measuring devices will be affixed to a platform in a manner to discourage vandalism and natural or unnatural intrusions (inclement weather, animals, etc.). Water-surface-elevation measuring devices will use SDI encoders for measuring values. Gate positions will be measured using gate-position indicators. Flow calculation equations that are used to compute flow on site with certain instrument types, such as a programmable data logger, will be developed under the supervision of the sponsoring agencies' hydrology and hydraulics monitoring units during the execution of this monitoring plan.

D.3.2 Rationale for Indicator Selection

The indicators selected for inclusion are required under CERP's *Quality Assurance Systems Requirements*, Chapter 6, Table 6.1, dated 7 December 2010. The headwater and tailwater values are used, along with gate openings or pump RPMs, to determine the flow of water through the structure.

D.3.3 Sampling Frequency and Duration

The sampling frequency and duration is governed by CERP's *Quality Assurance Systems Requirements*, Chapter 6, Table 6.1, dated 7 December 2010.

Surface water stages recording frequency will be 15 minutes, at 0, 15, 30, and 45 minutes past each hour (e.g. at 1500 hrs, 1515 hrs, 1530 hrs, and 1545 hrs).

Groundwater stages recording frequency will be 15 minutes.

Rainfall recording frequency will be 15 minutes.

Gate positions recording frequency will be 15 minutes.

Pump RPMs recording frequency will be by break point, with a minimum of one (1) recording per hour, up to 360 recordings per hour.

Computed flows computing frequency will be 15 minutes.

D.3.4 Assessment Process and Decision Criteria (Triggers and Thresholds)

Trigger elevations for surface water will take into consideration the design headwater and tailwater at the gages' respective structures to ensure that design limits are not reached. In addition, the decision criteria will be further refined as the operations of LOWRP are developed.

D.3.4.1 Data Collection

This section outlines the data collected.

D.3.4.2 Sample/Data Collection Standards and Ethics

No samples will be collected for hydrometeorological monitoring. Data will be collected following the required standards as described in this document.

D.3.4.3 Sample Submission

No samples will be collected for hydrometeorological monitoring.

D.3.4.4 Chain of Custody

No samples will be collected for hydrometeorological monitoring.

D.3.4.5 Quality Control Samples

No samples will be collected for hydrometeorological monitoring.

D.3.4.6 Data Validation

The USACE data validation process is subject to ER 1110-2-8155, *Hydrometeorological Data Management and Archiving*, dated 31 July 1996, and ER 1110-2-249, *Management of Water Control Data Systems*, dated 31 August 1994. The USACE data validation may be accomplished by automated or manual means. This process may include estimating values for missing or erroneous data.

The SFWMD procedures are described in their *2008 South Florida Environmental Repor*t, Appendix 2-1: Hydrological Monitoring Network of the South Florida Water Management District. The following paragraph is from a relevant section of that document:

"Several standard operating procedures (SOPs) were developed for data processing by the District…Many of these procedures and processes are automated. The Data Collection/Validation Preprocessing System (DCVP) database provides for the storage and extraction of preliminary time-series data for further inspection. Once data is extracted from DCVP, it is subjected to an initial QA/QC check in order to ascertain or improve data quality. This is accomplished through the use of the Graphical Verification Analysis (GVA) Program, a software tool which provides analysts with a graphical user interface in which to plot, edit, and apply quality tags and comments to data. The GVA application is used for the validation of the data. Once data has undergone analysis in GVA, it is uploaded into the DBHYDRO database, finalizing the preprocessing stage…"

D.3.4.7 Raw Data

Data collected by the SFWMD will be kept as raw archive files. The adjusted (QA/QCed) data will be stored as processed archive files. Data collected by the USACE is maintained in Oracle databases and further computations are applied to generate addition databases of computed data.

D.3.4.8 Data Validation Processing

The USACE data validation process is subject to ER 1110-2-8155, *Hydrometeorological Data Management and Archiving*, dated 31 July 1996 and ER 1110-2-249, *Management of Water Control Data Systems*, dated 31 August 1994.

The SFWMD procedures are described in their *2008 South Florida Environmental Report, Appendix 2-1: Hydrological Monitoring Network of the South Florida Water Management District.*

Data processing shall be approached with the same high accuracy standards for all sites/stations regardless of mandate or permit conditions. Flow and meteorological data must be summarized or derived through review, analysis, and interpretation before they can be placed in any meaningful context, then published. Data processing involves multiple steps: (1) data retrieval, (2) data review, (3) data verification and validation, (4) data analysis of raw time-series data to ensure data quality in support of environmental monitoring and assessment activities, (5) interpretation of analysis, and (6) knowledge management.

D.3.4.9 Data Storage and Archiving

Data collected or obtained by the USACE will be stored and archived in accordance with ER 1110-2-8155, *Hydrometeorological Data Management and Archiving*, dated 31 July 1996. The USACE maintains Oracle databases where all collected and computed water management data is stored/archived.

For the SFWMD, after the data validation process (generally with one week), all data are archived in a SFWMD database (DBHYDRO) and maintained so that end users can retrieve and review all information relative to a sampling event. If data are not suitable for DBHydro, they will be entered into the CERP Integrated Database (CID) on CERPZone through the Morpho interface. Field notes are maintained on an internal server either by scanning actual field note pages as PDFs (Portable Document Format) or by uploading narratives from field computers as CSVs (comma-separated values). All analytical data and field conditions are sent to a database designated by the sponsors for long-term storage and retrieval. The sampling agency or contractor maintains records of field notes and copies of all records relative to the chain of custody and analytical data. It is the responsibility of each agency or contractor to maintain both current and historical method and operating procedures so that at any given time the conditions that were applied to a sampling event can be evaluated. For any contracted work, original documents are to be provided to the SFWMD by the project completion date.

D.3.5 Documentation

For all documents, the following standards should apply:

- Print text, do not use cursive handwriting.
- Dates should be recorded as MM/DD/YYYY.
- Time should be recorded in 24-hour format using local time.
- Logs and notes should be recorded on site and at the time of collection.
- Entries are to be made in waterproof ink.
- Samplers should be properly trained.

D.3.5.1 Field Notes

No field samples will be collected for hydrometeorological monitoring. Relevant field observations will be noted in a bound waterproof notebook that is project specific. The following information will be entered into the field notes: project name, frequency, trip type, date, collectors, responsibilities, weather, preservation/acids, labs submitted to, sample ID, site ID, time collected, and sample type. Additional comments on observations, equipment cleaning, maintenance, and calibration will also be recorded.

D.3.5.2 Field Instrument Calibration Documentation

Records of field instrument calibration will be kept and SFWMD or USACE SOPs for calibration will be followed.

D.3.5.3 Corrections

Corrections to header sheets, field notes, or calibration sheets will only be made by staff who participated in the production of the document. Changes will be made by striking through the error, writing the correction, and initialing and dating the change. On occasion, a detailed explanation of the error may be required.

D.3.6 Quality Assurance and Quality Control

The following sections the quality assurance and quality control procedures.

D.3.6.1 System for Assessing Data Quality Attributes

The standards as set forth under the USACE and the SFWMD's respective requirements will be adhered to and followed. These are described and/or referenced under **subsection 2.3** of this document.

D.3.6.2 Data Quality Qualifiers

The data quality standards are outlinee in **subsection 2.2** of this document.

D.3.6.3 Field Audits

The data quality standards for hydrometeorological data are determined by the USACE and SFWMD's respective guidances and will be followed.

D.3.7 Data Analyses and Records Management

The USACE process is subject to ER 1110 2 8155, *Hydrometeorological Data Management and Archiving*, dated 31 July 1996, and ER 1110 2 249, *Management of Water Control Data Systems*, dated 31 August 1994.

The SFWMD procedures are described in their *2008 South Florida Environmental Report*, Appendix 2 1: Hydrological Monitoring Network of the South Florida Water Management District.

Please refer to **subsection 2.3** of this document for further information.

D.3.7.1 Data Quality Evaluation and Assessment

The data quality standards for hydrometeorological data are determined under the USACE and SFWMD's respective guidances and will be followed.

D.3.8 Adaptive Management Considerations

Where possible, LOWRP hydrometeorological data will support adaptive management by contributing data needed to address LOWRP uncertainties and future project adjustments. The adaptive management

strategies that will leverage hydrometeorological data include but are not limited to optimizing water deliveries from the K05 WAF and ASR wells to Lake Okeechobee.