Options to Reduce High Volume Freshwater Flows to the St. Lucie and Caloosahatchee Estuaries and Move More Water from Lake Okeechobee to the Southern Everglades

An Independent Technical Review by the University of Florida Water Institute

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Authors

Wendy D. Graham
Director, Water Institute
Professor and Carl S. Swisher Eminent Scholar Chair in Water Resources
University of Florida

Mary Jane Angelo
Director, Environmental and Land Use Law Program
Professor, Levin College of Law, University of Florida

Thomas K. Frazer
Director, School of Natural Resources and Environment
Professor, School of Forest Resources and Conservation, Institute of Food and Agricultural Sciences, University of Florida

Peter C. Frederick
Research Professor, Wildlife Ecology and Conservation, Institute of Food and Agricultural Sciences, University of Florida

Karl E. Havens
Director, Florida Sea Grant
Professor, School of Forest Resources and Conservation, Institute of Food and Agricultural Sciences, University of Florida

K. Ramesh Reddy
Graduate Research Professor and Chair, Soil and Water Science, Institute of Food and Agricultural Sciences, University of Florida

This report provides a review of relevant plans, projects and related technical documents as part of a broader effort to evaluate options to move more fresh water from Lake Okeechobee to the Everglades. The review was stimulated, in large part, by concern that recent regulatory releases of fresh water from Lake Okeechobee to the St. Lucie and Caloosahatchee estuaries have resulted in substantial negative ecological and economic impacts. Findings and opinions expressed herein are the collective work of a team of faculty affiliated with the University of Florida Water Institute and are based solely on pre-existing information.

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Executive Summary

Background and Technical Review Team Charge

It is widely recognized that the flood control and water delivery system that serves Florida's urban and agricultural interests has substantially and adversely impacted natural ecosystems in south Florida, including the St. Lucie and Caloosahatchee estuaries, Lake Okeechobee and the Everglades Protection Area (EPA). The environmental problems stem from periods when there is too much water, periods when there is too little water, and a regional delivery system that quickly transports nutrients from upstream agricultural and urban sources to natural systems where adverse impacts occur. When South Florida receives a large amount of rainfall, there are often damaging freshwater discharges to both east coast and west coast estuaries, whereas prolonged drought strains the capacity of the regional system to deliver sufficient water to its full complement of end users. Regardless of the regional hydrologic regime, much of the EPA remains chronically deprived of fresh water necessary to sustain remnant habitats and native biota.

For decades, planning has been underway by federal and state agencies as well as key stakeholders to develop solutions to water related issues in the South Florida Ecosystem. The Comprehensive Everglades Restoration Plan (CERP), Northern Everglades and Estuaries Protection Program (NEEPP) and River of Grass Planning Process (ROG) are exemplars of important planning efforts that guide contemporary restoration activities. Despite these extensive planning efforts, however, little has been done to solve the regional problems identified above.

In response to stakeholder concerns about the timing and completion of South Florida Ecosystem restoration, the 2014 Florida Senate authorized an independent technical review of options to reduce high volume freshwater flows to the St. Lucie and Caloosahatchee estuaries and move more water from Lake Okeechobee to the Everglades, to be conducted by the University of Florida (UF) Water Institute. Specifically, the interdisciplinary UF Technical Review Team was charged with reviewing existing documents that have set forth plans and projects to reduce regulatory discharges from Lake Okeechobee to the St. Lucie and Caloosahatchee estuaries and increase the flow of water from the lake to the southern Everglades; identifying scientific, engineering, legal and institutional constraints to implementing the identified plans and projects; and identifying options for accelerated and more effective protection of the estuaries and restoration of the Everglades. Key findings of the Technical Review Team are summarized below.

Challenges to Reducing High Volume Freshwater Flows to the Estuaries and Moving More Water South from Lake Okeechobee to the Southern Everglades

After extensive interviews with experts and evaluation of existing plans, supporting studies and other documentation, the UF Technical Review Team identified a number of fundamental challenges to reducing the frequency and duration of freshwater discharges to the St. Lucie and Caloosahatchee estuaries while at the same time increasing the flow of water south of the lake. These challenges include the complex and inter-connected nature of the Greater Everglades system with its flat topography, porous geology and highly variable climate; the reduced footprint of the Everglades system to approximately half its original size; the much larger capacity of canals and structures that provide inflow to Lake Okeechobee relative to those that provide outflow; the much smaller capacity of outflow canals and structures to carry water south of Lake Okeechobee versus east and west; flooding risks in agricultural and urban areas surrounding and southeast of Lake Okeechobee; legal limits for phosphorus loading to the EPA and Everglades National Park (ENP); regulation schedules for the Water Conservation Areas (WCAs) in the EPA intended to protect ridge, slough and tree island habitats and associated wildlife; constraints imposed by the existing and sometimes conflicting rights of legal water users; and the need to comply with existing laws and court orders.

Despite these challenges, the Technical Review Team concludes that relief to the estuaries and the ability to move more water south of Lake Okeechobee can be accomplished using existing technology. The solution is enormous increases in storage and treatment of water both north and south of the lake. Existing and currently authorized storage and treatment projects are insufficient to achieve these goals. The path forward requires significant long-term investment in the infrastructure of the South Florida hydrologic system.

Options to Reduce High Volume Freshwater Flows to the Estuaries and Move More Water South from Lake Okeechobee to the Southern Everglades

To reduce damage to the St. Lucie and Caloosahatchee estuaries freshwater inflow and nutrient loads from both Lake Okeechobee and the local basins must be reduced. On average, 70-80% of the freshwater discharge and 65-80% of the nutrient load to the St. Lucie and Caloosahatchee estuaries originates in the local basins, with the remaining balance contributed from Lake Okeechobee. Previous CERP, NEEPP and ROG planning exercises have all identified that providing large volumes of regional storage is essential to reduce freshwater discharges to the estuaries. The most recent estimates of required storage include:

- 400,000 acre-feet of water storage within the Caloosahatchee River watershed,
- 200,000 acre-feet of water storage within the St. Lucie River watershed, and
- approximately 1,000,000 acre-ft of water storage distributed north and south of Lake Okeechobee.

In spite of the repeated demonstrated need for large volumes of water storage, very little new storage has been designed or constructed in the system. For example, in the St. Lucie watershed it is estimated that approximately 200,000 acre-ft of storage is required. However, only one 40,000 acre-ft surface reservoir is currently under construction. In the Caloosahatchee watershed, it is estimated that approximately 400,000 acre-ft of storage is needed, but currently only one 170,000 acre-ft surface reservoir is being designed, and state and federal funds for its construction have not yet been appropriated. Furthermore, although at least one million acre-ft of storage is required either north or south of Lake Okeechobee, currently only four Flow Equalization Basins (FEBs) that provide 168,000 acre-ft of shallow storage are planned and they are sited south of Lake Okeechobee. Two of the FEBs (totaling 101,000 acre-ft) currently are under construction by the State and are scheduled to be completed by 2016. State construction of a third 11,000 acre-ft FEB will not begin until after 2018. The fourth CERP FEB has yet to be authorized by the US Congress.

Based on review and analyses, the Technical Review Team identified the following options to reduce damaging discharges to the St. Lucie and Caloosahatchee estuaries and move more water south from Lake Okeechobee:

1. Accelerate funding and completion of existing approved projects

To provide substantial improvement to the St. Lucie and Caloosahatchee estuaries, accelerate the funding and completion of existing federally authorized CERP projects designed specifically to provide relief to St. Lucie and Caloosahatchee Basins, i.e.:

- Indian River Lagoon-South (IRL-S) Project: Accelerate construction of the C-44 reservoir and associated Stormwater Treatment Area (STA). Aggressively pursue state and federal appropriations needed to design and construct remainder of the IRL-S project (including C-23, 24, 25 reservoirs and associated STAs, and restoration of over 90,000 acres of upland and wetland areas).
- C-43 Reservoir: Accelerate the design and aggressively pursue state and federal appropriations needed to design and construct project.

Current Basin Management Action Plans (BMAPs) will not achieve Florida Department of Environmental Protection (FDEP) approved Total Maximum Daily Loads (TMDLs). To achieve water quality standards in Lake Okeechobee, the St. Lucie estuary and the Caloosahatchee estuary, more aggressive BMAPs are required. New field-verified agricultural and urban Best Management Practices (BMPs) that protect water quality, advanced *in situ* treatment technologies, and the strategic placement of additional FEB-STAs in priority basins will be essential to achieve State and Federal water quality standards. Beyond existing and planned approaches, the substantial reservoir of legacy phosphorus in the Northern Everglades watersheds will necessitate new and more aggressive strategies to combat the mobility of phosphorus.

To substantially increase the volume of water moving from Lake Okeechobee to the Southern Everglades accelerate funding and completion of the State of Florida Restoration Strategies and the CERP Central Everglades Planning Project (CEPP), i.e.:

- Obtain federal authorization for CEPP,
- Accelerate the design and obtain state and federal appropriations for the construction of CEPP,
- Accelerate State funding and completion of Restoration Strategies,
- Conduct a careful analysis of CEPP project construction phasing to determine which CEPP features can be constructed as soon as possible and to develop a plan for completion of as many CEPP features as possible during the construction phase of Restoration Strategies, and
- Reconsider using the Talisman property for a deep storage reservoir with STA rather than the current design which uses the Talisman property for shallow FEBs.

Additional efforts, beyond the approved projects listed above, will be required to reduce Lake Okeechobee-triggered high discharges and nutrient loads to the St. Lucie and Caloosahatchee estuaries and to achieve dry season Everglades demand targets. Studies indicate that after the completion of the IRL-S, C-43, Restoration Strategies, and CEPP projects, lake-triggered high discharges to the St. Lucie and Caloosahatchee estuaries will be reduced by less than 55% and less than 75% of the dry season Everglades demand target will be delivered to the EPA. A series of options, beyond currently approved projects, to more fully achieve restoration objectives are summarized below.

2. Provide Water Storage and Treatment North of Lake Okeechobee

Conduct a strategic planning exercise to provide additional water storage and treatment north of Lake Okeechobee similar to the ROG Planning Process that was conducted south of the lake. The NEEPP Lake Okeechobee Phase II Technical Plan (LOP2TP) and the ROG Planning Process provide a sound foundation from which to plan, design, and build the additional storage and treatment needed north of Lake Okeechobee. A new strategic planning exercise would necessarily include a regional modeling effort that takes into account lessons learned and information gained since the CERP, NEEPP and ROG planning exercises. Examples of new information gained include the permitting requirements, engineering feasibility and costs, and inter-annual storage benefits associated with Aquifer Storage and Recovery (ASR), deep storage reservoirs, shallow water impoundments and dispersed water management (DWM), as well as the water quality benefits of Stormwater Treatment Areas (STAs) and other treatment technologies. New data gathering efforts and model developments will be required to simulate the cumulative impacts of a regional DWM system north of the lake on the quality, quantity and timing of flows into Lake Okeechobee as a function of climatic conditions, spatial location and density of DWM features on the landscape, and operation of the regional canal system. The Technical Review Team expects that the strategic plan will show that, while DWM on private lands may provide some benefits, DWM will fall short of providing the additional storage and treatment needed, even if fully implemented. Additional land north of Lake Okeechobee will need to be acquired for that purpose.

3. Provide Additional Water Storage, Treatment and Conveyance South of Lake Okeechobee

Develop a strategic plan for the next increment of south-of-lake storage, treatment and conveyance to pursue beyond CEPP to take advantage of new north-of-lake storage and treatment, and more closely meet the performance targets of both the estuaries and the Everglades ecosystems. Independent assessments suggest that an expansive gravity-driven wet flow-way throughout the Everglades Agricultural Area (EAA) may not be feasible or provide maximal benefits to the estuaries. However, the ROG planning process demonstrated that there are several possible options involving combinations of deep and shallow storage, and wet- and dry- flow-ways, coupled with STAs and enhanced conveyance that could provide significant benefit both for the estuaries and the Everglades, far beyond the benefits provided by the Kissimmee River Restoration (KRR), IRL-S, C-43, Restoration Strategies and CEPP projects. Achieving substantial reduction in lake-triggered discharges to the estuaries and substantial improvement toward the dry season Everglades demand target will require additional land between the lake and the EPA, e.g., the current U.S. Sugar land purchase option, lands from other willing sellers, and/or use of existing state-owned land (e.g., Holey Land and Rotenberger Wildlife Management Areas (WMAs)).

4. Deep Well Disposal of Excess Flows

Deep well disposal could be part of a long-term solution to reducing damaging discharges from Lake Okeechobee to the St. Lucie and Caloosahatchee estuaries, or it could provide an interim solution until additional water storage, treatment and conveyance capacity can be constructed south of the lake. If sufficient inter-annual storage and treatment north of the lake is determined to be economically or politically infeasible, or the analyses indicate that the captured water cannot be efficiently treated and conveyed south of the lake for use in subsequent dry seasons, the option of constructing a system of large injection wells to permanently dispose of excess flows from Lake Okeechobee in the deep Boulder Zone, rather than discharging to the estuaries, should be explored.

5. Operational Changes

Adjustments within the current Lake Okeechobee regulation schedule (LORS 2008) are unlikely to have a substantive effect on the occurrence of damaging high discharges to the estuaries. However, a substantially revised regulation schedule that provides more storage in the lake might provide those benefits. Developing a new regulation schedule requires completion of the on-going U.S. Army Corps of Engineers (USACE) Dam Safety Modification Study and guidance about the safety of the rehabilitated Herbert Hoover levee and operational structures in light of any new safety standards. The USACE should accelerate completion of the Dam Safety Modification Study so that modification of the Lake Okeechobee regulation schedule, if warranted, can occur as soon as possible. Development of a new regulation schedule will require balancing benefits of holding additional water in the lake for the express purpose of reducing damaging discharges to the estuaries and increasing agricultural, urban and ecosystem water supply versus potential adverse impacts to the lake's ecology.

In the interim, to provide incremental estuarine relief, Lake Okeechobee operations could be modified within the discretionary bands of LORS 2008. Increasing the dynamic range of storage in the lake could allow some additional water to be moved south to the EPA, and also provide increased dry season flows to the Caloosahatchee estuary and EAA. In addition, the regulation schedules of the Holey Land and Rotenberger WMAs could be modified to allow more water storage during both the wet and dry seasons. This modification of the WMA regulation schedules could be in keeping with current goals to restore natural hydroperiods, but will require the inflow/outflow infrastructure be upgraded to allow dynamic water level manipulations.

Future Uncertainties

Failure to draw on information about the range of possible future conditions risks the success of restoration project outcomes. Substantive research indicates clearly that climate change, changes in human demographics, energy costs and land use will affect Florida's future, yet there is little evidence that salient information is being incorporated into restoration project plans. Even if the future of these variables is highly uncertain, the possibility of future changes needs to be acknowledged, effects on restoration outcomes assessed, and flexibility incorporated into projects so that they can have positive outcomes over a broad range of conditions.

Path Forward

Even in the face of uncertainty, many existing plans and projects have been fully vetted and can be expected to yield substantial benefits to the citizens of Florida. Most of the projects are delayed because of a lack of funding. In the interim, the coupled human-ecological system is continuing to degrade in ways that may not be reversible. Monitoring and assessment of system performance is essential to guide projects and to detect and adapt to future surprises. Increased and sustained State and Federal funding is critical to provide additional water storage and treatment before the system becomes so degraded that major attributes reach tipping points that cannot be reversed.

I. Background and Technical Review Team Charge

An extensive network of man-made canals, levees and water control structures permeates the south Florida landscape. The land has been ditched, drained and otherwise reconfigured to provide flood protection and fresh water for a current population of more than eight million residents while simultaneously serving the needs of a multi-billion dollar agricultural industry (Hodges et al, 2014). Major projects in south Florida include the Herbert Hoover dike around Lake Okeechobee which was initiated in 1930, and the massive Central and Southern Florida (C&SF) Project, begun in 1948. From an engineering perspective, this regional water distribution and delivery system is highly effective at meeting its intended project purposes. Improved human welfare and economic prosperity are tangible consequences of these large projects targeted mainly at improving flood control and water supply. The water supply and flood control functions of the C&SF continue to be of critical importance to south Florida. The originally authorized C&SF Project also provided for conservation of natural resources and, in particular, the preservation of fish and wildlife. In this regard, however, the C&SF Project has underperformed and, in fact, has resulted in considerable ecological decline over time.

It now is widely recognized that the flood control and water delivery system that serves Florida's human population and agricultural interests has substantially and adversely impacted natural ecosystems in south Florida, including the St. Lucie and Caloosahatchee estuaries, Lake Okeechobee and the Everglades Protection Area (EPA) which includes the Water Conservation Areas (WCAs) and Everglades National Park (ENP) (Figure I-1). The environmental problems stem from periods when there is too much water, periods when there is too little water, and a regional delivery system that quickly transports nutrients from upstream agricultural and urban sources to natural systems where adverse impacts occur. When south Florida receives a large amount of rainfall, there are often damaging freshwater discharges to both east coast and west coast estuaries, whereas prolonged drought strains the capacity of the regional system to deliver sufficient water to its full complement of end users. During times of high rainfall, especially those following droughts, nutrients are flushed from soils and wetlands into Lake Okeechobee, the estuaries and the EPA. Yet, except for the periods of highest rainfall, much of the EPA including ENP, remains chronically deprived of fresh water necessary to sustain remnant habitats and native biota.

Reducing the frequency and duration of damaging freshwater discharges to the St. Lucie and Caloosahatchee estuaries while at the same time increasing the flow of water south through the Everglades and into Florida Bay is a complicated task. In the system's pre-engineered state, during high water events, the vast majority of water coming into Lake Okeechobee overflowed the southern rim of the lake and was carried south into the Everglades as sheet flow. However, urban and suburban development along the eastern and western margins of the historic Everglades, and conversion of marsh land south of Lake Okeechobee into agricultural production in what is now the Everglades Agricultural Area (EAA), have reduced the Everglades to approximately one half of its original size. As a consequence, the volume of water that can flow out of Lake Okeechobee to the south without causing harm to agricultural or urban/suburban areas has been reduced significantly.

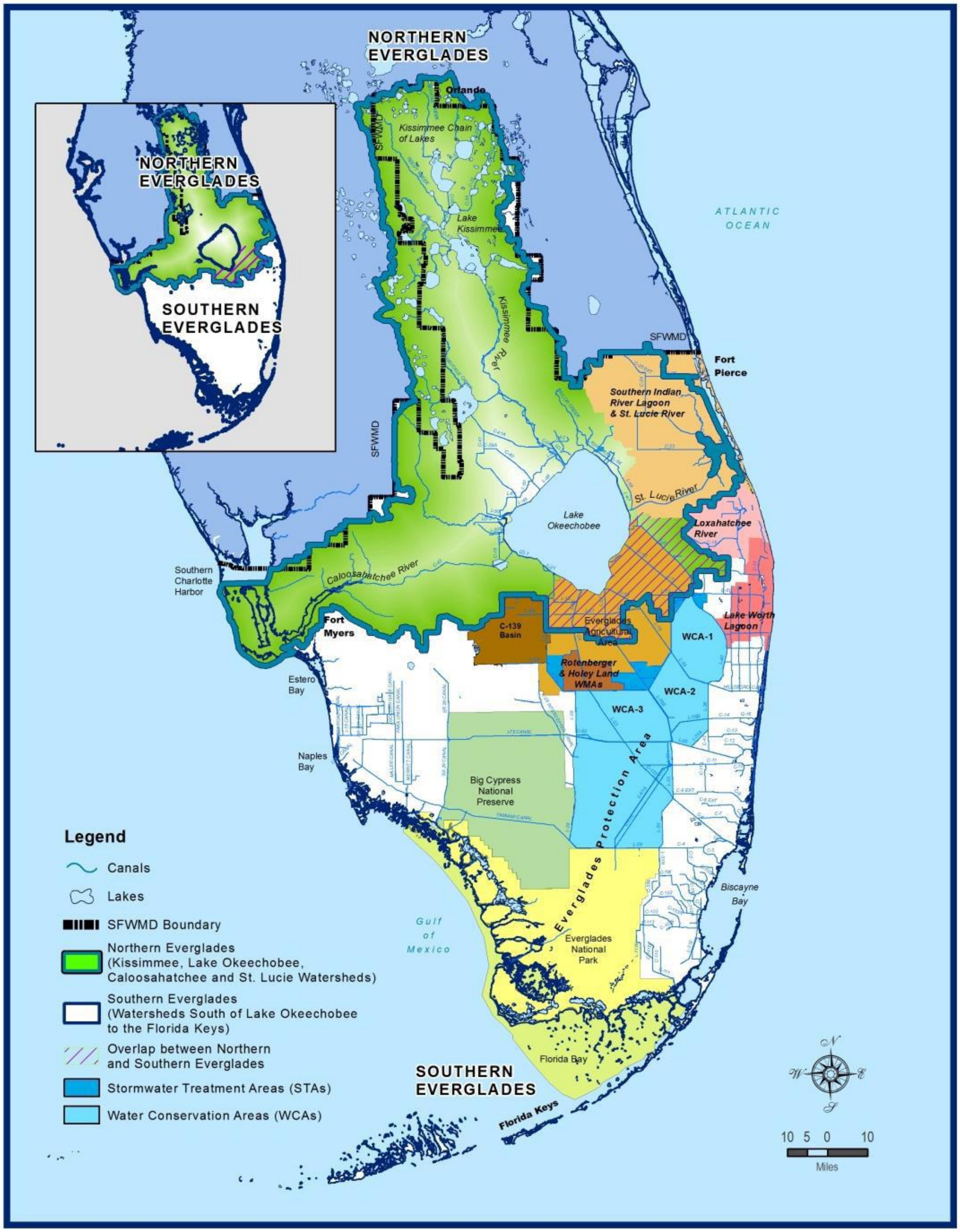

Figure I-1. Map of the Greater Everglades Ecosystem showing the extent of the Northern Everglades, Southern Everglades, Everglades Agricultural Area (EAA), Everglades Protection Area (EPA) and Water Conservation Areas (WCAs) (SFWMD, 2015)

A number of additional constraints limit the amount and timing of water that can be discharged to the south from Lake Okeechobee. These constraints include the much larger capacity of canals and structures that provide inflow to the lake than those that provide outflow; much smaller capacity of outflow canals and structures to carry water south of Lake Okeechobee versus east and west; flooding risks in agricultural and urban areas; legal limits for phosphorus loading to the EPA and ENP; and regulation schedules for the Water Conservation Areas (WCAs) in the EPA intended to protect ridge, slough and tree island mosaics and wildlife. These are familiar obstacles to those engaged in the process of Everglades restoration (see section II below for more detail).

For decades, planning has been underway to develop solutions to problems associated with the C&SF Project. In the 1990s, the US Army Corps of Engineers (USACE) carried out a Reconnaissance Study to evaluate potential approaches to regional restoration. That study and the resultant recommendations (USACE, 1994) led to the C&SF Restudy and ultimately to the Comprehensive Everglades Restoration Plan (CERP; USACE,1999) which is being implemented by the USACE and its local partner the South Florida Water Management District (SFWMD). Recently, these management entities have focused their efforts on a component of CERP, the Central Everglades Planning Project (CEPP; USACE, 2014b), which was designed to direct more water through the Everglades Protection Area, and deliver it ultimately to the estuaries of Everglades National Park and Florida Bay.

In 2013, after a particularly wet season in the region and large regulatory discharges from Lake Okeechobee to the St. Lucie and Caloosahatchee estuaries, concerns were raised again about the timing and completion of CERP and other restoration projects. Interest focused on accelerated construction and completion of projects that would reduce damaging freshwater releases to the estuaries and send more of that water, cleaned of phosphorus, to the Everglades. A broad suite of stakeholders has, in fact, questioned whether there are more immediate solutions, especially to the problem of high discharges of nutrient-laden fresh water to the estuaries. In response to the recommendations of the Florida Senate Select Committee on Indian River Lagoon and Lake Okeechobee Basin, the 2014 Florida Legislature appropriated $232 million to accelerate projects intended to take pressure off the estuaries and restore the Everglades.

Everglades Technical Review Team Study Objectives and Approach

In addition to appropriating funds to accelerate construction projects, the 2014 Florida Senate authorized an independent technical review of options to reduce damaging discharges to the St. Lucie and Caloosahatchee estuaries and move water from Lake Okeechobee to the Everglades, to be conducted by the University of Florida (UF) Water Institute. Specifically, the interdisciplinary UF Technical Review Team was charged with reviewing existing documents that have set forth plans and projects to reduce regulatory discharges from Lake Okeechobee to the St. Lucie and Caloosahatchee estuaries and increase the flow of water from the lake to the southern Everglades; identifying scientific, engineering, legal and institutional constraints to implementing the identified plans and projects; and identifying options for accelerated and more effective protection of the estuaries and restoration of the Everglades.

After extensive interviews with experts and evaluation of existing plans, supporting studies and other documentation, the Technical Review Team identified a number of fundamental challenges to reducing the frequency and duration of damaging freshwater discharges to the St. Lucie and Caloosahatchee estuaries while at the same time increasing the flow of water south through the Everglades and ultimately into Florida Bay. We present an analysis of these challenges in Section II of this report as they are crucial for understanding the constraints on potential solutions to water management issues in south Florida. Section III presents analyses of water storage needs for reducing freshwater discharge to the estuaries, and a summary of existing State and Federal approved plans that would achieve some measure of relief. Section IV provides insight into the treatment capacity needed to improve water quality and reduce nutrient delivery to Lake Okeechobee, the St. Lucie and Caloosahatchee estuaries, and also to move water south from Lake Okeechobee to the EPA in compliance with regulatory standards. Section V provides a series of options, beyond currently approved projects, to reduce damaging discharges to the estuaries and move more water south. Section VI summarizes future uncertainties that may impact restoration of the Greater Everglades Ecosystem and Section VII summarizes the findings and conclusions of the review team effort.

II. Challenges to Reducing High Volume Freshwater Flows to the Estuaries and Moving More Water South from Lake Okeechobee to the Southern Everglades

The Comprehensive Everglades Restoration Plan (CERP; USACE, 1999) was developed to provide regional solutions to problems associated with the Central and South Florida (C&SF) Project. The overarching goals of the plan are to achieve the restoration, preservation and protection of the south Florida ecosystem while providing for other water related needs of the region. Ecosystem restoration goals include: 1) improving the volume, timing and quality of water entering Lake Okeechobee and managing the lake as an ecological resource; 2) improving the volume, timing and quality of water delivered to the Caloosahatchee and St. Lucie estuaries; 3) improving the volume, timing, spatial distribution and quality of water entering the Everglades Protection Area (EPA); and 4) improving freshwater flows to Florida Bay. Additional goals include improving urban and agricultural water supplies.

CERP is generally accepted as the appropriate framework for dealing with decades of accumulated water related issues, however even after decades of planning and some project implementation, much of CERP has yet to be constructed and major regional problems remain. This section of the report discusses some of the key reasons that there continues to be major issues with regulatory discharges to the estuaries and a lack of an adequate volume of clean freshwater delivered to the Everglades.

1. A Complex Inter-Connected System

The Greater Everglades ecosystem is vast and complex. Its footprint is similar in size to the state of New Jersey, and many decades of engineering coupled with urban and agricultural development have added layers of complexity and expectations for performance that were not there even 40 years ago. The size, intricately balanced nature, and especially the many competing interests, make it very challenging for holistic solutions to emerge. The following sections illustrate the specific physical, ecological, design, and legal features that constrain solutions to almost any hydrologic issue in south Florida.

The first feature that constrains south Florida is the strong interconnectedness of the hydrologic system that serves so many interests. All parts of the Greater Everglades ecosystem share a common water resource, and the entire area is therefore a strongly connected hydrologic system. For example, the water stored in Lake Okeechobee is used to grow crops in the Everglades Agricultural Area (EAA), recharge aquifers used for public water supplies, provide dry season flows to the Caloosahatchee estuary, and to hydrate the Everglades Protection Area. Accordingly, actions taken to address storage, conveyance or distribution in one part of the system invariably affect other parts of the system. Further, the competing needs are typically synchronous - virtually all parts of the system are concerned with flood reduction during the rainy season, and all are competing for scarce water during the dry season. Compounding this situation is the fact that conversion of natural lands to agricultural and urban uses has increased nutrient loads creating a broad suite of negative impacts. In undertaking any restoration or re-planning of this water system, it is crucial to recognize that in the context of a strongly shared resource and high connectivity, trade-offs are usually unavoidable and difficult policy choices will have to be made.

2. Climatological, Topographic and Geologic Constraints

One of the most obvious drivers of hydrology and water management in the south Florida region is the marked variability in seasonal and annual rainfall that inexorably leads to patterns of overabundance and scarcity of water. Within the average year, 70% of rainfall comes in just five months, with a pronounced dry season during the rest of the year. Further, annual rainfall is highly variable from year to year, varying as much as 42 inches (82% of mean) between very wet and very dry years. This is in part due to large swings in global weather patterns that are driven by processes well outside the south Florida region. In winter months, the El Niño phase of the El Niño Southern Oscillation (ENSO) cycle can result in 2 – 7 times as much winter rainfall than during the La Niña phase (Abtew and Trimble 2010) and in the summer, rainfall is 40% higher in the warm phase of the Atlantic Multidecadal Oscillation than in the cold phase (Enfield et al., 2012). Furthermore, in summer months, tropical storms and hurricanes, which also are strongly driven by global weather patterns, can deliver up to 25 inches of rainfall (half the total average annual precipitation) to the region in periods of only a few days. Our ability to predict the occurrence or magnitude of any of these dominant, globally driven weather scenarios, even one or two months in advance, is poor, and hence there is limited ability to make proactive operational changes in the system to mitigate the resulting massive hydrological variability. While the annual wet-dry cycle is somewhat predictable from a management point of view, the interannual swings are not, and the need to accommodate large, unpredictable fluctuations in rainfall will always be an overarching concern for human populations in south Florida.

Another major driver of water management in south Florida is topography and geology. The land is extremely flat, making it difficult to move large quantities of water quickly by gravity. Even with some of the largest pump stations in the world, the flat topography places clear constraints on the speed with which any response can occur. Further, the flat landscape also offers virtually no natural storage areas – without boundaries water spreads out, which means that the ability to store water must be created by constructing surface impoundments or aquifer storage and recovery systems. The ability to contain water in any space is uniquely limited in south Florida by the underlying parent rock – highly porous limestone. The construction of dikes or ditches from this material is inherently problematic because of the high transmissivity, and rapid movement of large volumes of water out of surface impoundments and into nearby areas through groundwater seepage can only be controlled with constructed and expensive seepage barriers. Finally, the ability to store water underground through aquifer storage and recovery systems is constrained by the existence of locally intact confining layers above the target storage zone, as well as the hydraulic and geochemical characteristics of the target storage zone. In south Florida, this storage zone varies in extent, competence, and hydrologic connectivity with other parts of the aquifer. This means that underground storage is only effective in certain places, and the characteristics of storage and recovery are ultimately difficult to predict.

The highly variable rainfall and flat, porous landscape serve to create a highly variable hydrologic system (Duever et al., 1994), in which periods of water scarcity and flood are fundamental characteristics. The porous geology and extremely flat topography, in combination, impose important constraints on the ability to control water and store it.

3. Engineering Constraints due to System Design

Historically, water entered Lake Okeechobee mainly from the Kissimmee River to the north, Fisheating Creek to the west and from various smaller rivers, creeks and broad seepage fronts. The vast majority of water exited the lake at the southern end into a large number of natural creeks that dispersed into a dense forest of pond apple and then sawgrass plains. In its currently engineered condition Lake Okeechobee receives substantially more water inflow from the north than can be discharged south (to the EAA, the L-8 basin or the WCAs), and the Everglades itself has been reduced to approximately half its former footprint. This is a largely planned hydrologic design with a primary purpose to provide flood control for agricultural and urban areas around and to the southeast of the lake, (USACE, 1955a). In the current system, with a levee surrounding the lake, and relatively small canals to the south, the only outlets with adequate capacity to quickly release large amounts of water from the lake are the canals that discharge to the St. Lucie and Caloosahatchee estuaries, C-44 and C-43, respectively.

In addition, there are constraints on the volume of water that can be held in the lake itself. Historically the lake's margin fluctuated considerably, and higher flows simply meant that the lake edge was farther away from the center than in lower flow years. During the wet season, the lake typically overflowed its southern boundary and the vast majority of outflow was to the Everglades. Now the lake is more like a bathtub and the upper limit of water level, and storage capacity of the lake, are determined by the design constraints of the Herbert Hoover Dike. When water levels rise, the lake does not expand. Instead, it becomes deeper and floods its internal marsh or littoral zone (Aumen, 1995). A number of different US Army Corps of Engineer (USACE) regulation schedules have regulated when water is discharged from the lake. Between 2000 and 2008 an operating schedule called WSE (Water Supply and Environment) was followed. It was intended to provide the necessary amount of flood protection while also allowing the lake to meet the needs of water users and minimize environmental effects on the lake, estuaries, WCAs and Everglades. Most recently, a schedule called Lake Okeechobee Regulation Schedule 2008 (LORS 2008) has been used, which aims to hold the lake between 12.5 and 15.5 ft. surface elevation (above mean sea level) to minimize the risk of dike failure during a period when the USACE is reinforcing the levee and water control structures around the lake. While there is operational flexibility built into this schedule (see Section V.5) changes in water storage created by this flexibility are small compared to the volumes of water that must be accommodated in high rainfall years.

This basic problem of constrained outflows from Lake Okeechobee is fundamental to the issue of regulatory releases to the St. Lucie and Caloosahatchee estuaries. To reduce flows to the estuaries, a substantially greater amount of regional storage and enhanced water conveyance are needed. Furthermore, because legal constraints resulting from water quality concerns (see Section II.5), it is currently impossible to simply flow much of this water south of Lake Okeechobee without reducing its phosphorus content. Thus, it is inescapable that additional regional storage of large volumes of water is an essential part of any solution to reducing damaging discharges from Lake Okeechobee to the St. Lucie and Caloosahatchee estuaries. Furthermore, moving the stored water south to the Everglades Protection Area will require substantial additional treatment and improved conveyance.

4. Need for Sustained, Long-term, Holistic Planning and Execution

Historically, policy decisions regarding water supply and flood control planning in south Florida have been driven by reaction to individual major weather events and water issues. The Herbert Hoover Dike, for example, was one of the most massive public works projects of its time and was a direct and rapid response to the 1926 hurricane that destroyed towns south of Lake Okeechobee. Similarly, the 1947-48 floods were a major driver for protecting the east coast with levees that eventually expanded into forming the WCAs. Drought and fires during the early 1930s, 1940s, and 1960s were similarly influential in the notion of impounding water for urban and recreational use, and at one point impoundments were even a design feature of Everglades National Park. Yet storing water in the WCAs to combat the effects of floods and drought resulted in hydroperiods that were not within the range of tolerance for plants and animals typical of the Everglades. While each of these historical responses was perhaps appropriate at the time, they either ignored or led to unintended consequences, often of equal magnitude to the issue being addressed.

This pattern of reacting to individual events rather than planning for a full range of possible outcomes over the long term, leads to the commitment of money and resources to individual "fixes." In an era of reduced funding for public works projects, this can greatly reduce the ability to respond to other aspects that may not have been as prominent at that particular time. One of the most significant and related barriers to Everglades restoration success has been the lack of a sustained commitment of human and financial resources by both state and federal partners, a topic discussed in greater detail in Section VI.

The history of south Florida water management has shown that short-term, highly directed solutions often create other problems of large magnitude, either because of premeditated tradeoffs, or due to unintended consequences. Solutions to the issues of damaging releases to the St. Lucie and Caloosahatchee estuaries and insufficient flows south of Lake Okeechobee to the Everglades

Protection Area are strongly connected to a complex set of problems and competing stakeholders throughout the region. Thus regional planning with long time horizons, and sustained, long term execution are key elements needed to achieve long term resolution to the current issues.

5. Legal Context

An unavoidable reality of any action designed to meet the objective of reducing discharge to the estuaries and moving additional water south to the EPA is that it must take place within the context of a complex set of statutes, regulations, consent decrees, and other legally binding agreements. An array of federal and state statutes and regulations, as well as compacts with Tribes and local government regulations govern activities that occur within the greater Everglades ecosystem. In addition, decades of federal and state litigation under a variety of statutes and regulatory schemes have resulted in a number of court opinions, court orders, and consent decrees that impose further legal constraints on activities in the Everglades. Although the legal issues surrounding Everglades restoration are far too numerous and complex to be covered fully in this report, a discussion of several key legal constraints is warranted. These legal constraints relate to a few key issues, including public health and safety, water supply, flood protection, water quality, endangered species, and the right to use water.

Issued Addressed by C&SF authorized purposes

Much of what governs activities in the Everglades is set forth in a number of federal laws authorizing C&SF projects, which articulate prescribed "authorized purposes" for each project. These purposes, together with statutory requirements imposing restriction on the local sponsor of the projects set forth certain limitations on activities that can take place. The specific authorized purposes for the public laws authorizing projects within the C&SF dating back to the 1930s include: flood control (Public Laws 71-250, 80-858, 87-874 and 90-483); navigation (Public Laws 71-520 and 80-858); water supply (including for agricultural, and municipal, and industrial uses) (Public Laws 80-858, 90-843 and 87-874); preservation of fish and wildlife (Public Laws 80-858, 85-624, 90-843 and 930205); drainage and water control (Public Laws 80-858, 87-874 and 90-843); preservation of the Everglades National Park (Public Laws 90-843 and 101-229); water supply for the Everglades National Park (Public Laws 80-858, 90-843, 91-282, 98-181, 99-190, 101-229 and 100-676); recreation (Public Laws 90-843 and 78-534); protection of water quality (Public Laws 90-843, 92-500 and 95-217); prevention of saltwater intrusion (Public Laws 80-858, 90-843 and 87-874); and groundwater recharge (Public Laws 80-858 and 87-874). Projects authorized by Congress for these specific purposes are carried out and maintained in a manner that achieves the specified purposes. For example, a project that was authorized for flood control purposes would not be modified in a manner that would subordinate flood control to recreational purposes. These historic Congressional authorizations, along with more recent federal activities such as Water Resources Development Act of 2000 (WRDA 2000) (Pub. Law 106-541) and the adoption of the LORS 2008 regulation schedule, clearly place protection of public health and safety from events such as dam failure or flooding as paramount. Through a series of these authorizations dating back to 1930, Congress sought to accomplish flood control by authorizing the construction of the large canal systems to discharge excess water to the St. Lucie and Caloosahatchee estuaries. Likewise, protection of water supply ranks as a high priority in many of these authorizations.

Beyond the authorized purposes set forth in federal law, state law also includes similar purposes. For example, Section 373.1501, F.S., which authorizes SFWMD as the local sponsor of the C&SF project, provides that, in its role as local sponsor, SFWMD shall, among other things, “consider all applicable water resource issues, including water supply, water quality, flood protection, threatened and endangered species, and other natural systems and habitat needs”. Section 373.1502, F.S., requires that permits issued for component projects comply with water quality standards; that discharges from project components not pose a serious danger to public health, safety or welfare; and that any impacts to wetlands or threatened or endangered species be avoided, minimized, and mitigated.

This multitude of “purposes” articulated by both federal and state law for various aspects of Everglades Restoration can, in some cases, create conflicts and challenges. Federal and State agencies responsible for carrying out aspects of Everglades Restoration must continually work within this framework to try to find solutions that meet a wide range of objectives that can be difficult to reconcile.

Rights of Existing Legal Users of Water

State law rather than federal law generally governs the use of water. In Florida, water use is regulated by the water management districts pursuant to chapter 373 of Florida Statutes (F.S.). Section 373.219, F.S. authorizes the water management districts to issue permits for the consumptive use of water. Other than for the domestic consumption of water by individual users, permits are required for all uses of water. Once a permit is issued, the permittee maintains the right to use the amount of water authorized by permit under the conditions set forth in the permit for the duration of the permit. Permits are typically issued with 20-year durations. Water management districts may not issue permits that will interfere with any presently existing legal user of water. (373.223(1)(b), F.S.). In other words, the districts are prohibited from issuing new permits that would reduce the amount of previously allocated water available to existing permit holders. In the context of Everglades restoration, the rights of existing legal users of water through water management district consumptive use permits must be recognized. Restoration projects cannot interfere with these legal rights. Accordingly, in some situations existing consumptive use permits may impose constraints on restoration projects. In addition to these protections of existing legal users set forth in the general water use permitting provisions, Florida law expressly addressing Everglades-related matters further directs SFWMD to “provide reasonable assurances that the quantity of water available to existing legal users shall not be diminished by implementation of [C&SF] project components so as to adversely impact existing legal users, that existing level of service for flood protection will not be diminished . . . and that water management practices will continue to adapt to meet the needs of the restored natural environment." (373.1501(5)(d), F.S.

The requirement that CERP projects, in particular, protect existing legal users of water and provide flood protection is further codified in WRDA 2000. Section 601(h)(1) of this Act states that the overarching objective of CERP is the "restoration, preservation, and protection of the South Florida ecosystem while providing for other water-related needs of the region, including water supply and flood protection." Section 601(h)(5) provides the savings clause which makes clear that neither the USACE nor the local sponsor, SFWMD, should eliminate or transfer existing legal sources of water, including those for agricultural or urban water supply, allocation or entitlement to the Seminole Indian tribe of Florida, the Miccosukee Indian tribe of Florida, water supply for the Everglades National Park, or water supply for fish and wildlife. Also included in the savings clause is a requirement that implementation of CERP shall not reduce levels of service for flood protection that were in existence on the date of enactment of WRDA 2000 and in accordance with applicable law. Finally, the savings clause states that nothing in the Everglades portion of WRDA 2000 amends, alters, prevents, or otherwise abrogates rights of the Seminole Indian Tribe under the compact among the tribe, the state, and the SFWMD.

Water Quality

Water Quality Issues in the EPA

Currently, the majority of the legal constraints on moving water south into the EPA revolve around water quality concerns. Although the primary focus of Everglades restoration is to "get the water right" by restoring the hydrology of the system, water quantity and water quality are inextricably linked and any effort to address water quantity concerns cannot occur in isolation from water quality concerns. One of the significant constraints to moving water out of Lake Okeechobee to the south is the need to ensure that water discharge to the Everglades Protection Area complies with federal and state water quality requirements. In particular, numeric phosphorus standards have been established for the EPA and for the ENP must be met. Currently, water discharged from Lake Okeechobee through STAs into WCAs is not in compliance with water quality standards due to high phosphorus levels (see Section IV). The history of Everglades issues related to compliance with water quality standards has been the subject of two significant and ongoing lawsuits. Both of these cases make it clear that discharging water into the Everglades Protection Area in a way that does not comply with U.S. Environmental Protection Agency (USEPA)-approved state water quality standards is considered to be a violation of federal law.

The first of the two significant water quality-related federal cases began in 1988 when the U.S. Attorney for the Southern District of Florida filed a lawsuit against the State of Florida and the SFWMD alleging that Florida's lack of enforcement of water quality laws and discharges through state-controlled structures threatened the water quality of the Everglades National Park and the Loxahatchee National Wildlife Refuge (United States v. South Florida Water Management District, No. 88-1886S.D. Fla.). In 1991 Florida conceded liability and settled the case via a consent decree, which was approved by the court in 1992. Under the terms of the consent decree, the State of Florida agreed to take actions to ensure all discharges to the Park and the Refuge met the long-term phosphorus levels set forth in the consent decree by 2002. To accomplish this, the state committed to build and operate a minimum of 32,600 acres of Stormwater Treatment Areas (STAs) and to establish a regulatory program that would require farmers in the EAA to implement Best Management Practice (BMPs) to reduce nutrient waste from the farms. The parties continued to actively pursue aspects of this litigation, which ultimately resulted in a modified consent decree which, among other things, extended the deadline for compliance with long-term phosphorus standards from 2002 to 2006. The modified consent decree remains in effect and under the jurisdiction of the court. Pursuant to Appendix A of the consent decree, water entering the Everglades National Park is governed by a prescribed compliance methodology. Failure to comply with the long-term phosphorus levels as determined by the Appendix A compliance methodology is considered a violation.

The second of the two significant federal lawsuits was initiated when the Miccosukee tribe petitioned the USEPA to review the Everglades Forever Act (EFA) as a change in Florida water quality standards. Under the federal Clean Water Act (CWA) section 303(c), EPA is required to review and approve state water quality standards and changes to the standards. (33 U.S.C. § 1313(c)). After a series of USEPA decisions that were challenged and the resulting court decisions, USEPA ultimately reviewed the EFA and found it was in compliance with the CWA. Subsequently, in 2003, the EFA was amended, which revived the lawsuit. Finally, in an April 14, 2010 Order, Judge Gold ruled that USEPA's 2009 "Determination", that the EFA complied with the CWA, failed to address a prior ruling of the court and directed USEPA and FDEP to take certain steps to comply with their mandatory duties under the CWA. Ultimately, the lawsuit resulted in USEPA issuing a document known as the September 2, 2010 "Amended Determination." In the Amended Determination, USEPA stated that it was "notifying FDEP that the narrative and numeric nutrient criteria in the State's water quality standards are not being met for the Everglades Protection Area." The Amended Determination was intended to provide an enforceable plan for ensuring that the water quality entering the Everglades Protection Area (EPA) from the Everglades Agricultural Area (EAA) and the C-139 Basin complied with the narrative and numeric phosphorus criteria, which were already in place for the EPA.

The Amended Determination specifically addressed each of the directives ordered by Judge Gold. These actions include: (1) revisions to USEPA's 2009 Determination; (2) directions to Florida for correcting deficiencies in both Florida's Phosphorus Rule and the Amended Everglades Forever Act; (3) provisions for the "manner and method for obtaining enforceable WQBEL within time certain"; (4) requirements to measure and submit annual reports on cumulative impacts until water quality standards are attained; (5) directions to Florida to conform all National Pollutant Discharge Elimination System (NPDES) permits under the CWA and EFA permits pursuant to both the Court's 2008 order and the 2010 order by eliminating all nonconforming language and by including the WQBEL presented in the Amended Determination; (6) establishment of an "enforceable framework for ensuring compliance with the CWA and Applicable Regulations."

The Amended Determination, for the first time, established a Water Quality-Based Effluent Limitation (WQBEL) that was required to be included in all permits for discharges from STAs. This WQBEL is intended to ensure that water leaving the STAs is of high enough quality to ensure compliance with narrative and numeric nutrient criteria. The WQBEL provided that total P concentrations in the discharge from the STAs may not exceed either: 10 ppb as an annual geometric mean in more than two consecutive years; or 18 ppb as an annual flow-weighted mean. USEPA maintains that "[c]ompliance with both parts of the WQBEL is necessary to assure that the STA discharges will not cause an exceedance of the long-term criterion of 10 ppb." The Amended Determination also provides detailed instructions to the State of Florida on how to meet the WQBEL, including specific milestones that must be met. The Amended Determination also provided an opportunity for the state to develop an alternative proposal for achieving water quality standards in the EPA. Ultimately, the state devised its own plan, known as "Restoration Strategies" to ensure compliance with water quality standards. In this plan the state committed to several projects that will create more than 6,500 acres of new STAs and creation of Flow Equalization Basins (FEBs), which will provide 112,000 acre-ft of additional water storage. The plan also includes additional source control. USEPA approved this plan as well as a revised WQBEL that requires that the flow-weighted mean (FWM) Total Phosphorus (TP) concentrations at STA discharge points not exceed (1) an annual FWM of 13 µg/L in more than three out of five years and (2) an annual FWM of 19 µg/L in any one year, as an alternative to the plan and WQBEL set forth in the Amended Determination.

In 2012, FDEP issued both NPDES discharge permits and EFA watershed permits that incorporate this WQBEL. Water leaving the STAs and entering the WCAs must meet WQBEL set forth in these permits. Because WQBEL's are not expected to be met until the completion of Restoration Strategies, the SFWMD and the FDEP have entered consent orders in which the FDEP has articulated its finding that it is clearly in the public interest to exercise its enforcement discretion to allow the continued operation of STAs while the corrective actions required by the consent order are implemented.

Water Quality Issues in the St. Lucie and Caloosahatchee Estuaries

Unlike the discharges to the EPA, discharges to the St. Lucie and Caloosahatchee estuaries are not subject to strict quantitative effluent limitations. Discharges to the EPA require both NPDES and EFA permits, which, as described above, both contain a numeric WQBEL for phosphorus. Discharges from Lake Okeechobee to the aforementioned estuaries are not subject to NPDES or EFA permitting requirements and consequently, legally-binding numeric effluent limitations do not apply. State adopted and USEPA-approved water quality standards and Total Maximum Daily Loads (TMDLs), however, have been established for both the St. Lucie and Caloosahatchee estuaries. A TMDL represents, in essence, the amount of a particular pollutant that a particular water body can assimilate without resulting in a violation of a water quality standard. TMDLs are the means by which water quality criteria can be translated into water-quality based effluent limitations in NPDES permits, or other types of pollution limitations under state regulatory programs.

The State of Florida implements TMDLs through its Basin Management Action Plans (BMAPs), which serve as "blueprints" for restoring impaired waters by reducing pollutant loadings. (403.067(7)(a), F.S.). BMAPs contain a comprehensive set of strategies, some regulatory and some nonregulatory, designed to meet TMDLs. Regulatory strategies include providing WQBELs in NPDES or other pollutant discharge permits. For sources of pollutant loading that are not subject to discharge permitting requirements, such as for the lake discharges to the St. Lucie and Caloosahatchee estuaries, BMAPs include non-regulatory strategies, such as urban and agricultural best management practices and conservation programs. These broad-based plans are developed with local stakeholders—they rely on local input and local commitment—and they are adopted by Secretarial Order to be enforceable. BMAPs have been established for both the St. Lucie and Caloosahatchee estuaries. In addition, a BMAP has been established for Lake Okeechobee to bring lake water into compliance with the established TMDL for phosphorus.

The Endangered Species Act and Migratory Bird Treaty Act

Another federal law that has significantly affected Everglades restoration is the Endangered Species Act (ESA) (16 U.S.C. §§ 1531 to 1544). The ESA is the primary federal statute governing activities that may affect threatened or endangered species. It is administered and enforced by two separate agencies. The United States Fish and Wildlife Service (FWS) within the Department of the Interior implements the ESA with regard to freshwater and terrestrial species. The National Marine Fisheries Service (NMFS) within the Department of Commerce implements the ESA with regard to marine and anadromous species. These two agencies, referred to collectively as “the Services,” are responsible for listing species as endangered or threatened and implementing regulations to protect the listed species and their habitats. Two substantial protections are afforded species listed pursuant to the ESA. The first, set forth in Section 9 of the ESA, prohibits the “taking” of listed species (16 U.S.C. §1538). The statute defines the term “take” broadly to include to “harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct” 16 U.S.C. § 1532(19). The Services have further defined the term “harm” to include acts that involve significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering. This broad interpretation has been upheld by the U.S. Supreme Court. Moreover, additional habitat protection is afforded where the Services have designated “critical habitat” for a particular listed species. The ESA authorizes the Services to assess penalties for unauthorized “takes” of listed species and authorizes courts to award injunctive relief to prevent the takes from occurring or continuing. Moreover, the ESA contains a “citizen suit” provision, which authorizes citizens to bring suit and act as private attorneys general to enforce the law under where the Services have failed to do so. Because the take prohibition applies to “any person,” any of the activities related to Everglades restoration that are carried out by the State or the Federal government must ensure that unauthorized takes do not occur. Section 10 of the ESA authorizes the Services to issue permits to authorize specific “takes” of a listed species, if the “taking is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity,” and “will not appreciably reduce the likelihood of the survival and recovery of the species in the wild.” A permit applicant seeking an incidental take permit must develop a “habitat conservation plan” that minimizes and mitigates impact of the taking to the maximum extent practicable.

The other significant regulatory program under the ESA is the consultation requirement set forth in Section 7(a)(2) of the Act (16 U.S.C. § 1536). Unlike the “take” prohibition, which applies to ”any person”, the consultation requirement applies only to federal agencies. This section requires that, prior to engaging in any federal agency action that “may affect” listed species, the federal agency must consult with the Services to “insure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of [critical habitat] of such species.” The phrase “jeopardize the continued existence of a listed species” includes actions that can reasonably be expected, directly or indirectly, to appreciably reduce the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species.

Formal consultation can be avoided only where the agency determines, with written concurrence of the Services, that the proposed action is “not likely to adversely affect” listed species. The purpose of the consultation process is for the Services to determine whether the federal agency action is likely to jeopardize the continued existence of listed species. The consultation process culminates in the issuance of a Biological Opinion (BiOp). If a jeopardy finding is made, the BiOp must include “reasonable and prudent alternatives” (RPAs) that if implemented would avoid jeopardy. Although the action agency has discretion to choose whether to implement the RPAs, if the Agency’s action results in a take, the Agency will be liable under section 9, unless such a take is provided for by an incidental take statement (ITS) in the BiOp. An ITS describes actions that will not be considered a prohibited take and which sets forth “reasonable and prudent measures” which must be complied with to be covered by the ITS (40 C.F.R. Part 402). Finally, Section 7(a)(1) of the ESA imposes an obligation on federal agencies to use their existing authorities to conserve endangered and threatened species. Because the C&SF and CERP are federal projects, the USACE is subject the consultation requirement of Section 7of the ESA.

The Migratory Bird Treaty Act (MBTA) implements four international treaties that are aimed at protecting migratory birds (16 U.S.C. § 703). The scope of the MBTA is quite broad and covers almost all native North American birds. Some, but not all, migratory birds covered by the MBTA are also a listed species under the ESA and, thus, both Acts would apply to those species. Many of the endangered species in the everglades are birds that are also protected by the MBTA. As with the ESA, the MBTA prohibits “takes” of covered species. Although the MBTA does not define the term “take,” regulations define it to mean “pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt” any of the foregoing (50 C.F.R. 10.12). Although not well-defined, the MBTA’s definition of “take” appears to be narrower than the definition under the ESA, which, as described above, may include significant habitat modification or degradation where it actually kills or injuries wildlife. Thus, although some general habitat changes may not be violations of the MBTA, actions such as construction of projects or flooding areas in a way that actually kill birds could be violations of the MBTA.

Because of its subtropical nature and geographical location, south Florida is home to a large number of endangered species, many of which are highly dependent upon the ecological conditions that were characteristic of an un-drained south Florida landscape. At least four of these are of primary concern in considering hydrological restoration and the routing of water within the EPA – Cape Sable Seaside Sparrow (*Ammodramus maritimus sociabilis*), Wood Stork (*Mycteria americana*), Snail Kite (*Rostrhamus sociabilis*) and American Crocodile (*Crocodylus acutus*). CERP was designed in part to improve conditions for many of these species through restoration of habitat quality, largely through hydrological change. However, the road to achieving many of those restored conditions involves massive construction and temporary conditions that may temporarily negatively impact some species. In addition, the Everglades ecosystem has been reduced in area by approximately half and thus, habitat available for endangered species has been dramatically reduced. Moreover, many of the most imperiled species use habitat that is artificial, and thus, may not contain all of the features and buffers that were typical of historical natural habitat.

The ESA is designed to err on the side of protection of species, and it becomes most protective in the case of species with very low population size. The global population of Cape Sable Seaside Sparrows exists entirely within ENP and may consist of fewer than 3,000 individuals, and many fewer breeding individuals. The Cape Sable Seaside Sparrow requires relatively dry conditions, and it now nests in parts of Everglades National Park that may be over-drained relative to historical conditions in order to protect those nests. Restoring hydrological conditions in the park could therefore present a direct threat to one or more of the current sub-populations of this bird, unless the population moves to another location.

Actions in one part of the highly compartmentalized south Florida ecosystem strongly affect conditions in others. The ability to keep the Cape Sable Seaside Sparrows habitat dry enough during the high water periods of the mid-1990s, for example, required deep, long-term storage of water in WCA 3 (see Figure I-1 for WCA 3 location). Long-term, deep conditions in WCA 3 strongly affects the viability of tree islands there, many of which are used by the endangered Snail Kite. Both conditions triggered lawsuits from different parties using the ESA as a tool. Especially with populations that are already critically low, the ESA is sensitive to even temporary conditions that may impair the species in question.

USACE has consulted with the FWS on numerous projects related to Everglades restoration dating back to 1983 and a number of BiOps have been issued. One of the most significant BiOps was the 2010 Biological Opinion for Everglades Restoration Transition Plan (ERTP). The ERTP was designed to provide a flexible multispecies approach to water management and operations in WCA-3 by balancing the water needs of multiple species. The ERTP BiOp, among other things, evaluated effects of WCA-3A operation and regulatory releases on, and set forth reasonable and prudent measures considered necessary and appropriate to minimize the take of, the Cape Sable Seaside Sparrow, the Everglades Snail Kite and the Wood Stork. Most recently, in March of 2014, the FWS issued "Programmatic Biological Opinion and Select Concurrence to the Central Everglades Planning Project on Effects to Threatened or Endanger Species and Critical Habitat". This document sets forth reasonable and prudent measures (RPMs) that the FWS considers necessary and appropriate to minimize the take of the Cape Sable seaside sparrow, the Everglades Snail Kite, the Wood Stork, and the Eastern Indigo Snake (*Drymarchon couperi*). The RPMs in these and other BiOps influence whether and the manner under which restoration projects and operations are carried out.

Summary

The ability to change water management in substantial ways in south Florida is constrained by a number of laws that protect the rights of existing legal users of water, including urban populations, native American tribes, agriculture, and Federal land holders, as well as by laws protecting endangered species, migratory birds and water quality. Large-scale changes in the volume of flow south of Lake Okeechobee affects many of these users, and any flows south of the lake toward the Everglades Protection Area are particularly constrained by the need to meet stringent water quality standards. Thus, the ability to ameliorate negative effects of freshwater releases to the St. Lucie and Caloosahatchee estuaries is strongly linked to the need to clean that water to meet legal requirements and to avoid conflicts with existing users.

III. Existing State and Federal Plans to Reduce High Volume Freshwater Flows to the Estuaries and Move More Water South from Lake Okeechobee to the Southern Everglades

1. Introduction

As discussed in Sections I and II, reducing the frequency and duration of damaging freshwater discharge to the St. Lucie and Caloosahatchee estuaries and increasing the flow of water south is a complicated task because 1) Lake Okeechobee inflow capacity currently exceeds outflow capacity by as much as 4-6 fold depending on hydrologic conditions, and 2) the capacity of outflow canals and structures to carry water south of the Lake is currently much smaller than the capacity of outflow canals and structures to carry water east and west to the St. Lucie and Caloosahatchee estuaries, respectively. Figure III-1 presents the distribution of flows released from Lake Okeechobee for the May 1997-April 2014 time period, for Water Year (WY) 2014 (May 2013-April 2014), and for the WY 2014 wet season (June 2013-October 2013). These figures illustrate that, over the long-term, annual average east/west releases to the estuaries represented 66% of the Lake Okeechobee outflow (45% to Caloosahatchee and 21% to St. Lucie), while southerly releases to the EAA, L-8 basin and WCAs represented 34% of the Lake Okeechobee outflow (Figure III-1a). For the extremely wet WY 2014 the annual percentages of east/west versus southerly flows did not change appreciably (Figure III-b), however, during the WY 2014 wet season the estuaries received 87% of the outflow from Lake Okeechobee, while only 13% went south. It should be noted that these releases include both water supply and regulatory releases.

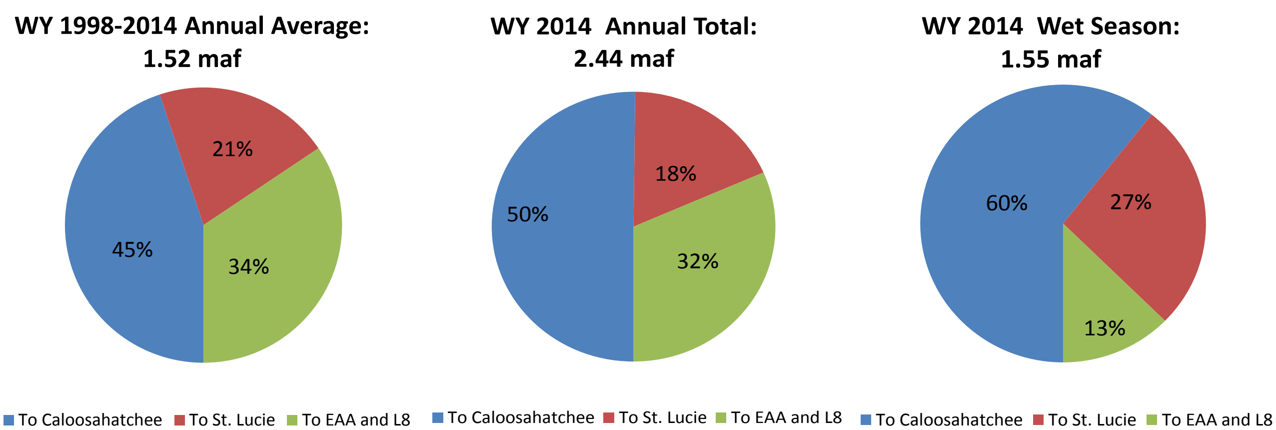

Figure III-1 Distribution of Lake Okeechobee Releases in million acre-ft (maf) for a) Long-term annual average for May 1997-April 2014, b) Annual total for WY 2014 (May 2013-April 2014), c) Wet season totals for WY 2014 (June 2013-Ocotober 2014). Data from SFWMD.

Compounding this problem of high releases of freshwater from Lake Okeechobee, both the St. Lucie and the Caloosahatchee basins contribute significant additional local runoff to their estuaries (Figure III-2). For the St. Lucie the long-term annual average (WY1997-WY2014) contribution of local basin runoff to the total freshwater inflows was 77%, while the contribution during WY2014 was 70%. For the Caloosahatchee the long-term average (WY1997-WY2014) contribution of the local basin runoff to the total freshwater inflows was 68%, while the contribution during WY2014 was 62%. For both basins local runoff is a larger contributor of freshwater inflows than Lake Okeechobee. Thus, to reduce damaging high freshwater discharge to the estuaries, inflows from both Lake Okeechobee and the local basins must be reduced.

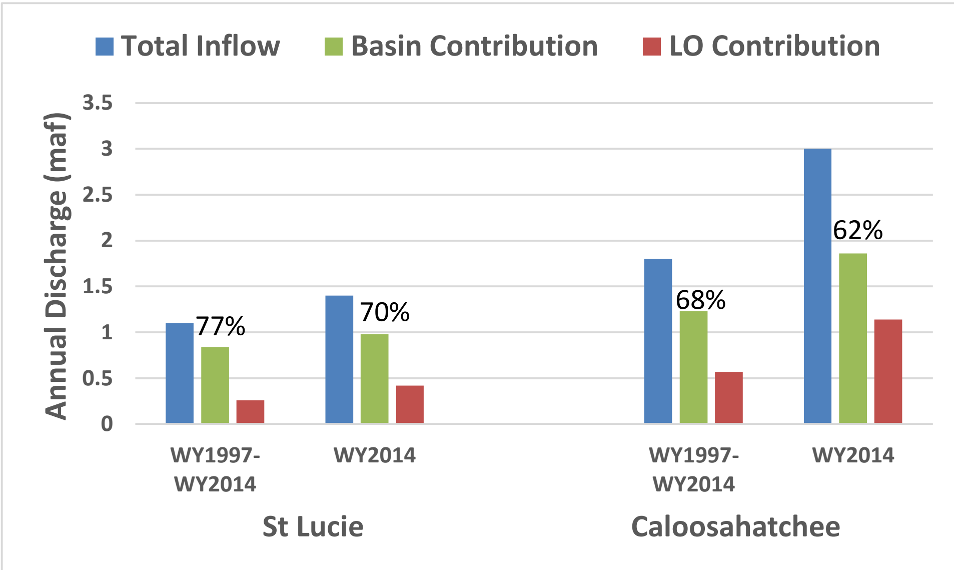

Figure III-2 Total Freshwater Inflow, Lake Okeechobee Contribution and Local Basin Contribution to the St. Lucie River and Caloosahatchee River Basins in million acre-ft (maf). Data from SFWMD (SFWMD, 2015).

Freshwater inflows generate direct and indirect effects in the Caloosahatchee and St. Lucie estuaries (Barnes, 2005; Sime, 2005). Low salinity stresses many biotic components of these estuarine systems. For example, prolonged exposure to low salinity increases mortality, disease and loss of recruits for oysters, which can lead to degraded reefs and loss of infauna, epifauna and fish associated with these reefs (Tolley et al., 2006; Parker et al., 2013). Lower salinity also increases physiological stress on seagrasses, which represents a second, key structural habitat (Buzzelli et al., 2012). This direct stress combines with increased shading, an indirect result of turbidity transported in freshwater inflows, phytoplankton blooms transported to the estuaries or blooms stimulated by increased nutrient loads, to lead to loss of seagrasses and subsequent changes in invertebrate and fish assemblages (Gilmore, 1995; Millie et al., 2004; Buzzelli et al., 2012; Phlips et al., 2012; Wang et al., 2012). Freshwater inflows also have transported toxic microalgae into the St. Lucie estuary, with a substantial bloom of *Microcystis aeruginosa* being recorded in 2005 (Phlips et al., 2012). To reduce these impacts of freshwater inflows on the estuaries, performance criteria have been established which set limits on the frequency and magnitude of high monthly discharges to the estuaries.

The frequency, magnitude and duration of freshwater discharges to the St. Lucie and Caloosahatchee estuaries that exceed established flow targets between 1994 and 2014 are shown in Figures III-3 and

III-4. In the last 20 years, total flows to the St. Lucie estuary have exceeded high mean monthly flow targets (occurrences between 2000 cfs and 3000 cfs) 10% of the time and very high monthly mean flow targets (>3000cfs) 12% of the time. Restoration targets, on the other hand, are 6.3% and 1.4%, respectively (SFWMD, 2009a; Table III-1). Similarly, in the last 20 years flows to the Caloosahatchee estuary have exceeded high targets (>2800cfs) 28% of the time and very high targets (>4500cfs) 15% of the time versus restoration targets 0.7% and 0%, respectively (SFWMD, 2009b, Table III-2). Damaging high discharges typically occur in June through October when significant rainfall in the Kissimmee River Basin results in large inflows to Lake Okeechobee and the structural, ecological and legal constraints discussed in Section II limit the amount of water that can be discharged south of the Lake. Most recently this occurred in the summer of 2013 (WY 2014) when Lake Okeechobee received 2.4 million acre-ft of inflow during the months of June through October. This, together with high rainfall in the local basins, resulted in 5 consecutive months of damaging discharges to the Caloosahatchee estuary (2.1 million acre-ft, of which 45% was from Lake Okeechobee and 55% was from local basin runoff) and four consecutive months of damaging discharges to the St. Lucie estuary (1.0 million acre-ft, of which 37% was from Lake Okeechobee and 63% was from local basin runoff).

Low flows are also a concern in the Caloosahatchee basin. In the last 20 years flows to the Caloosahatchee estuary have fallen below the low flow target (450 cfs) 28% of the time versus a restoration target of 0%. Low flows typically occur during the November to May dry season when rainfall is reduced and agricultural and urban water demands compete with the Caloosahatchee estuary for releases from Lake Okeechobee. Low flows currently are less of a concern in the St. Lucie estuary.

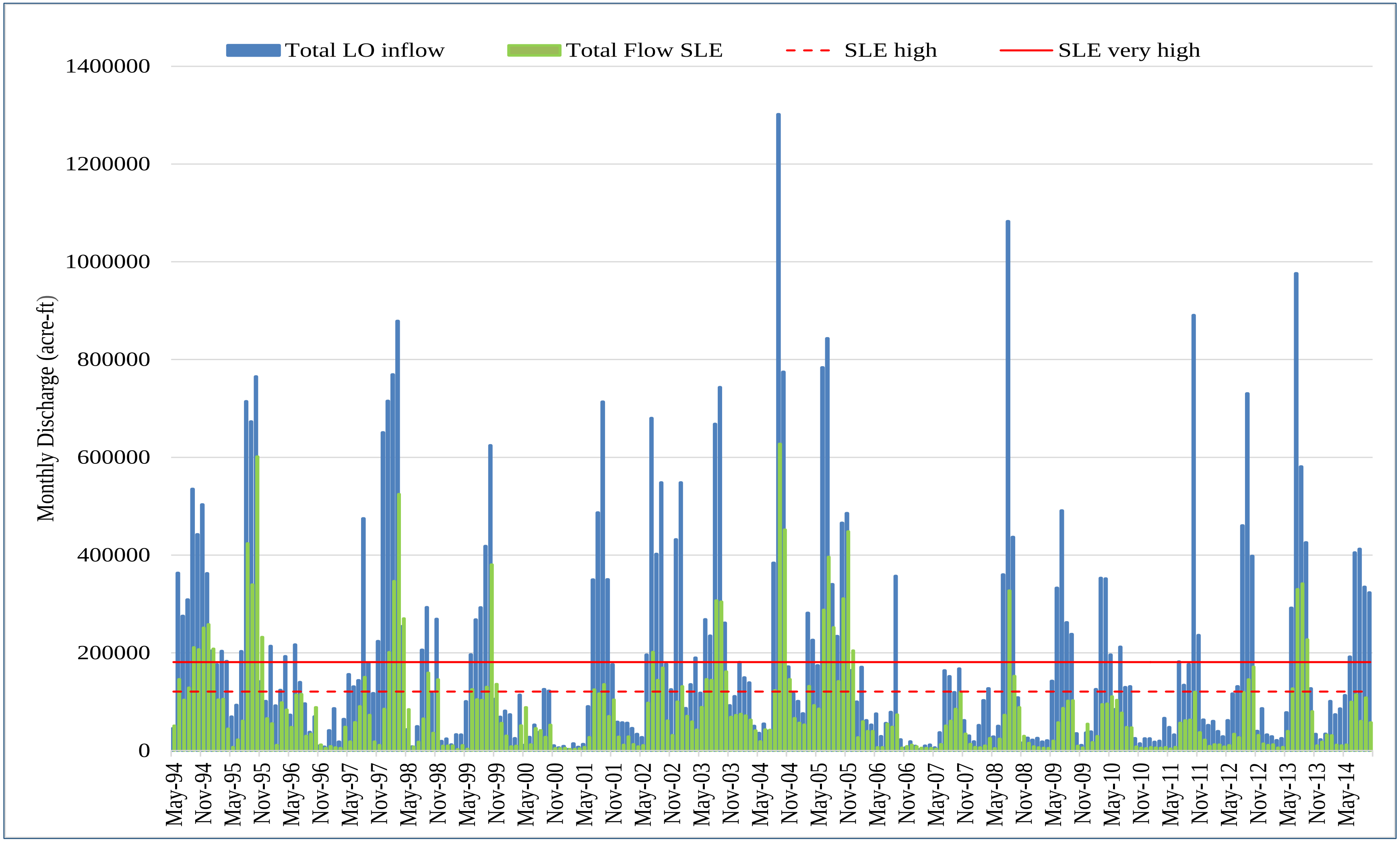

Figure III- 3: Total monthly flows into Lake Okeechobee and discharges to the St. Lucie estuary. Dashed horizontal line indicates damaging high discharges and solid horizontal line indicates damaging very high discharges to the estuaries. The WSE Lake Okeechobee regulation schedule was in effect from July 2000 to March 2008. The LORS 2008 regulation schedule has been in effect from April 2008 to present. Data from SFWMD.

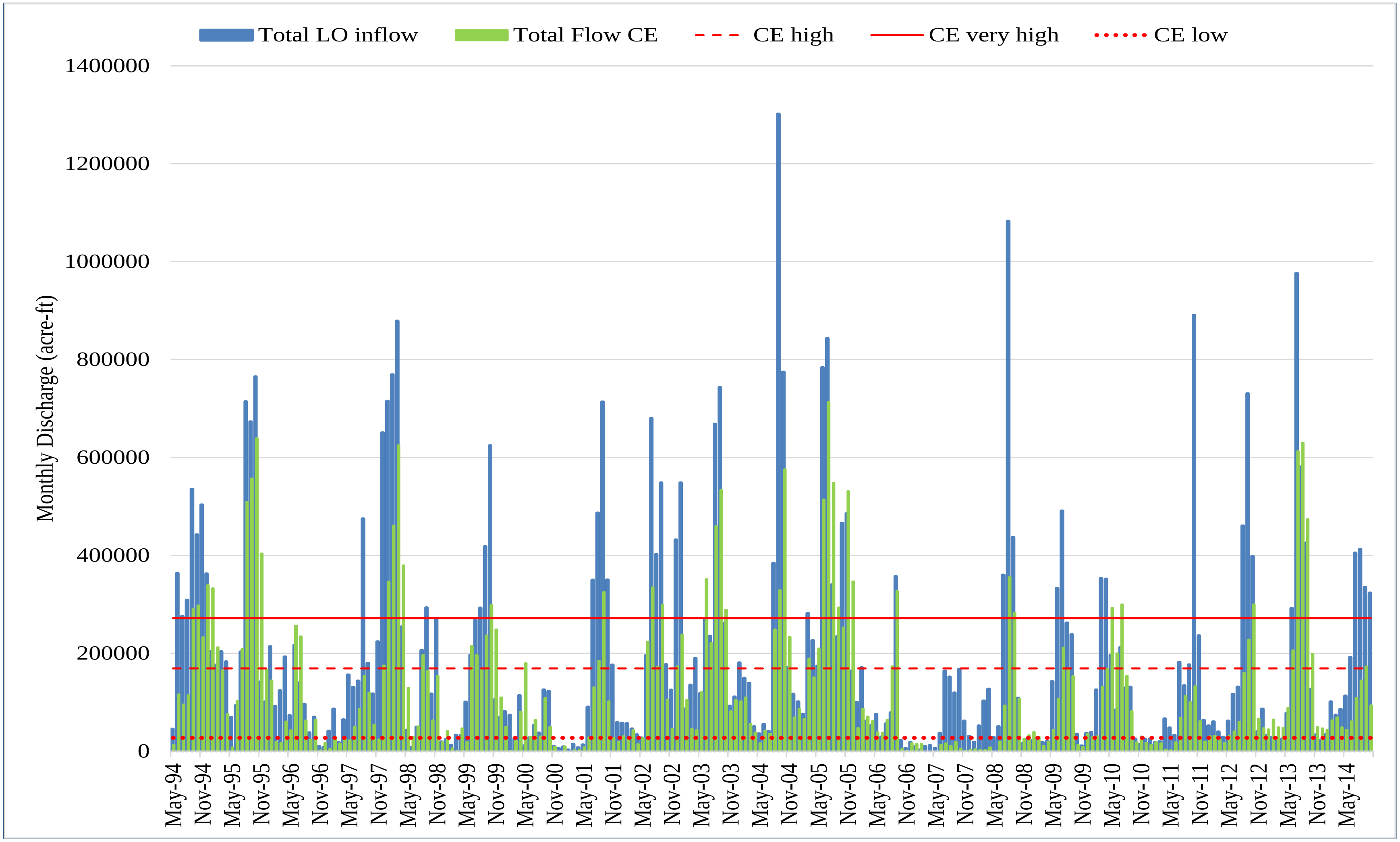

Figure III-4: Total flows into Lake Okeechobee and discharges to the Caloosahatchee estuary. Dashed horizontal line indicates damaging high discharges and solid horizontal line indicates damaging very high discharges to the estuaries. Dotted horizontal line indicates damaging low discharges. The WSE Lake Okeechobee regulation schedule was in effect from July 2000 to March 2008. The LORS 2008 regulation schedule has been in effect from April 2008 to present. Data from SFWMD.

2. Planning Efforts

a. Comprehensive Everglades Restoration Plan (CERP)

As discussed in Section II, the overarching objective of the Comprehensive Everglades Restoration Plan (CERP; USACE, 1999) which resulted from the Central and Southern Florida (C&SF) Project Comprehensive Review Study (known as the Restudy) was the restoration, preservation and protection of the south Florida ecosystem while providing for other water related needs of the region. In particular, the impacts to the Caloosahatchee and St. Lucie estuaries that the Restudy aimed to mitigate were extreme fluctuations in discharge, i.e. too much or too little fresh water.

Modeling analyses conducted using the peer-reviewed South Florida Water Management Model (SFWMM; SFWMD, 2005) during the Restudy demonstrated that large amounts of storage are needed in the system to reduce damaging high volume discharges of fresh water to the St. Lucie and Caloosahatchee estuaries, as well as to maintain minimum dry season flows to the Caloosahatchee estuary and to move more water south from Lake Okeechobee. The Restudy recommended a comprehensive plan containing over sixty project features to improve the quality, quantity, timing and distribution of water supply throughout the South Florida ecosystem and increase water supply for urban and agricultural needs. Specific projects intended to improve conditions in the estuaries and move more water south of Lake Okeechobee included:

- A 200,000 acre-ft above-ground reservoir in the Kissimmee River region north of Lake Okeechobee to reduce the amount of runoff entering Lake Okeechobee during the wet season, shorten the duration of damaging high water levels within the lake, reduce the frequency of high volume discharges to the Caloosahatchee and St. Lucie estuaries, and supplement flows to the lake during the dry season.
- A 50,000 acre-ft above ground reservoir and a 20,000 acre-ft stormwater treatment area in the Taylor Creek/Nubbin Slough Basin to attenuate flows to Lake Okeechobee and reduce the amount of nutrients flowing to the lake.
- 200 Aquifer Storage and Recovery (ASR) wells around Lake Okeechobee to store up to 1.0 billion gallons per day (bgd) of excess lake water (that would either be lost through discharge to tide or create harmful high water conditions in the lake) and return the stored water to the lake for use during drought years.
- A 160,000 acre-ft above-ground reservoir, and 44 ASR wells with a total capacity of 220 million gallons per day (mgd), in the Caloosahatchee River C-43 basin to capture basin runoff and releases from Lake Okeechobee to reduce damaging discharges and provide water quality benefits to the estuary in the wet season, and to provide environmental base flows to the estuary and other water supply benefits during the dry season.

- A 40,000 acre-ft above-ground reservoir in the St. Lucie C-44 basin and 349,400 acre-ft of above-ground reservoir storage in the C-23/C-24/C-25 basins to attenuate local basin runoff and provide water quality benefits to the St. Lucie estuary in the wet season and provide a supplemental source of water for irrigation and environmental base flows to the estuary in the dry season.
- A 360,000 acre-ft above-ground reservoir in the Everglades Agricultural (EAA) to provide storage and reduce damaging flood releases from the EAA to the WCAs, reduce Lake Okeechobee regulatory releases to the estuaries, meet EAA irrigation and Everglades water demands, and increase flood protection in the EAA.

b. Northern Everglades and Estuaries Protection Program (NEEPP)

In 2007, outside of the CERP planning process, the State of Florida Legislature initiated the Northern Everglades and Estuaries Protection Program (NEEPP; Section 373.4595, F.S.). The goal of NEEPP was to promote a comprehensive, interconnected watershed approach to protecting Lake Okeechobee and the Caloosahatchee and St. Lucie rivers and estuaries that specifically addressed both water quality and the quantity, timing and distribution of water to the natural systems. The program resulted in the development of the Lake Okeechobee Watershed Construction Project Phase II Technical Plan (SFWMD, 2008), the St. Lucie River Watershed Protection Plan (SFWMD, 2009a), and the Caloosahatchee River Watershed Protection Plan (SFWMD, 2009b).

The Lake Okeechobee Watershed Construction Project Phase II Technical Plan (LOP2TP; SFWMD, 2008) identified construction projects, along with on-site measures intended to prevent or reduce pollution at its source to achieve water quality targets for the lake. In addition, the plan included projects for increasing water storage north of Lake Okeechobee to achieve more desirable lake levels and reduce harmful, high-volume freshwater discharges to the Caloosahatchee and St. Lucie estuaries. Components of the Lake Okeechobee Plan included:

- Implementing Best Management Practices (BMPs) on more than 1.7 million acres of farmland.
- Building treatment wetlands to clean water flowing into the lake.
- Using other innovative nutrient control technologies to reduce phosphorus loads from the watershed.
- Creating between 900,000 and 1.3 million acre-ft of water storage north of the lake through a combination of above-ground reservoirs, underground storage and alternative water storage projects on public and private lands (note this estimate included existing storage and planned state and CERP projects).

The St. Lucie River Watershed Protection Plan (SFWMD 2009a) was developed to reduce nutrient loads to meet Total Maximum Daily Loads (TMDLs) and reduce the frequency and duration of undesirable salinities in the estuary while also meeting other water related needs such as water supply and flood protection. Building on the expected results from implementation of the LOP2TP, and incorporating the authorized CERP Indian River Lagoon - South (IRL-S) Final Integrated Project Implementation Report projects (USACE, 2004; see description in Section III.2.a below) the St. Lucie River Watershed Plan included:

- Implementation of BMPs on more than 297,000 acres of agricultural lands and on nearly 84,000 acres of urban lands.
- Construction of approximately 11,800 acres of reservoirs and more than 8,500 acres of STAs.
- Restoration of approximately 95,000 acres of wetlands and natural areas within the St. Lucie River watershed.
- Removal of more than 8 million cubic yards of muck sediment from the St. Lucie Estuary.
- Provision for approximately 200,000 acre-ft of water storage within the St. Lucie River watershed (in addition to the 900,000 acre-ft per year minimum storage needs identified in the Lake Okeechobee watershed).

The Caloosahatchee River Watershed Protection Plan (SFWMD, 2009b) identified a combination of watershed storage and water quality projects needed to help improve the quality, timing and distribution of water in the natural ecosystem. Working in concert with the expected results from implementing the LOP2TP, and incorporating the planned CERP C-43 reservoir (USACE, 2010; see description in Section III.2.b below), the Caloosahatchee River Watershed Protection Plan included:

- Implementation of BMPs on more than 430,000 acres of agricultural lands and 145,000 acres of urban lands.
- Construction of approximately 36,000 acres of reservoirs and 15,000 acres of STAs and Water Quality Treatment Areas.
- Restoration of more than 2,000 acres of wetlands within the Caloosahatchee River Watershed.
- Provision of approximately 400,000 acre-ft of water storage within the Caloosahatchee River Watershed (in addition to the 900,000 acre-feet minimum storage needs identified in the Lake Okeechobee Watershed).

It should be noted that these plans assumed that all water related needs of the region including water supply and flood protection must continue to be met. They also assumed Everglades water deliveries within the constraints of the system with the Acceler8 projects constructed (C-43 Reservoir, C-44 Reservoir and STA, Broward Water Preserve Areas, Site 1 Reservoir, and EAA Phase A-1 Reservoir; SFWMD, 2004) and a version of the Modified Water Deliveries to ENP was operational. However, full restoration of Everglades flows south of Lake Okeechobee were not provided by these plans.

c. River of Grass (ROG) Planning Process

In 2008, the SFWMD had an option to purchase a large amount of land in the Everglades Agricultural Area (EAA) from willing sellers, with the possibility to carry out land trades to achieve a contiguous corridor through the EAA for storage, treatment and conveyance of water to the Everglades. During this time the volume of storage needed to reduce lake-triggered damaging discharges to the Caloosahatchee and St. Lucie estuaries and move more water south of Lake Okeechobee was re-evaluated as part of the River of Grass (ROG) Phase 1 planning process. Screening-level modeling studies were conducted using the peer-reviewed Reservoir Sizing and Operations Screening model (RESOPS, SFMWD 2009c). These modeling analyses, conducted for the 41-year (1965-2005) period of record, assumed that the Kissimmee River Restoration (KRR) was complete, the C-43 and C-44 reservoirs were constructed (for details see Sections III.2a, b below), and the Lake Okeechobee Regulation Schedule was optimized using the upper bound from LORS 2008 (for details see Section V.5.a below). Various alternatives were evaluated with regard to their effectiveness in meeting a set of standard performance measures including percent reduction in lake-triggered high discharges to the St. Lucie (> 2000 cfs) and the Caloosahatchee (>2800 cfs) estuaries, and the ability to deliver the target dry season Everglades demand. The performance maps below (Figures III-5a-c; taken from SFWMD 2009d) show the percent reduction in lake-triggered high flow discharges to the estuaries, the percent of the dry season Everglades demand met, and the increase in mean annual flow to the Everglades for various combinations of storage north and south of Lake Okeechobee. According to these screening level estimates approximately one million acre-ft (maf) of storage can achieve a 90% reduction in lake-triggered discharge to the estuaries, meet 90% of the Everglades dry season target, and provide approximately 350,000 additional acre-ft of annual flow to the Everglades. Furthermore, a variety of north and south of lake storage configurations can effectively be used to meet these restoration objectives. It is important to note that this analysis focused on lake-triggered high discharge events, and thus the 1 maf estimate does not include the additional storage required within the Caloosahatchee and St. Lucie basins to attenuate local discharges to the estuaries. In addition to evaluating storage needs the ROG also estimated the additional treatment capacity required for the additional flows to meet Everglades legal water quality standards. For details on additional plans and projects to achieve water quality goals see Section IV.

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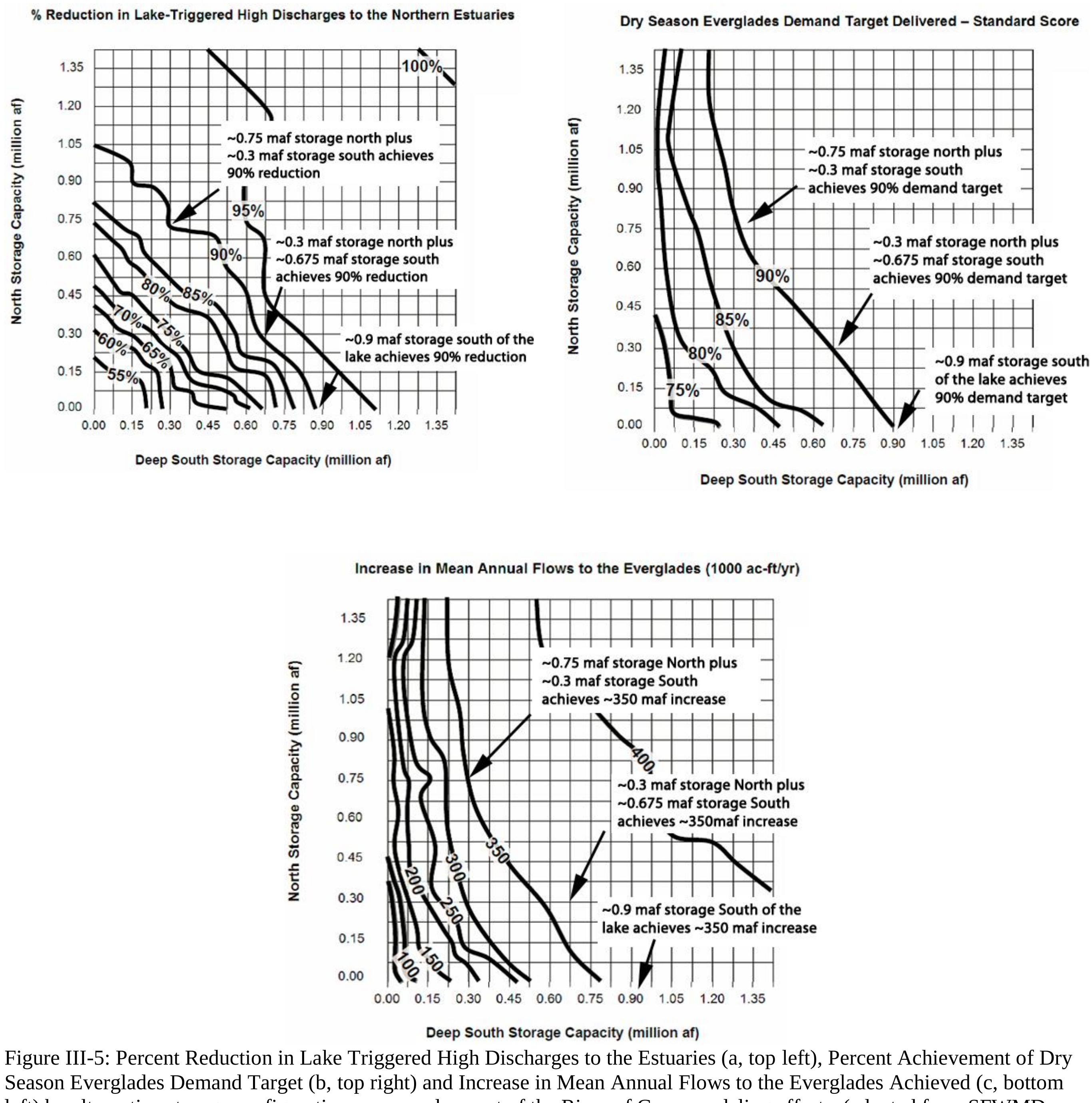


Figure III-5: Percent Reduction in Lake Triggered High Discharges to the Estuaries (a, top left), Percent Achievement of Dry Season Everglades Demand Target (b, top right) and Increase in Mean Annual Flows to the Everglades Achieved (c, bottom left) by alternative storage configurations proposed as part of the River of Grass modeling efforts. (adapted from SFWMD, 2009d). Various options to achieve 90% reduction in performance targets, and the increase in flows to the Everglades that this represents are noted on the figures.

In summary, the CERP, NEEPP and the ROG planning exercises all identified the need for an extremely large volume of new storage in the Greater Everglades system. The most recent estimates include:

- 400,000 acre-feet of water storage within the Caloosahatchee River watershed,
- 200,000 acre-feet of water storage within the St. Lucie River watershed, and
- approximately 1,000,000 acre-feet of water storage distributed north and south of Lake Okeechobee.

Additional water quality treatment projects needed to discharge the stored water to the lake, estuaries and EPA are described in Section IV.

3. Construction Project Status

Each of the planning efforts described above indicated clearly that large volumes of storage are required to reduce damaging freshwater discharges to the estuaries and move more water south of Lake Okeechobee. The following section summarizes the status and expected benefits of current CERP and NEEPP construction projects resulting from the planning efforts described above that are intended to provide portions of the required storage. The ROG process did not progress past the planning stage, and did not result in any planned construction projects outside of CERP.

a. CERP Indian River Lagoon-South (IRL-S) Project

Project Summary: The IRL-S Project is a CERP Project located within Martin and St. Lucie Counties (Figure III-6). The purpose of the project is to improve surface-water management in the C-23/C-24, C-25, and C-44 basins for habitat improvement in the St. Lucie River Estuary and southern portions of the Indian River Lagoon (USACE 2004). Project features include the construction and operation of four above ground reservoirs to capture water from the C-44, C-23, C-24, and C-25 canals for increased storage (130,000 acre-ft), the construction and operation of four STAs (approximately 8,700 acres) to reduce sediment, phosphorus, and nitrogen to the estuary and lagoon, the restoration of over 90,000 acres of upland and wetland habitat, the redirection of water from the C-23/24 basin to the north fork of the St. Lucie River to attenuate freshwater flows to the estuary, and muck removal from the north and south forks of the St. Lucie River and middle estuary.

Expected Benefits: The IRL-S project is expected to provide significant water-quality improvement benefits to both the St. Lucie River and Estuary and Indian River Lagoon by reducing the load of nutrients, pesticides, and suspended materials from basin runoff. The project is also expected to reduce damaging freshwater runoff from the local basin to the estuary. Modeling studies using the peer-reviewed SFWMM (SFWMD, 2005) and the Natural

Systems Model for the St. Lucie (NSM-IRL) estimated, based on the 1965 to 1995 simulation period, that the number of occurrences of mean monthly flow discharged to the estuary between 2,000 cfs and 3,000 cfs would be reduced from 7.5% of the time for the 1995 base condition (which assumes no CERP projects are in place) to 4.3% of the time if the entire IRL-S project, but no other CERP projects were constructed (Table III-1). Furthermore, modeling results estimated that the number of occurrences of mean monthly flow above the very high target of 3,000 cfs would be reduced from 3.5% to 1.9% if the entire project were constructed (Table III-1). The modeled performance of the IRL-S project achieves the restoration targets published by USACE (2004) and comes very close to achieving the restoration targets published by SFWMD (2009a).

Status: The IRL-S Project was authorized by the US Congress in 2007. Funding has been appropriated for the first phase of the project, the C-44 reservoir (approximately 40,000 acre-ft storage) and an associated STA (approximately 6,300 acre treatment area). To expedite completion of the C-44 project, in July 2014 the SFWMD Governing Board agreed to construct the C-44 STA, the pump station and a portion of the system discharge canal and the USACE agreed to construct the reservoir. The agencies entered into an amended Project Partnership Agreement in July 2014 to reflect this agreement, and the USACE completed the first construction contract of the project in the same month. In August 2014, the SFWMD Governing Board awarded the contract for the construction of a spillway that will serve as the single point of water movement out of the entire C-44 project. The estimated date of completion for the C-44 project is 2020. Funds have not yet been appropriated for the C-23, C-24, or C-25 reservoirs and associated STAs, or the habitat restoration projects.

Table III-1: Existing Conditions, Restoration Targets and Expected Benefits IRL-S Project. Percentages indicate percent of time the monthly flow condition occurs under specific scenarios. Red-colored percentages have not achieved restoration goals. Green-colored percentages have achieved restoration goals.

Condition	St. Lucie	
	# mean monthly flows between 2000 and 3000 cfs	# mean monthly flows >3000 cfs
Restoration Targets 1965-1995 (USACE, 2004)	<18 mo in 31 years[3] (4.8%)	<10 mo in 31 years[3] (2.7%)
Restoration Targets (1970-2005 (SFWMD, 2009a)	<21 mo in 36 years[1] (6.3%)	<6 mo in 36 years[1] (1.4%)
Historical Performance 1994-2014	24 mo in 20 years[2] (10%)	29 mo in 20 years[2] (12%)
1995 base condition with no CERP projects	28 mo in 31 years[3] (7.5%)	13 mo in 31 years[3] (3.5%)
Future with complete IRL-S project	16 mo in 31 years[3] (4.3%)	7 mo in 31 years[3] (1.9%)

[1]based on simulations from 1970-2005 period of record (Figure 6.5-1, SFWMD 2009a)
[2]based on observed flows 1994-2014
[3]based on simulations for 1965-1995 period of record (Table 6-6, USACE 2004)

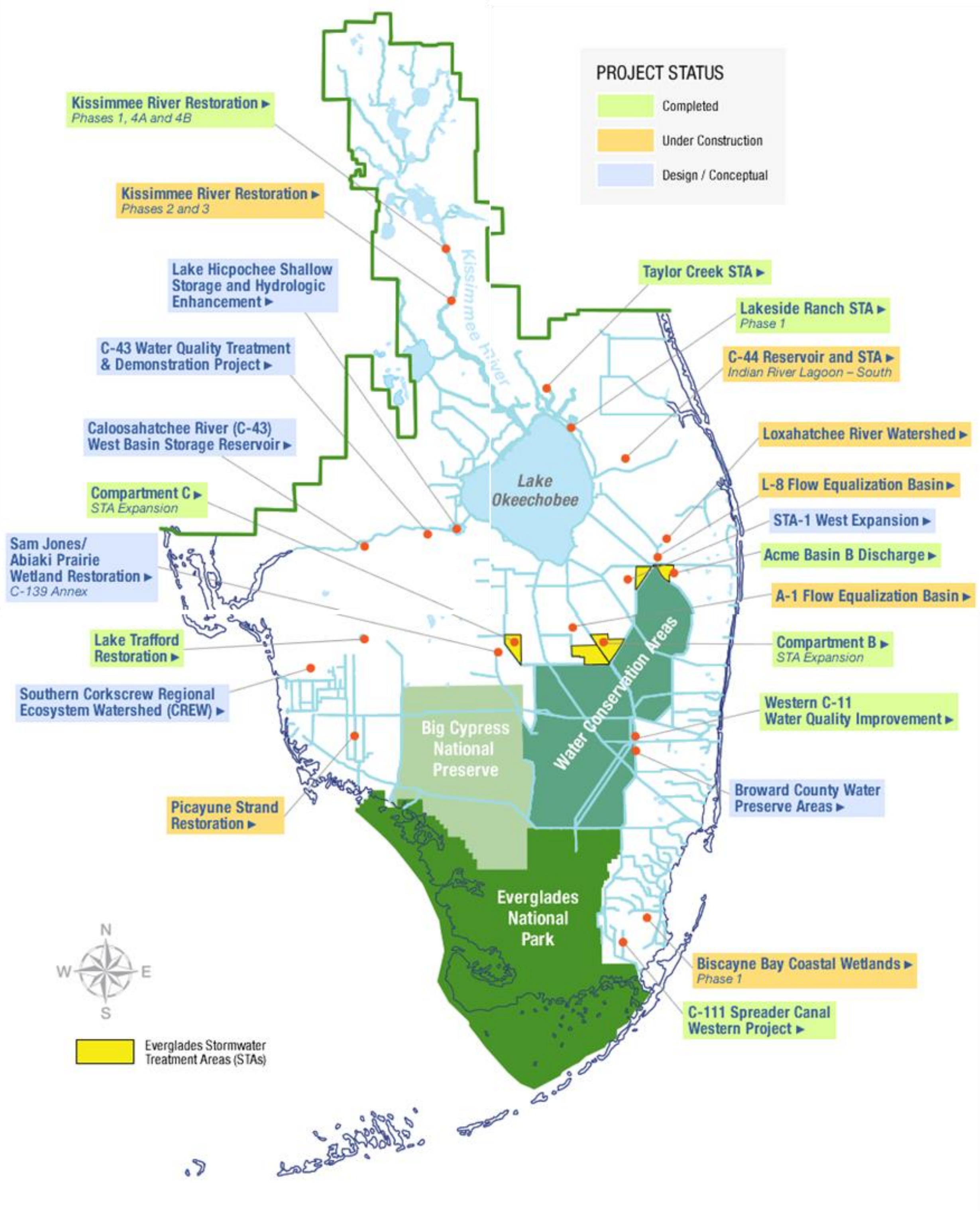


Figure III-6 Map showing locations of Greater Everglades Ecosystem Restoration Construction Projects that are completed (green), under construction (orange) or in Design or Conceptual Phase (blue) (from SFWMD http://www.sfwmd.gov/restorationprogress).

b. CERP Caloosahatchee River (C-43) West Basin Storage Projects

Project Summary: The Caloosahatchee River (C-43) West Basin Storage Reservoir Project is a CERP project that provides approximately 170,000 acre-ft of above-ground storage in a two-cell reservoir in Hendry County (Figure III-6). The primary functions of the Caloosahatchee reservoir are to capture excess basin runoff and discharges from Lake Okeechobee during periods of high volume flows, and to provide an additional source of water to maintain desirable salinity in the Caloosahatchee Estuary during periods of low flow (USACE, 2010).

Expected Benefits: Modeling studies using the SFWMM (SFWMD, 2005) and the Freshwater Caloosahatchee River Basin Model (FCRB) estimated that, based on the 1965 to 2000 time period, the project will reduce the number of months that flows to the estuary are below the restoration target of 450 cfs from 40% of the time for a future without project condition (which assumed that the KRR project was operational, but no CERP projects had been completed) to 28% of time if all CERP projects, including the selected C-43 project, were constructed (Table III-2). Furthermore, the number of months that flows to the estuary are above mean monthly high flow target of 2,800 cfs are estimated to be reduced from 9.3% of the time for the future without project condition to 2.7% if all CERP projects were constructed, and the number of months that flows to the estuary exceed the very high mean monthly flow target of 4,500 cfs are estimated to be reduced from 2.7% of the time to 0% (USACE, 2010). The modeled performance of the C-43 project does not achieve the low flow or high flow restoration targets, but does achieve the very high restoration target published by SFWMD (2009b, Table III-2).

Status: In June 2014, the federal government authorized this project via the 2014 Water Resources Reform and Development Act (WRRDA), however, federal funds have not yet been appropriated. In the 2014 Legislative Session, the State of Florida appropriated $18 million dollars to design and construct an early start interim project that will provide approximately 2,200 acre-ft of static storage.

Table III-2: Existing Conditions, Restoration Targets and Expected Benefits of C-43 Project. Percentages indicate percent of time the monthly flow condition occurs under specific scenarios. Red-colored percentages have not achieved restoration goals. Green-colored percentages have achieved restoration goals.

Condition	Caloosahatchee		
	# mean monthly flows < 450 cfs	# mean monthly flows > 2800 cfs	# mean monthly flows > 4500 cfs
Restoration Targets	0 mo in 36 years[1] (0%)	<3 months in 36 years[1] (0.7%)	0 mo in 36 years[1] (0%)
Historical Performance 1994-2014	68 mo in 20 years[2] (28%)	68 mo in 20 years[2] (28%)	37 mo in 20 years[2] (15%)
Future without any CERP projects simulated for C-43 Project (2010)	43 mo in 9 years[3] (40%)	10 mo in 9 years[3] (9.3%)	3 mo in 9 years[3] (2.7%)
Future with complete CERP including C-43 Project (2010)	30 mo in 9 years[3] (28%)	3 mo in 9 years[3] (2.7%)	0 in 9 years[3] (0%)

[1]based on simulations from 1970-2005 period of record (Figures 6.5-1 and 6.5-2, SFWMD 2009b)
[2]based on observed flows 1994-2014
[3]based on simulations for the 1965-2000 period of record, however only 9 years containing 3 wet, 3 dry and 3 normal years out of the 36 year simulation were analyzed (Table 5-10, USACE 2010).

c. CERP Aquifer Storage and Recovery (ASR) Pilot Projects and Regional Study

Project Summary: Aquifer storage and recovery (ASR) is a mechanism for providing inter-annual water storage underground through injection wells in the wet season to be withdrawn in subsequent dry seasons for beneficial purposes as surface water. The CERP Restudy (USACE, 1999) called for a total of 333 ASR wells, including 200 located around Lake Okeechobee intended to store up to 1.0 billion gallons per day (bgd) of excess lake water that would either be lost through discharge to tide or create harmful high water conditions in the lake. The stored water is intended to be returned to the lake for use during drought years. Due to the unprecedented magnitude of ASR implementation proposed in CERP, three ASR pilot projects and an ASR regional study were proposed to evaluate its technical and regulatory feasibility.

Status: The ASR pilot facilities were used to conduct scientific and engineering studies regarding the technical performance and regulatory compliance of the ASR concept. Three 5 mgd pilot studies were proposed in the CERP Restudy: the Kissimmee River ASR Pilot, the Hillsboro ASR Pilot and the Caloosahatchee River (C-43) basin ASR Pilot. ASR facilities consisting of recharge and recovery pumps, filtration and UV pre-treatment systems, ASR and monitoring wells, and on-site storage ponds were designed, constructed and operated at the Kissimmee River and Hillsboro sites between 2007 and 2013. The third pilot site in the Caloosahatchee River (C-43) basin was abandoned because geotechnical testing and exploratory well construction indicated the site was not suitable for development of an ASR storage zone.

Results from the two successful pilot facilities indicated that recovery efficiencies were 100% at the Kissimmee River facility and ranged from 20-40% at the Hillsboro facility where the Floridan Aquifer water was brackish (USACE, 2013). Operating pressures did not compromise the overlying Hawthorn confining unit, and no pressure or water quality effects were observed in the surficial aquifer, at either site. The recharge water quality (primarily color) caused problems with the UV disinfection system at both sites resulting in frequent detections of coliform bacteria in the treated water. Thus, a more robust disinfection system will be required in future permanent facilities. Issues associated with arsenic mobilization in the recovered water resolved themselves over time during the pilot studies. Furthermore, mercury and methylmercury concentrations declined during the storage phase of the ASR cycle, and phosphorus concentrations also declined (e.g., from a mean of 66 μg/l +/- 42 μg/l in recharged water to a mean of 10.8 μg/l +/- 11.6 μg/l in recovered water at the Kissimmee River site (USACE, 2013). Although the operational testing costs at the pilot sites were considered to be high, several recommendations were made to improve cost-effectiveness in future permanent facilities (USACE, 2013).

The ASR regional study is an on-going data collection and regional modeling effort to analyze the effect of the ASR well network on water levels and water quality within the regional aquifer systems, and on existing water users and surface-water bodies. In the ASR Regional Model Production Scenario Report (USACE, 2014a), it was suggested that operation of 333 wells in the South Florida region would likely produce undesirable hydrogeological impacts. The report recommended a smaller system consisting of approximately 94 ASR wells in the Upper Floridan Aquifer (with an assumed 70% recovery), 37 ASR wells in the Avon Park Permeable Zone (with an assumed 30% recovery) and additional 101 wells in the deep Boulder Zone (with an assumed 0% recovery). Of these wells, 139 were located in the Lake Okeechobee basin (47 Upper Floridan, 31 Avon Park and 61 Boulder Zone), 27 were located in the Caloosahatchee Basin (9 in the Upper Floridan, 1 in the Avon Park and 17 in the Boulder Zone) and the remaining 66 were located in basins southeast of Lake Okeechobee. The Final Report for the ASR regional study is currently under peer review and is scheduled to be completed in 2015.

d. NEEPP Lake Okeechobee Watershed Construction Project Phase II Technical Plan

Plan Summary: The LOP2TP required 900,000 to 1,300,000 acre-ft of storage in the Lake Okeechobee watershed to manage lake stages in Lake Okeechobee within a desirable range, and reduce damaging freshwater releases to the Caloosahatchee and St. Lucie estuaries. Plan elements for capturing and storing water in the Lake Okeechobee watershed included the following above-ground reservoirs, Aquifer Storage and Recovery (ASR) wells, and Dispersed Water Management (DWM) projects:

- Above-ground Storage Reservoirs: Although the LOP2TP specified that 900,000 to 1,300,000 acre-ft of storage was needed, only three storage reservoirs with a total storage capacity of approximately 440,800 acre-ft, were identified in the initial implementation plan (Table III-3, from SFWMD (2008)). While these facilities were modeled and evaluated as surface water reservoirs, the plan indicated that the storage benefits derived from these types of projects might also be attained through smaller-scale DWM on private lands, ASR, surface water reservoirs, or a combination of these. The plan specified that the appropriate mix of storage would become more defined as results from ASR pilots and the ASR Regional Study became available.

Table III-3 Location and Capacity of LOP2TP Storage Features (from SFWMD 2008)

Storage ID	Sub-watershed	Storage Capacity (acre-ft)	TP load reduction to Lake (metric tons/yr)	Source Water
Kissimmee East Storage	Lower Kissimmee	200,000	6.5	• Receives flows from and discharge back to the Kissimmee River • Stored water can potentially also be diverted to the TCNS Sub-watershed for additional treatment
Kissimmee Storage	Lower Kissimmee	161,263	12	• Receives flows from and discharges to Kissimmee River • CERP-LOW Project feature
Istokpoga Storage	Istokpoga Indian Prairies	79,560	7	• Receives flows from Lake Istokpoga/Indian Prairie and discharges to Indian Prairie • CERP-LOW Project feature

- Aquifer Storage and Recovery: To complement surface storage the LOP2TP also identified four ASR facilities, with a total capacity of 66 mgd (Table III-4, from SFWMD, 2008)). These ASR facilities were expected to be completed during the initial 2008-2010 implementation stage. It was anticipated that additional ASR features would be identified in the future to help meet the storage goal of the plan after the Lake Okeechobee ASR pilots and the ASR Regional Study were completed.
- Dispersed Water Management (DWM) Program: The goals and objectives of the DWM Program are to provide shallow water storage to enhance Lake Okeechobee and estuary health by reducing discharge volumes, reducing nutrient loads to downstream receiving waters, and expanding groundwater recharge opportunities. The four main categories of projects under the DWM Program include storage and retention projects on private lands, storage and retention projects on public lands, Northern Everglades Payment for Environmental Services (NE-PES) projects on ranch lands, and Water

Farming Payment for Environmental Services (WF-PES) pilot projects on fallow citrus lands. The LOP2TP included the implementation of approximately 100,000 acre-ft of alternative water storage projects on public and private lands in the Lake Okeechobee watershed during the initial 2008-2010 implementation phase.

Table III-4. Location, water storage and TP load reduction for LOP2TP ASR (from SFWMD 2008)

ASR ID	Sub-watershed	Storage (acre-ft)	TP load reduction (metric tons/yr)	Comments
Kissimmee Pilot	Lower Kissimmee	3,780 (5 million gallons per day (mgd))	0.1	• One 5 mgd ASR well built, operated and tested between 2007 and 2013
Paradise Run 10-well System	Lower Kissimmee	22,950 (50 mgd)	1.4	• Maximum pumping capacity of up to 50 mgd
Seminole Brighton Reservoir ASR System		3,780 (5 mgd)	0.8	• One 5 mgd ASR well system to be located along the C-41 Canal on the western edge of the Seminole Brighton Reservation in Glades County
Taylor Creek ASR Reactivation	Taylor Creek/Nubbin Slough Sub-watershed	5,400 (6 mgd)	1.2	• Assessment and eventual reactivation of the TCNS ASR system • One 6 mgd well system is proposed adjacent to the L-63N Canal

Expected Benefits: Modeling analyses were conducted using the Northern Everglades Regional Simulation Model (NERSM) for the 1970 to 2005 time period. The 2005 base condition (which assumed that no CERP or LOP2TP projects were in place and that Lake Okeechobee releases to the estuaries and WCAs were based on the Water Supply/Environmental (WSE) regulation schedule) was compared to the Future Base Condition (which assumed that the KRR and Acceler8 projects, i.e. C-43 reservoir, C44 reservoir and STA, Broward Water Preserve Areas, Site 1 Reservoir, Modified Water Deliveries to Everglades National Park, limited version of Everglades rainfall deliveries, and EAA Phase A-1 Reservoir, were in place) and the Future with LOP2TP Condition which assumed that, in addition to the Future Base, the LOP2TP was fully implemented (including 914,000 acres of reservoir storage, 54,000 acres of STAs and 66 mgd of ASR) (Table III-5).

Modeling results indicated that the occurrences of undesirable high flows to the St. Lucie estuary between 2,000 cfs and 3,000 cfs would be reduced from 8.5% of the time over the 36 year simulation period for 2005 base conditions to 7.6% for the Future with LOP2TP, versus a restoration target of 4.9% (Table III-5). Furthermore, modeling analyses estimated that undesirable very high flows greater than 3,000 cfs would be reduced from 6.4% of the time for the 2005 base condition to 4.2% of the time for the Future with LOP2TP versus a restoration target of 1.4%.

For the Caloosahatchee estuary, modeling analyses estimated that the occurrences of undesirable high flows above 2,800 cfs would be reduced from 19% of the time over the 36 year simulation period for 2005 base conditions to 12% of the time for the Future with LOP2TP, versus a restoration target of 0.7% (Table III-5). Furthermore, modeling analyses estimated that undesirable very high flows greater than 4,500 cfs would be reduced from 8.6% to 4.2% versus a restoration target of 0%, and that undesirable low flows less than 450 cfs would be reduced from 44% to 4.2%, versus a restoration target of 0%. Thus, while the LOP2TP is estimated to achieve substantial improvement of estuary conditions it does not achieve the restoration targets published by SFWMD (2009a,b).

Table III-5: existing conditions, restoration targets and expected benefits of NEEPP projects. Percentages indicate percent of time the monthly flow condition occurs under specific scenarios. Red-colored percentages have not achieved restoration goals.

Condition	St. Lucie		Caloosahatchee		
	# mean monthly flows between 2000 and 3000 cfs	#mean monthly flows > 3000 cfs	# mean monthly flows < 450 cfs	# mean monthly flows > 2800 cfs	# mean monthly flows > 4500 cfs
Restoration Targets	<21 mo in 36 years[1] (4.9%)	<6 mo in 36 years[1] (1.4%)	0 mo in 36 years[2] (0%)	<3 months in 36 years[2] (0.7%)	0 mo in 36 years[2] (0%)
Historical Performance 1994-2014	24 mo in 20 years[3] (10%)	29 mo in 20 years[3] (12%)	68 mo in 20 years[3] (28%)	68 mo in 20 years[3] (28%)	37 mo in 20 years[3] (15%)
2005 base condition (with no CERP or NEEPP projects)	37 mo in 36 years[1] (8.5%)	28 mo in 36 years[1] (6.4%)	189 mo in 36 years[2] (44%)	80 mo in 36 years[2] (19%)	37 in 36 years[2] (8.6%)
Future base condition (including KRR and Acceler8 projects)	38 mo in 36 years[4] (8.8%)	21 mo 36 years[4] (4.2%)	32 mo in 36 years[4] (4.2%)	55 mo in 36 years[4] (12%)	25 mo in 36 years[4] (4.2%)
Future with LOP2TP	33 mo in 36 years[4] (7.6%)	18 mo 36 years[4] (4.2%)	18 mo in 36 years[4] (4.2%)	51 mo in 36 years[4] (12%)	18 mo in 36 years[4] (4.2%)
Future with LOP2TP, St. Lucie and Caloosahatchee River Protection Plans	25 mo in 36 years[1] (5.8%)	17 mo in 36 years[1] (3.9%)	4 mo in 36 years[2] (0.9%)	44 mo in 36 years[2] (10%)	16 mo in 36 years[2] (3.7%)

[1]based on simulations from 1970-2005 period of record (Figure 6.5-1, SFWMD 2009a)
[2]based on simulations from 1970-2005 period of record (Figures 6.5-1 and 6.5-2, SFWMD 2009b)
[3]based on observed flows 1994-2014
[4]based on simulations from 1970-2005 period of record (Figures 8-6, 8-7and 8-8, SFWMD 2008)

Status:

- None of the above-ground reservoirs have been sited, authorized, designed or constructed. Initial planning and design work on the two reservoirs associated with the CERP Lake Okeechobee Watershed (LOW) Project began in 2004 with the goal of having a Project Implementation Report by 2009. However work was suspended in 2010 due to unresolved policy concerns about cost-sharing water quality/stormwater treatment area features proposed and included in the tentatively selected plan.
- One 5 mgd pilot ASR facility has been designed, constructed and successfully tested in the Kissimmee River basin. None of the additional planned ASR facilities have been sited, designed or constructed.
- As of 2014, the total DWM either in operation or under construction in the Lake Okeechobee watershed was roughly estimated through preliminary modeling studies to be approximately 60,500 acre-ft (Table III-6, SFWMD (2015)).

Summaries, expected benefits and status of projects to improve water quality in the Lake Okeechobee watershed are described in Section IV.

Table III-6. Dispersed Water Management Projects in the Lake Okeechobee Watershed (from SFWMD, 2015).

Project Name	**Category**	**Status**	**Estimated Storage Benefits (acre-ft/yr)**
Buck Island Ranch	NE-PES 1	Operational	1,573
Dixie West	NE-PES 1	Operational	315
Dixie Ranch	NE-PES 1	Operational	856
Lost Oak Ranch	NE-PES 1	Operational	374
Triple A Ranch	NE-PES 1	Construction	397
Willaway Cattle and Sod	NE-PES 1	Operational	229
XL Ranch	NE-PES 1	Operational	887
Blue Head Ranch	NE-PES 2	Construction	3,462
West Waterhole Pasture	Private Lands FRESP	Operational	5,000
Rafter T Ranch	Private Lands FRESP	Operational	1,145
Payne and Son Ranch	Private Lands FRESP/WRP	WRP Operational	932
Williamson Cattle Company	Private Lands FRESP/WRP	WRP Operational	150
Nicodemus Slough	Private Lands	Construction	34,000
Avon Park Air Force Range	Public Lands	Operational	10,000
Sumica Tract	Public Lands	Operational	281
Istokpoga Marsh Watershed Improvement District	Public Lands	Construction	950

e. NEEPP St. Lucie River Watershed Protection Plan

Plan Summary: Specific elements of the St. Lucie Watershed Protection Plan intended to provide increased water storage capacity required to reduce damaging discharges to the St. Lucie estuary and improve low flow conditions included:

- The LOP2TP elements described in Section III.2.d above.
- The regional CERP IRL-S project described in Section III.2.a above.
- The CERP Ten Mile Creek Water Preserve Area Critical Project located in St. Lucie County at the headwaters of the North Fork of the St. Lucie River along Ten Mile Creek. This project, as originally designed, consisted of an aboveground reservoir of approximately 550 acres, designed to store up to 6,000 acre-ft of water. The project also included a 100-acre STA to treat flows from the reservoir.
- Local alternative DWM projects developed on private, public, and tribal lands to prevent runoff from reaching the regional drainage system or improve the timing of its delivery.

Expected Benefits: Modeling analyses conducted for the St. Lucie Watershed Protection Plan using the Northern Everglades Regional Simulation Model (NERSM) for the 1970-2005 period of record estimated that the proposed plan would reduce the occurrences of undesirable high flows between 2,000 cfs and 3,000 cfs from 8.5% of the time during the 36 year simulation period for 2005 base conditions (which assumed that no CERP or LOP2TP projects were in place and that Lake Okeechobee releases to the estuaries and WCAs were based on the WSE regulation schedule) to 5.8% of the time for the Future with Plan (which assumed the KRR, all Acceler8 projects described above, and all elements of both the LOP2TP and the St. Lucie Watershed plans were fully constructed). Furthermore, modeling analyses estimated that undesirable very high flows greater than 3,000 cfs would be reduced from 6.4% of the time to 3.9% for the 36 year simulation period. While the St. Lucie Watershed Protection Plan is estimated to provide some improvement in performance over the LOP2TP it still does not achieve the performance targets published by SFWMD (2009a).

Status:

- The LOP2TP elements: See Section III.2.d above.
- CERP IRL-S project: See Section III.2.a above.
- Ten Mile Creek Project: Construction of this project was completed by the USACE in 2005, however, it did not perform as designed. In an August 11, 2014 letter, the SFWMD requested that the USACE “deauthorize the project, terminate the Project Cooperation Agreements, and extinguish any real estate certifications associated with the project. Following these steps, the SFWMD will take ownership and responsibility for converting

the Ten Mile Creek Project into a functional facility designed to provide necessary storage and water treatment options."

- Dispersed Water Management: As of 2014, the DWM either in operation or under construction in the St. Lucie watershed was roughly estimated through preliminary modeling studies to be approximately 23,000 acre-ft (Table III-7, SRWMD (2015)). This includes contributions from the U.S. Department of Agriculture Natural Resources Conservation Service (USDA NRCS) Wetland Reserve Program (WRP) and other programs, the Florida Department of Agriculture and Consumer Affairs (FDACS) BMP program, agricultural landowners, agricultural organizations, non-governmental organization, and local governments.

Summaries, expected benefits and status of projects to improve water quality in the St. Lucie watershed are described in Section IV.

Table III-7: SFWMD Dispersed Water Management Projects in the St. Lucie Watershed (from SFWMD, 2015).

Project Name	**Category**	**Status**	**Estimated Storage Benefits (ac-ft/yr)**
Alderman-Deloney Ranch	NE-PES 1	Operational	147
Caulkins Citrus	Water Farming	Operational	6,780
Evans Properties (Alt. E-1)	Water Farming	Construction	3,635
Spur Land and Cattle/Bull Hammock Ranch	Water Farming	Construction	870
Harbour Ridge	Private Lands	Operational	667
Indiantown Citrus Growers Phase I and II	Private Lands	Operational	3,550
Adams Ranch Cattle and Citrus Operations (ARCCO) (C-23/C-24 Complex)	Public Lands	Operational	190
C-23 Interim Storage (Section D - PC55)	Public Lands	Operational	110
C-23 Interim Storage (Section C)	Public Lands	Construction	212
Williamson Ranch/Turnpike Dairy	Public Lands WRP	Operational	547
Allapattah Parcels A and B - Phase I	Public Lands WRP	Operational	3,500
Allapattah Parcels A and B - Phase II	Public Lands WRP	Construction	1,243
Allapattah H Canal	Public Lands	Operational	1,610

f. NEEPP Caloosahatchee River Watershed Protection Plan

Plan Summary: Specific elements of the Caloosahatchee River Watershed Protection Plan intended to provide increased water storage capacity to reduce damaging high discharges to the Caloosahatchee estuary and improve low flow conditions included:

- The LOP2TP described above.
- CERP C-43 basin storage reservoir project described above.
- Additional Reservoir Storage Sites
    - C-43 Distributed Reservoirs

  - Harns Marsh Improvements
  - West Lake Hicpochee Project
  - Yellowtail Structure Construction
  - Hendry County Storage
  - Hendry Extension Canal Widening
  - East Caloosahatchee Storage
  - Additional Caloosahatchee Storage (beyond the C-43 reservoir)
- Aquifer Storage and Recovery sites including the Cape Coral and Lee County Well Field site projects.
- DWM in the Barron Water Control District, Recyclable Water Containment Areas, and Recycled Water Containment Area in the S-4 Basin.

Expected Benefits: Modeling analyses conducted for the Caloosahatchee River Watershed Protection Plan exercise estimated that, based on the 1970 to 2005 time period, the proposed plan would reduce the occurrences of undesirable high flows above 2,800 cfs from 19% of the time under 2005 base conditions (which assumed that no CERP or LOP2TP projects were in place and that Lake Okeechobee releases to the estuaries and WCAs were based on the WSE regulation schedule) to 10% for the Future with plan (that assumed the KRR, all Acceler8 projects described above, and all elements of both the LOP2TP and the Caloosahatchee Watershed plans were fully constructed). Furthermore, modeling analyses estimated that undesirable very high flows greater than 4,500 cfs would be reduced from 8.6% to 3.7% of the time, and undesirable low flows less than 450 cfs would be reduced from 44% to 0.9% of the time. While the Caloosahatchee watershed plan is estimated to achieve improvements in performance over the LOP2TP it still does not achieve the performance targets published by SFWMD (2009b).

Status:

- The LOP2TP elements: See Section III.2.d above.
- CERP C-43 basin storage reservoir project: See Section III.2.b above.
- Lake Hicpochee Hydrologic Enhancement Project - North: Construction is scheduled to begin in FY2015.
- Dispersed Water Management: The total DWM either in operation or under construction in the Caloosahatchee River watershed is estimated through preliminary modeling studies to be approximately 9,900 acre-ft (Table III-8, from SFWMD (2015)). This includes contributions from the U.S. Department of Agriculture Natural Resources Conservation Service (USDA NRCS) Wetland Reserve Program (WRP) and other programs, the FDACS BMP program, agricultural landowners, agricultural organizations, non-governmental organization, and local governments.

Summaries, expected benefits and status of projects to improve water quality in the Caloosahatchee watershed are described in Section IV.

Table III-8. SFWMD Dispersed Water Management Projects in the Caloosahatchee Watershed (from SFWMD, 2015).

Project Name	Category	Status	Estimated Storage Benefits (ac-ft/yr)
Mudge Ranch	NE-PES 2	Operational	392
Barron Water Control District	Public Lands	Operational	5,000
ECWCD Mirror Lakes/Halfway Pond Phase I	Public Lands	Operational	1,000
BOMA	Public Lands	Operational	836
Six Mile Cypress Slough North	Public Lands	Construction	1,400
C-43 Interim Temporary Storage	Public Lands	Operational	1,250

g. State of Florida Restoration Strategies

Plan Summary: To address water quality concerns associated with existing flows to the Everglades Protection Area (EPA), the South Florida Water Management District (SFWMD), Florida Department of Environmental Protection (FDEP), and United States Environmental Protection Agency (USEPA) established a Water Quality-Based Effluent Limit (WQBEL) intended to achieve compliance with the State of Florida's numeric phosphorus criterion in the EPA. In addition, they identified "Restoration Strategies", a suite of additional water quality projects to work in conjunction with the existing Everglades Stormwater Treatment Areas (STAs) to meet the WQBEL (SFWMD, 2012; see details of legal requirements in Section II.4). The Restoration Strategies projects primarily consist of Flow Equalization Basins (FEBs), STA expansions, and associated infrastructure and conveyance improvements along three flow paths (Eastern, Central, Southern). The primary purpose of FEBs is to attenuate peak stormwater flows prior to delivery to STAs and provide dry season benefits, while the primary purpose of STAs is to use biological processes to reduce phosphorus concentrations to achieve the WQBEL (See Section IV for more details on water quality problems and potential solutions). Additional water quality projects for the eastern flow path include the L-8 FEB in the S-5A Basin with approximately 45,000 acre-ft of storage and an STA expansion of approximately 6,500 acres that will operate in conjunction with STA-1W. The additional project in the central flow path is the A-1 FEB with approximately 56,000 acre-ft of storage on the A-1 Talisman property that will attenuate peak flows to STA-3/4, and STA-2 and Compartment B. In the western flow path an FEB with approximately 11,000 acre-ft of storage and approximately 800 acres of effective treatment area within STA-5 are being added (Figure III-7).

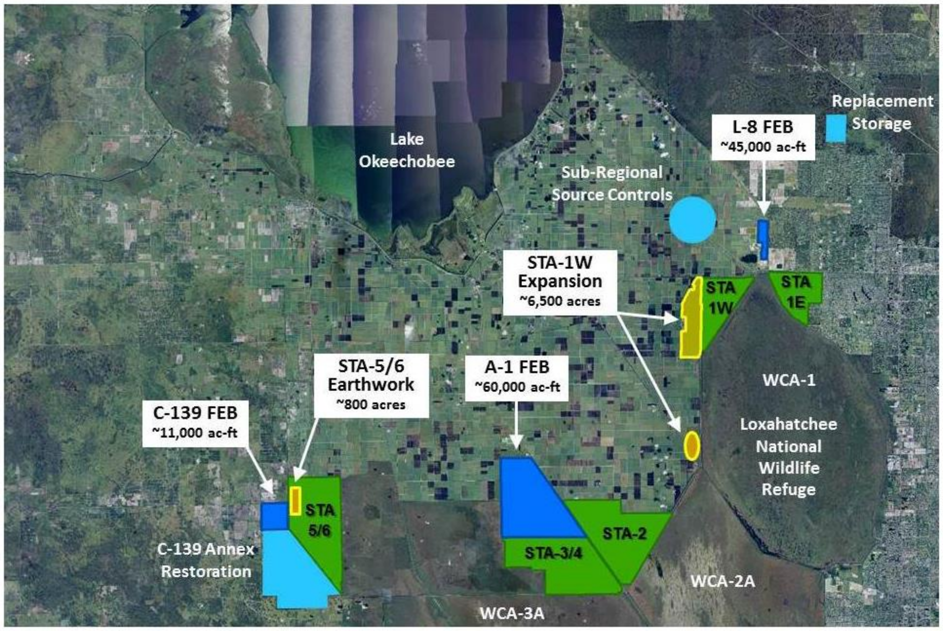


Figure III-7: Location of Restoration Strategies FEBs and STA Expansions (SFWMD, 2012).

Expected Benefits: Modeling using the Dynamic Model for Stormwater Treatment Areas (DMSTA) (Walker and Kadlec, 2011) and the peer-reviewed SFWMM (SFWMD 2005) indicates that the proposed additional FEBs and STAs will allow approximately 1.5 million acre-ft of inflows to the EPA to achieve the WQBEL. DMSTA has not undergone a formal, external peer-review. As stated by NRC (2012) "External peer review is important, particularly for models that are used extensively in the planning process, and peer review of the DMSTA is a high priority." For more details about the expected benefits of Restoration Strategies see Section IV.

Status: The 45,000 acre-ft eastern flowpath FEB (L-8) and the 56,000 acre-ft Central Flowpath FEB (A-1) are under construction and expected to be complete in 2016. The design of the STA 1W expansion is in process. The entire Restoration Strategies project is projected to be completed in 2025.

h. CERP Central Everglades Planning Project (CEPP)

Plan Summary: The overarching purpose of the Central Everglades Planning Project (CEPP) is to improve the quantity, quality, timing and distribution of water flows to the Caloosahatchee and St. Lucie estuaries, Central Everglades, and Florida Bay while increasing water supply for municipal, industrial and agricultural users. In general, ecosystem restoration objectives were focused on providing additional water to the Everglades by capturing freshwater discharges from Lake Okeechobee that would otherwise have gone to the St. Lucie and Caloosahatchee estuaries. Timing of deliveries and distribution of the flows to the Everglades and improvements to water supply for municipal, agricultural, and Tribal use were also evaluated. Options for achieving restoration were constrained to maximize use of existing infrastructure capacity (i.e. canals, STAs and Restoration Strategies projects), and to use existing, previously-impacted, publicly-owned land in the EAA acquired for the purpose of environmental restoration (e.g., the Talisman property).

Initial screening efforts (USACE, 2014b) resulted in two cost-effective options to achieve restoration objectives:

- Two 14,000 acre Flow Equalization Basins (FEBs) with an ability to store a maximum of 112,000 acre-ft, i.e. a new FEB on the A-2 Talisman parcel and the previously planned FEB on the A-1 Talisman parcel that was included in Restoration Strategies (described in Section III.2.g), with Lake Okeechobee operations optimized for agricultural water supply in the EAA. This option was estimated to provide approximately 210,000 acre-ft of additional water annually to the Everglades system at an expected cost of $360-550 million.

- A 12-foot deep 21,000 acre reservoir with an ability to store a maximum of 252,000 acre-ft and a 7,000 acre STA constructed on both the A-1 and A-2 Talisman parcels, also with Lake Okeechobee operations optimized for agricultural water supply in the EAA, at a cost of approximately $2 billion. This configuration provided the greatest benefits to the Caloosahatchee and St. Lucie estuaries and delivered 240,000 ac-ft of additional water to the Everglades rather than 210,000 ac-ft, under the FEB plan. However, as a result of the 400-600% increase in cost to provide approximately 20% greater benefits over the FEB option, the 12-foot reservoir configuration was eliminated from further consideration.

The final recommended CEPP project is expected to provide a substantial increase in flow of clean water to the Everglades. Water will be routed to two 14,000 acre FEBs which will provide storage capacity, attenuate high flows, and may provide incidental water quality benefits prior to delivery to State owned and operated STAs. The STAs will reduce phosphorus concentrations in the water to meet required water quality standards. Re-routing this treated water south and redistributing it across spreader canals is intended to facilitate hydropattern restoration in WCA 3A (Figure I-1). This, in combination with Miami Canal backfilling and other CERP components, is intended to re-establish a 500,000-acre flowing system through the northern most extent of the remnant Everglades. The treated water will be distributed through WCA 3A to WCA 3B and ENP via structures and creation of the Blue Shanty Flowway. The Blue Shanty Flowway is intended to restore continuous sheetflow and re-connection of a portion of WCA 3B to ENP and Florida Bay. A seepage barrier wall and pump station are designed to manage seepage to maintain levels of flood protection and water supply in the urban and agricultural areas east of the WCAs and ENP.

Expected Benefits: CEPP Modeling, using the peer-reviewed RESOPS model (SFWMD, 2009c) for the 1965-2005 time period, indicated that the final recommended plan would send an additional 210,000 acre-ft/year of water from Lake Okeechobee south to the Everglades Protection Area on an annual average basis compared to a “Future without Project” condition which assumed that the IRL-S, C-43, KRR, and Restoration Strategies projects were completed (USACE, 2014b). This additional flow is approximately 70% of the 300,000 acre-ft/year additional flow envisioned in the 1999 Restudy, and 30% of the 700,000 acre-ft/year additional flow identified in the revised pre-drainage target used in the River of Grass Planning Process.

For the St. Lucie estuary, modeling based on the 41 year (1965-2005) time period estimated that high mean monthly flows (between 2,000 cfs and 3,000 cfs) from Lake Okeechobee would occur approximately 11% of the time for Existing Condition Baseline (ECB, which assumes no CERP projects are constructed), approximately 11% of the time for the Future Without Project Condition (FWO which assumes IRL-S, C-43, KRR and Restoration Strategies are constructed) and reduced to 7.1% of the time for the Future with Project Condition (FWP, that assumes CEPP is also constructed) (Table III-9). Furthermore modeling estimated that very high mean monthly flows (>3,000 cfs) to the St. Lucie estuary would be reduced from 8.7% for the EBC to 6.3% for the FWO condition, to 5.7% for the FWP (USACE, 2014b).

For the Caloosahatchee estuary modeling estimated that the project would reduce high mean monthly flows (>2,800 cfs) from Lake Okeechobee from 19% for the EBC, to 16% for the FWO to 14% for the FWP (Table III-9). Similarly very high flows (>4,500 cfs) were estimated to be reduced from 8.7% to 6.7% to 6.3% for the EBC, FWO and FWP, respectively. Low flows to the Caloosahatchee estuary were estimated to be reduced from 24% of the time for the EBC, to 5.2% of the time for the FWO, to 4.7% of the time for the RWP condition (USACE, 2014b).

Thus, the modeling results indicate that the CEPP project, although producing significant benefit for the Central Everglades, produces only relatively modest improvements in high flow conditions and almost no improvement in very high flow conditions for the St. Lucie and Caloosahatchee over that obtained from the IRL-S, C-43 and KRR projects. Modeling results were not presented for the CEPP project alone (i.e. without completion of the IRL-S, C-43 and KRR); however, it is likely that virtually no benefits would be realized for the St. Lucie and Caloosahatchee estuaries without the increased storage and flow attenuation provided by those projects.

Table III-9: existing conditions, restoration targets and expected benefits of proposed projects. Percentages indicate percent of time the monthly flow condition occurs under specific scenarios. Red-colored percentages have not achieved restoration goals.

Plan	St. Lucie		Caloosahatchee		
	# mean monthly flows between 2000 and 3000 cfs	#mean monthly flows > 3000 cfs	# mean monthly flows < 450 cfs	# mean monthly flows > 2800 cfs	# mean monthly flows > 4500 cfs
Restoration Targets	<21 mo in 36 years[1] (4.9%)	<6 mo in 36 years[1] (1.4%)	0 mo in 36 years[2] (0%)	<3 months in 36 years[2] (0.7%)	0 mo in 36 years[2] (0%)
Historical Performance 1994-2014	24 mo in 20 years[3] (10%)	29 mo in 20 years[3] (12%)	68 mo in 20 years[3] (28%)	68 mo in 20 years[3] (28%)	37 mo in 20 years[3] (15%)
CEPP Existing Condition Baseline, i.e. no CERP projects (2014)	52 mo in 41 years[4] (11%)	43 mo in 41 years[4] (8.7%)	116 mo in 41 years[4] (24%)	94 mo in 41 years[4] (19%)	43 mo in 41 years[4] (8.7%)
Future without CEPP project (includes IRL-S, C-43, KRR and Rest. Strat.) (2014)	54 mo in 41 years[4] (11%)	31 mo in 41 years[4] (6.3%)	27 mo in 41 years[4] (5.2%)	81 mo in 41 years[4] (16%)	33 mo in 41 years[4] (6.7%)
Future with CEPP selected plan (2014)	35 mo in 41 years[4] (7.1%)	28 mo in 41 years[4] (5.7%)	23 mo in 41 years[4] (4.7%)	68 mo in 41 years[4] (14%)	31 mo in 41 years[4] (6.3%)

[1]based on simulations from 1965-2000 period of record (Figure 6.5-1, SFWMD 2009a)
[2]based on simulations from 1965-2000 period of record (Figures 6.5-1 and 6.5-2, SFWMD 2009b)
[3]based on observed flows 1994-2014
[4]based on simulations for 1965-2005 period of record (Tables 4-1 and 5.1-2, Figures 6-7 and 6-8, USACE 2014b)

Status: The CEPP PIR and EIS Report has been prepared and signed by the Chief of the US Army Corps of Engineers. It is now undergoing additional review by the Secretary of the Army (Civil Works) and the Office of Management and Budget. It will be formally transmitted to the US Congress upon completion of those reviews.

The achievement of CEPP benefits for the Central Everglades depends on the successful completion of SFWMD's Restoration Strategies project. Once Restoration Strategies is complete it is expected that the STAs that are part of Restoration Strategies will adequately treat the existing flows plus additional water provided by CEPP (total 1.5 million acre-ft/year) to meet the established WQBEL. The agencies have taken the position that construction of CEPP features cannot commence until Restoration Strategies is complete and found to be in compliance with the WQBEL. Pursuant to this position, even using the most optimistic assumptions, CEPP is not estimated to be complete for a minimum of 24 years. This long time frame for project completion is due, in part, to the need for coordinated phasing of individual projects and some unavoidable constraints. Nevertheless, some of the constraints cited as limiting CEPP project construction appear to be discretionary rather than mandatory. In particular, the USACE PIR states that "all features of the State's Restoration Strategies must be completed and meet state water quality standards prior to initiating construction of most CEPP project features." It is clear that any water leaving any of the STAs must comply with the WQBEL, or prior to completion of Restoration Strategies, must be in compliance with the NPDES and Everglades Forever Act permits and accompanying consent orders. Consequently, CEPP will not be able to function until Restoration Strategies is complete and in compliance with state water quality standards. However, this does not necessarily mean that construction of most CEPP features cannot commence prior to completion of Restoration Strategies. Construction of certain features of CEPP could begin during the time Restoration Strategies projects are being constructed, and greatly shorten the aggregate time necessary for both projects to be operational.

A careful analysis of CEPP project construction phasing should be conducted to determine which of the CEPP features could usefully be initiated prior to the completion of Restoration Strategies, and to develop a plan for completion of as many CEPP features as possible during the construction phase of Restoration Strategies. Other CEPP features may need to be constructed or completed after Restoration Strategies is complete, however, it is likely that some of the work can be done simultaneously with Restoration Strategies construction thereby potentially significantly reducing the number of years before CEPP can be fully implemented. In its 2014 report*, Progress Toward Restoring the Everglades* (NRC, 2014)*,* the National Research Council concluded that the current timeline for completion of CEPP construction is "unreasonable and undesirable" and recommended that USACE and SFWMD "look for creative implementation strategies to reduce existing constraints." Specifically, the NRC recommended that the agencies "investigate implementation, and permitting alternatives that would enable [CEPP] to move forward as quickly as possible with WQBEL-compliant discharges."

4. Summary

Repeated planning exercises have shown that large volumes of inter-annual storage are required north, south, east and west of Lake Okeechobee to manage Lake Okeechobee levels within a desirable range, reduce damaging high and low flows to the St. Lucie and Caloosahatchee estuaries, and move more water south for agricultural, urban and ecosystem uses. In spite of this, very little new storage has been designed or constructed. In the St. Lucie watershed approximately 200,000 acre-ft of storage is required according to the most recent estimates, yet only one approximately 40,000 acre-ft surface reservoir currently is under construction (Table III-10). In the Caloosahatchee watershed approximately 400,000 acre-ft of storage is required according to most recent estimates yet only one 170,000 acre-ft surface reservoir currently is being designed and federal funds for its construction have not yet been appropriated. According to the River of Grass Planning effort at least one million acre-ft of storage is required in some combination north or south of Lake Okeechobee, yet only 168,000 acre-ft of shallow storage in FEBs has been sited south of Lake Okeechobee, with 101,000 acre-ft currently under construction. Throughout the Lake Okeechobee, St. Lucie and Caloosahatchee watersheds approximately 92,000 acre-ft of DWM projects have been established, but the efficacy of this type of local, typically intra-seasonal, water retention for managing Lake Okeechobee levels within a desirable range, reducing damaging discharges to the St. Lucie and Caloosahatchee estuaries, or providing long-term storage of water that can be used for agricultural, urban or environmental uses in subsequent dry seasons is unknown.

If the currently authorized CERP projects, i.e. the complete IRL-S project and the C-43 project, are constructed, and the Kissimmee River Restoration Project is completed, it is estimated that very high volume damaging freshwater discharges to the St. Lucie estuary would be reduced from 8.7% of the time to 6.3% of the time versus a restoration target of 1.4%. Similarly, very high volume damaging freshwater discharges to the Caloosahatchee estuary would be reduced from 8.7% to 6.7% if these authorized projects were constructed, versus a restoration target 0%. If the CEPP project is also authorized and constructed, the occurrences of very high volume damaging freshwater discharges will be marginally reduced over these estimates, i.e. to 5.7% for the St. Lucie and to 6.3% for the Caloosahatchee. To further reduce very high freshwater discharges at approximately one million acre-ft of additional storage must be constructed, either north or South of Lake Okeechobee, as envisioned in both the LOP2TP and the River of Grass Planning Process.

As indicated above, the CEPP modeling analyses indicated that the deep reservoir-STA option on the Talisman property provided 140,000 acre-ft more storage and higher benefits to both the estuaries and the Everglades than the selected FEB plan, but was rejected due to cost considerations. Given that 1) it is clear that large volumes of storage are needed throughout the South Florida System to reach restoration objectives, 2) the cost of deep storage is unlikely to decrease, and 3) the Talisman property is currently the only state-owned non-conservation property suitable for deep storage in the EAA, this is a decision that could be revisited during the development of the detailed design phase for the CEPP FEB.

Table III-10: Summary of Estimated Storage Required by Plans and Provided by Approved Projects[1]

Plan	Estimated Storage Required to Achieve Restoration Targets			
	EAA	North of Lake Okeechobee	St. Lucie Watershed	Caloosahatchee Watershed
CERP Restudy Plan (1999)	360,000 acre-ft deep reservoir	250,000 acre-ft deep reservoirs, 1000 mgd ASR	389,400 acre-ft deep reservoirs	160,000 acre-ft deep reservoir 220 mgd ASR
NEEPP Plans (2008-2009)	KRR and all Acceler8 projects assumed operational	900,000-1,300,000 acre-ft reservoirs, ASR, DWM	200,000 acre-ft reservoirs, DWM	400,000 acre-ft reservoirs, ASR, DWM
ROG plan (2009-2010)	1,000,000 - 1,350,000 acre-ft deep reservoirs, shallow reservoirs, shallow dry storage areas, FEBs		C-44 Reservoir and STA assumed operational	C-43 Reservoir assumed operational
Project [1]	**Existing Approved Projects to Provide Components of Required Storage**			
Authorized IRL-S Project			130,000 acre-ft deep reservoirs	
Designed C-44 Project (component of IRL-S)			40,000 acre-ft deep reservoir	
Authorized C-43 Project				170,000 acre-ft deep reservoir
Restoration Strategies	112,000 acre-ft FEB[2]			
CEPP Project	56,000 acre-ft FEB			

[1] None of the projects in this table are operational at the time of report writing. CEPP is currently awaiting Federal authorization. See previous sections for details on status of each project.
[2] Includes 45,000 acre-ft in eastern flow-way, 56,000 acre-ft in central flowway and 11,000 acre-ft in western flow-way

To provide substantial improvement to the St. Lucie and Caloosahatchee estuaries accelerate the funding and completion of existing authorized CERP projects designed specifically to provide relief to St. Lucie and Caloosahatchee Basins, i.e. :

- IRL-S Project: Accelerate construction of C-44 reservoir and STA. Aggressively pursue state and federal appropriations needed to design and construct remainder of the project (including C-23, 24, 25 reservoirs and STAs, and restoration of over 90,000 acres of upland and wetland areas).
- C-43 Reservoir: Accelerate design and aggressively pursue state and federal appropriations needed to design and construct this project.

To substantially increase the volume of water moving south from Lake Okeechobee to the Everglades, accelerate funding and completion of the State of Florida Restoration Strategies and the CERP Central Everglades Planning Project (CEPP) . i.e.:

- Obtain federal authorization for CEPP.
- Accelerate the design and obtain state and federal appropriations for the construction of CEPP.
- Accelerate state funding and completion of Restoration Strategies.
- Conduct a careful analysis of CEPP project construction phasing to determine which CEPP features can be constructed as soon as possible and to develop a plan for completion of as many CEPP features as possible during the construction phase of Restoration Strategies.
- Reconsider using the Talisman property for a deep storage reservoir with STA rather than for shallow FEBs during the CEPP detailed design phase.

All modeling studies that assess restoration potential for CERP, NEEPP and ROG plans and IRL-S, C-43, and CEPP projects assume that the KRR has been completed. However, no modeling studies have isolated the potential of the KRR to affect discharges to the northern estuaries, or to affect the ability to move water south from Lake Okeechobee. Although it is not possible from existing model runs to discern the individual contribution of the KRR project to these larger restoration goals, the Technical Review Team expects that it is likely to be relatively minor. Nevertheless, the KRR is expected to provide significant benefits within the Lake Okeechobee watershed and should be completed as soon as possible.

As indicated in Table III-10, even after these existing approved projects are constructed significant additional water storage, treatment and conveyance will be required to fully achieve restoration goals. Section IV reviews existing state plans and projects to improve water quality. Section V reviews additional options (beyond approved projects) to provide the additional required water storage, treatment and conveyance.

IV. Existing State Plans to Improve Water Quality

The need to store substantial volumes of water both north and south of Lake Okeechobee is well recognized to both reduce high freshwater flows to the Caloosahatchee and St. Lucie estuaries and move more water south of Lake Okeechobee to the Everglades Protection Area (EPA) (Section III). Increased storage capacity in and of itself is not sufficient, however, to reduce damage to the estuaries and the EPA which is due to both problems with the volume, timing and distribution of freshwater flows and high nutrient loads. Even if all storage needs were achieved, water quality remains a significant problem for the St. Lucie and Caloosahatchee estuaries and a direct legal hurdle for moving water south of the lake into the EPA. Thus, a holistic and coordinated approach to providing both storage and treatment is needed to maintain water quality and protect these systems and the ecosystem services they provide.

Overall, water quality concerns represent a major management concern, and they have a profound influence on any decision or plan to store and convey water in the Greater Everglades ecosystem. State and federal agencies have relied heavily on scientific literature to evaluate best management practices and available treatment technologies, and to identify on-site management practices and construction projects that will help reduce nutrient loads in the discharged water. In this section, we review water quality related issues in the context of existing state and federal restoration plans to reduce damaging discharges to the Caloosahatchee and St. Lucie estuaries, and move more water south of Lake Okeechobee. From a water quality perspective, phosphorus (P) is unambiguously the nutrient of greatest concern in Lake Okeechobee and the Southern Everglades. For the St. Lucie and Caloosahatchee estuaries nitrogen (N) is also a concern.

1. Greater Everglades Watershed Descriptions

Northern Everglades-Lake Okeechobee Watershed

Lake Okeechobee, the heart of the Greater Everglades Ecosystem, receives water that originates in a 3.4 million acre watershed. The watershed is comprised of six sub-basins, Upper Kissimmee, Lower Kissimmee, Taylor Creek/Nubbin Slough, Lake Istokpoga, Indian Prairie, and Fisheating Creek (Figure IV-1; SFWMD, 2015). Three sub-basins situated west, east, and south of the lake, in general, do not contribute water to Lake Okeechobee; i.e. water is discharged away from the lake. In combination, the aforementioned six sub-basins deliver approximately 88% of the freshwater that enters Lake Okeechobee (SFWMD, 2014). Land use in the watershed is primarily agriculture (51%) with natural areas (31%) and urban development (10%) accounting for the majority of the balance. Approximately 18% and 15% of the Lake Okeechobee watershed exists as wetlands and open water bodies, respectively, with these systems being the final recipients of discharges from adjacent terrestrial systems (FDEP, 2014a).

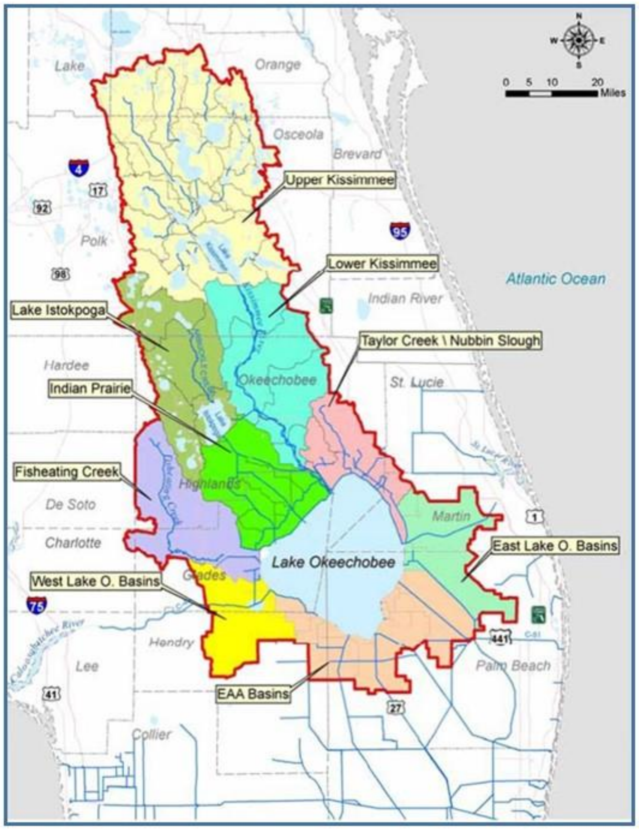


Figure IV-1. The Lake Okeechobee watershed (delineated by the red line) and color-coded sub-basins (Source: SFWMD).

Northern Everglades- Caloosahatchee River and St. Lucie River Watersheds

To the west and east of Lake Okeechobee, lie the Caloosahatchee River watershed (CRW) and the St. Lucie River watershed (SLRW). Both watersheds have been extensively altered as a result of changes in land use and hydrology. Flows from Lake Okeechobee and surface water runoff from these two watersheds have a major influence on the physics, chemistry, biology, and ecology of both the Caloosahatchee River and St. Lucie River estuaries, with freshwater flows and nutrient inputs representing two major influences (Barnes, 2005; Sime, 2005).

The CRW (C-43 Basin) is comprised of five sub-basins (Figure IV-2). Approximately 55% of the watershed is represented by the S-4, East Caloosahatchee (adjacent to Lake Okeechobee) and West Caloosahatchee sub-basins. The remaining 45% of the watershed includes the Tidal

Caloosahatchee and Coastal Caloosahatchee sub-basins. The total watershed area is 1,090,381 acres, with 34.6% attributed to agriculture, 18.5% to urban and developed lands; 15.9% to wetlands; 12.5% to upland forests; 11.7% to water, and 5.6% to rangelands. The remaining area is identified as used for transportation, communication, and utilities, and barren land (SFWMD, 2015).

The SLRW is comprised of seven sub-basins that drain into the St. Lucie River or its estuary (SLRE; Figure IV-2). These include: C-44; C-23; C-24; C-25; Basin 4, 5, and 6; North Fork; South Fork; and a portion of South Coastal sub-basins. The total watershed area is 537,805 acres, with 53.9% of the area used for agriculture. Other land uses/classifications include urban and built up (19.1%); wetlands (10.9%); upland forests (6.8%); water (3.3%); and rangelands (3.2%). The remaining area is identified as being used for transportation, communication, utilities, and barren land (SFWMD, 2015).

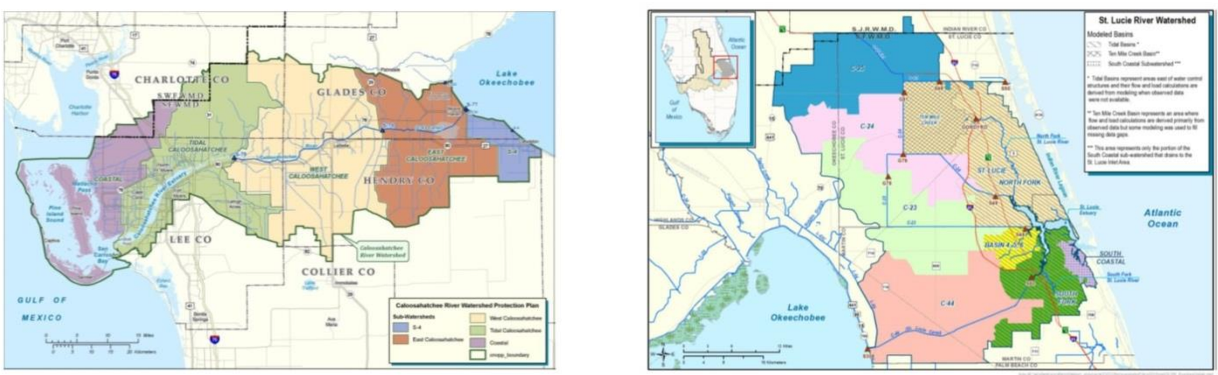


Figure IV-2. Map showing Caloosahatchee River watershed (CRW) (left panel) and St. Lucie River watershed (SLRW) (right panel) (source: SFWMD 2015).

Southern Everglades- Everglades Agricultural Area and C-139 Basins

South of Lake Okeechobee lay the EAA and C-139 basin (Figure IV-3). The EAA is ~ 700,000 acres (Buzzelli et al., 2012) and is dedicated largely to the production of sugarcane, vegetables and sod. A protective levee separates the EAA from northwest Palm Beach County and Miami-Dade County. The C-139 basin (170,000 acres) is located west of the EAA, with pasture, row crops, citrus, sugarcane and agriculture being the dominant land uses.

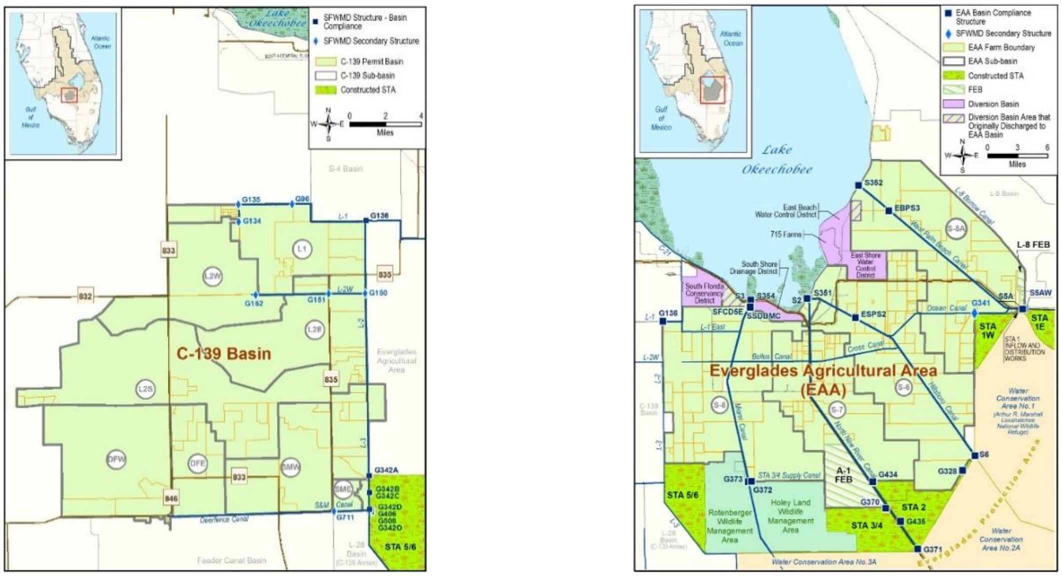


Figure IV-3. Map showing C-139 (left panel) and the Everglades Agricultural Area (right panel) watersheds (source: SFWMD)

2. Greater Everglades Watershed Nutrient Loads

Northern Everglades-Lake Okeechobee Watershed

Freshwater flows and associated nutrient loads to Lake Okeechobee and the Caloosahatchee and St. Lucie estuaries are driven, in large part, by regional rainfall patterns, which can be quite variable, especially in the wake of tropical storms and hurricanes. Phosphorus (P) is a limiting nutrient and primary determinant of productivity within the terrestrial (upland), wetland and aquatic ecosystems of the Greater Everglades. For the past several decades P imported into the basin, primarily to improve agricultural production, has largely accumulated in soils and sediments. In addition to current P imports, the legacy P in the basin has become a constant source of P to the lake and estuaries. As such, these ecosystems, whether they exist north, east, west or south of Lake Okeechobee, are sensitive to anthropogenic nutrient loads. Increased P loads have, in fact, accelerated the eutrophication process across the south Florida landscape. Although much attention is focused on phosphorus as the nutrient of concern, nitrogen too is delivered to Lake Okeechobee and the loading rates are, as expected, highly correlated.

To avoid excessive P delivery to Lake Okeechobee and the associated algal blooms and growth of exotic and nuisance aquatic plants in the littoral zone, FDEP established a Total Maximum Daily Load (TMDL) of 140 metric tons of P per year (FDEP, 2014a). This load includes 35 metric tons of P per year from atmospheric deposition, resulting in an allowable P load from the watershed of 105 metric tons per year. Since 1974, annual total P loads to Lake Okeechobee have exceeded 500 metric tons nearly 50% of the time (Figure IV-4). Averaged over the 41-year period of record, the annual P load is approximately 3.6 times the annualized TMDL. Thus, annual average P loads will have to be reduced by more than 350 metric tons per year to meet the current TMDL for the lake.

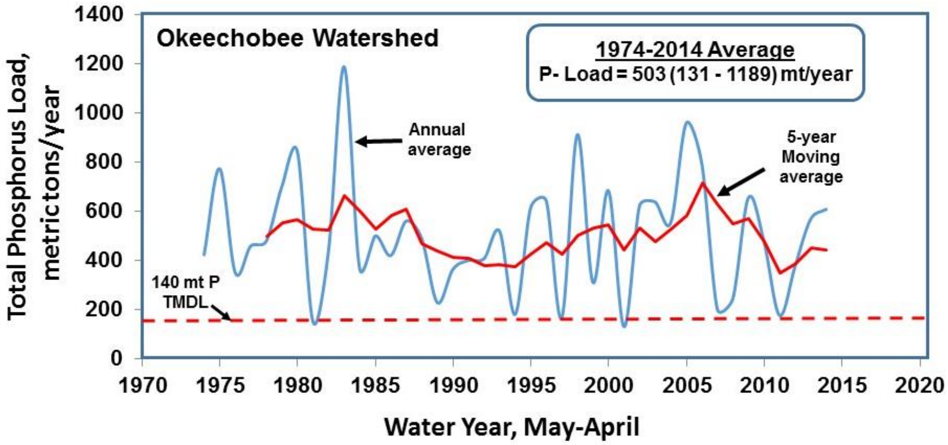


Figure IV-4. Annual and 5 year-moving average of total phosphorus (TP) loads to Lake Okeechobee between 1974 and 2014. The TMDL target of 140 metric tons (mt) (red dashed line) is indicated for comparison (Data source: SFWMD, 2015).

Annual P loads are highly variable and quite clearly influenced by climatic conditions (precipitation in particular), along with changes in land use and water management activities. During wet years, large volumes of water (~ 3 million acre-feet) are delivered to the lake, while in dry years the volume of water delivered to the lake can be less than 1 million acre-ft. Annual P loads to Lake Okeechobee reflect this variation, with high P loads observed during wet years and low P loads during dry years (Figures IV-4 and IV-7). In fact, Jawitz and Mitchell (2011) reported that 80% of the P load to Lake Okeechobee is delivered in approximately 73 days in any particular year. This unequal load distribution presents enormous challenges for water resource managers.

Overall, ~11,000 metric tons of P per year are imported into the Lake Okeechobee watershed (1,392,874 ha), with slightly more than half (51%) being exported and 49% (5,350 metric tons per year) remaining in the system (HDR, 2010). Phosphorus that remains in the watershed and is stored in soils is considered a legacy pool that can contribute to overall P load even after P imports are decreased. Legacy P can substantially extend the time required for a wetland or aquatic system to recover from an impaired state and/or revert to a stable condition that is compliant with an adopted water quality standard (Figure IV-5). This legacy P can be classified as either reactive or non-reactive. The reactive pool is comprised of P that potentially can be released from the watershed, whereas non-reactive P is considered to exist in a stable pool and is essentially immobile. The reactive P pool represents approximately 65% of the legacy P in soils (Reddy et al., 2011). Recent reports estimate that 170,000 metric tons of P is stored in Lake Okeechobee watershed soils (Reddy et al., 2011; SWET, 2008a,b). This estimate equates to approximately 110,500 metric tons of reactive P which can potentially be leached out of the watershed. Thus, legacy P in the Lake Okeechobee watershed could sustain contemporary P loading rates, i.e. 500 metric tons per year, for more than two centuries. Clearly, there is need to fully recognize the potential contribution of legacy P to any future P-loading scenario.

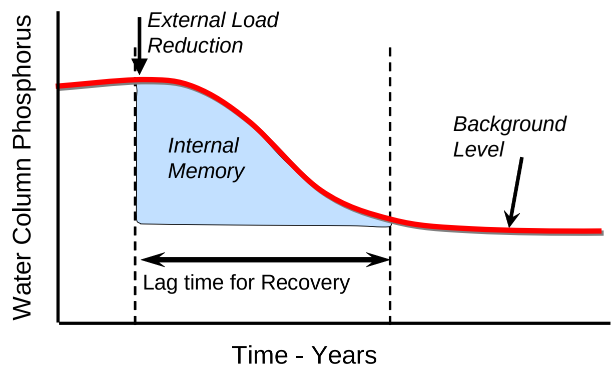


Figure IV-5. Schematic showing the effects of internal phosphorus memory in the watershed on ecosystem recovery (Reddy and DeLaune, 2008).

The six sub-basins within the Lake Okeechobee watershed contribute differing quantities of water and P (Figure IV-6), but, in all cases, overall P loads are highly correlated with the combined sub-basin water discharge (Figure IV-7). High water discharge to the lake and correspondingly high P loads (> 900 metric tons per year) resulted from hurricanes that affected the region in 2005 and 2006. Low water discharges associated with drier years, e.g., WY1997, WY2001, WY2007, WY2008 and WY2011, generated markedly lower average P loads (155 metric tons per year). As a means of differentiating the six sub-basins, P loads are compared for the following conditions: (1) baseline average P loads during WY1991-WY2005, (2) baseline average P loads during WY2001-2012, (3) the most recent drought year – WY2011, and (4) the most recent wet year – WY2014 (Figure IV-8).

Phosphorus originating in the Indian Prairie, Fisheating Creek, and Lake Istokpoga sub-basins increased between the two baseline periods (WY1991- WY2005 and WY2001-WY2012) by 16, 27, and 52%, respectively. During the same two time periods, P loads decreased by 3, 19, and 20%, respectively, for the Upper Kissimmee, Lower Kissimmee, and Taylor Creek/Nubbin Slough sub-basins. During WY2011, a drought year, P loads were reduced in all of the sub-basins relative to either of the baseline periods. In combination, only 177 metric tons of P were delivered to Lake Okeechobee in WY2011 (SFWMD, 2015). In more recent years, total P loads to the lake have increased markedly. In WY2012, WY2013, and WY2014, 377, 569, and 609 metric tons of P were delivered to Lake Okeechobee, respectively. The increases, as noted above, can be attributed to an increase in rainfall in the watershed and subsequent discharges to the lake. Long-term P loads (1991-2012) from Taylor Creek/Nubbin Slough, Indian Prairie, and Fisheating Creek contributed more than 55% of the P load, but only comprised 27% of the available watershed area. These observations suggest that these latter sub-basins be considered as having high priority in establishing P control strategies to reduce P loads.

Further evidence for a need to focus on certain sub-basins arises from a consideration of phosphorus loads normalized per unit area (Figure IV-9). These data provide additional insight into the relative stability of stored P and its capacity to be released into the surface water system. On a per unit area basis, the Taylor Creek/Nubbin Slough sub-basin released P at higher rates than other sub-basins, regardless of the time frame considered. Notable is the observation that the P loads originating in the Taylor Creek/Nubbin Slough basin, both total and per unit area, declined markedly between the two baseline periods reflecting some success in nutrient remediation efforts. In contrast, P loads from the Indian Prairie basin increased between the two baseline periods and represent a management concern.

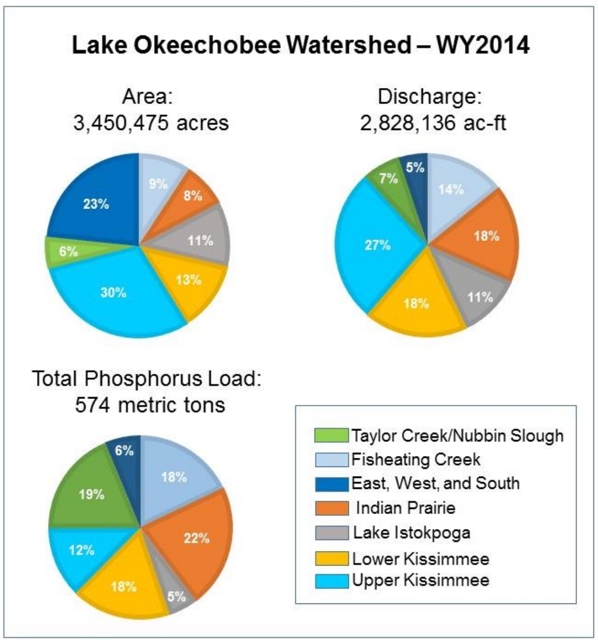


Figure IV-6. Relative proportion of WY2014 freshwater delivery and total phosphorus load to Lake Okeechobee from each of the following sub-basins: Upper Kissimmee, Lower Kissimmee, Lake Istokpoga, Indian Prairie, and Taylor Creek/Nubbin Slough. Note that the East, West and South sub-basins contribute little to water delivery and P load to the lake relative to their combined area (Data source: SFWMD).

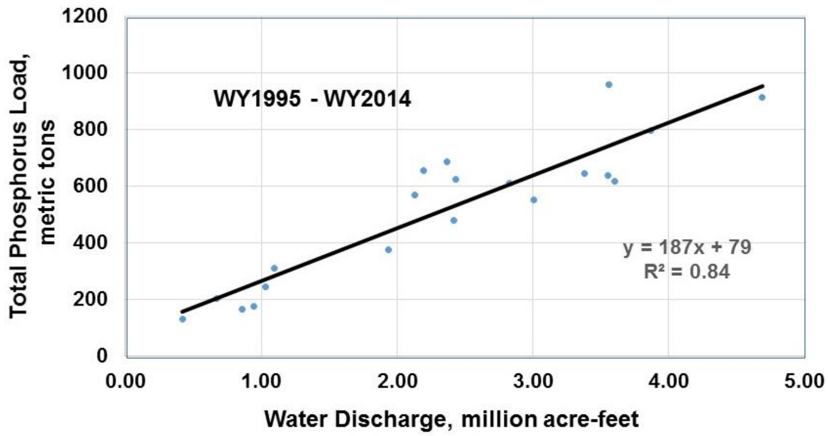


Figure IV-7. Relationship between water discharge and total P loads between WY1995 and WY2014 (Data source: SFWMD).

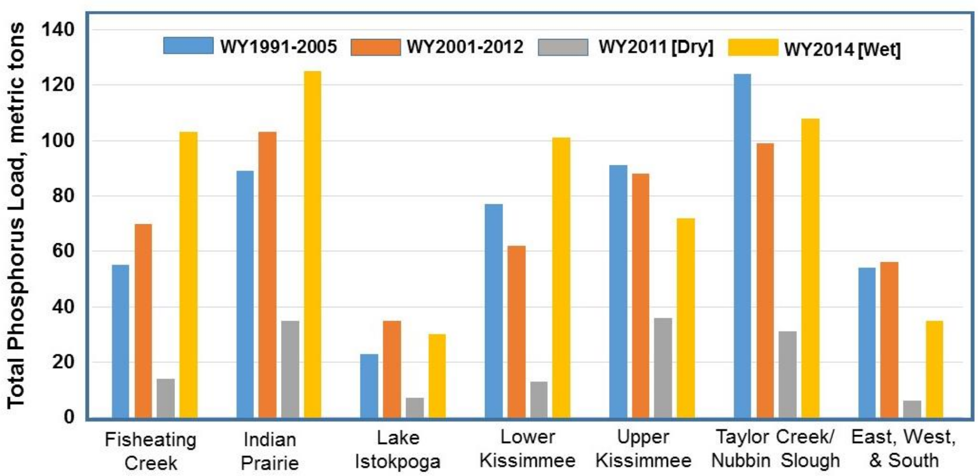


Figure IV-8. Annual total phosphorus loads from sub-basins within the Lake Okeechobee watershed. Note that these loads do not include atmospheric deposition of phosphorus (Data source: SFWMD, 2015).

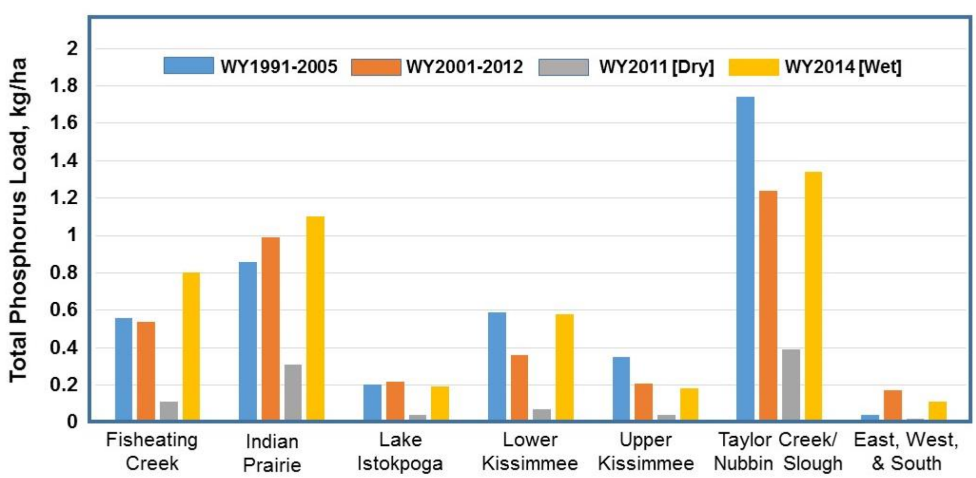


Figure IV-9. Annual phosphorus release rates (kg P/ha) from sub-watersheds to Lake Okeechobee (Data source: SFWMD, 2015).

All currently developed nutrient source control programs for the Lake Okeechobee watershed primarily focus on P reduction, but consideration should be given to nitrogen control as well because the ratios of these nutrients can yield variable effects on eutrophication of waterbodies (Jacoby and Frazer, 2009) and are particularly important in estuaries. Loads of N to Lake Okeechobee measured between WY2000 and WY2014 ranged from 2,500 to 8,800 metric tons N per year (Figure IV-10).

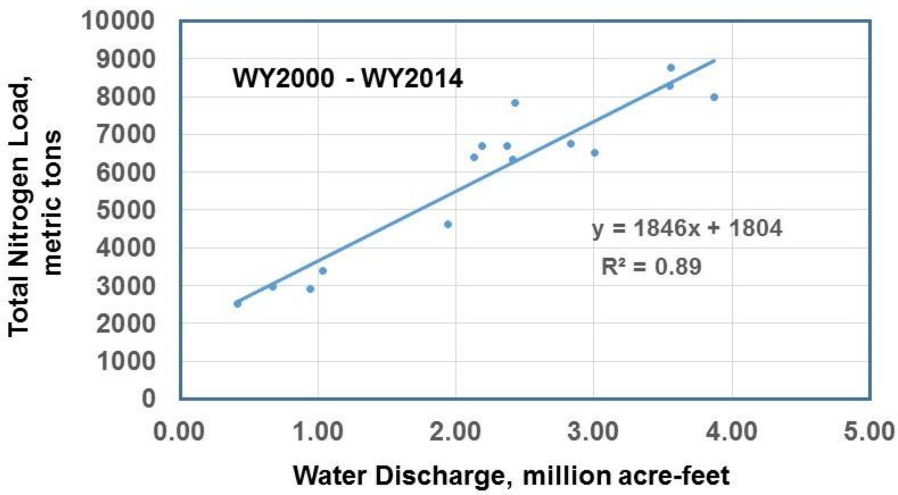


Figure IV-10. Relationship between water discharge and total N loads during WY2000 to WY2014 (Data source: SFWMD, 2015).

During the past 15 years, 11 water years corresponded to wet years and high N loading rates (range: 4,620 to 8,775 metric tons per year) were recorded, including WY2005 and WY2006 in which hurricanes resulted in substantial regional rainfall. Drought conditions during the period of record occurred in WY2001, 2007, 2008, and 2011. The average annual N load to Lake Okeechobee during this time was only 2,947 metric tons (range: 2,517 to 3,393 metric tons per year). Furthermore, during WY2000 to WY2014, the N load per unit of P load or the ratio of N to P loads ranged from 10 to 13 during wet years as compared to 14 to 19 during dry years. Such variation highlights differences in the cycling of these two important elements. Unlike P, N undergoes several biogeochemical transformations including the conversion of nitrate to gaseous end products such as nitrous oxide and nitrogen gas via the denitrification process and loss of ammonia as a consequence of volatilization (Reddy and Delaune, 2008). The denitrification process is facilitated by wet or flooded soil conditions. It is likely that during wet years, substantial nitrogen is lost to the atmosphere as a consequence of denitrification in the Lake Okeechobee watershed, thus reducing the amount of N delivered to the lake relative to P. Under wet soil conditions, P accumulated in soils can be solubilized and exported with water moving through the system (Reddy et al., 2011), thus exacerbating a shift toward lower N to P ratios. During drier years, high N to P load ratios are reflective of a slower release of P and rapid mineralization of organic N to ammonium and nitrate. In fact, up to 90% of the nitrogen present in the water delivered to the lake is organic in nature, and it must be mineralized to inorganic N by microbial organisms before it is made available to other biota.

Northern Everglades-Caloosahatchee and St. Lucie River Watersheds

Both phosphorus and nitrogen loads in the Caloosahatchee and St. Lucie River watersheds are significantly correlated with water discharge, with coefficients of determination (r^2) of 0.70 and 0.99, respectively. The long-term average annual P load to the CRE (WY1997-WY2014) was estimated to be 282 metric tons with 23% derived from Lake Okeechobee (Figure IV-11).

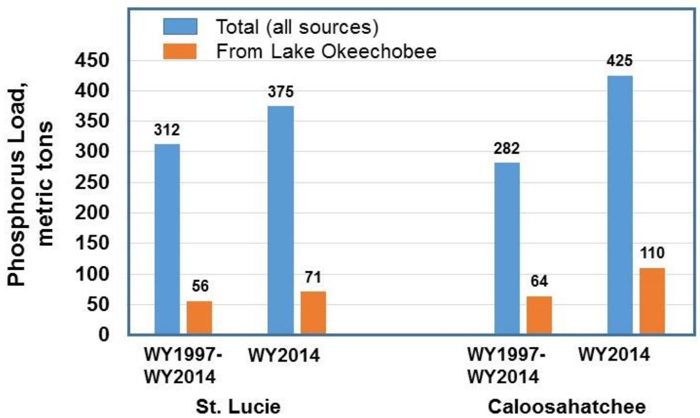


Figure IV-11. Phosphorus loads to St. Lucie River and Caloosahatchee River estuaries (SFWMD, 2015).

The long-term average annual N load to the CRE (WY1997-WY2014) was estimated to be 2,952 metric tons with 34% derived from the lake (Figure IV-12). With regard to the SLRE, the long-term average annual P load (WY1997-WY2014) was 312 metric tons with 18% derived from Lake Okeechobee, and the long-term average annual N load (WY1997-WY2014) was 1,715 metric tons with 32% derived from the lake. Substantial precipitation and subsequent high hydraulic loading during WY2014 increased P loads to the CRE to 425 metric tons with 26% contributed from Lake Okeechobee, P loads to the SLRE to 375 metric tons of P with 19% contributed from Lake Okeechobee, N loads to the CRE to 5,100 metric tons with 37% contributed from Lake Okeechobee, and N loads to the SLRE to 2,200 metric tons with the relative contribution from the lake remaining approximately equal to the long-term average; i.e. 31%. In combination, these results suggest that approximately 65-80% of the nutrient load to CRE and SLRE is derived from their respective watersheds, with only 20-35% contributed by Lake Okeechobee.

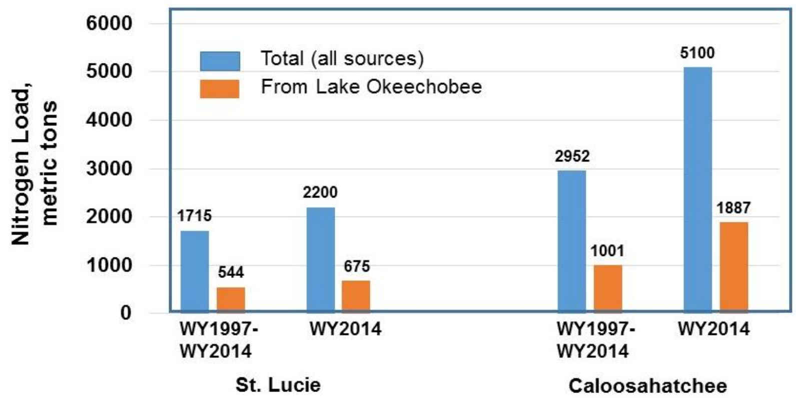


Figure IV-12. Nitrogen loads to St. Lucie River and Caloosahatchee River estuaries (SFWMD, 2015).

Southern Everglades

Moving water south, especially into the Everglades Protection Area (EPA), requires adherence to stringent water quality standards (see Section II-5), especially as they relate to P. Agricultural Best Management Practices (BMPs) and Stormwater Treatment Areas (STAs) are intended to reduce overall P loads to the EPA. In fact, the Everglades Forever Act (EFA) mandates implementation of BMPs followed by monitoring to assess the effectiveness of source control programs to achieve required P loads at the basin scale and reduce P loads to the STAs. The largest source of P and other nutrients to the EPA, is the Everglades Agricultural Area (EAA) (Figure IV-13). Total P concentration (flow-weighted mean (FWM) concentration) in the outflow from the EAA over the period of record averaged 132 µg P/L with a range of 64 to 243 µg P/L. During WY2014, P concentrations in EAA outflow were 94 µg P/L, which is markedly lower than 35-year average value.

As mandated by the EFA, the EAA basin is required to achieve a 25% reduction in TP loads discharged when compared to the designated baseline period, with adjustments to account for variation in rainfall (see SFWMD, 2015). Since agricultural BMPs were implemented on 640,000 acres south of Lake Okeechobee estimated load reductions have surpassed the required 25% load reduction, for example achieving a 63% reduction of observed loads versus modeled loads estimated assuming no BMPs were implemented. This equates to an average of approximately 180 metric tons per year of modeled P reduction, with 105 metric tons per year released to STAs for further treatment (SFWMD, 2015). Since WY1996, modeling estimates indicate that agricultural BMPs have resulted in a total cumulative reduction in total P load of approximately 2,853 metric tons, which represents a long-term reduction of 55 percent (SFWMD, 2015).

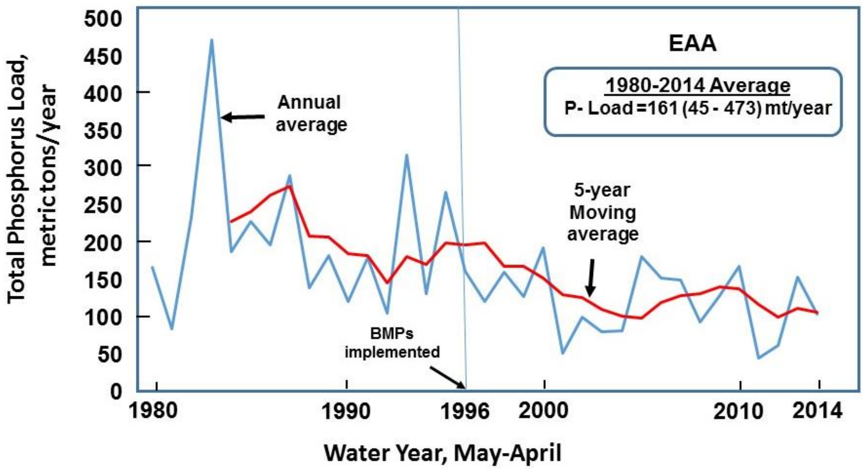


Figure: IV-13. Long-term (WY1980-WY2014) phosphorus loads from the EAA Basin (SFWMD, 2015).

For the EPA, another source of P and other nutrients is the C-139 basin (170,000 acres). The goal for this basin is to maintain P loads at or below historic baseline loads. The 35-year average annual P load (WY1980 through WY2014) was estimated at 37 metric tons, while the average target load for the same period was 30 metric tons P per year (Figure IV-14). From WY1980 through WY2014, total P concentrations (FWMC) in outflows from the C-139 basin averaged 189 µg P/L, and concentrations ranged from 69 to 363 µg P/L (SFWMD, 2015). Recent reduced P loads are consistent with the implementation of the comprehensive BMP plan in 2011. Loads have exceeded the target in only 2 of the most recent four years.

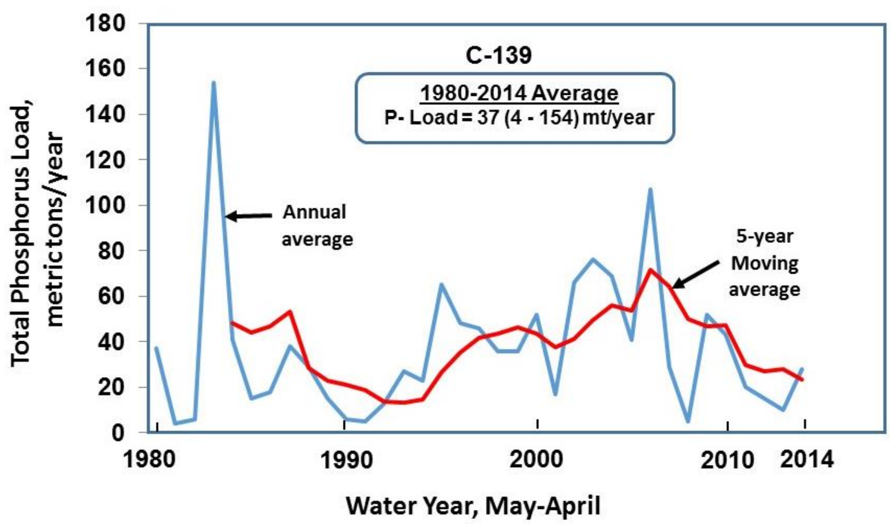


Figure IV-14: Long-term (WY1980-WY2014) phosphorus loads from the C-139 Basin (Data source: SFWMD).

3. Current and Planned Management of Greater Everglades Watershed Nutrient Loads

The State of Florida has invested more than $2 billion during the last two decades to improve water quality in south Florida ecosystems including both the northern and southern Everglades (Figure IV-15). A review of current and planned nutrient reduction efforts in all regional watersheds provides insights into challenges associated with moving clean water south.

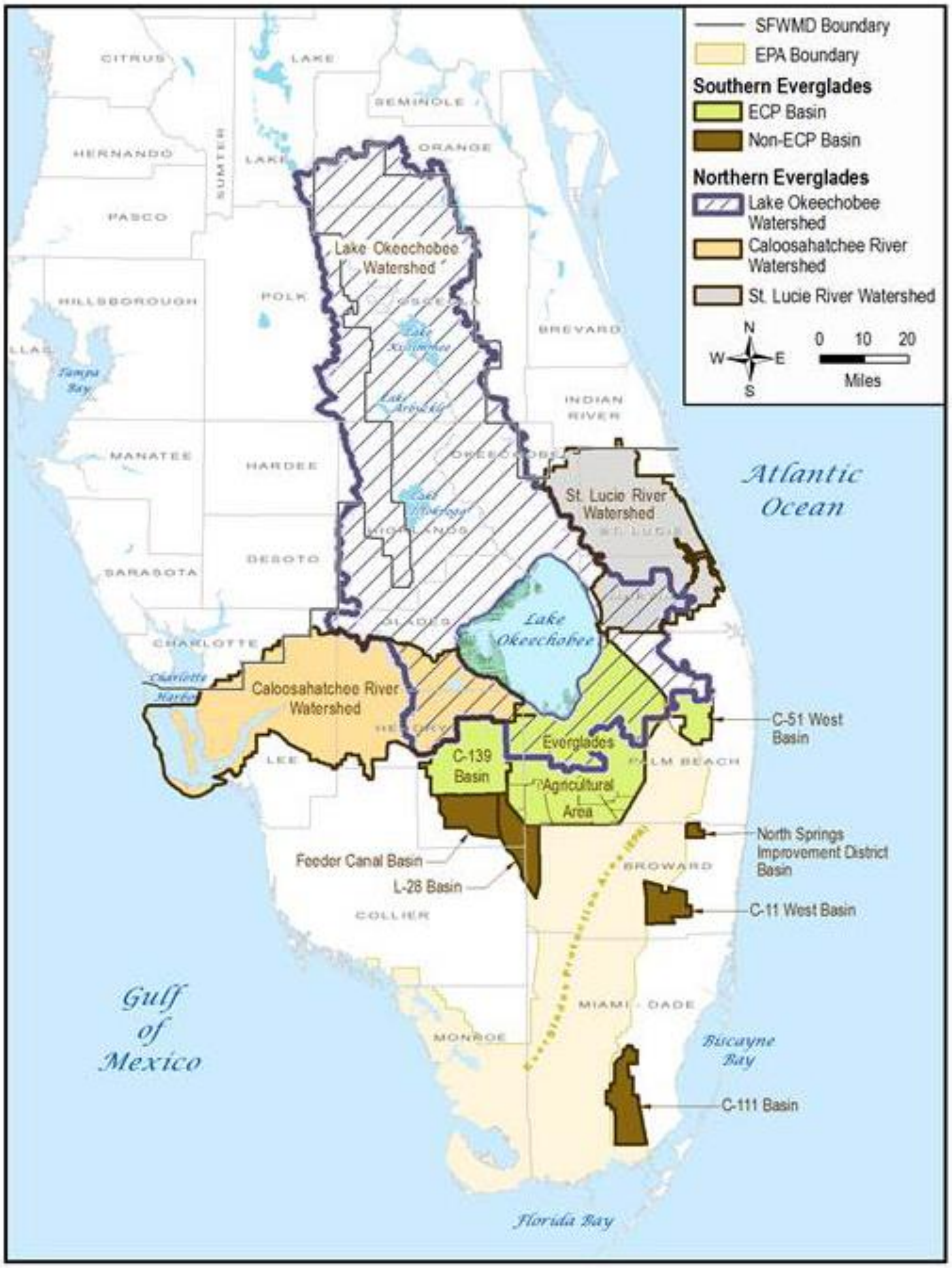


Figure IV-15. Watersheds in the Northern Everglades as well as ECP and non-ECP basins in the Southern Everglades Ecosystem (Source: SFWMD).

Specific guidance for current and planned management activities is provided in a suite of assessments and plans. In 2001 the FDEP established a Total Maximum Daily Load (TMDL) for the Lake Okeechobee watershed. TMDLs were established for the St. Lucie Basin and the Caloosahatchee Estuary in 2008 and 2009, respectively. As discussed in Section III.2.b, in 2007 the State of Florida Legislature initiated the Northern Everglades and Estuaries Protection Program (NEEPP) to promote a comprehensive, interconnected watershed approach to protecting Lake Okeechobee and the Caloosahatchee and St. Lucie rivers and estuaries that specifically addressed both water quality and the quantity, timing and distribution of water to the natural systems. The program resulted in the development of the Lake Okeechobee Watershed Construction Project Phase II Technical Plan (SFWMD, 2008), the St. Lucie river Watershed Protection Plan (SFWMD, 2009a), and the Caloosahatchee River Watershed Protection Plan (SFWMD, 2009b) which identified construction projects, along with on-site measures intended to prevent or reduce pollution at its source to achieve water quality targets for the Lake Okeechobee and the Caloosahatchee and St. Lucie estuaries. Since the NEEPP reports were prepared, Basin Management Action Plans (BMAPs) have been developed for the Lake Okeechobee, St. Lucie and Caloosahatchee basins (FDEP, 2012, 2013, 2014a). These BMAPs provide the blueprint to meet the TMDLs established by the FDEP to address water quality issues in the Northern Everglades. Planning efforts and projects that address water quality issues in the Southern Everglades include the Florida Water Resources Act, Comprehensive Everglades Restoration Plan, and Everglades Forever Act.

Northern Everglades - Lake Okeechobee Basin Management Action Plan (BMAP)

Several state (SFWMD, FDEP, FDACS) and federal (USACE, DOI) agencies, local governments, and stakeholders have been working cooperatively to address inter-related issues that affect reductions in TP loads and enhance ecosystem services provided by Lake Okeechobee. In 2008, the Lake Okeechobee Phase II Technical Plan (LPO2TP) identified construction projects, along with on-site measures (Best Management Practice, BMPs) intended to prevent or reduce pollution at its source to achieve water quality targets for the lake. In December 2014, the FDEP adopted the Lake Okeechobee BMAP (FDEP, 2014a). BMAP projects are designed for phased implementation to achieve the TMDL established for Lake Okeechobee, with initial effort focused on the six sub-basins that contribute approximately 89% of the total P load to the lake: Fisheating Creek; Indian Prairie, Lake Istokpoga, Lower Kissimmee, Upper Kissimmee, and Taylor Creek/Nubbin Slough (Figure IV-4). Phase 1 proposed BMAP projects for these sub-basins include urban and agricultural BMPs, Dispersed Water Management (DWM), Stormwater Treatment Areas (STAs), Floating Aquatic Vegetation Treatment (FAVT), Hybrid Wetland Treatment Technology (HWTT), natural systems restoration, and education and outreach (Table IV-1). Descriptions of these projects and their expected water quality benefits are summarized below and in Table IV-2. Phase I BMAP projects will be completed over the next 10 years. These projects are expected to reduce total P by approximately 150 metric tons per year when completely implemented, out of a required total P reduction of approximately 370 metric tons per year.

Table IV-1. Basin Management Action Plan for Lake Okeechobee Watershed (source: FDEP, 2014a). Sub-basins: Fisheating Creek (FC); Indian Prairie (IP); Lake Istokpoga (LI); Lower Kissimmee (LK); Upper Kissimmee (UK); Taylor Creek/Nubbin Slough (TCNS).

Entities	Project/Program Type	Sub-basins
FDACS	BMPs (voluntary or cost-share) – Agricultural lands	FC, IP, LI, LK, UK, and TCNS
Counties	BMPs – Urban and Municipal	IP, LI, LK, UK, and TCNS
SFWMD	Dispersed Water Management (DWM)	FC, IP, LI, LK, UK and TCNS
SFWMD, FDACS, and FDEP	Stormwater Treatment Areas (STAs)	IP and TCNS
FDACS	Floating Aquatic Vegetation Treatment (FAVT)	FC, IP, LI, LK, UK, and TCNS
FDACS	Hybrid Wetland Treatment Technology (HWTT)	TCNS
SFWMD	Restoration	LK and UK
Counties	Public education/outreach	FC, IP, LI, LK, UK, and TCNS

Best Management Practices (BMPs)

Implementation of Best Management Practices as outlined in BMAPs can (1) improve water quality and reduce P loads from sub-basins to Lake Okeechobee; (2) increase coordinated efforts to address surface water quality issues by state and local governments; (3) engage stakeholders in decision-making and priority setting processes; (4) increase understanding of basin hydrology, sources of pollutants, legacy P, and water quality; and (5) increase public awareness of complex issues (FDEP, 2014a). Appropriate BMPs have been proposed for agricultural and urban lands, but it is often difficult to assess their effectiveness with regard to improving water quality and reducing loads of P due to climate variability, landscape heterogeneity and limited monitoring funds. It is estimated that the current BMP programs will remove approximately 32.8 metric tons P per year (FDEP, 2014a); however these model predictions lack robust validation due to a dearth of data. Furthermore, none of the proposed BMPs address the issue of legacy P. Chemical amendments and treatment of hot spots may be needed to reduce the release of legacy P.

Dispersed Water Management (DWM)

Dispersed water management refers to the distribution of water across a highly parceled landscape using relatively simple structures (FDEP, 2014a). The SFWMD initiated a DWM program entitled the Northern Everglades Payment for Environmental Services (NE-PES). Under this program, cattle ranchers are compensated for providing water storage and nutrient retention on private lands (Bohlen et al., 2009; Lynch and Shabman, 2011). The DWM program is planned to extend to all six sub-basins (FDEP, 2014a). This approach provides shallow water storage, and, in some cases, it can reduce P and N loads. However, flooding of lands and resulting anaerobic conditions in soils can potentially solubilize some of the stable, legacy P and increase its mobility in surface or groundwater. In addition, flooding may cause a shift in vegetation to water tolerant plants that may not be grazed readily by cattle. However, the benefits of storing water on ranchlands during peak flows might offset such negative effects. It is estimated that the current DWM programs will remove approximately 10.2 metric tons of P per year (FDEP, 2014a). However, as discussed in more detail in Section V.2, new data gathering and modeling efforts are required to more accurately simulate the cumulative impacts of DWM on the quality, quantity and timing of flows into Lake Okeechobee.

Hybrid Wetland Treatment Technology (HWTT)

Hybrid Wetland Treatment Technology relies on a combination of chemical treatments and wetlands to remove P at sub-basin and parcel levels. Currently, five HWTT systems are operating in the Taylor Creek/Nubbin Slough sub-basin, with approximate removal of 7.6 metric tons of P per year (FDEP, 2014a). It should be noted that these systems require less land than STAs but more intensive management of vegetation. Disposal of the floating aquatic vegetation (in this case, water hyacinths) and potential insect damage to the systems' monocultures remain unknowns that hamper evaluation of the long-term sustainability of P removal by such systems. Further evaluation is needed to determine the long-term sustainability of expected P removal rates and cost of operating these systems.

Floating Aquatic Vegetation Tilling Systems (FAVT)

Similar to HWTT systems, Floating Aquatic Vegetation Tilling Systems grow floating aquatic vegetation (such as water hyacinths) in shallow reservoirs, but the biomass and associated nutrients are tilled into the soil during dry seasons rather than being harvested. Currently, one FAVT is operating in the Fisheating Creek sub-basin, with P removal estimated at 8.6 metric tons per year (FDEP, 2014a). At present, there is not adequate information to evaluate the long-term sustainability of P removal by this system because biomass incorporated into the soil undergoes rapid decomposition and it releases P and other nutrients that can enter the water column once the soil is flooded. Further evaluation is needed to determine the long-term sustainability of expected P removal rates and cost of operating these systems.

Stormwater Treatment Areas (STAs):

The lessons learned and knowledge gained during the operation of Southern Everglades STAs over the last two decades suggest that STAs also can be designed and constructed in the sub-basins north of Lake Okeechobee to reduce P loads. Furthermore Flow Equalization Basin (FEB)-STA technology offers substantial promise as a P load reduction tool and may aid also in meeting some needed water storage needs (see Section III). At present, four sub-basins, TCNS, IP, FC, and LK, generate approximately 80% (400 metric tons per year) of the P load to Lake Okeechobee. Currently, three STAs are in various phases of implementation in the TCNS sub-basin with a total 3,671 acres (1,486 ha) and 3,200 acres of effective treatment area. It is estimated that the current STA projects will remove approximately 22 metric tons P per year (FDEP, 2014a).

Table IV-2. Total phosphorus loads and reduction targets for the Lake Okeechobee watershed. (source: FDEP, 2014a).

Category	Total Phosphorus, metric tons/year
Total P load [1975-2014][1]	503
Baseline P load [1991-2005][1]	517
Baseline P load [2001-2012][1]	512
TMDL (including contribution from atmospheric deposition)	140
Reductions needed to achieve TMDL	372
Projects identified in 6 sub-basins	103
Fisheating Creek[2]	[18.9]
Indian Prairie[2]	[11.8]
Lake Istokpoga[2]	[1.8]
Lower Kissimmee[2]	[23.3]
Taylor Creek/Nubbin Slough[2]	[40.8]
Upper Kissimmee[2]	[6.8]
Projects under development in Indian Prairie; Taylor Creek/Nubbin Slough; Lake Istokpoga; Upper Kissimmee[3]	46-48
Additional P reduction needed to meet TMDL	**221-223**

[1]Data Source: Table 8-2 (SFWMD, 2015) numbers include measured loads plus atmospheric deposition contribution
[2]Data Source: Table 24 (FDEP, 2014a)
[3]Data source: Table 22 (FDEP, 2014a)

To reduce P loads to Lake Okeechobee by the additional approximately 220 metric tons P per year needed to achieve the TMDL approximately 27,000 acres (11,000 ha) of STAs and associated FEBs would be needed, assuming an average total P removal of 20 kg/ha (18 lb/acre) P per year. The long-term (21 year) average P removal of STA-1W (south of the lake) is estimated to be approximately 10 kg/ha (9 lb/acre) P per year with an average effluent quality of < 50 ug/L (SFWMD, 2015). The P removal in pilot scale STAs in Taylor Creek/Nubbin Slough (north of the lake) is estimated between 16-21 kg/ha (14 to 19 lb/acre P) per year. North of the lake P load reduction is more important than P concentration in the outflow water, in contrast to STAs south of the lake where outflow concentrations are regulated by the WQBEL. With appropriate modifications in design and management strategies, including the addition of FEBs, P removal rates for STAs north of the lake are likely to achieve 20 kg/ha (18 lb /acre) P per year.

The Phase 1 BMAP projects described above are expected to achieve a total P reduction of approximately 150 metric tons per year when completely implemented, out of a total required reduction of approximately 370 metric tons per year (Table IV-2). Additional strategies such as new field-verified BMPs that protect water quality, *in situ* technologies that immobilize legacy P (e.g. by chemical amendments) and additional FEBs and STAs will be needed to achieve the Lake Okeechobee TMDL. FEB-STAs, based on existing information, are a logical choice for enhanced treatment. Approximately 27,000 additional acres of STAS and associated FEBs would be needed to reduce P loads by 220 metric tons per year.

Northern Everglades - Caloosahatchee Estuary BMAP

The Caloosahatchee Estuary has been determined to be impaired by nutrients, and in 2009 the FDEP adopted the Caloosahatchee Estuary TMDL for total nitrogen (TN), which has been linked to high chlorophyll-*a* concentrations. Current estimated TN loading to the Caloosahatchee estuary is 11,490,281 lbs (5,212 metric tons) per year (FDEP, 2012). Approximately 85% of the TN load (9,736,039 lb/year, 4416 metric tons/year) is contributed by basins upstream of S-79 and 15% (1,754,242 lb/year, 796 metric tons/year) is contributed by basins downstream of S-79 (FDEP, 2012). The Caloosahatchee Estuary BMAP and its associated projects are only intended to address TN reductions in the basins downstream of S-79. Because domestic wastewater loads are estimated to be less than 1% of the TN loading downstream of S-79, the BMAP focuses on stormwater load reductions. TN sources above S-79 will be addressed by other efforts.

The Caloosahatchee Estuary Basin BMAP was adopted in 2012 (FDEP, 2012), following completion of a stakeholder driven processes that was focused on identifying projects that had been constructed since 2000, or are planned to be built within the first five years after BMAP adoption (2012-2017). These projects include structural urban stormwater projects, street sweeping, public education and fertilizer ordinances, conservation land purchases, hydrologic restoration and agricultural BMPs. Overall, the first five-year iteration (2012-2017) BMAP projects proposed by stakeholders are expected to reduce stormwater TN loads by 155,488 lbs (71 metric tons), or approximately 40 percent of the 388,719 lbs (176 metric tons) per year stormwater TN reduction required to achieve the TMDL downstream of S-79. Estimated load reduction as of November 2013, including those projects given credit before BMAP adoption, was 140,465 lbs (64 metric tons) per year of TN (Figure IV-16).

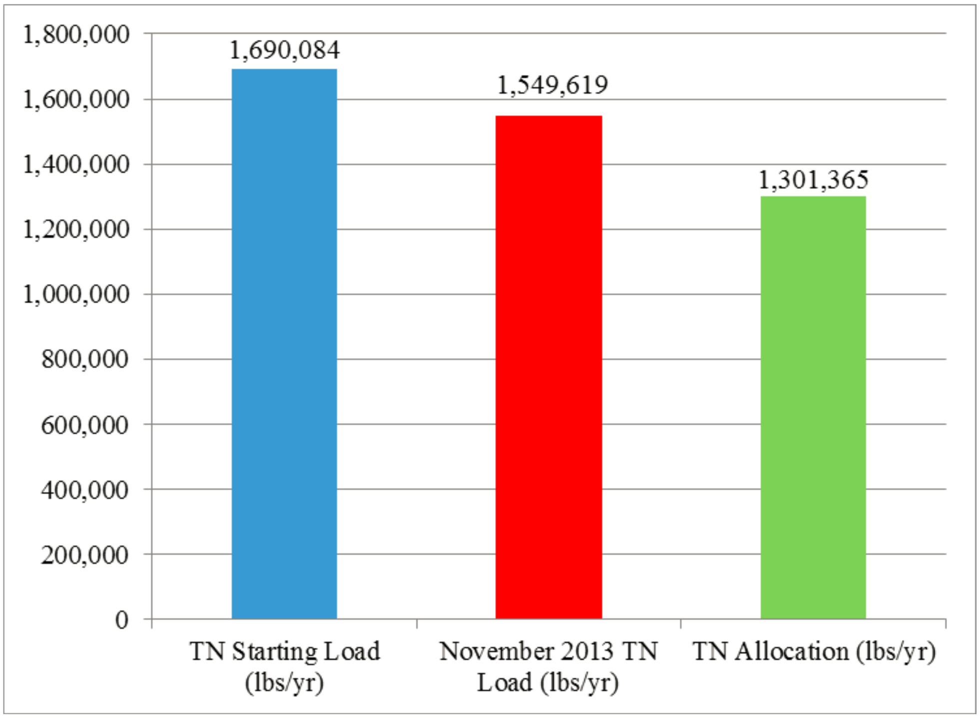


Figure IV-16. Progress toward the Caloosahatchee Estuary Total Nitrogen TMDL through November 30, 2014. The first bar is the starting load for urban and agricultural stormwater runoff in the basin. The second bar shows the current estimated loading after the implementation of proposed BMAP projects. The third bar is the total load allowed for urban and agricultural runoff to meet the TMDL (Source: FDEP, 2014c) .

The Caloosahatchee River Watershed Protection Plan (SFWMD, 2009b) identified a combination of watershed storage and water quality projects to improve the quality, timing and distribution of flows throughout the system. In addition to urban and agricultural BMPs, the plan recommended construction of approximately 15,000 acres of STAs, for a total potential reduction of 1,840 metric tons (approximately 4,000,000 lbs) of TN per year and 166 metric tons (361,000 lbs) of P per year (SFWMD, 2009b). If this plan were implemented, it would remove a significant portion (35%) of the TN loads from both upstream and downstream of S-79; however, no STAs are currently designed or sited in the Caloosahatchee basin. The first stage of the C-43 Water Quality Treatment and Test Facility, intended to investigate and test wetland treatment for removing TN and other constituents, is anticipated to begin in fiscal year 2015. In addition, a 540 acre site to test the feasibility of using Floating Aquatic Vegetative Tilling to remove TN is operating in the East Caloosahatchee Watershed. At present there is no requirement to reduce to P loads to the Caloosahatchee estuary.

Northern Everglades - St. Lucie River and Estuary BMAP

Long-term St. Lucie River Watershed TN and TP loads (WY1997-WY2014), exclusive of Lake Okeechobee contributions, are estimated at approximately 2,429,832 lbs (1,102 metric tons) TN per year and 597,552 lbs (271 metric tons) TP per year, respectively (SFWMD, 2014b). The TMDL requires a reduction to 1,136,633 lb (515 metric tons) TN per year and 127,016 lbs (58 metric tons) TP per year (Figure IV-17). Lake Okeechobee loads are assumed to be addressed by the Lake Okeechobee BMAP.

The St. Lucie River and Estuary Basin BMAP was adopted in 2013 (FDEP, 2013) following completion of a stakeholder-driven process that was focused on identifying projects that have been constructed since 2000, or are planned to be built within the first five years after BMAP adoption (2013-2018). The first iteration BMAP projects include agricultural BMPs, public education and fertilizer ordinances, street sweeping, and urban stormwater and wastewater projects. These first iteration projects are expected to achieve reductions of approximately 316,024 lbs (143 metric tons) N per year and 121,250 lbs (55 metric tons) P per year (Figure IV-17). It is estimated that total load reductions as of June 2014 were 477,789 lbs/year (217 metric tons) TN and 130,542 lbs/year (60 metric tons) TP, exceeding the first iteration BMAP target. Nevertheless these load reductions represent only approximately 36% (TP) and 28% (TN) of the TMDL required reductions, thus additional nutrient reduction strategies are required to meet the TMDL.

In addition to these BMAP projects the CERP C-44 project includes construction of a 7,300 acre STA with an effective treatment area of 6,300 acres that is expected to remove approximately 180,780 lbs (82 metric tons) TN per year and 57,320 lbs (26 metric tons) TP per year (SFWMD, 2015). These removal estimates appear to be based on the P removal rate of approximately 10 kg /ha per year that has been achieved south of the lake. However, with effective management this STA can likely be loaded at a higher rate than those south of the lake, and thereby achieve an increased total P removal of up to 20 kg/ha per year. There is one Hybrid Wetland Treatment Technology test facility currently operating in the St. Lucie watershed and one is under development.

Based on the assumptions made for the additional STAs required for the Lake Okeechobee Watershed (i.e. removal of 20kg P/ha per year), approximately 16,000 acres (6400 ha) of STAs (beyond the C-44 STA and current BMAP projects) are needed in the St. Lucie watershed to remove the additional 284,000 lb (128 metric tons) TP per year required to meet the TMDL. Based on nitrogen to phosphorus load ratios in the St. Lucie basin, this acreage of STAs will remove approximately 1,280,000 lb (580 metric tons) total N per year.

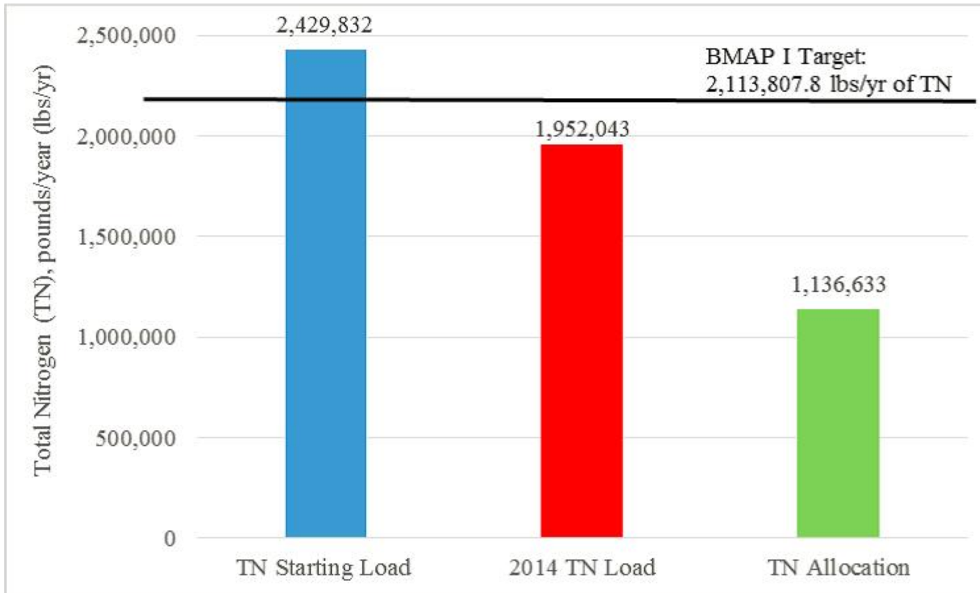


Figure IV-17. Progress toward the St. Lucie River and Estuary total nitrogen TMDL through June 30, 2014. (Source: FDEP, 2014b).

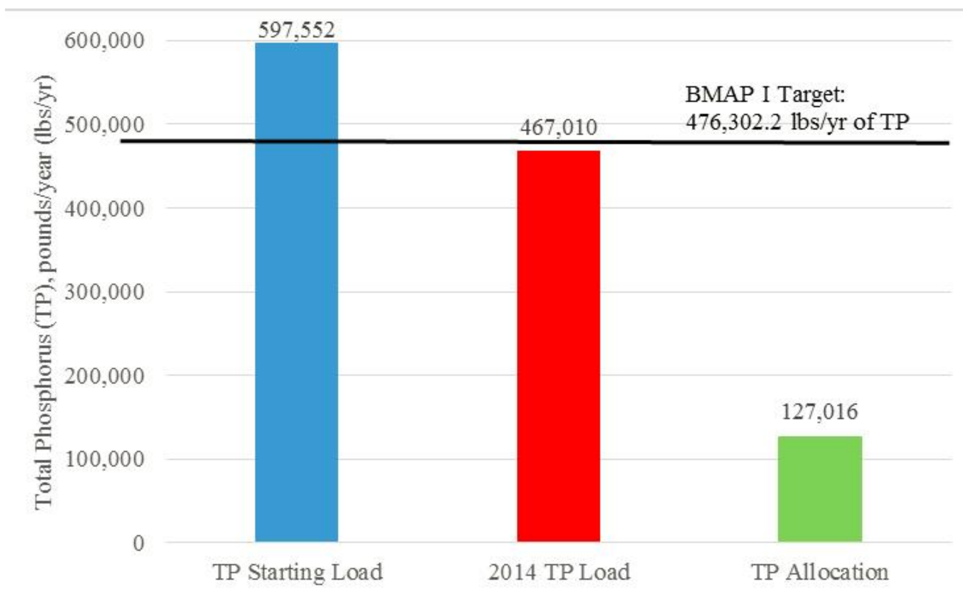


Figure IV-18. Progress toward the St. Lucie River and Estuary total phosphorus TMDL through June 30, 2014 (Source: FDEP, 2014b).

Current and planned BMAP projects in the Caloosahatchee and St. Lucie basins will not reduce nutrient loads to the level needed to achieve their respective TMDLs. Rather, in the first five years of BMAP implementation the FDEP expects (SFWMD, 2015):

- Modest improvements in water quality trends in the watershed tributaries as well as each estuary (St. Lucie and Caloosahatchee);
- Decreased loading of the applicable target pollutants (TP, TN, and BOD);
- Increased coordination between state and local governments and within divisions of local governments in problem solving for surface water quality restoration;
- Determination of effective projects through the stakeholder decision-making and priority-setting processes;
- Enhanced public awareness of pollutant sources, pollutant impacts on water quality, and corresponding corrective actions;
- Enhanced understanding of basin hydrology, water quality, and pollutant sources.

Additional strategies such as new field-verified BMPs that protect water quality, *in situ* technologies that immobilize legacy P (e.g. by chemical amendments) and additional FEBs and STAs are needed. Approximately 15,000 acres of STAs are needed in the Caloosahatchee River Watershed for the potential reduction of 1,840 metric tons of total N and 166 metric tons of total P per year. Approximately 16,000 acres of STAs are needed in the St. Lucie River Watershed for potential reduction of 130 metric tons of total P per year and 585 metric tons of total N per year. The N to P load ratio from the Caloosahatchee River Watershed is approximately 10 as compared to a ratio of 4 to 5 for St. Lucie River Watershed. These ratios suggest that the St. Lucie River Watershed has much more legacy P than the Caloosahatchee River Watershed.

Southern Everglades - Restoration Strategies

The Everglades Forever Act (EFA; Section 373.4592, F.S.) required that strategies to decrease nutrient loads in water discharged downstream be developed for both the Everglades Construction Project (ECP) and non-Everglades Construction Project (non-ECP) basins in the Southern Everglades. As a result, 57,000 acres of constructed wetlands, known as Stormwater Treatment Areas (STAs), were built on former agricultural lands at the interface of the EAA and the WCAs to reduce excess TP from surface waters prior to discharging that water into the Everglades Protection Area (EPA) (Figure IV-19). The STAs currently in operation include: STA-1E; STA-1W; STA-2; STA-3/4; and STA-5/6.

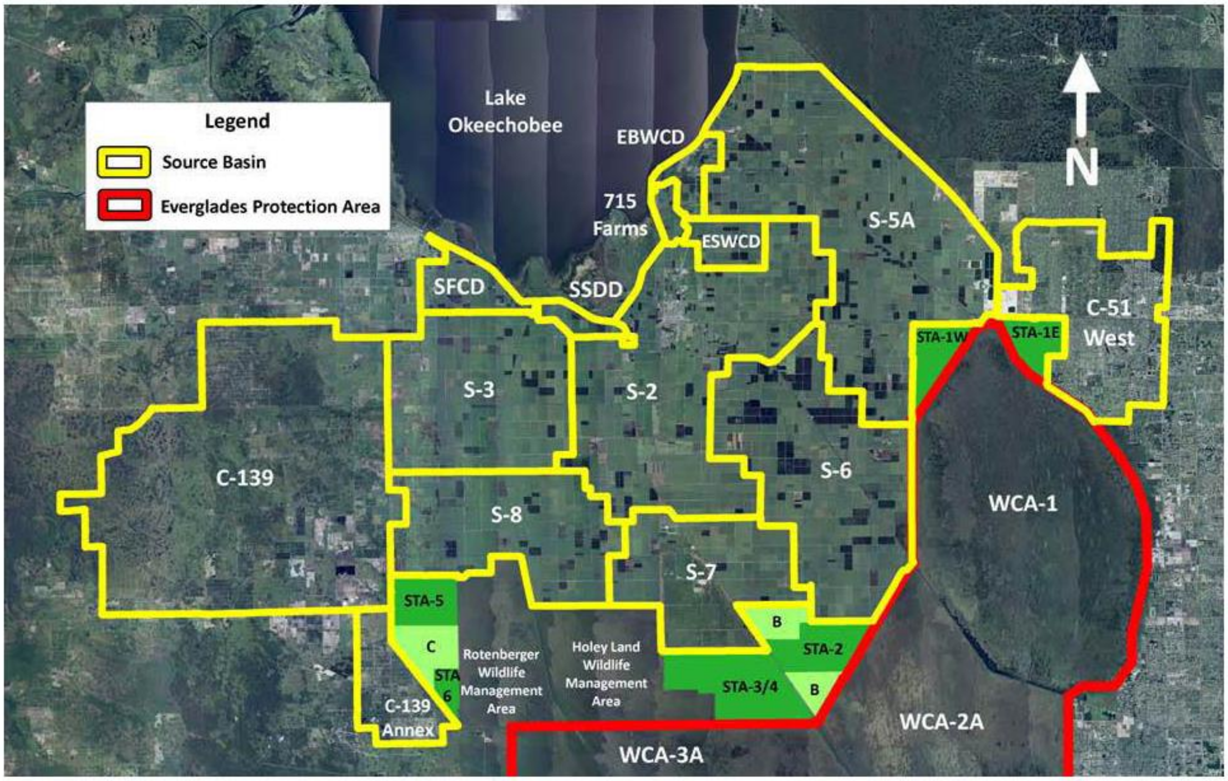


Figure IV-19. Map showing the Everglades Agricultural Area Basins and C-139 Basin, and associated Stormwater Treatment Areas (SFWMD, 2015).

As discussed in Section II.5, in response to USEPA's 2010 "Amended Determination" in the federal litigation over EPA's approval of Florida's water quality standards, SFWMD, USEPA, and FDEP established a Water Quality-Based Effluent Limit (WQBEL) for TP in discharges from STAs order to achieve compliance with the 10 µg P/L long-term geometric mean standard in the EPA. The WQBEL requires that the flow-weighted mean (FWM) TP concentrations at STA discharge points not exceed (1) an annual FWM of 13 µg/L in more than three out of five years or (2) an annual FWM of 19 µg/L in any one year (SFWMD, 2012). To achieve the WQBEL in 2012 the State of Florida developed a plan known as the "Restoration Strategies Regional Water Quality Plan" (Restoration Strategies, SFWMD, 2012). Restoration Strategies included a suite of projects to improve water quality and a 10-year, $50 million research program to investigate critical factors that regulate the sustainable removal of phosphorus by STAs.

The planned suite of Restoration Strategies projects includes more than 6,500 acres of new STAs and 110,000 acre-feet of additional water storage in FEBs. These projects are located in the Eastern Flow Path (STA-1E and STA-1W), Central Flow Path (STA-2, and STA3/4), and Western Flow Path (STA-5 and STA-6) (Figure IV-20).

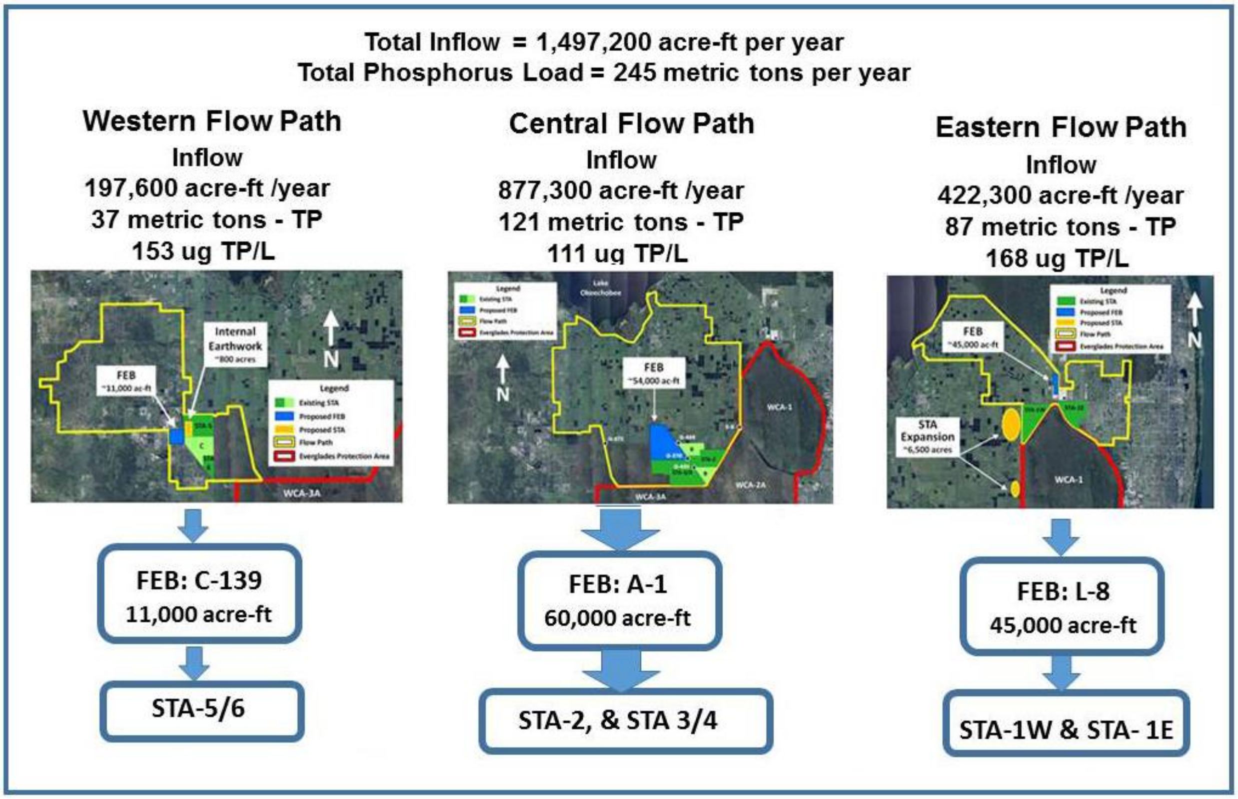


Figure IV-20. Phosphorus loads to western, central, and eastern flowpath (Data source: SFWMD, 2012).

The Eastern Flow Path will receive a 45,000 acre-ft FEB adjacent to L-8 canal to attenuate peak flows and optimize hydraulic loading rates to STA-1W and STA-1E. The addition of approximately 6,500 acres near STA-1W will increase total treatment capacity to 422,300 acre-ft of runoff water according to modeling results using the Dynamic Model for Stormwater Treatment Areas (DMSTA) model (Walker and Kadlec, 2011) and the peer-reviewed South Florida Water Management Model (SFWMM). In the Central Flow Path, a 54,000 acre-ft FEB adjacent to the North New River Canal will attenuate peak flows and optimize hydraulic loading rates to STA-3/4. In addition, approximately 800 additional acres for STA-5 will increase total treatment capacity to 877,300 acre-ft of water according to modeling results using DMSTA and SFWMM. The Western Flow Path will receive an 11,000 acre-feet FEB that will attenuate peak flows and optimize hydraulic loading rates for a total of 197,600 acre-ft of runoff from the C-139 Basin to STA-5/6 (DMSTA and SFWMM). In total, current plans include FEBs and STAs with the potential to treat approximately 1.5 million acre-ft of water, with the DMSTA model predicting long-term, FWM outflow concentrations of 12 µg/L, which suggests compliance with the WQBEL target.

The Science Plan will investigate critical factors that influence phosphorus treatment and performance, especially at low levels of total P. Specific investigations will include the effects of microbial activity, phosphorus flux, inflow volumes and timing, inflow phosphorus loading rate and concentrations on phosphorus outflow, phosphorus removal by specific vegetation speciation, and the stability of accreted phosphorus. The DMSTA model does not currently consider internal dynamics (such as short circuiting, vegetation die-off, internal regeneration of P, and extreme events), but research conducted as part of the Science Plan could provide information to include internal dynamics in the model. The combination of FEBs and STAs show promise for meeting the WQBEL requirements. The FEBs should help to attenuate peak stormwater flows prior discharge into STAs, thus improving the long-term sustainability of STAs to improve the water quality. New approaches (including improved models) developed as a result of this effort may provide additional innovative strategies to improve the performance of STAs to achieve the WQBEL.

4. Summary

In the context of the Everglades restoration, water storage and water quality issues are inextricably linked. Along with increased storage, increased treatment capacity is needed to achieve the Lake Okeechobee, St. Lucie and Caloosahatchee TMDLs, and if the stored water is to be moved south from Lake Okeechobee and discharged from the STAs into the EPA, it must comply with the established WQBEL. Legacy P in the Lake Okeechobee watershed is of particular concern because current efforts to achieve the Lake Okeechobee TMDL have proven inadequate. None of the current BMAPs for the Lake Okeechobee, St. Lucie or Caloosahatchee watersheds will achieve their respective TMDLs within the next 5 years. Therefore, additional controls, such as FEBs, STAs, and aggressive BMPs that include in-situ immobilization of legacy P by chemical amendments, will be needed to meet TMDL targets. These shortcomings have even more substantial consequences for the Caloosahatchee River and St. Lucie River estuaries because the BMAPs established for both of these systems assume that the targets for Lake Okeechobee have been met. Furthermore, substantially more FEB-STA treatment capacity will be required to move water south from Lake Okeechobee to the EPA if Lake Okeechobee’s TMDL is not met.

To achieve water quality standards in Lake Okeechobee, the St. Lucie estuary, and the Caloosahatchee estuary, more aggressive BMAPs must be developed. New field-verified BMPs that protect water quality, advanced *in situ* technologies that immobilize legacy P, and the strategic placement of FEB-STAs in the Northern Everglades priority basins will be essential to achieve water quality targets. Beyond existing and planned approaches, the substantial reservoir of legacy P in the Northern Everglades watersheds will necessitate new and more effective strategies to combat the mobility of P. Furthermore, as discussed in Section III, the funding and completion of the FEBs and STAs specified by Restoration Strategies should be accelerated to achieve compliance with the EPA WQBEL more quickly.

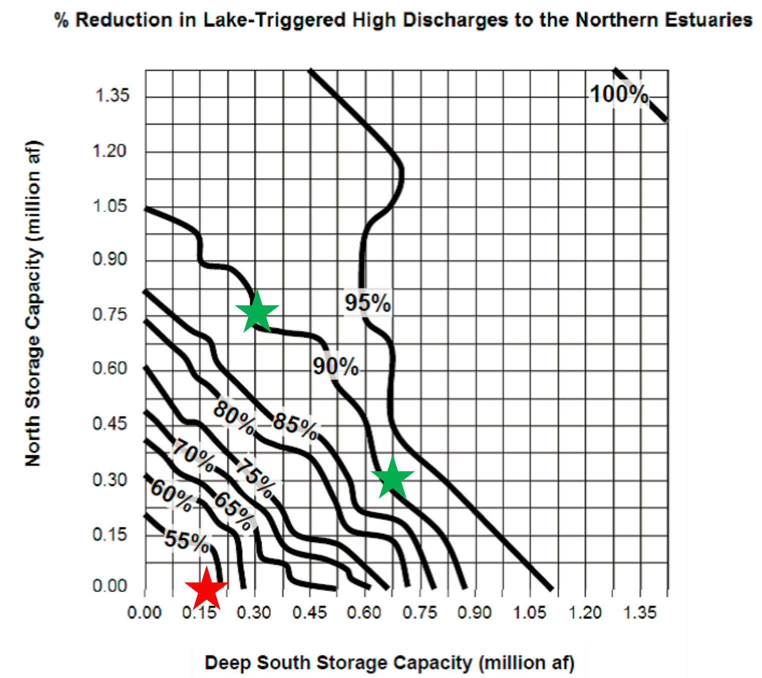
V. Options (beyond approved projects) to Reduce High Volume Freshwater Flows to the Estuaries and Move More Water South from Lake Okeechobee to the Southern Everglades

1. Introduction

Repeated planning exercises, described in Section III, have shown that large volumes of inter-annual storage are required north, south, east and west of Lake Okeechobee to manage Lake Okeechobee levels within a desirable range, reduce damaging high and low flows to the St. Lucie and Caloosahatchee estuaries, and move more water south for agricultural, urban and environmental uses. Furthermore, as described in Section IV, to discharge this stored water to Lake Okeechobee and the St. Lucie and Caloosahatchee estuaries in compliance with their respective Total Maximum Daily Loads (TMDLs), and to the Everglades Protection Area (EPA) in compliance with its Water Quality Based Effluent Limit (WQBEL), significant additional treatment will be required. The red star on Figure V-1 shows the restoration performance of the system which can be expected after the completion of the Kissimmee River Restoration (KRR), and the construction of the C-43, C-44, Restoration Strategies and Central Everglades Planning Project (CEPP) projects, based on the River of Grass modeling study (SFWMD, 2009d). The KRR project is expected to attenuate peak flows to Lake Okeechobee; the C-43 and C-44 projects are expected to significantly reduce local-basin triggered high flows and improve dry season flows to the St. Lucie and Caloosahatchee estuaries; and the Restoration Strategies and CEPP projects together are expected to increase the delivery of clean water to the EPA to an average of 1.5 million acre-ft per year. Nevertheless, Figure V-1 indicates that even after these projects are constructed, lake-triggered high discharges to the St. Lucie and Caloosahatchee estuaries will be reduced by less than 55%, and less than 75% of the dry season Everglades demand target will be delivered to the EPA over the 41-year simulation period. Two possible configurations that provide a 90% reduction in lake-triggered discharges and delivery of 90% of the dry season Everglades demand are shown with green stars on Figure V-1. These two example configurations require approximately 1) 750,000 acre-ft new storage north of the lake and 132,000 acre-ft additional storage south of the Lake (i.e. beyond the CEPP/Restoration Strategies Flow Equalization Basin (FEBs)), or 2) 300,000 acre-ft storage north of the lake and 507,000 acre-ft additional storage south of the Lake.

The following sections present options for additional efforts, beyond the approved projects, to provide the additional storage and treatment required to more fully achieve the restoration objectives of reducing lake-triggered high discharges to the estuaries and moving more water south.

a)



b)

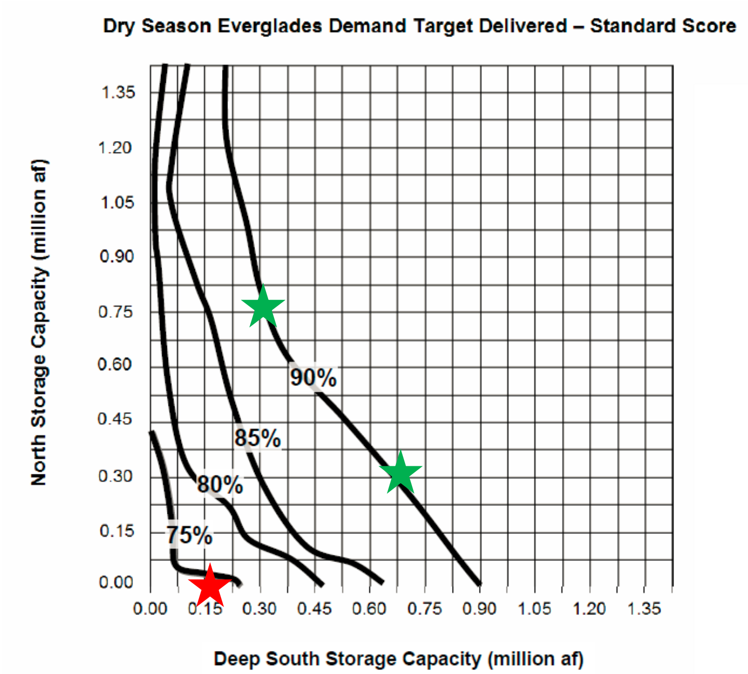


Figure V-1: a) Percent Reduction in Lake Triggered High Discharges to the St. Lucie and Caloosahatchee estuaries (top) and b) Percent Achievement of Dry Season Everglades Demand Target (bottom) by alternative storage configurations (adapted from SFWMD, 2009d) . System performance after Restoration Strategies and CEPP add 112,000 ac-ft of storage south of the lake is indicated by the red star. Green stars indicate two possible future configurations that would achieve 90% restoration.

2. Storage and Treatment North of Lake Okeechobee

Figure V-1, produced as part of the River of Grass planning process (SFWMD, 2009d), shows that storage can be effective at reducing damaging discharges to the St. Lucie and Caloosahatchee estuaries whether it is constructed north or south of the lake. Storage north of the lake is effective for managing lake levels within a desirable range and thus reducing damaging discharges to the estuaries. Furthermore, water storage and treatment is needed north of the lake to meet the Lake Okeechobee TMDL. However, due to the extended time it takes to route water from north of the lake to the Water Conservation Areas (WCAs), northern storage is not likely to be as effective as southern storage in meeting the timing and distribution objectives of water deliveries to the EPA. Furthermore, it is likely that water stored north of the lake, if passed through the Lake or through perimeter canals subject to agricultural runoff, may need to undergo additional water quality treatment to meet applicable standards before it is released to the EPA. Thus, the additional required storage will be needed to be distributed both north and south of the lake to achieve all restoration objectives. The green asterisks on Figure V-1 indicate that between 300,000 and 750,000 acre-ft of additional storage north of the lake will improve achievement of restoration goals in the St. Lucie and Caloosahatchee estuaries and the Everglades considerably. Options to provide additional storage north of the lake include combinations of ASR wells, deep storage reservoirs, shallow storage impoundments, and dispersed water management. The advantages and disadvantages of each of these types of storage are briefly summarized below. Options to treat the stored water before it is released to Lake Okeechobee to help achieve the TMDL are discussed in Section IV.

Aquifer Storage and Recovery (ASR):

ASR wells inject and store excess water underground in the wet season with the goal of extracting the water in subsequent dry seasons for water supply. Advantages of ASR wells include 1) in sufficient numbers they are able to provide for substantial inter-annual storage, 2) they require a minimal land surface footprint, and 3) they have been shown to provide a reduction in phosphorus concentrations in recovered water in CERP pilot studies. Disadvantages of ASR wells include 1) high operation and maintenance costs due to pumping and required treatment prior to injection (filtration and UV disinfection), 2) highly colored water may reduce UV disinfection performance to below regulatory requirements for injection, and 3) recovery efficiency is site specific depending on local hydrogeological characteristics (e.g. ~100% at the Kissimmee River Pilot site, ~ 20-40% at the Hillsboro Pilot site, and not feasible at the Caloosahatchee River Basin Pilot site) For more details on the ASR pilot study see Section III.3.c.

Surface Reservoirs:

Above-ground storage reservoirs are used to capture and hold normal and peak flows during wet seasons. Water is then discharged during dry seasons when flows are needed for urban, agricultural or natural system uses. Water depths in above-ground reservoirs proposed to date typically range from 4-12 feet, with vegetation management and dam safety concerns being the limiting factors. Deep 12-ft storage reservoirs have relatively high construction costs (approximately $9,900 per acre-ft, excluding land costs estimated in the CEPP planning effort) compared to shallow 4-ft water impoundments (approximately $4,900 per acre-ft, excluding land costs estimated in CEPP planning effort) due to additional dam safety requirements. Both deep reservoirs and shallow impoundments are operationally flexible and offer the potential to improve the timing and distribution of water to the natural system. Storage reservoirs and shallow impoundments are allowed to experience dry-outs during extended drought periods and are not intended to provide substantial fish and wildlife habitat value or water quality treatment capability. In fact, reservoirs and impoundments may cause water quality problems, such as algae blooms when water is held for substantial periods of time and may release soil phosphorus following dry-outs. Deep reservoirs are advantageous in that they have a reduced land footprint, e.g., a 12-ft reservoir requires one-third of the land that a 4-ft impoundment requires for the same amount of storage. Shallow reservoirs are advantageous in that they are not required to meet dam safety standards, however, they have the potential for higher operation and maintenance issues related to exotic vegetation management within large shallow footprints. Using the construction costs estimated for the CEPP planning effort, and assuming sufficient land is available for purchase, shallow storage will be cheaper than deep storage on a per acre foot basis as long as land costs remain below $30,000 per acre.

Dispersed Water Management:

Dispersed water management (DWM) provides short-term (intra-seasonal) local water retention, peak flow attenuation, and onsite hydrologic restoration, typically on private lands or in publicly owned wetlands management or wildlife refuge areas. Advantages of DWM include that it 1) improves natural habitat, and 2) it has the potential to increase local storage and thus attenuate the magnitude of peak flows to the lake, 3) it has the potential to increase evapotranspiration and thus reduce total flows to the lake, and 4) it provides economic incentives to ranchers and citrus growers to maintain the land in its current use rather than selling the land or converting it into more intensive uses which have the potential to create more nutrient loading and exacerbate water quantity issues. Disadvantages of DWM include 1) it is a non-permanent, land-owner implemented solution with associated monitoring and maintenance issues, 2) there is high uncertainty related to long-term (inter-annual) storage benefits because stored water will likely evaporate or infiltrate within the season and thus not be available for use in subsequent droughts, 3) there is high uncertainty in water quality treatment capability due to the potential for increased phosphorus release upon re-wetting after dry-downs, and 4) limited modeling tools currently exist to evaluate hydrologic and water quality performance. A regional data collection and modeling study, similar to that being conducted for ASR (see Section III.3.c above), is needed to evaluate the cumulative impact of a regional DWM system north of the Lake on the quality, quantity and timing of flows Lake Okeechobee, and its potential for inter-annual storage of water that could be used in subsequent dry years, as a function of climatic conditions, spatial location and density of DWM features on the landscape, and operation of the regional canal system.

Summary:

The Lake Okeechobee Phase II Technical Plan and the River of Grass Planning Process provide a sound foundation from which to plan, design, and build the additional storage and treatment needed north of Lake Okeechobee. To determine the most cost-effective means of providing the required storage and treatment a strategic planning exercise should be conducted north of Lake Okeechobee similar to the River of Grass Planning Process conducted south of the lake. The goal of this exercise should be to determine the best combinations and locations, and logical phasing of the various types of storage that will provide the desired benefits to the lake, St. Lucie and Caloosahatchee estuaries and EPA. This will require a regional modeling effort that takes into account lessons learned and information gained since the CERP, NEEPP and ROG planning exercises regarding the permitting requirements, engineering feasibility and costs, and inter-annual storage benefits associated with ASR, deep storage reservoirs, shallow water impoundments and dispersed water management. New data gathering efforts and model developments will be required to simulate the cumulative impacts of a regional DWM system north of the Lake on the quality, quantity, and timing of flows into Lake Okeechobee as a function of climatic conditions, spatial location and density of DWM features on the landscape, and operation of the regional canal system. The Technical Review Team expects that the modeling study will show that, while DWM on private lands may provide some benefits, providing the additional storage and treatment needed will require acquisition of additional land north of the Lake (i.e. from approximately 25,000 acres if 300,000 acre-ft is provided by deep storage, up to approximately 187,500 acres if 750,000 acre-ft is provided by shallow water impoundments).

3. Additional Storage, Treatment and Conveyance South of Lake Okeechobee

In addition to the north of lake storage discussed above, the green asterisks on Figure V-1 indicate that provision of between 132,000 and 507,000 acre-ft of additional storage, treatment and conveyance south of the lake (i.e. in the EAA) will improve achievement of restoration goals for both the St. Lucie and Caloosahatchee estuaries and the Everglades considerably. Storage areas within the EAA have the advantage of being able to store excess water from within the EAA basin and upstream sources (i.e. Lake Okeechobee and its inflow sources). Because of the existing canal system in the EAA, storage located between the Miami River and North New

River Canals is strategically located to store excess runoff from significant portions of the EAA basin and makes maximum use of existing infrastructure. Storage and treatment in the EAA can effectively be used to meet Everglades targets, presuming the construction of new outflow/delivery infrastructure within the EPA. Options to provide additional storage south of the lake include combinations of deep storage reservoirs, shallow water impoundments, wet flow-ways, and dry-flow-ways. Each of these storage options will also require additional STA acreage to provide the required water treatment. In the next section we review past evaluations of flow-way and flow-way like plans and evaluate their efficacy and feasibility to provide significant restoration benefits in the current, highly modified regional ecosystem.

a. Plan 6 and Other Flow-way Options

Introduction

One concept for restoring more flow to the Everglades, which was first identified in a report of the Jacksonville District of the US Army Corps of Engineers (USACE, 1955a) and referred to as 'Plan 6' (Figure V-2) is a *'flood-way from Lake Okeechobee to Conservation Area 3 …* that … *would discharge by gravity with a spillway structure at the lake end to regulate discharge.'* In this report the USACE noted that '*benefits from provision of the flood-way (flow-way) would consist of reduction in maximum lake stages and hence reduction of the amount of water diverted through the St. Lucie Canal, which would reduce damages along the lower St. Lucie River.'* The report also noted that *'water supply to Water Conservation Area 3 would not be available during drought periods*' and that *'discharge from the flood-way would cause water level in Conservation Area 3 to rise during flood periods, necessitating increases in levee heights and additional water control structures.'* In the report it also was noted that *'a spillway would be required at the centerline of the Lake Okeechobee levee to control discharge from the lake and, during hurricanes, to limit discharges through the flood-way as required to prevent damages from wind tides and waves.'* In that report the USACE identified the need for a spillway designed to handle a maximum of 20.6 ft of water in the lake. The anticipated diversion capacity from the lake to the south via the flood-way system was 4,800 cfs at lake stage 17.4 ft and 16,800 cfs at lake stage 20.6 ft.

The Technical Review Team was unable to secure documentation as to why this particular plan was not carried forward. Nevertheless, it is clear that engineers at that time were working under a very different set of conditions than exist at present. First, they assumed that water could flow across the EAA by gravity. Today, due to soil subsidence, this is no longer possible and would, in fact, require a more engineered configuration that includes reservoirs and pumps to move water south over that same expanse of land. Second, the engineers envisioned a lake reaching very high levels (up to 20.6 ft) that today we know would negatively impact the lakes ecology, the littoral zone in particular (Havens, 2002; Havens and Gawlik, 2005).

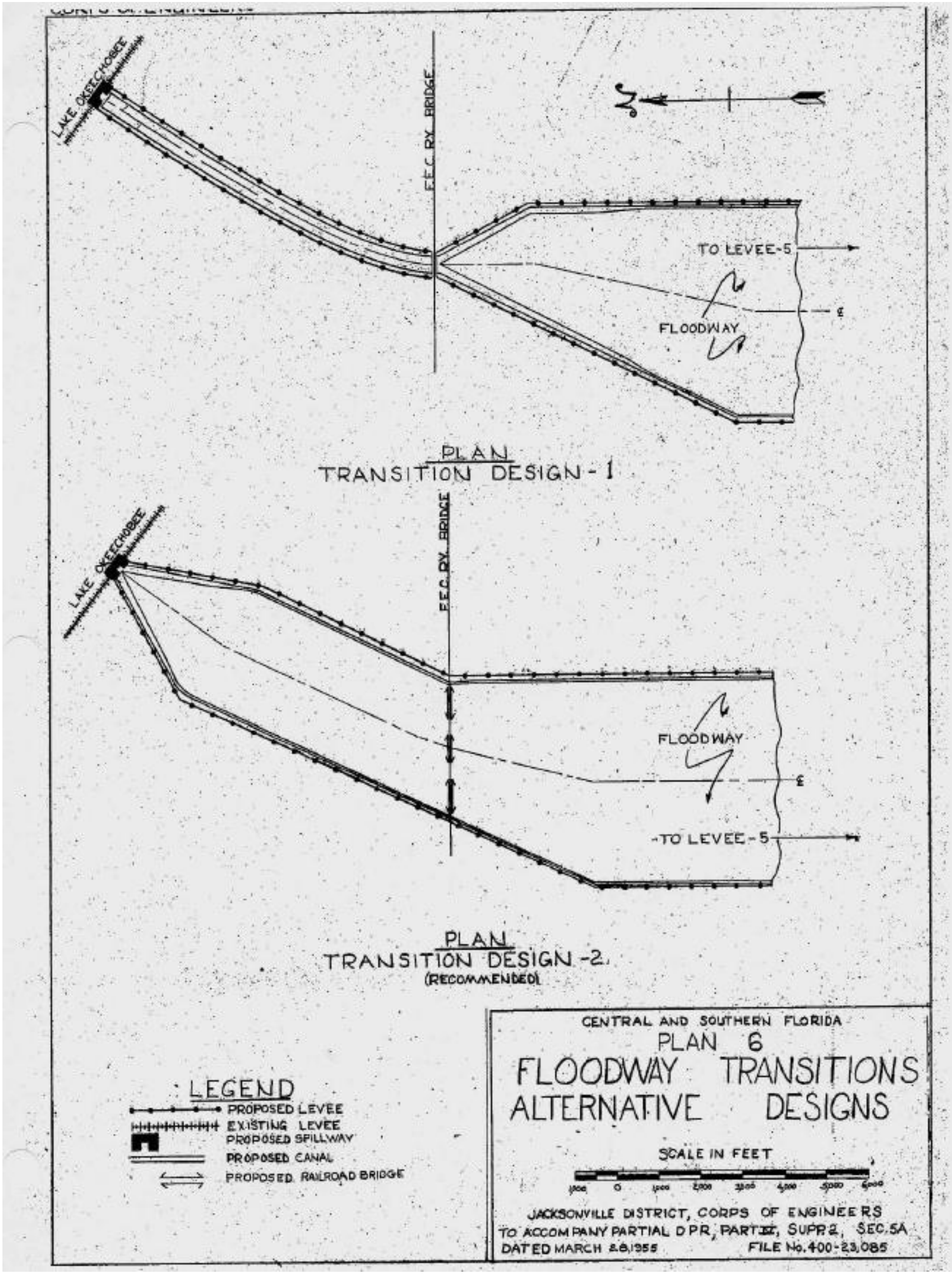


Figure V-2. Plan 6, a flow-way from Lake Okeechobee through the EAA to the Everglades, as illustrated in USACE (1955b). Note that north is to the left in the orientation of this illustration.

The USACE Reconnaissance Report

The US Army Corps of Engineers performed an initial evaluation of Everglades restoration plans in the early 1990s, and provided results in a Reconnaissance Report (USACE, 1994). That study emphasized that the aim was to formulate restoration plans '*with the premise that the hydrological restoration would create a system that could function similarly to the way it functioned under pre-drainage conditions*' (the pre-drainage system was a continuous broad flow path from the Upper Kissimmee to Florida Bay).

One of the plans considered in the Reconnaissance study was Plan 6. In this case, there was not a spillway at the lake, and the flow-way started two miles north of the Bolles Canal, varying in width (east-west) from 13.1 miles to 7.2 miles, and with a length of 22.5 miles (Figure V-4). It was bounded on the west and east by the Miami and North New River Canals, respectively. Water would be introduced by two pump stations – with capacities of 4,170 cfs (from the Miami Canal) at the northwest corner of the flow-way and 2,460 cfs (from the North New River Canal) at the northeast corner of the flow-way. The capacity of the flow-way itself to deliver water south was estimated at 6,600 cfs.

During the Reconnaissance study, there were public workshops where preliminary results of restoration plans were presented. It was noted in the Reconnaissance Report that there was strong opposition to Plan 6, however, it was kept in the mix of plans for further analysis because of its potential technical merits.

Relative to other plans evaluated as part of the Reconnaissance Report, Plan 6 allowed for the largest spatial extent of wetlands (1,815,000 acres; RR Table 11, Page 202), the greatest amount of sheet-flow (1,658,000 acres; RR Table 11, page 202) and the greatest amount of storage capacity (8,777,000 acre-ft RR Table 11, Page 202). On the other hand, Plan 6 had a projected implementation cost that was among the highest of all the plans considered ($592 million; RR Table 7, Page 192) and the highest equivalent average annual cost ($114 million; RR Table 9, Page 196). Plan 6, because it involved unconstrained gravity flow, did not perform as well as other more managed plans that aimed to restore natural flow patterns across the Tamiami Trail (RR, page 177). Likewise, Plan 6 performed poorly with regard to its projected community suitability index for the marl prairie habitat in the southern Everglades (RR Figure 18, Page 182). The plan was determined to have "good" performance with regard to reducing water discharges to the St. Lucie and Caloosahatchee Estuaries, although not as "good" as several other more engineered plans (RR Figure 18, Page 182).

In the Summary presented on RR Page 188 it was stated that one of the *'most important elements in the final plan to restore the Everglades will be … enlargement of conveyance capacity from Lake Okeechobee through the EAA'* and in an accompanying table that listed project elements recommended for consideration in the subsequent C&SF Restudy (page 229, Table 12), a '*flow-way within the area between Miami and North New River Canals'* was included as one of those elements.

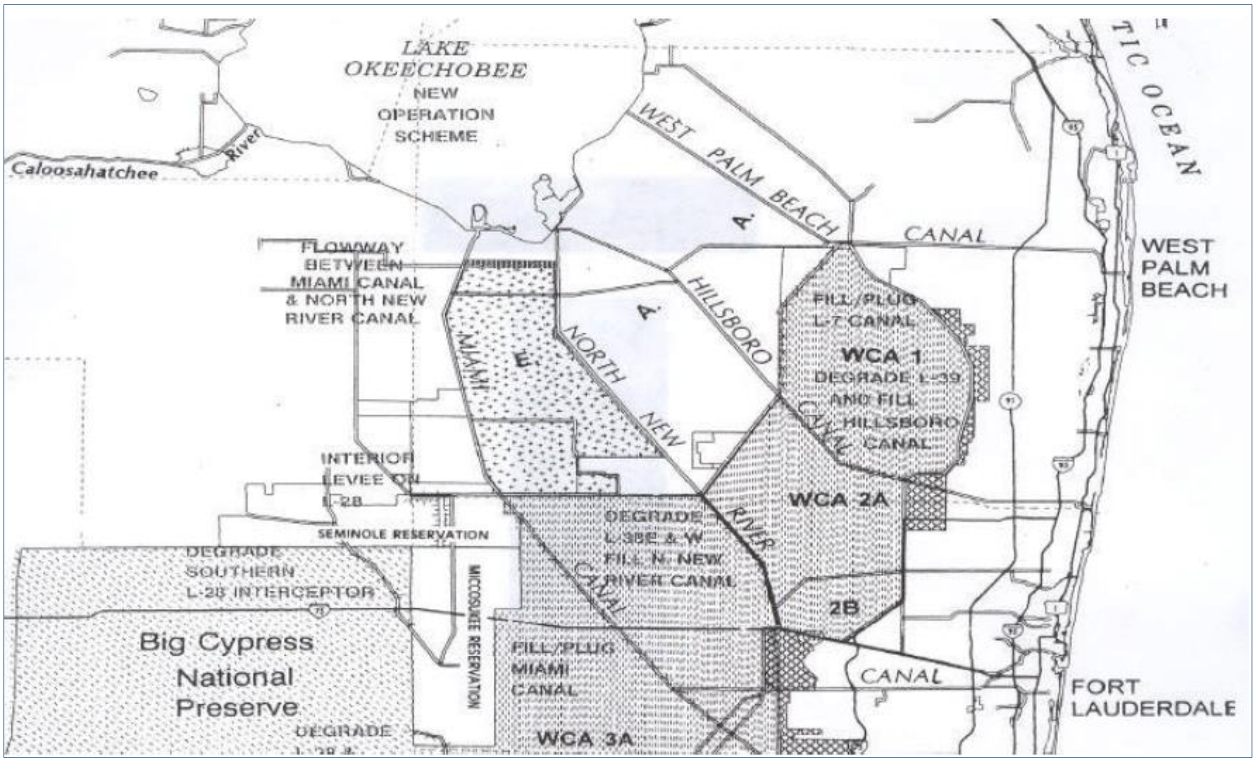


Figure V- 4 The EAA flow-way (stippled area on this map between the Miami and North New River Canals) identified in Plan 6 of the USACE Reconnaissance Report (USACE, 1994).

The C&SF Restudy (CERP, 1999)

In spite of the recommendation provided in the Reconnaissance Report, Plan 6 was not included as an alternative formally evaluated in the C&SF Restudy, for the following reason (from Appendix B CERP, 1999):

> *"A flow-way is generally described as a broad shallow marsh area that is used to flow water freely from Lake Okeechobee to one or more of the WCAs. The concept includes creation of an Everglades-type environment having both storage and water quality benefits.*
>
> *Evaluation of the concept shows several erroneous assumptions about the feasibility. Problems with soil subsidence, ET, seepage management, vegetation, timing of flows, and lack of flow events is evident. Addressing other EAA issues would be required if a flow-way cuts through and dividing the area, including*

numerous roads, bridges, and railroad relocations. Soil subsidence in the EAA has substantially reduced the hydraulic head that drives the southward flow of water; hence, velocities and flow rates are greatly reduced. By spreading the water over shallower areas (as opposed to reservoirs) and maintaining proper hydration of a functioning marsh habitat, the ET loss could easily be doubled. A long, rectangular configuration can have a 75 percent longer levee than a squared one, thus increasing seepage management features.

Because nutrient-laden soil would be flooded for the flow-way, cattails would most likely dominate the vegetation and not the desirable Everglades habitat. Flow-ways would not be able to hold back water going to the WCAs. The continuous delivery of that water would exacerbate the already high stages in the northern parts of the WCAs.

Thus, the timing of flows from flow-ways would not be manageable or beneficial for the remaining Everglades. Perhaps the most crucial element–water flowing from the Lake to the WCAs–is not present in dry or even normal years! For example, during the long periods from 1970-1982 or 1985-1994, no significant excess Lake water was available for the flow-way. Only demand releases to the Everglades were made from the Lake during those periods. Water delivered to the Everglades on a demand basis through a flow-way would not be effective because of increased travel times and increased ET losses. The only years where water could flow for a long duration are wet periods similar to 1969-1970, 1982-1983, and 1994-1995. In those years, the stages in the WCAs are already too high and additional flow from flow-ways would be damaging, not beneficial.

Summarizing, the flow-way is a concept that creates a water supply burden on the system without clear hydrologic benefits. The need for flow-ways would have to be justified for other reasons rather than hydrology alone."

One major difference in the EAA region where the Plan 6 flow-way was sited between 1955, when the USACE first developed the concept, and the time of the C&SF Restudy is the large amount of subsidence in the EAA due to loss of peat (Aich et al., 2013). Today's EAA is much like a shallow basin and water removal during high rainfall periods requires pumping. A gravity flow-way in the EAA would no longer have a north to south elevation gradient, but rather a drop and then increase in elevation, resulting in an area that would hold water, but not passively allow it to flow south. This situation conflicts directly with one of the major concepts of a flow-way as a near-natural solution that could depend on gravity flow and not require the use of energy (diesel, electricity, etc.) to move water south.

South of Lake storage and conveyance alternatives identified in the River of Grass Planning Process

As discussed in Section III.1.c, in 2008 the SFWMD had an option to purchase a large amount of land in the Everglades Agricultural Area (EAA) from willing sellers, with the possibility to carry out land trades to achieve a contiguous corridor through the EAA for conveyance of water to the Everglades. In facilitated meetings, various stakeholders were asked to provide concepts for how land in the EAA could be used to construct storage, treatment and conveyance projects that would reduce harmful discharges of water to the estuaries and increase the amount of freshwater that could be delivered to the Everglades. The peer-reviewed RESOPS model (SFWMD, 2009c) was used to evaluate various stakeholder proposed alternatives with regard to their effectiveness in meeting a set of standard performance measures, including the percent reduction in high lake-triggered discharges to the St. Lucie (>2000cfs) and Caloosahatchee (>2800cfs) estuaries and the ability to provide the target Everglades dry season demand. Calculations also were carried out for each alternative regarding the amount of STA acreage (and cost) that would be needed to meet Everglades P standards, under conditions of Lake Okeechobee outflow water ranging in concentration from 40 to 200 ppb TP.

The River of Grass stakeholder alternatives (Table V-1, SFWMD 2009e) included various configurations of deep and shallow reservoirs, wet and dry flow-ways, widened and reconfigured EAA canals, and STAs. The Everglades River of Grass Northern Expansion option (Figure V-5), included large wet flow-ways through the EAA with no engineered reservoirs or STAs, quite similar in concept to Plan 6 considered in the USACE Reconnaissance Report (USACE, 1994). As indicated in Table V-1, alternatives that performed best for the estuaries were the most engineered and required large, deep storage. For example, the Chain of Lakes alternative, which included a number of inter-connected reservoirs (Figure V-6), reduced damaging discharges to the estuaries by 94% with 500,000 acre-ft of storage north of Lake Okeechobee. In contrast, the Everglades River of Grass Northern Expansion alternative (Figure V-5), with its large passive flow-ways in the EAA and approximately the same volume of storage north of the lake (550,000 acre-ft), reduced damaging discharges by just 77%. The River of Grass Northern Expansion alternative also had considerably poorer performance than the more engineered Chain of Lakes alternative in regard to meeting the Everglades dry season water demands. In fact, the River of Grass Northern Expansion alternative was one of the least effective plans evaluated in regard to helping the estuaries with the issue of regulatory discharges or the Everglades with the issue of too little water in the dry season. Thus similar results, from an entirely different modeling approach, mirrored those in the USACE Reconnaissance Report (1994), i.e. unmanaged gravity flow of water south of Lake Okeechobee is less beneficial to the estuaries and Everglades than more managed scenarios.

It is notable that in the River of Grass planning process, an alternative called the Marshall Plan Element 6 (not to be confused with Plan 6 of the USACE because of its very different configuration) that included both a large storage reservoir and a large wet flow-way (Figure V-7) in the EAA had good performance for the estuaries (95% high flow reduction) and the Everglades (89 score, Table V-1). However, this plan included 650,000 acre-ft of storage north of the lake, so it is not possible to discern whether the benefits came from that added northern storage or the deep storage elements within the EAA.

Table V-1. Planning alternatives considered in the River of Grass planning process, with information on the size of north-of-lake storage, a summary of the plan components and the performance measure results for the estuaries (percent reduction in damaging regulatory releases) and Everglades (standardized score, higher is better). The Everglades Benefit is the ability to deliver needed water south in the dry season (SFWMD, 2009e).

Alternative	**Summary**	**North of Lake Storage (acre- ft)**	**Estuary Benefit**	**Everglades Benefit**
Estuary Driven Everglades Restoration	Deep storage, large dry flow-ways, below ground canals and STAs	1,000,000	96%	98
Everglades River of Grass Northern Expansion	Large gravity wet flow-ways in central and northeast EAA	550,000	77%	80
Chain of Lakes	Large shallow lakes connected by wide canals and an ecoslough	500,000	94%	91
Florida Crystals	Large, dry flow-way and large STAs	500,000	76%	73
Restoration Plus Employment	Large deep storage and STAs	300,000	95%	96
Marshall Plan Element 6	Large, deep storage, managed wetland, large, wet flow-way, and large STAs	650,000	95%	89
Performance	Large, deep storage and large STAs	200,000	95%	95
Performance – Cost Plan	Large, deep storage, large, shallow storage, large STAs, wide below ground conveyance canals	300,000	94%	91
Reservoir within Lake Okeechobee	Large deep reservoir within Lake Okeechobee, dispersed storage west of Lake Okeechobee wide below ground conveyance canals, STAs	0	93%	86

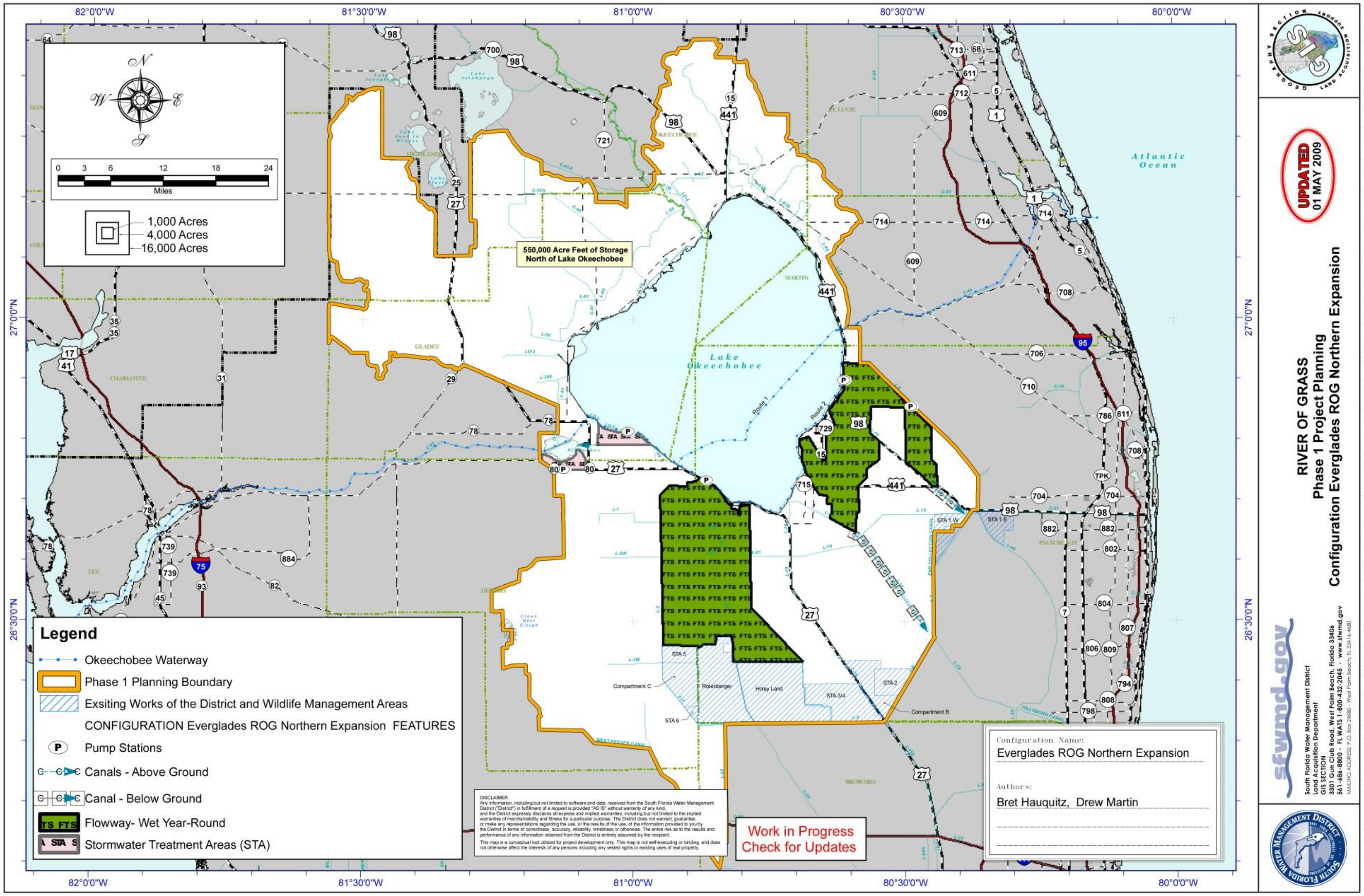


Figure V-5. The 'Everglades River of Grass Northern Expansion' alternative in the River of Grass planning process did not yield favorable outcomes with regard to reducing damaging high regulatory water discharges from Lake Okeechobee to the estuaries, or delivering water south to the Everglades. This alternative included 550,000 acre-ft of north-of-lake storage (from SFWMD ROG planning process).

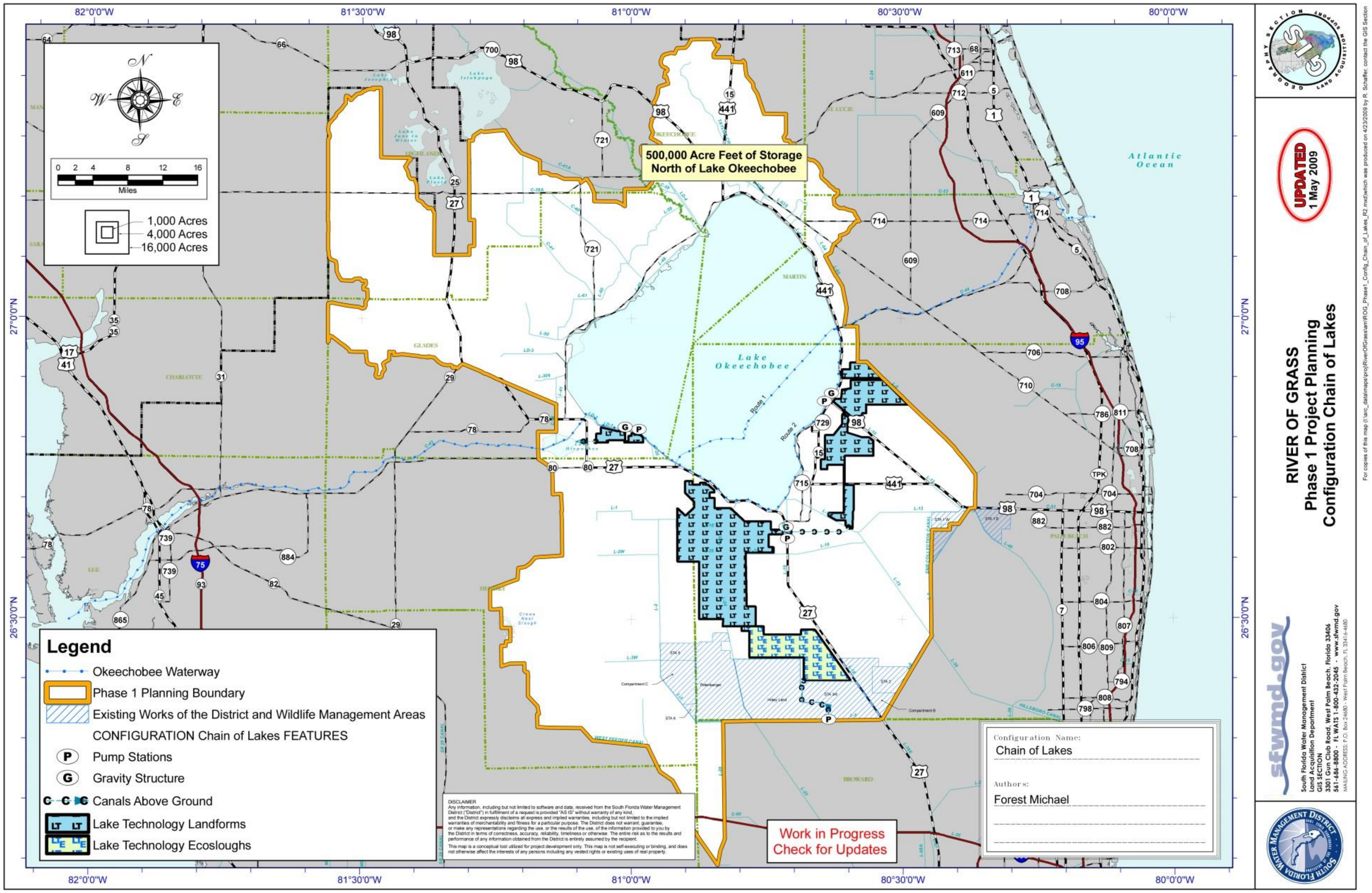


Figure V-6: The Chain of Lakes alternative in the River of Grass planning process that had good performance with regard to reducing damaging high discharges of water from Lake Okeechobee to the estuaries. This alternative included 500,000 acre-ft of north-of-lake storage (from SFWMD ROG planning process).

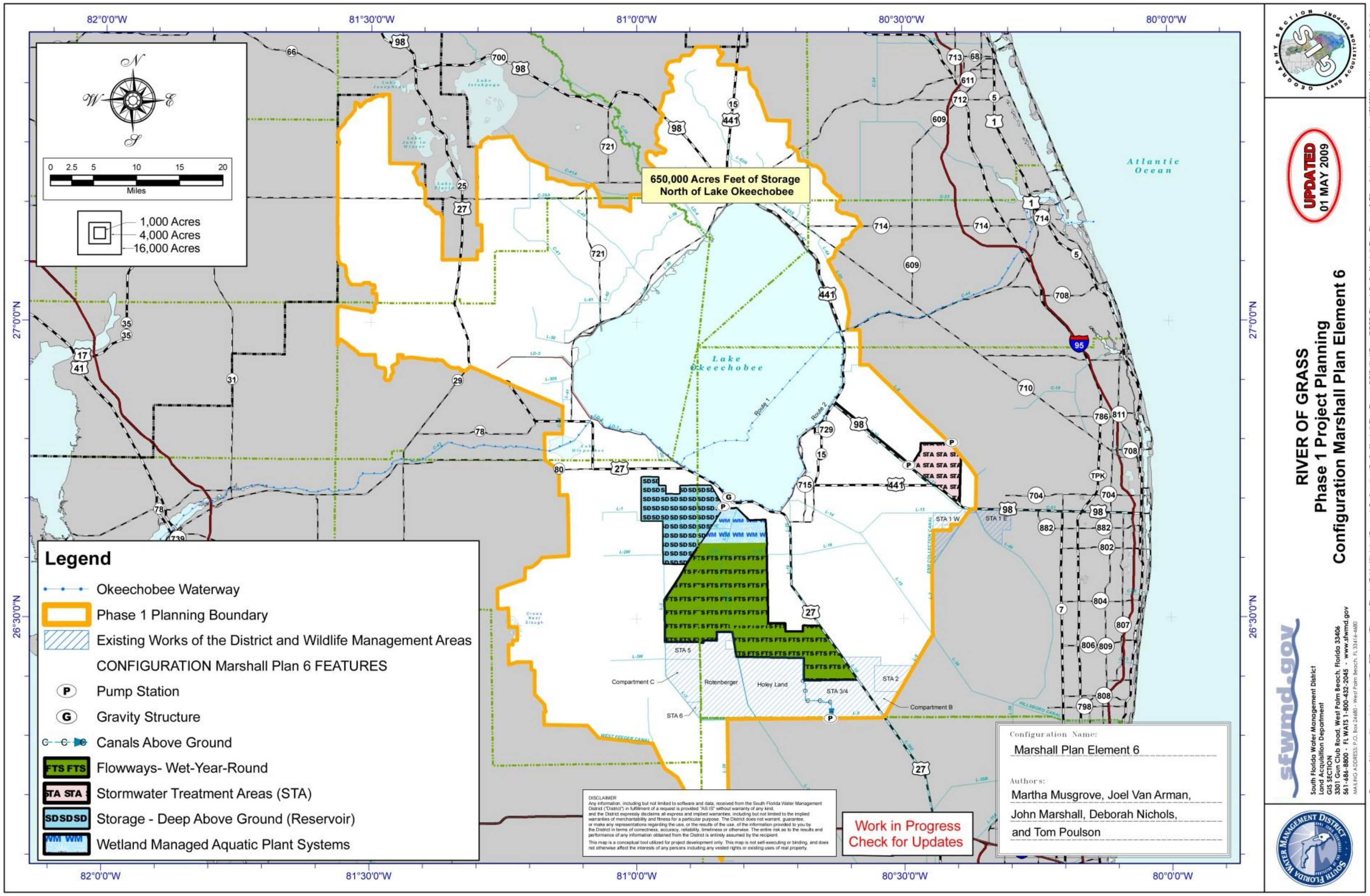


Figure V-7. The Marshall Plan Element 6 alternative in the River of Grass planning process included a large reservoir south of the lake and a large flow-way. This alternative scenario had good outcomes for the estuaries and Everglades, however it included 650,000 acre-ft of storage north of the lake (from SFWMD ROG planning process).

Summary

The concept of creating a flow-way to carry water from Lake Okeechobee through the EAA to the WCAs has existed since 1955. While it may seem intuitive that re-establishing a broad flow-way from near Lake Okeechobee to the northern Everglades is a sound restoration strategy, independent assessments indicate that modifications of the landscape have, to a large degree, compromised options to do so. In both the USACE Reconnaissance Report (1994) and the SFWMD River of Grass planning process (2009), results indicated that a passive EAA flow-way is not the optimal approach for addressing problems of too much water going to the estuaries in the wet season or too little water going to the Everglades in the dry season. Furthermore, creation of a large wet flow-way in the EAA region creates additional wetlands restoration objectives and additional water demands in a system that is already heavily constrained.

b. Other South of the Lake Storage, Treatment and Conveyance Options

Although an expansive passive wet flow-way throughout the EAA may not be the best solution, the River of Grass planning process demonstrated that there are several possible options involving combinations of deep and shallow storage, and wet- and dry- flow-ways, coupled with STAs and enhanced conveyance to provide significant benefit for both the estuaries and the Everglades, beyond CEPP (Figure V-1 and Table V-1). Figure V-1 indicates that if between 300,000 to 750,000 acre-ft of storage can be provided north of the lake, between 132,000 to 507,000 acre-ft of additional storage south of the lake will be sufficient to provide 90% reduction in lake-triggered high flows to the estuaries and achieve 90% of the dry season target. If this required storage were to be provided strictly though deep 12-ft reservoirs, new land area between approximately 11,000 and 43,000 acres would be required south of Lake Okeechobee. If the required storage were provided strictly through shallow 4-ft impoundments, the land area requirement triples to approximately 33,000 to 129,000 acres.

To provide the required land area for additional storage, conveyance and treatment south of the Lake there are a number of options that should be considered: 1) purchase of private land in the EAA (including the current U.S. Sugar land purchase option or land from other willing sellers) to use or trade for deep and/or shallow storage and treatment opportunities, 2) develop a cost-sharing program for on-farm or sub-regional multi-farm shallow storage and treatment opportunities, and 3) use existing state owned wildlife management areas such as Holey Land and Rotenberger for storage and treatment opportunities. There is some evidence to indicate that creating new storage and conveyance along the western boundary of the EAA, where Lake Okeechobee water is cleaner and excess treatment capacity exists in STA 5/6, may be a promising option.

Purchase of Private Lands

Currently, the state of Florida has an option to purchase approximately 46,000 acres in the EAA (Figure V-8). The option is set to expire in October 2015. Thus, the state has a limited window of opportunity to purchase this land at market prices. Given the limited opportunity and the uncertainty of any future similar opportunities to purchase large acreages of lands in the EAA, the state should consider this time-limited option. The particular 46,000 acres at issue may be useful for additional storage and treatment or may serve as lands that the state could trade with other agricultural interests in the area if land in different locations are needed.

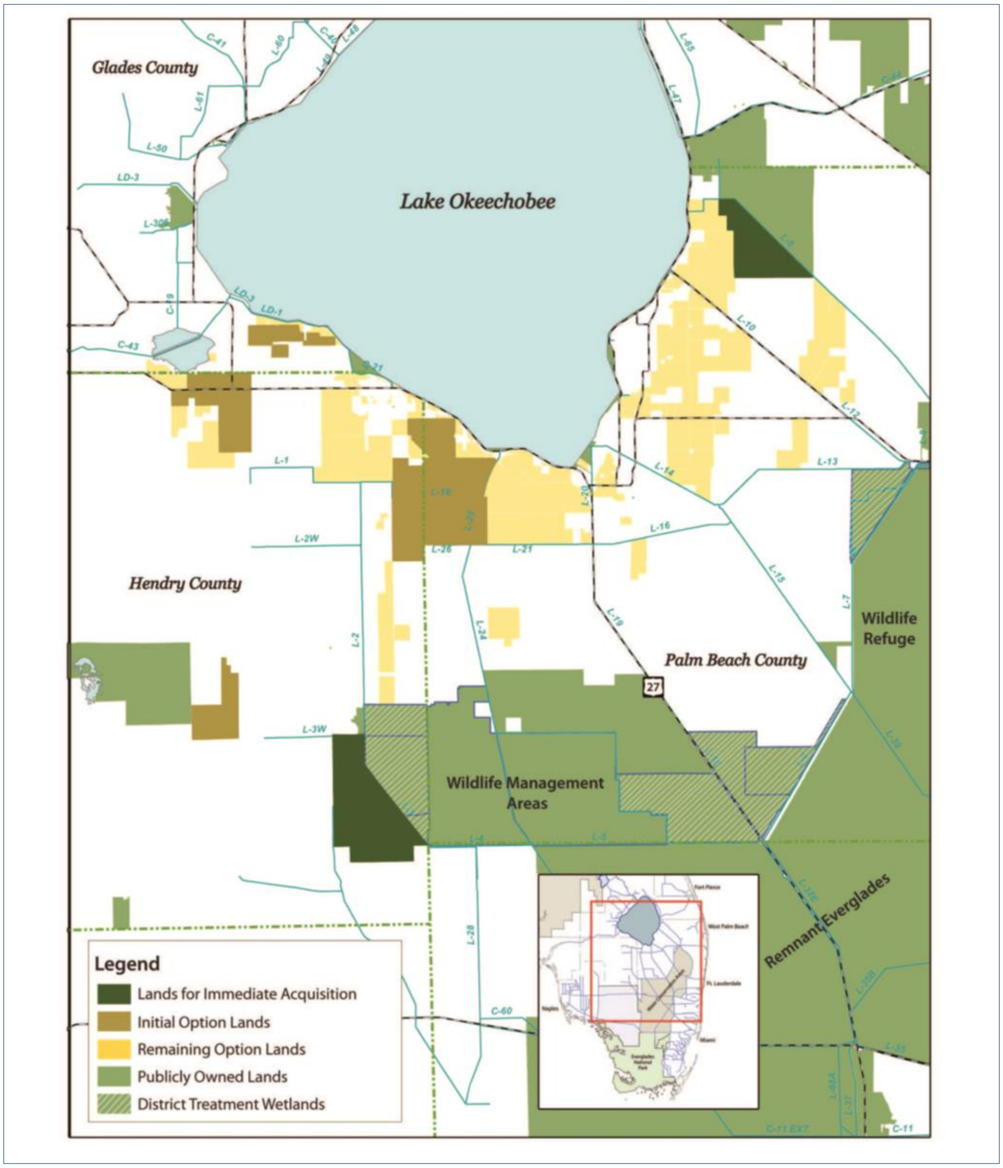


Figure V-8. Map of U.S. Sugar Options Lands. Dark green-shaded lands have already been acquired. The option for the brown-shaded lands expires in October 2015 (from SFWMD http://www.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/rog_map_2010_0804.pdf).

Develop a Cost-Sharing Program for on-farm or multi-farm storage

Another option for additional storage and treatment south of Lake Okeechobee is to increase on-farm or sub-regional multi-farm storage opportunities through cost-sharing or Payment for Environmental Services programs similar to those offered north of the Lake. Utilizing existing farmlands, either individually or in the aggregate, it is possible that wet-season storage could be constructed to provide water supply for agriculture during the dry season and thus reduce competition between agricultural water demands in the EAA and water needs in the Caloosahatchee estuary. The feasibility, costs and benefits of such a program should be examined.

Convert Holey Land and Rotenberger Wildlife Management Areas to Storage and/or STAs

Holey Land and Rotenberger are designated Wildlife Management Areas (hereafter HLWMA and RWMA) and constitute approximately 30,000 and 33,000 acres, respectively. Once part of a vast sawgrass plain, these areas exist presently as impounded marshes situated just south and west of the EAA and immediately adjacent to STAs 3/4 and 5/6 (Figure V-9). Because of their location within a conceptual and historical flow path of water from Lake Okeechobee south, these marsh lands have been suggested as potential water storage areas at various times in the past. They are large, situated close to canals, and, from a geographic perspective, are centrally located in the complex of lands in which water from Lake Okeechobee, and the EAA are cleaned and stored.

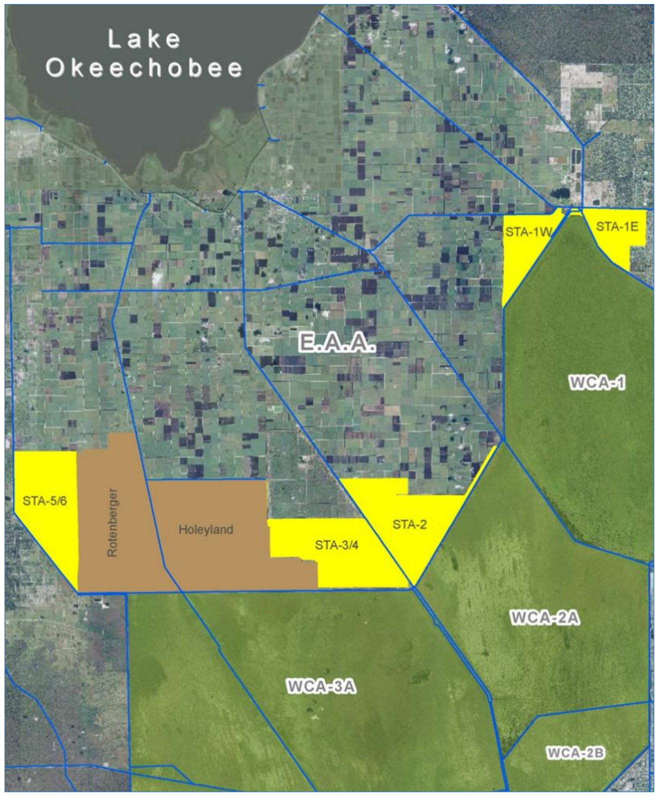


Figure V-9: Map of Holy-Land and Rotenberger Wildlife Management Areas (from SFWMD).

These lands are owned by the State of Florida and have been under the management authority of the Florida Fish and Wildlife Conservation Commission (FWC) (and its predecessor the Florida Game and Freshwater Fish Commission) since they were established in 1968 (HLWMA) and 1975 (RWMA). Both HLWMA and RWMA have been historically over-drained, and have undergone considerable changes with regard to soil elevation and vegetation type, with a clear movement toward more woody and shrubby vegetation. This is generally believed to be a consequence of a reduced hydroperiod. Although degraded compared to pristine marsh, these areas still maintain many characteristics of the sawgrass plain, and are probably restorable to that condition with proper water management.

Both HLWMA and RWMA are currently managed by the FWC for recreation, hunting and wildlife viewing. They are designated as Outstanding Florida Waters, and each is designated for restoration as part of the Everglades Forever Act of 1994. Both HLWMA and RWMA are identified as targets for ecological restoration in the CERP, however, they are not included in the Everglades Protection Area.

These lands have previously been considered for use as water supply impoundments as part of an effort to reduce agricultural back-pumping to Lake Okeechobee (see Barnett, 1986). A feasibility report prepared by the SFWMD (Barnett, 1986) concluded that while impounded water storage in HLWMA and RWMA could provide considerable dry season water supply to the

EAA, there was little effect of wet season storage, largely because both areas were already flooded to capacity during the summer. As a consequence of opposition by environmental groups and state agencies, the proposal to use HLWMA and RWMA for water storage was voted down by the SFWMD in March 1983 and has not been formally revived since. Several formal and informal plans that incorporate flow-way features south of Lake Okeechobee have either included HLWMA and/or RWMA as part of the flow-way, for FEBs and/or for STAs, however, none of these options have been included in any currently approved restoration plan.

As mentioned above, together the HLWMA and RWMA comprise approximately 63,000 acres, and if flooded to a depth of 4 feet, could accommodate a maximum of approximately 250,000 acre-ft of storage. If flooded to a maximum depth of 12 feet, they could accommodate a maximum of approximately 750,000 acre-ft While these storage figures are rough and there are important engineering constraints that may push these numbers downward, this illustrates that these lands have the potential to store a substantial amount of water.

However, there are a significant number of infrastructural and political obstacles that would have to be overcome to use these lands. For example, neither HLWMA nor RWMA currently has the infrastructure necessary to handle large volumes of inflows or outflows, and the dikes are currently not designed to hold large volumes. Furthermore, the RWMA is situated on the western edge of the former sawgrass plain, and water would need to be pumped to and away from it to make that storage useful. Use of these WMAs for storage would destroy the current vegetative structure. This was a clearly defined outcome identified in the Barnett (1986) feasibility report, and all deeply impounded areas of former Everglades have shown similar responses – loss of tree islands and plant diversity, lack of regeneration of sawgrass and trends toward an open water system.

The use of HLWMA and RWMA as storage and treatment areas would be a reversal of the restoration processes envisioned for these areas in CERP, and a conversion would result in a net reduction of restorable Everglades habitat. If the entire area were used as deep storage, these lands would become almost completely incompatible with their current designation and usage. However, the areas outside HLWMA and RWMA currently being managed as STAs have proven to be highly productive in terms of bird abundance and biodiversity. These biological functions are compatible with certain kinds of hunting, birding and recreation, and it is possible that these human activities could be accommodated in STAs within the HLMA and RWMA. However, it should be clear that conversion to STA or storage would be incompatible with restoration of these areas to anything like their original sawgrass plain habitat, and given the investment in infrastructure, that recreation and hunting would probably become secondary rather than primary objectives for STAs within HLWMA and RWMA.

As a result, the conversion of these WMAs to STAs or FEBs would need to clear significant political and cultural hurdles, and require significant investment for infrastructure. The designation of both areas as Outstanding Florida Waters (OFWs) may need to change if they were being used explicitly to improve water quality. While this designation can be removed, it would be a clear signal of change in goals and philosophy regarding the use of these state lands.

All of the current STAs and FEBs have been placed on previously impacted (farmed) lands purchased by the state for the purpose of cleaning water from the EAA. Using public recreation lands, and lands that remain restorable to Everglades habitat for cleaning runoff from private agricultural lands has in the past been forcefully opposed. One possible way to address this complaint and potential legal hurdle would be to provide an unambiguous means of using HLWMA and RWMA to only store and treat water from Lake Okeechobee, without any input from the EAA. This would present a substantial infrastructure investment, since the existing canals connecting the two WMAs to Lake Okeechobee can handle only small volumes at present and pass through agricultural lands However, the capacity of STA 5/6 is thought to be under-utilized with current water sources for the same reason, and creation of infrastructure to bring Lake water to 5/6 could probably also be sized to serve HLWMA and RWMA.

In summary, the HLWMA and RWMA have the capacity to provide between 250,000 – 750,000 acre-ft of storage with associated STAs for water treatment. However, significant infrastructural investment would have to be made to use either of these areas for storage or treatment purposes and this usage would require re-designation of use, which has historically run into strong public and agency opposition. Nevertheless, given the scarcity of available land from willing sellers in the EAA, and the strategic location of HLWMA and RWMA on the boundary of the EPA, it is an option that should be considered.

c. Summary

Based on results of the River of Grass Phase 1 screening analyses, and the finding that CEPP provides only modest relief to the problems of high regulatory discharges to the estuaries, a strategic plan should be developed for the next increment of south-of-the-lake storage, treatment and conveyance to pursue beyond CEPP, to more closely meet the performance targets of <u>both</u> the estuaries and Everglades ecosystems. Depending on the type of storage provided, and how much storage can be constructed north of the lake, more closely achieving the performance targets will require between 11,000 to 129,000 acres of additional land between the lake and the EPA, e.g. the US Sugar option lands, lands from other willing sellers, and/or use of existing state owned land (e.g. Holey Land and Rotenberger WMAs). There is some evidence to indicate that creating new storage and conveyance along the western boundary of the EAA, where Lake Okeechobee water is cleaner and excess treatment capacity exists in STA 5/6, may be a promising option.

4. Deep Well Disposal of Excess Flows

If sufficient inter-annual storage and treatment north of the lake is found to be economically or politically infeasible, or the analysis indicates that the captured water cannot be efficiently treated and conveyed south of the lake for use in subsequent dry seasons, the option of constructing a system of large deep disposal wells to permanently dispose of excess flows from Lake Okeechobee could be explored. While deep injection wells alone could not entirely prevent damaging discharges to the St. Lucie and Caloosahatchee estuaries in an extreme wet season, they could operate in conjunction with other storage elements to help reduce estuarine discharges.

Deep injection wells involve disposing of fluids via injection wells deep below the earth's surface and have been used extensively in the State of Florida for more than 20 years (USEPA, 2005). Deep injection wells are classified by the USEPA as belonging to one of five classes, depending upon the nature of the fluid to be discharged and the depth of the well. The requirements for siting, permitting, and monitoring, and the costs for construction and operation vary significantly by well class.

Class I deep injection Wells are used to inject nonhazardous waste such municipal wastewater effluent or stormwater runoff below the lowermost underground source of drinking water (USDW). A USDW is defined as an aquifer that contains a total dissolved solids concentration of less than 10,000 milligrams per liter. Class I injection wells must be constructed, maintained, and operated so that the injected fluid remains in the injection zone, and interchange of water between aquifers is prevented. According to the FDEP Underground Injection Control website there are more than 180 active Class I wells in Florida (FDEP 2014d, http://www.dep.state.fl.us/water/uic/).

Permitting requirements for Class I deep injection wells are generally easier to meet than those for ASR wells, because ASR wells typically inject into drinking-water aquifers, whereas deep injection wells typically inject into aquifers containing salty water. Deep injection wells also have the added advantage of permanent disposal of stormwater that contains excess nutrients. Additionally, injection wells can typically be operated at higher pumping rates than ASR wells because water is injected into an aquifer of higher transmissivity (i.e. the cavernous Boulder Zone in South Florida which has extremely high transmissivities on the order of 3,000,000 ft^2/day, Johnson and Bush (1988)). The primary disadvantage of using deep injection wells is that once the water is injected it cannot be typically be recovered. Figure V-10 shows a deep injection well system compared with a typical ASR well and water well.

A typical deep injection well is 24-30 inches in diameter and can dispose of 10-30 MGD of excess water per well (SFWMD, 2009a; Maliva and Missimer, 2006). Maliva and Meissimer

(2006) proposed consideration of fifty 30 MGD Class I deep injection wells for South Florida that would provide 1.5 bgd of disposal capacity. Similarly, the ASR regional modeling study (USACE, 2014) recommended one hundred and one 10 MGD injection wells into the Boulder Zone, for a total disposal capacity of 1 bgd. If a network of deep injection wells with a combined disposal capacity of 1 bgd were operated continuously for a period of 100 days it could dispose of approximately 307,000 acre-ft of excess water which could reduce the depth of water in Lake Okeechobee by almost a foot. However, disposing of excess water with this network would have to take place proactively -- managed in concert with other storage elements, lake levels, and in anticipation of extreme events -- since it would not provide sufficient pumping capacity to quickly dispose of extremely large wet season flows (such as occurred in WY 2014).

Summary

If sufficient inter-annual storage and treatment north of the lake is found to be economically or politically infeasible, or the analysis indicates that the captured water cannot be efficiently treated and conveyed south of the lake for use in subsequent dry seasons, the option of constructing a system of large deep disposal wells to permanently dispose of excess flows from Lake Okeechobee should be explored. Deep injection wells could be part of a long-term solution to reduce damaging discharges to the St. Lucie and Caloosahatchee estuaries, or they could provide an interim solution until additional storage, treatment and conveyance capacity can be constructed south of Lake Okeechobee.

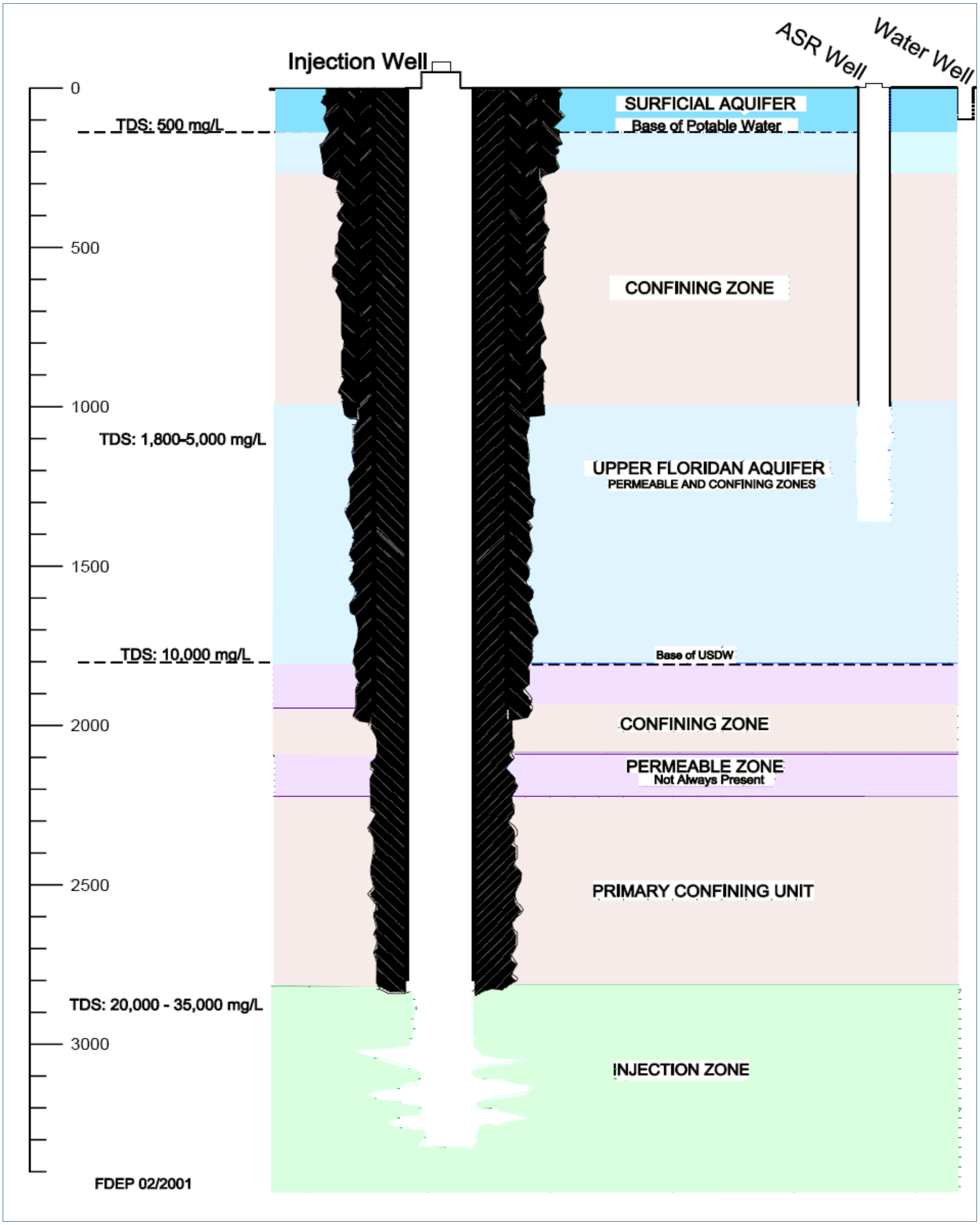


Figure V-10. Typical Municipal Class I Injection Well, Aquifer Storage and Recovery Well, and Water Well in Southeast Florida (from FDEP http://www.dep.state.fl.us/water/uic/docs/ASR_mun.pdf, accessed Feb 12, 2014).

5. Operational Changes

a. Modification of Lake Okeechobee Regulation Schedule

Introduction

Lake Okeechobee was designed to be the central water storage feature of the Central and South Florida (C&SF) Flood Control Project when the latter was constructed in the 1950s and 60s. However, the lake has an unusual configuration for a flood control reservoir: (a) it has no spillway to allow water to exit when water levels reach a level that is unsafe for the perimeter levee; and (b) the inflow capacity of water exceeds the outflow capacity by as much as 4 to 6-fold (depending on hydrologic conditions, rainfall and antecedent water levels in the lake). When water levels in the lake are high and a large amount of rainfall occurs in the basin north of the lake, large inflows can occur and the lake can rise several feet in just a short period of time, presenting a potentially dangerous scenario in which the structural integrity and function of the levee are compromised.

The large canals to the St. Lucie and Caloosahatchee estuaries are the main ‘relief valves’ for removing water from the lake when water levels are high, because canals leading south have a much smaller conveyance capacity, are limited in their ability to take water by regulation schedules of the WCAs, and are limited by additional factors including threatened and endangered species and by rules regarding maximal amounts of phosphorus that can be discharged into the Everglades (see Section II.5).

Dike Rehabilitation

In 2007, the US Army Corps of Engineers (USACE) initiated a greater than $300 million effort to reinforce the Herbert Hoover Dike that surrounds Lake Okeechobee. Components of this project include installation of a cutoff wall inside the levee (dike) and replacing water control structures around the lake. A phased work plan was proposed where areas of the dike that were determined from geotechnical studies to be at greatest risk of breach under condition of high water and/or tropical storms would be retrofitted first. However, in 2011 the USACE changed its approach. After completing the construction of a cut-off wall between Belle Glade and Port Mayaca in 2013, the USACE opted next to replace 32 water control structures around the lake, which were considered the next greatest risk of levee failure (SFWMD 2013). Concurrently, the USACE is conducting a comprehensive Dam Safety Modification Study on the Herbert Hoover Dike to determine what additional structural and non-structural alternatives are required to reduce risk to an acceptable level, and to develop a roadmap for their implementation.

Regulation Schedule

Because the underlying reason for levee rehabilitation was concern regarding risk of structural failure, as evidenced by extensive piping and sinkhole formation after high water years, the USACE formally adopted a new regulation schedule for the lake in April 2007 and implemented it in 2008. The Lake Okeechobee Regulation Schedule of 2008 (LORS 2008) was designed to hold the lake at what the USACE considered to be safer levels (from a flood control perspective) until the Dam Safety Modification Study is completed, the risk of failure more rigorously evaluated, and modifications required to reduce the risk to an acceptable level are completed.

The LORS 2008 has many features that are similar to the earlier Water Supply/Environmental (WSE) regulation schedule: (a) it has seasonally varying 'bands' that identify different zones related to the amount of water to be released from the lake to protect the levee; (b) there is a water shortage zone below the bottom band of LORS 2008 where the South Florida Water Management District has the authority to implement water use restrictions; and (c) releases of water from the lake for flood control purposes are determined, in part by rainfall outlook, tributary hydrologic conditions and multi-season climate outlooks (USACE 2008).

One major difference between LORS 2008 and the earlier schedule is the aim of LORS 2008 to hold Lake Okeechobee at a lower level, by allowing for regulatory discharges to the St. Lucie and Caloosahatchee Estuaries and to the Everglades Water Conservation Areas. According to the USACE *'one of the primary goals of LORS is to maintain a lake level between 12.5 and 15.5 feet.'* This is done by managing water within bands shown in Figure V-11, as follows:

High lake management band - includes lake levels above 16 feet in advance of the wet season, or levels above 17.25 feet during the dry season. Within this band, operations are focused on reducing the lake level, freeing up additional capacity for runoff from future heavy rain events. Maximum water releases typically occur when the lake is in this band.

Operational bands – these are five sub-bands that guide decisions to balance the needs of all users, while maintaining a lake level in a 12.5 to 15.5 ft range prescribed in the USACE Water Control Manual. Toward the lower end of the range, the USACE relies heavily on input from the SFWMD to assist with water allocations. In the upper bands regulatory releases are made by the USACE for the purpose of flood protection.

Water shortage management band - this band includes lake levels below 10.5 feet in advance of the wet season, or levels below 13 feet at the start of the dry season. In this band, the USACE typically defers decisions on water releases to the SFWMD.

When water levels are in the lower operational bands and in the water shortage zone, the SFWMD balances human and environmental needs and makes recommendations to the USACE about water releases (e.g., environmental water deliveries to the Caloosahatchee Estuary) based on Adaptive Protocols, which are procedures adopted by the SFWMD Governing Board in September 2010 (SFWMD 2010).

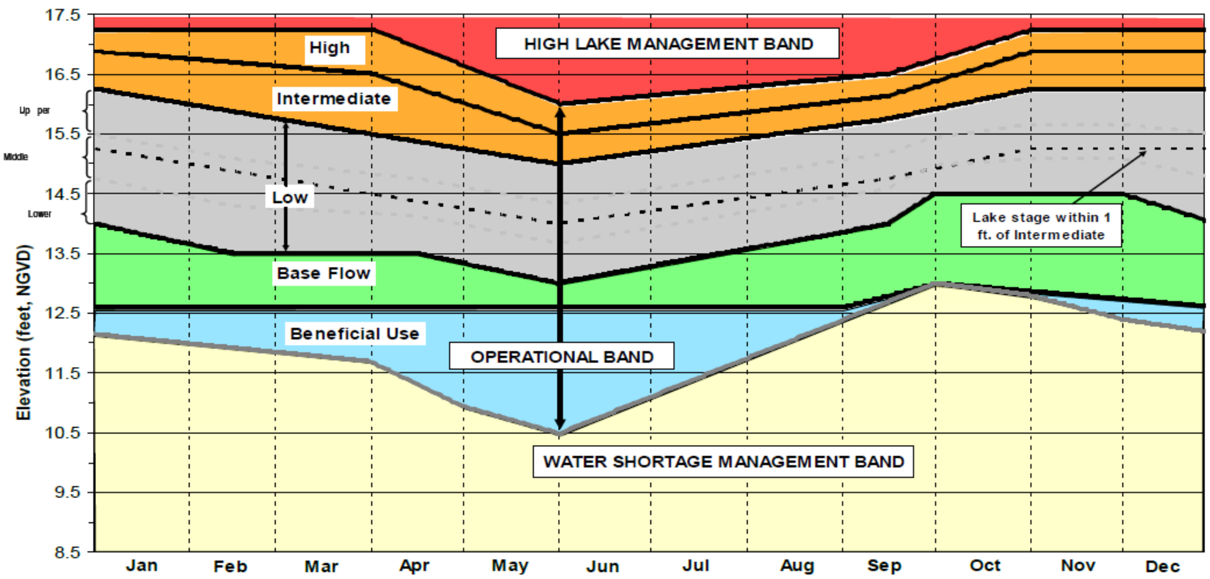


Figure V-11. The 2008 Lake Okeechobee Regulation Schedule (LORS 2008), showing operational bands referenced in the text as well as the zones where the SFWMD may implement water use restrictions because the lake is very low. Source: USACE Water Control Manual for Lake Okeechobee, March 2008.

Effects of the Lower Schedule

Because LORS 2008 aims to hold water levels lower in Lake Okeechobee relative to the WSE schedule, the storage capacity of the lake has been functionally reduced. Thus, both regulatory discharges to the estuaries and water shortage restrictions are expected to occur more frequently, and be of greater magnitude and duration, for like climatic and hydrologic conditions (EIS, USACE 2007).

Modeling studies conducted for the Environmental Impact Statement (EIS) produced pursuant to the requirements of the National Environmental Policy Act (NEPA) using the same 41 year climatic record for LORS 2008 and WSE showed that for the St. Lucie Estuary, *"All alternatives (of LORS) had high flows (>3,000 cfs) of longer duration than the No Action Alternative (WSE). The 14-day moving average total inflow exceeded 3,000 cfs for more than ten weeks (five two-week periods) in Alternatives A through E while the No Action Alternative (WSE) had no such occurrences. When the high flow events increase substantially in duration impacts to the* *estuary can be more adverse. Oysters and sea grasses (sic) may be negatively affected. These sessile species cannot move to areas of preferred salinity ranges although they can tolerate low salinity levels for short durations. These species become more susceptible to disease and predation as the duration of extreme high flow events increase."*

The same negative impacts to the Caloosahatchee Estuary were projected by modeling in the EIS: *"All alternatives (of LORS) had high flows (>4,500 cfs) of longer duration than the No Action Alternative (WSE). This was reflected in the total number of weeks of high flows greater than five weeks and at times, Alternatives Band C, had very long duration flows in the 13 to 16 week range. The No Action Alternative had the fewest number of weeks of high flow greater than five weeks."*

According to the EIS, holding the lake lower also has potential adverse consequences for consumptive use of lake water, which is used to irrigate agricultural crops to the southeast, south and southwest of the lake, and to maintain a freshwater head that helps prevent saltwater intrusion to urban well fields along the lower east coast metropolitan area of Florida. Modeling results identified that the average water cutback volume to permitted users in 8 drought years was, cumulatively, 124,000 acre-ft with WSE and 223,000 acre-ft with LORS 2008 for the same 41-year period of record. Likewise, the number of months with adequate water to maintain a desired minimal flow to protect submerged vegetation in the upper Caloosahatchee Estuary (450 cfs) was reduced from 216 under WSE to 143 with the LORS 2008 (USACE 2007).

EIS modeling scenarios project what the effects of a change in regulation schedule would be if all conditions were held constant except for regulatory release decisions. However, attributing observed estuarine effects across different time periods to differences in the regulation schedules is difficult because differences in regulatory releases are, in fact, governed by a large number of factors aside from the release schedule. These factors include the amount and timing of lake inflows, antecedent lake levels, contemporaneous conditions downstream of the lake that constrain the ability to move water south, and local basin runoff.

This point is illustrated in Figures III-3 and III-4 (Section III) which show the Lake Okeechobee inflows and the estuary outflows spanning both the period that the WSE schedule was in place (July 2000 to March 2008) and the period that LORS 2008 has been in place (April 2008 to present). During the WSE time period freshwater inflows to the St. Lucie estuary exceeded its very high target (>3,000 cfs) 12% of the time versus 5% of the time for the LOR2008 time period. Similarly, freshwater inflow to the Caloosahatchee estuary exceeded its very high target (>4,500 cfs) 17% of the time during the WSE time period versus 10% of the time for the LORS 2008 period. Thus, even though WSE performs better than LORS 2008 in simulations using identical conditions, high discharges to the estuaries actually occurred more frequently under WSE than under LORS 2008 due to the differences in weather patterns and hydrologic conditions. Given the extreme rainfall conditions that occurred in the summer of 2013 it is unlikely that any reasonable regulation schedule could have avoided damaging estuarine discharges given the current C&SF design.

Opportunities for Holding More Water in the Lake

In general, it is the timing and duration of extreme rainfall events that determines whether a regulatory release must take place under the current C&SF system design. Therefore, small adjustments within the discretionary bands of LORS 2008 may be able to shave the peaks off damaging high flows to the estuary or perhaps reduce their duration, but they are unlikely to change their frequency of occurrence. However, the completion of the Dam Safety Modification Study, and the execution of its recommendations for reducing the risk of failure, could provide an opportunity for substantive changes to the Lake Regulation Schedule that could produce significant benefits for the estuaries and move more water south of Lake Okeechobee.

Clearly, a decision to change the regulation schedule to hold more water in the lake needs to evaluate tradeoffs between benefits to the estuaries and water supply and adverse impacts to the lake's littoral zone, which has been shown to have optimal ecological structure and function in a water level range of 12 to 15 ft (Havens, 2002). Furthermore, it may be prudent to simultaneously re-evaluate the lake's minimum water level (ML) of 11 ft, to determine if it is scientifically sound. This ML was set largely to protect food resources of the federally-endangered Everglades Snail Kite, to prevent loss of peat from exposed lake sediments and to prevent woody upland plants from becoming established in the littoral zone (SFWMD 2000). However, in 2000-01 the lake experienced an extreme drought, with water levels falling as low as 9.1 ft and remaining near or below 10 ft for over 7 months (Havens et al., 2007). The system was highly resilient and did not suffer long term adverse effects from the low water levels during that event. Thus, today lake ecologists consider periodic low lake level conditions to be highly beneficial for native biota including commercially important sport fish (SFWMD 2014). However, recurrent extremely low lake levels may impact the littoral zone, submerged vegetation and fisheries (Havens and Steinman, 2013).

Based on the stage-storage curve for Lake Okeechobee (SFWMD, 1986), raising the allowable maximum lake stage (trigger points in every operational band and upper band) by just 0.5 ft could add approximately 225,000 acre-ft of static storage, and potentially a greater amount of dynamic storage over the course of a year if that water was released from the lake in a beneficial manner. Furthermore, lowering the minimum level of the lake from 11 to 10 ft would free up an additional approximately 330,000 acre-ft of water for use by agriculture, urban areas and for downstream ecological benefits (e.g., for support of aquatic plants, reducing salinity and flushing of algal blooms in the upper Caloosahatchee Estuary).

Based on research conducted in the late 1990s and early 2000s, and summarized in Havens and Gawlik (2005) and Havens (2002), there are some attributes of Lake Okeechobee hydrology that have a high degree of certainty in regard to their ecosystem impacts. For example:

- Lake stages in the range of 15.5 ft or higher result in mixing of phosphorus and sediment-rich water from the center of the lake with waters in the nearshore region, which cause adverse impacts to submerged plants and increases in algal blooms.
- Lake stages in the range of 17 ft or higher result in a high level of erosion of the littoral shoreline during times of high wind/wave energy, and also to large incursions of phosphorus into the littoral zone, which in the past has contributed to an expansion of cattail.
- A spring recession of lake water levels to near 12 ft lake stage is beneficial for wading birds, snail kites, submerged plants and the lake's fishery, as long as it is not quickly followed by a rise in water level.

Based on that same research, an optimal 'lake stage envelope' of 12 to 15 ft was established, and it is here where more uncertainty occurs. There are not sufficient data to discern whether similar ecological benefits would occur from a yearly range of 11.5 to 15.5 ft or 12.5 to 15.5 ft (or some other combination of low and high stages). As noted above, there also is uncertainty, now that the recovery from a severe drought has been observed, about whether a minimum water level of 11 ft is overly protective of the lake ecosystem.

Summary

Given the possibility of reducing estuary discharges by storing more water in the lake, either incrementally by modifying operations with the discretional bands of LORS 2008, or substantially by establishing a new lake regulation schedule, a rigorous analysis should be conducted that weighs the benefits (reduced damaging high and low estuary discharges, reduced water shortage emergencies) vs. costs (lake impacts) of adjustments to the lake's minimal level, and associated changes in water allocation rules, as well as the location of bands in the USACE regulation schedule.

Based on the available information, it does not appear that adjustments within the current LORS 2008 schedule will have a substantive effect on the occurrence of high damaging discharges to the estuaries. However, a substantially revised regulation schedule that provided considerably more dynamic storage in the lake could provide those benefits and should be considered, along with trade-offs including potential adverse impacts to the lake's littoral zone, submerged vegetation and fisheries. Developing a new regulation schedule first requires completion of the USACE Dam Safety Modification Study and guidance about the safety of the Herbert Hoover levee and operational structures. The USACE should be urged to accelerate completion of the Dam Safety Modification Study so that the modification of the Lake Okeechobee regulation schedule can occur as soon as possible. In the interim, to provide incremental estuarine relief, Lake Okeechobee operations could be modified within the discretionary bands of LORS 2008 to allow some additional water to be moved south to the EPA, and also provide increased dry season flows to the Caloosahatchee estuary and EAA.

b. Modification of Holey Land and Rotenberger Regulation Schedules

Section V.3.b above considered the possibility of converting both the HLWMA and the RWMA for use as shallow storage and STAs to increase the storage, treatment and conveyance capacity south of Lake Okeechobee. This section considers the less radical option of modifying their regulation schedules under their current management regime, to contribute to reductions in harmful discharge to the St. Lucie and Caloosahatchee estuaries.

Under this option HLWMA and RWMA would be used in their current form and designation to receive clean water, and to increase transient storage within those areas during times of high discharge. Under some high discharge conditions, the WCAs become too full to receive more water from the STAs, creating a bottleneck. Additional post-treatment storage could help to alleviate this problem. Both WMAs are in close proximity to one or more STAs, and are therefore in a reasonable geographic position for this purpose. The current hydrologic management plans for both areas call for water depths that mimic historical flooding regimes, with an explicit goal of moving vegetative communities from the over-dried, shrubby and woody condition, towards a more historically typical sawgrass marsh with occasional embedded sloughs and tree islands (FWC, 2007). In both areas, this means a move toward longer hydroperiods than have been typical of the past 35 years.

While RWMA may be at or close to the desired longer hydroperiod, longer hydroperiods in HLWMA have not been achieved because of structure-limited ability to move water in and out of the impounded marsh. Inflows occur at a single point (G200A see Figure V-12), which has been out of operation because of hurricane damage in 2006, and as a result HLWMA has been rainfall-driven, or close to it, for nearly a decade. During 2014, temporary pumps were installed that allow for the inflows at that location. However, this is a temporary fix and more permanent infrastructure would be needed in the long term. The second and perhaps more important long term problem in HLWMA is outflows, which currently occur at several points along the L5 borrow canal. These outflows are poorly placed for efficient movement of water since they are nearly two feet higher than the lowest edge (northeast corner, see Fig V-13). In other words, much of HLWMA must remain flooded after the water level has dropped below the level of the current outflow structures. New outflow structures have been proposed for the much lower northeast corner, but construction is currently constrained by lack of funding.

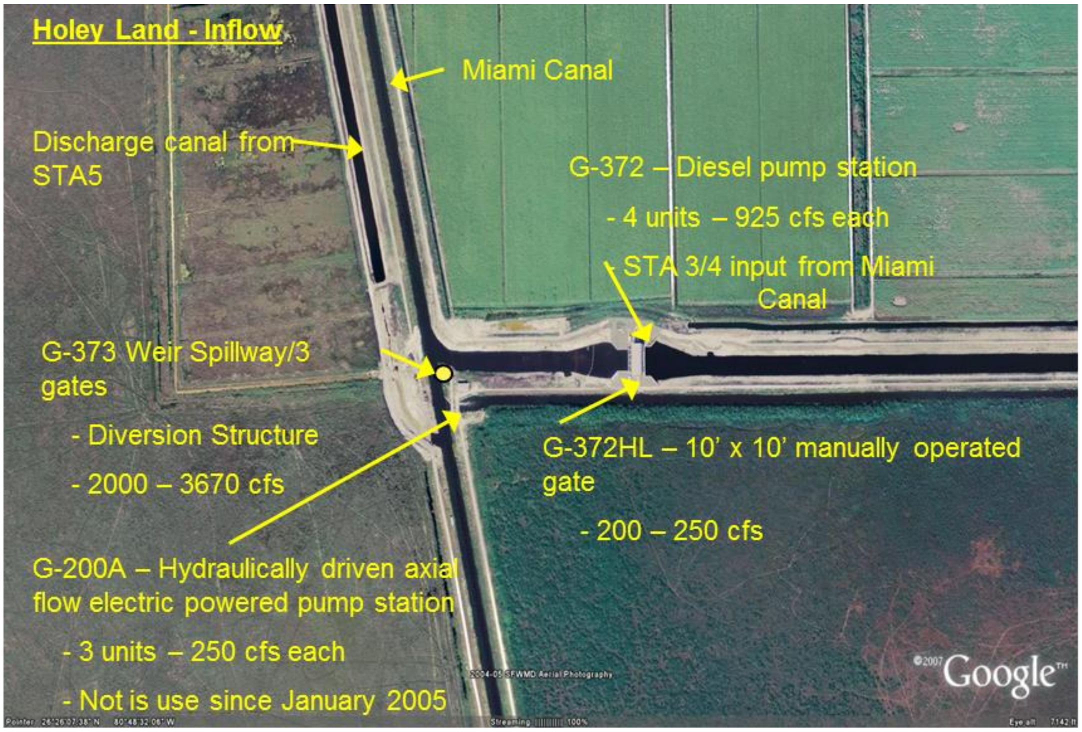


Figure V-12. Northwest corner of Holey Land Wildlife Management Area, showing inflow structures. Figure courtesy of the Florida Fish and Wildlife Conservation Commission.

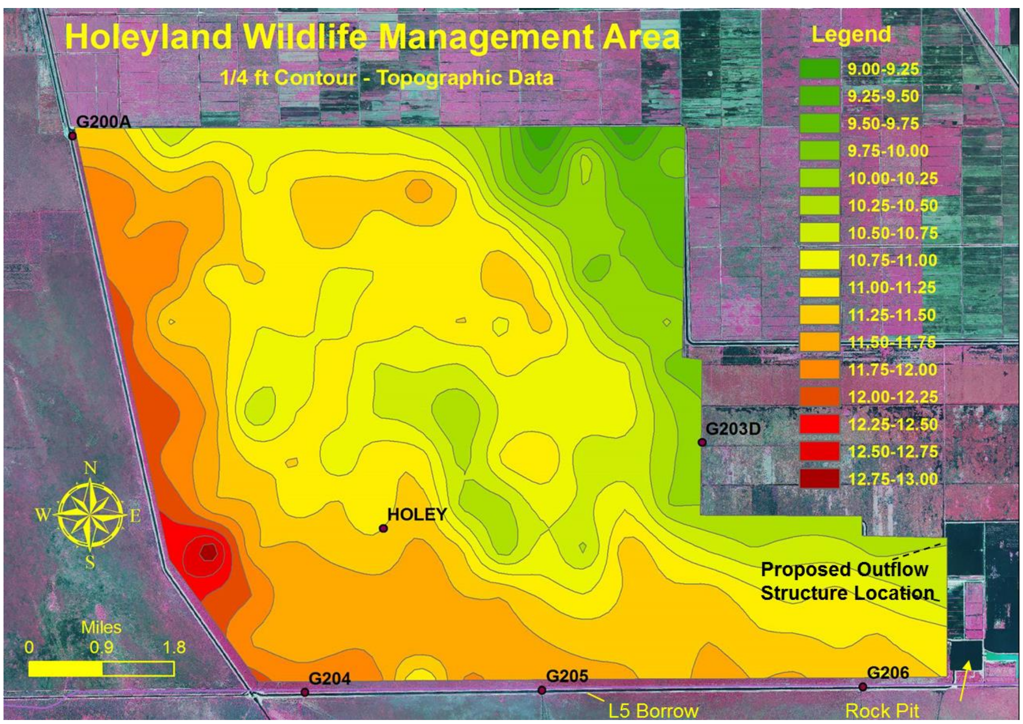


Figure V-13. Contour map of Holey Land Wildlife Management Area. Figure courtesy of the Florida Fish and Wildlife Conservation Commission.

At present, water levels in HLWMA are generally above its regulation schedule in the wet season, and therefore it is not able to receive wet season flow (Fig V-13). However, the lack of effective outflow structures from HLWMA means that especially during the wet season, much of the water can only leave by evapotranspiration. Thus, any water added to the system during the wet season must stay for long periods, resulting in high probability of damaging the vegetative communities through long lasting flooding. The current water management schedule is clearly designed to avoid this condition. With infrastructure that allows for more active manipulation of inflows and outflows, water storage could be much more dynamic, allowing the ability to remove water relatively quickly after short term storage. Storing an additional 1 – 2 feet of water for a period of 2 – 3 weeks, for example, may not be permanently damaging to vegetation. What is important is that there is a means to quickly remove the water after that time – which can only be achieved through more efficient inflow and outflow structures.

There also appears to be some potential for increased dry season storage in HLWMA based on the optimum hydrograph under the current management plan (Figure V-14). Historical average stages during the dry season from 1990 to 2010 were between 0.5 and 1.0 feet lower than the preferred stage, indicating that during the dry season this WMA could store a minimum of 31,000 acre-ft of water more than it currently does. This offers a modest increase in dry season storage, and in some years it is possible that this storage could reduce some releases to the estuaries and allow FEBs, STAs, and Lake Okeechobee to be maintained at lower dry season levels. It is unclear how often such dry season storage would be useful, and, in the general context of the requirement for long-term regional storage, it is not interannual, nor is it very large.

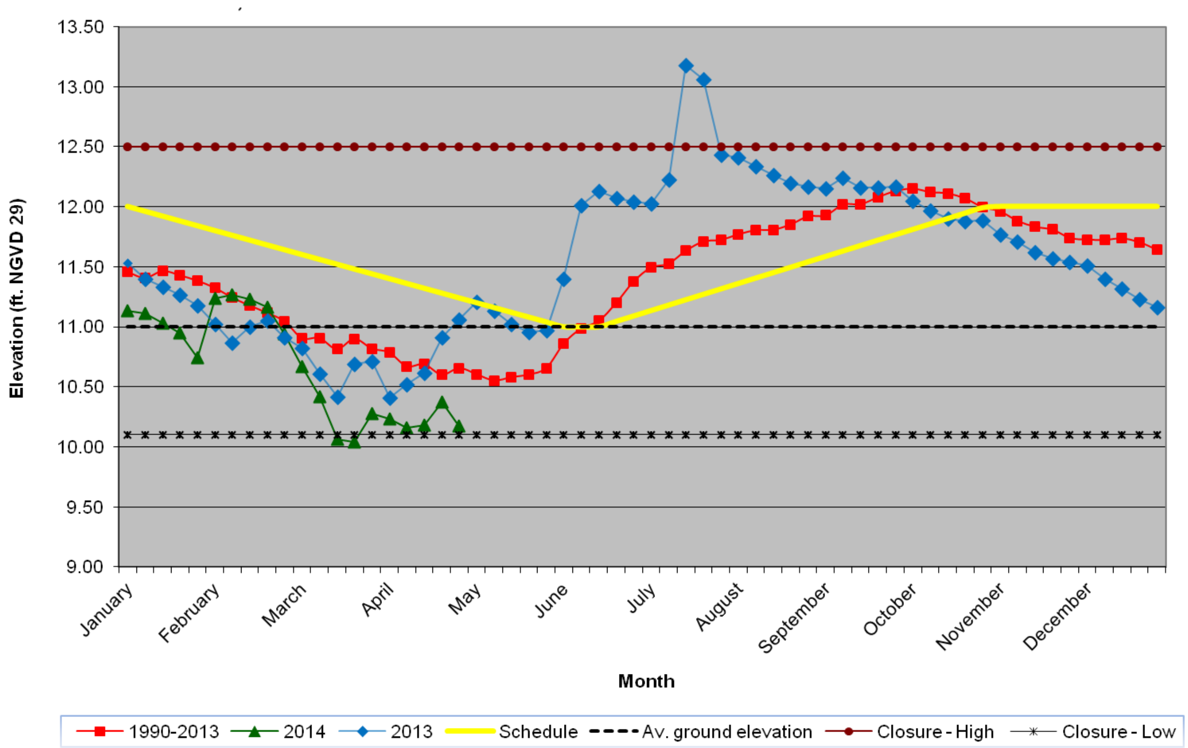


Figure V-14: Holey Land WMA monthly stage levels for 2013, 2044, and 1990-2013 average. Also shown are ground elevation and high and low closure criteria. Figure courtesy of the Florida Fish and Wildlife Conservation Commission.

Summary

In summary, modest increases in dry season storage (approximately 31,000 acre-ft) appear to be achievable and desirable in HLWMA, which under some conditions could provide buffer for ensuing wet season capacity upstream. There is also the potential for increased dynamic storage (approximately 66,000 – 130,000 acre-ft) during the wet season in HLWMA, but only over short periods of several weeks at a time. Both dry and wet season storage would require funding and construction of new water control structures at inflow and outflows of HLWMA.

VI. Future Uncertainties

Success in restoring a more natural timing, distribution and volume of clean water to the Everglades, while reducing harmful discharges to the St. Lucie and Caloosahatchee estuaries, depends on the short and long-term outcomes of operational decisions and construction projects. The performance of those decisions and projects is subject to variation depending on future conditions.

CERP was developed under the principle of 'stationarity,' which is assuming that the future will be like the past. This is best exemplified by the fact that all of the modeling runs done to determine hydrologic performance in CERP were based on a pattern of rainfall and surface water movements that happened in the prior 30-year period. CERP also made assumptions about the rate of population growth and water demands in southeast Florida, assumed no changes in land use and water demands in the agricultural areas around the lake, and assumed no changes in per capita water use.

If any of these variables that affect the availability of water should change substantially in future decades, this could greatly alter the real outcomes of regional restoration. Research to date suggests that major changes are likely to occur.

1. Potential Effects of Climate Change

In 2013, a group of scientists from Florida universities and state/federal agencies held a series of workshops, culminating in a scenario planning exercise. The same approach that was used to screen restoration alternatives in the Restudy was adopted, using the South Florida Water Management Model (SFWMM, 2005), driven by projections of what climate and sea-level rise might be in the year 2060. Obeysekera et al. (2014) describe the details of the selection of climate change scenarios and the use of that regional model.

In short, the modeling considered three possible future scenarios: (1) future base condition, i.e., no changes in hydrology other than those resulting from completion and operation of CERP projects; (2) future base condition plus a 1.5 degree C rise in temperature with the resulting rise in evapotranspiration and a 1.5 ft rise in sea level; and (3) future base conditions plus increased temperature and evapotranspiration, and a change in annual rainfall of ±10 %, plus a 1.5 ft rise in sea level. These temperature and precipitation scenarios reflect the range of projections from Obeysekera et al. (2011) (Figure IV-1). The sea-level rise scenario is a mid-range estimate from those being used by the USACE in their regional planning for projects to be constructed in south Florida (Figure VI-2).

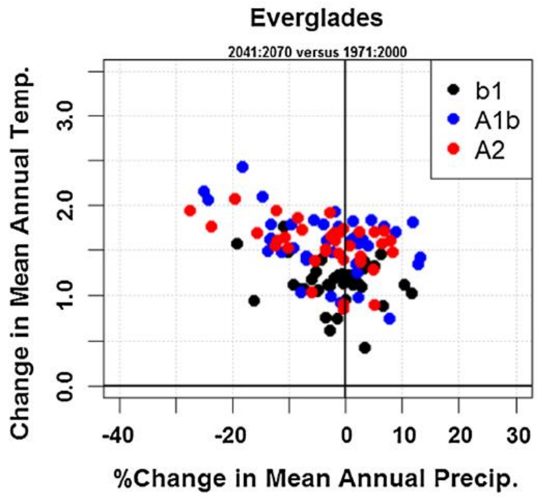


Figure VI-1. Predictions of the changes in temperature and rainfall from an ensemble of climate models run for different IPCC future scenarios. The average increase in temperature using this approach is 1.5 degrees C by 2060, and rainfall is not well predicted, with estimates varying from plus to minus 10 percent (Source: Obeyesekera, 2011).

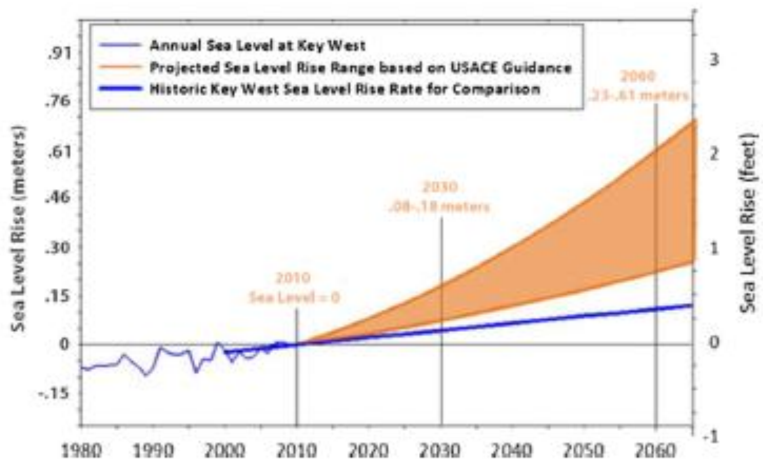


Figure VI-2. The range of sea-level rise that is considered by the USACE in planning coastal projects in south Florida. A rise of 1.5 ft is in the middle of the range for 2060 and was the value used in the modeling conducted by Obeysekera (2014).

The SFWMM assumed no changes to the current regulatory schedule for Lake Okeechobee and did not account for other measures (physical or operational) that might be adopted to ameliorate adverse effects of water availability caused by climate change. For this exercise, potential evapotranspiration (ET) was estimated using a simple method (Abtew et al.,2011) where an increase in temperature is directly translated into an effect on potential ET. Further, the modeling did not assume any changes in the seasonal dynamics of rainfall or ET. While such changes may occur, there currently are no regional projections to guide such scenarios. Output from the SFWMM included a water mass balance, 41-year hydrographs (1965–2006), and stage duration curves (which indicate the percent of time a particular surface elevation is exceeded in the particular modeling scenario). These results were produced for all the major regions of the greater Everglades, from Lake Okeechobee to Florida Bay, and were evaluated by the same experts who were involved in alternatives evaluations during the Restudy, to project what the outcomes would be with regard to ecological and societal impacts. In the future scenario with just an increase in rainfall (no change in temperature or ET), the regional system would be wetter (Figure VI-3, left panel). However, this is a highly unlikely future scenario and in fact, Figure VI-1 indicates that none of the climate models predict this scenario will occur. In a more likely scenario with a warmer future ET would be greater, and with no change in rainfall the entire regional system would experience a water deficit. In a hot and dry future, i.e., increased temperature and evapotranspiration and 10% less rain, the result is extreme water deficits and severe impacts to both the ecological systems and the built environment (Figure VI-3, right panel).

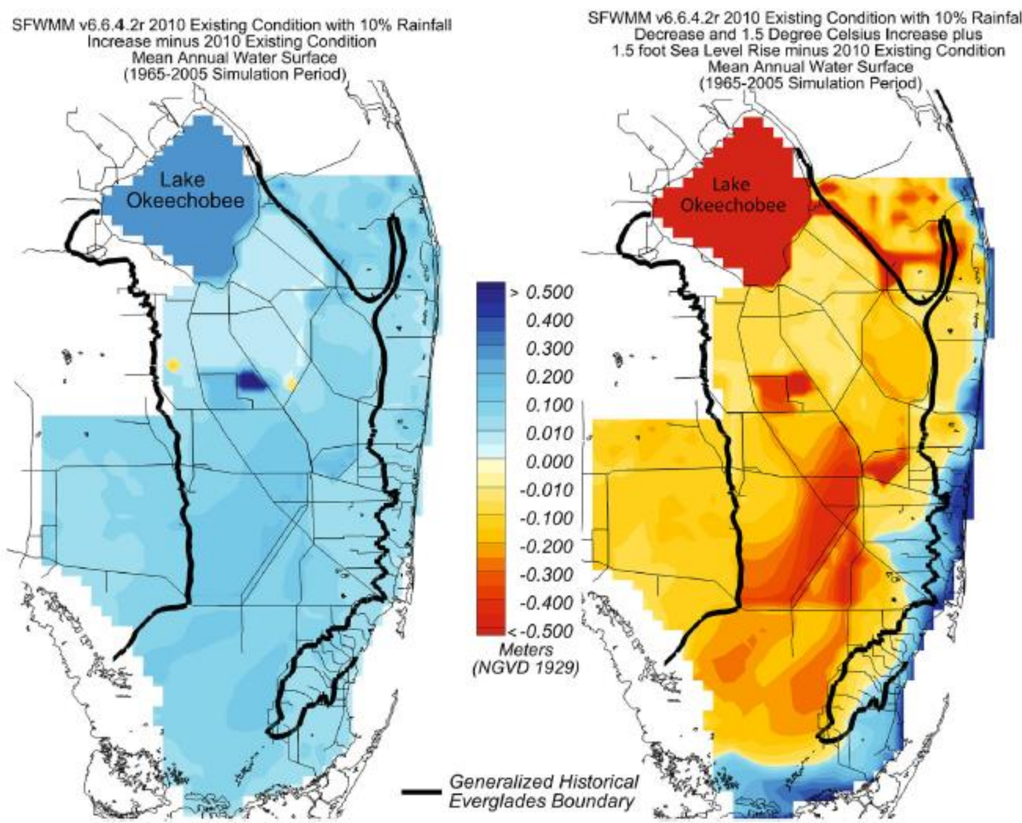


Figure VI-3. Two extreme scenarios for 2060 based on the regional simulation modeling performed by Obeysekera (2014). On the left, the entire system is wetter than today, however this only would occur if rainfall increases by ten percent AND the future is not warmer. The latter is unlikely. On the right, the entire system is extremely dry due to warmer temperatures, higher ET and less rainfall, and the lower east coastal areas are inundated by rising seas.

In the case of Lake Okeechobee (Havens and Steinman, 2013), by comparing 40-year lake stage hydrographs, which show daily changes in water levels in the lake, it can be seen that in a future with increased temperature and more rain, water levels are identical to the future base (the two lines are on top of one another in Figure IV-4). If it becomes warmer and ET increases, but rainfall does not also increase, lake levels drop considerably, as do outflows to the estuaries (St. Lucie regulatory releases are reduced by 62% and Caloosahatchee regulatory releases are reduced by 56%). If it becomes warmer and rainfall declines by ten percent, the lake becomes very low, staying below what is considered an ecologically optimal zone of 12 to 15 ft nearly 80 percent of the time, and sometimes it drops as low as 5 ft. Under this scenario the lake is extremely low for prolonged periods of time, during which it would be impossible for vessels to navigate across the lake or for water from the lake to meet downstream needs.

In the hot/dry future scenario, discharges to the estuaries are greatly reduced. Regulatory discharges to the St. Lucie Estuary decline by 95% and regulatory discharges to the St. Lucie Estuary decline by 90%. While this scenario may seem extreme, it is a possible future state of south Florida.

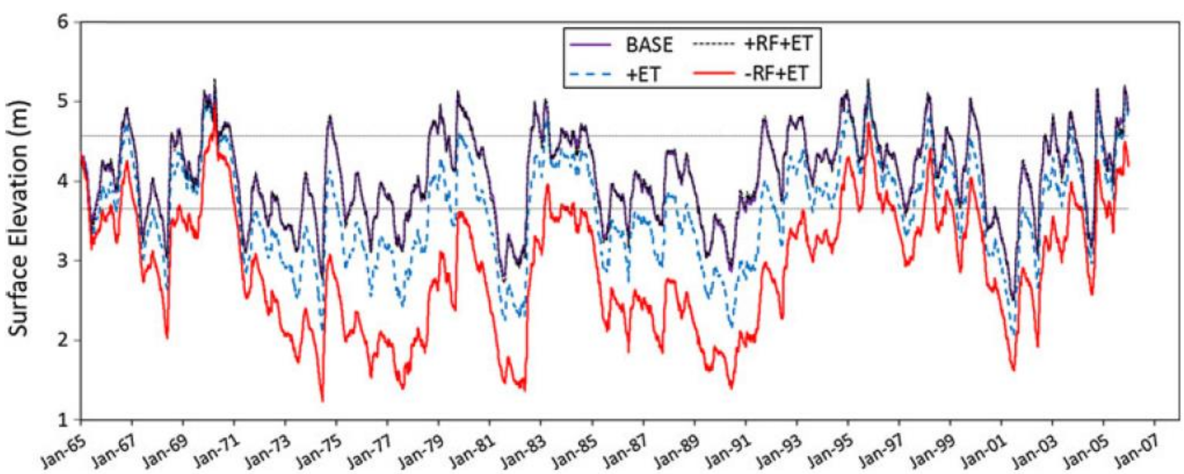


Figure VI-4 Historical (41-year) hydrographs for Lake Okeechobee, based on output from the South Florida Water Management Model and assuming four different regional conditions: Future base – 2060 conditions of projected water demands based on population estimates and anticipated configuration of the regional flood control system including new projects built as part of the Comprehensive Everglades Restoration Plan; +ET—same conditions as the future base, with increased regional evapotranspiration calculated from a temperature increase of 1.5 degrees C; +RF+ET - same as +ET scenario, with a 10% increase in rainfall compared to the historic conditions; -RF+ET - same as the +ET scenario, with a 10% decrease in rainfall. The two horizontal dashed lines delineate the zone that has been identified as optimal for lake elevation in most years to support a diverse assemblage of plants, fish, wading birds, and a variety of ecosystem services provided by the lake. The +RF+ET hydrograph is hidden beneath the base, as lake stages are nearly identical for the entire period of record. (Havens and Steinman 2013).

Other regions of the Everglades landscape responded in a similar manner to the future climate scenarios (Nungesser et al., 2014) with a substantial increase in future rainfall being required to counter-balance the anticipated increases in temperature and ET. Futures without that additional rainfall experience prolonged periods of drying of the Water Conservation Areas and

Everglades, are more at risk for fires that can destroy peat, and suffer losses to native vegetation including sawgrass and tree islands and the fish and wildlife that they support. In the most extreme situation of a future with higher temperatures and less rain, there are long periods during which there is no water in much of the Everglades, which also would risk coastal well fields, because of the lack of fresh water hydraulic head to hold back salt water. This problem is exacerbated because there is at the same time a projected rise of sea level by 1.5 ft and thus a greater need for fresh water from the regional ecosystem to maintain the fresh water-salt water interface at a desirable location.

Warmer surface waters, both in Lake Okeechobee, the St. Lucie and Caloosahatchee rivers and the estuaries, can be expected to result in more frequent and severe blooms of potentially toxic algae, because warmer water has synergistic positive effects with nutrients on the growth of the algae that cause those blooms (Moss et al., 2011). This means that in the Caloosahatchee, where algal blooms already are a common summer occurrence, there will be a greater need for environmental pulse releases from the lake to push the blooms out to sea in a warmer future – yet in a drier future, the water may not be available.

Any climate induced change in hydrology will also have a profound influence on the biogeochemical processes that underlie the structure and function of uplands, wetlands, and aquatic ecosystems within the Greater Everglades (Delpla et al., 2009; Orem et al., 2014; Reddy and Delaune, 2008; Reddy et al., 2010; Twilley, 2007). Extreme variations in temperature and precipitation resulting from climate change, for example, can affect transport of particulate matter, nutrients, and other constituents from uplands/wetlands to downstream receiving waters and exacerbate eutrophication related issues. Warmer soils and irregular precipitation patterns will likely increase the rates of microbial activity, organic matter decomposition and nutrient regeneration, and export of pollutants downstream. During dry conditions P is often bound to soils and is relatively stable, but under prolonged flooded conditions P can be solubilized and exported to downstream resulting in increased nutrient loads (Reddy et al., 2010). Dry conditions can also promote the release of nitrous oxide from soils, while flooded conditions result in the production of methane gas. Both nitrous oxide and methane are well known greenhouse gasses. Dry conditions in wetlands can lead to the oxidation of sulfides and a decrease in soil pH, which, in turn, can result in solubilization of P (Reddy and Delaune, 2008). During flooded conditions, sulfate can be reduced to sulfide; a process that promotes methyl mercury formation. Although many of the processes noted above currently occur in the Everglades ecosystem, a change in process rates can have substantial consequences for nutrient reduction and remediation efforts. Ultimately managers and regulators involved in Everglades restoration activities should consider more fully how climate change may affect nutrient reduction goals.

2. Effects of Changes in Human Population Size, Location and Land Use

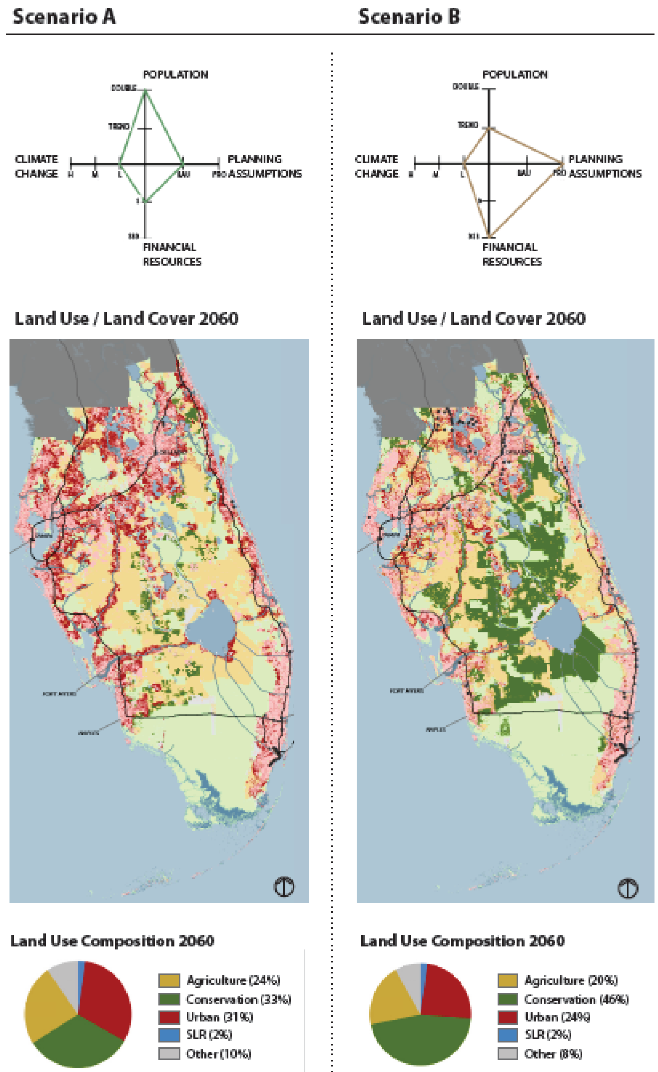
Future changes in population size are highly uncertain, because as seen in recent years, they can rise and fall with the economy. However, it is expected that over the next few decades, several million more people will live in Florida, adding to the current population that has just reached 20 million. Researchers at the Massachusetts Institute of Technology (MIT) conducted a project called ‘addressing the challenge of climate change in the greater Everglades landscape’ with funding from the US Fish and Wildlife Service and the US Geological Survey. They examined possible future scenarios with high vs. low sea-level rise, high vs. low financial resources used to mitigate impacts of climate change, pro-active planning vs. no advance action and a doubling of population size over the next 50 years vs. continued growth at the current rate (Vargas-Moreno and Flaxman, 2010).

The scenarios show a great range of different outcomes with regard to how land use will change and where people will live in 50 years (Figure VI-6). Both factors have a large potential influence on water demands, and are not considered at this time in any Everglades restoration planning.

3. Other Possible Future Changes

Per-capita consumption of water is another unknown, and if it declines markedly, could offset some of the adverse consequences of a future with less available freshwater. However, it is unknown to what extent water conservation measures will be implemented over the next 50 years, either by choice of users or by legal mandates.

Another uncertainty that could affect ecosystem restoration is the price of energy. The current C&SF and the proposed restoration plans require large amounts of energy to operate. The Department of Defense has in recent years considered energy to be its single largest future constraint, and as such a critical threat to national security (U.S. Army. 2014). Thus the annual energy costs of pumping water in a fully restored South Florida ecosystem could be substantial.



Total Land Use Area (in millions of acres)	2020	2040	2060
Agriculture	6.19	5.52	4.69
Conservation	6.00	6.16	6.32
Urban	4.51	5.20	5.98
Sea Level Rise	0.33	0.38	0.44
Other	2.26	2.03	1.86

Total Land Use Area (in millions of acres)	2020	2040	2060
Agriculture	6.00	4.96	3.85
Conservation	6.50	7.65	8.80
Urban	4.29	4.47	4.62
Sea Level Rise	0.33	0.38	0.44
Other	2.18	1.83	1.58

Figure VI-6. Two scenarios of land use and human population distribution in 2060 under different assumptions (upper scenario diagram), showing a wide range of outcomes, from one with a large amount of natural area north and south of Lake Okeechobee in a future with a high level of pro-active planning and small amount of climate change (right-hand panel) to a near-complete loss of natural areas north of the lake in a future following little pro-active planning (left-hand panel) (from Vargas-Moreno and Flaxman, 2010)

4. Uncertainty in Future Funding

Dealing with the issues of damaging freshwater releases to the St. Lucie and Caloosahatchee Estuaries and insufficient flow of clean fresh water to the Everglades requires a large expenditure of federal and state funds. In a future with a growing human population and unknown changes in their geographic distribution and water needs, it is reasonable to expect that future costs of addressing these issues will rise, particularly if the cost of land increases substantially at the same time that there is an increased need for buying large areas of land to store and treat water.

Figure VI-7 illustrates the historical trend in spending for CERP projects from both state and federal sources and Figure VI-8 illustrates state and federal spending for both CERP and non-CERP projects in South Florida. Between 2002 and 2008 Florida's spending substantially outpaced federal spending, however Florida's spending has declined significantly since 2008 (NRC, 2014). Furthermore, federal spending has also declined since 2010 (NRC, 2014). If these patterns continue it may be impossible to ameliorate the problems facing the estuaries and Everglades.

It is notable that in FY14 the Florida Legislature appropriated over $200M in new funds for restoration projects, including a variety of projects that will help to address the issues facing the Everglades and estuaries. A long-term commitment of federal and state funds will be required to substantively address the issues in the long term and in the context of the uncertainties noted above.

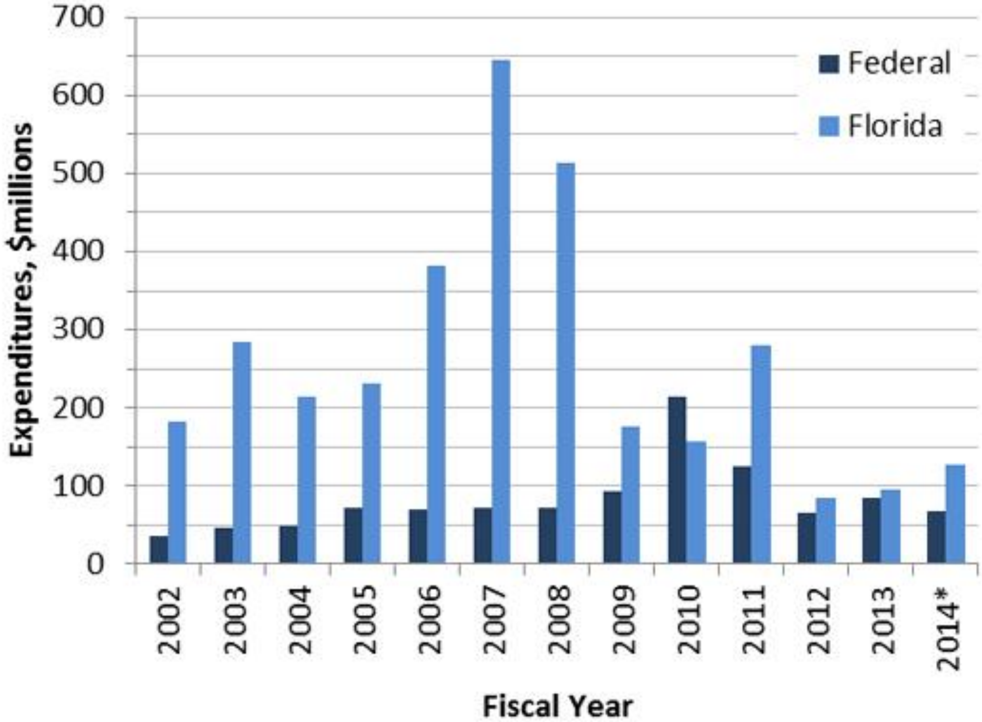


Figure VI-7. Spending on CERP projects by federal and state governments (from NRC, 2014).
NOTE:* Requested.

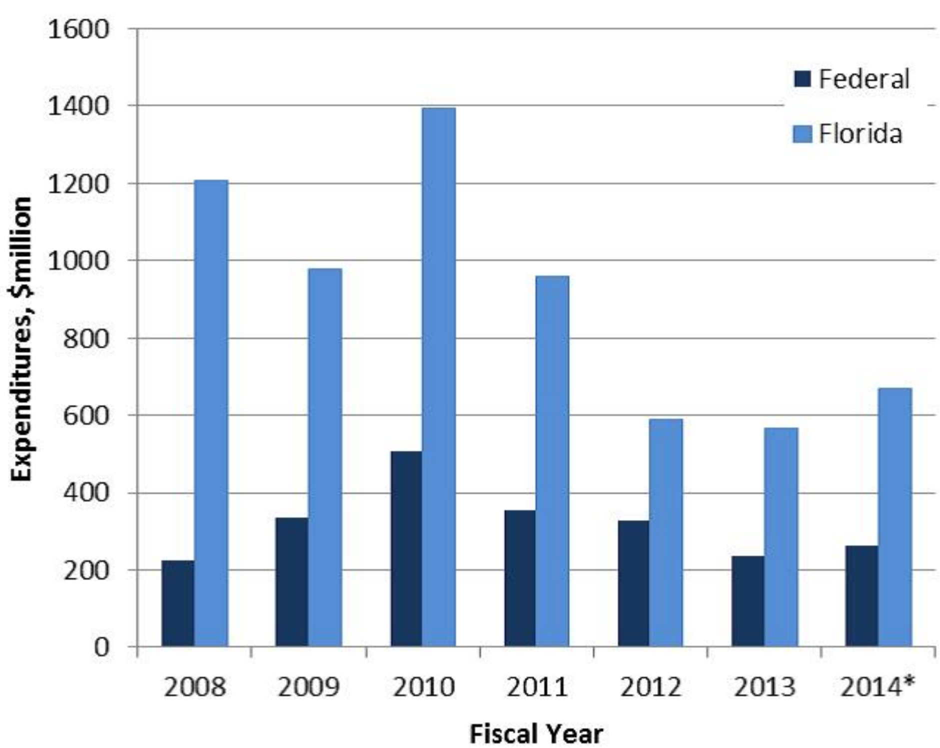


Figure VI-8 Federal and state spending related to South Florida ecosystem restoration activities, including CERP and non-CERP projects and related expenditures (from NRC, 2014)
NOTE:* Requested

5. Summary

There are major uncertainties associated with the outcomes of Everglades restoration. These include uncertainties related to climate change, human population size, geographic location of population centers, changes in land use and funding. Substantive research and modeling has been done to identify how climate change, changes in human demographics and changes in land use may affect Florida's future, yet there is little evidence that the information from this research and modeling is being incorporated into restoration project plans. Projects appear to be planned and executed with the assumption of stationarity (the world of the future is like the world of the past) and this likely will not be true for critical drivers including rainfall, evapotranspiration, temperature, sea level and where people live and how they use the land. Failure to draw on information about future conditions risks successful project outcomes. Even if the future of the aforementioned parameters is highly uncertain, the possibility of future changes needs to be acknowledged, effects on restoration outcomes assessed, and flexibility be incorporated into projects so that they can have positive outcomes over a broad range of conditions.

Even in the face of uncertainty, many existing plans have been fully vetted and can be expected to yield substantial benefits to the citizens of Florida. Most of those plans are not proceeding because of a lack of funding. In the interim, there is considerable evidence that the ecological system is continuing to degrade in ways that may not be reversible. Monitoring and assessment of system performance is essential to guide projects and to detect and adapt to future surprises. Increased and sustained State and Federal funding is critical to achieve restoration before the system becomes so degraded that major attributes reach tipping points that cannot be reversed. The recent decline in funding should be addressed by the lead agencies, Congress and the Florida Legislature so that sufficient financial and human resources are available to complete critical restoration elements in an accelerated and effective manner.

VII. Summary and Conclusions

The Technical Review Team concludes that relief to the estuaries and the ability to move water south of Lake Okeechobee can be accomplished using existing technology. The solution is enormous increases in storage and treatment of water both north and south of the lake. Existing and currently authorized storage and treatment projects are insufficient to achieve these goals. The path forward requires significant long-term investment in the infrastructure of the South Florida hydrological system.

To reduce damage to the St. Lucie and Caloosahatchee estuaries freshwater inflow and nutrient loads from <u>both</u> Lake Okeechobee <u>and</u> the local basins must be reduced. On average, 70-80% of the freshwater discharge and 65-80% of the nutrient load to the St. Lucie and Caloosahatchee estuaries originates in the local basins, with the remaining balance contributed from Lake Okeechobee. Previous Comprehensive Everglades Restoration Plan (CERP), Northern Everglades and Estuaries Protection Program (NEEPP) and River of Grass (ROG) planning exercises have all identified that providing large volumes of regional storage is essential to reduce freshwater discharges to the estuaries. The most recent estimates of required storage include:

- 400,000 acre-feet of water storage within the Caloosahatchee River watershed,
- 200,000 acre-feet of water storage within the St. Lucie River watershed, and
- approximately 1,000,000 acre-ft of water storage distributed north and south of Lake Okeechobee.

In spite of the repeated demonstrated need for large volumes of water storage, very little new storage has been designed or constructed in the system. For example, in the St. Lucie watershed it is estimated that approximately 200,000 acre-ft of storage is required. However, only one 40,000 acre-ft surface reservoir is currently under construction. In the Caloosahatchee watershed, it is estimated that approximately 400,000 acre-ft of storage is needed, but currently only one 170,000 acre-ft surface reservoir is being designed, and state and federal funds for its construction have not yet been appropriated. Furthermore, although at least one million acre-ft of storage is required either north or south of Lake Okeechobee, currently only four Flow Equalization Basins (FEBs) that provide 168,000 acre-ft of shallow storage are planned and they are sited south of Lake Okeechobee. Two of the FEBs (totaling 101,000 acre-ft) currently are under construction by the State and are scheduled to be completed by 2016. State construction of a third 11,000 acre-ft FEB will not begin until after 2018. The fourth CERP FEB has yet to be authorized by the US Congress.

Based on review and analyses, the Technical Review Team identified the following options to reduce damaging discharges to the St. Lucie and Caloosahatchee estuaries and move more water south from Lake Okeechobee:

1. Accelerate funding and completion of existing approved projects

To provide substantial improvement to the St. Lucie and Caloosahatchee estuaries, accelerate the funding and completion of existing federally authorized CERP projects designed specifically to provide relief to St. Lucie and Caloosahatchee Basins, i.e.:

- Indian River Lagoon-South (IRL-S) Project: Accelerate construction of the C-44 reservoir and associated Stormwater Treatment Area (STA). Aggressively pursue state and federal appropriations needed to design and construct remainder of the IRL-S project (including C-23, 24, 25 reservoirs and associated STAs, and restoration of over 90,000 acres of upland and wetland areas). Total Storage Provided in St. Lucie watershed: 130,000 acre-ft of 200,000 acre-ft required.
- C-43 Reservoir: Accelerate the design and aggressively pursue state and federal appropriations needed to design and construct project. Total Storage Provided in Caloosahatchee watershed: 170,000 acre-ft of 400,000 acre-ft required.

Current Basin Management Action Plans (BMAPs) will not achieve FDEP approved Total Maximum Daily Loads (TMDLs). To achieve water quality standards in Lake Okeechobee, the St. Lucie estuary and the Caloosahatchee estuary, more aggressive BMAPs are required. New field-verified agricultural and urban Best Management Practices (BMPs) that protect water quality, advanced *in situ* treatment technologies, and the strategic placement of additional FEB-STAs in priority basins will be essential to achieve State and Federal water quality standards. Beyond existing and planned approaches, the substantial reservoir of legacy phosphorus in the Northern Everglades watersheds will necessitate new and more aggressive strategies to combat the mobility of phosphorus.

To substantially increase the volume of water moving from Lake Okeechobee to the Southern Everglades, accelerate funding and completion of the State of Florida Restoration Strategies and the CERP Central Everglades Planning Project (CEPP), i.e.:

- Obtain federal authorization for CEPP,
- Accelerate the design and obtain state and federal appropriations for the construction of CEPP,
- Accelerate State funding and completion of Restoration Strategies,

- Conduct a careful analysis of CEPP project construction phasing to determine which CEPP features can be constructed as soon as possible and to develop a plan for completion of as many CEPP features as possible during the construction phase of Restoration Strategies, and
- Reconsider using the Talisman property for a deep storage reservoir with STA rather than the current design which uses the Talisman property for shallow FEBs.

Total Treatment and Conveyance Capacity to Everglades Protection Area (EPA) after CEPP and Restoration Strategies: 1.5 million acre-ft per year of 1.7 million acre-ft per year 1999 CERP target and 2.0 million acre-ft per year 2009 River of Grass target.

Additional efforts, beyond the approved projects listed above, will be required to reduce Lake Okeechobee-triggered high discharges and nutrient loads to the St. Lucie and Caloosahatchee estuaries and to achieve dry season Everglades demand targets. Studies indicate that after the completion of the IRL-S, C-43, Restoration Strategies, and CEPP projects, lake-triggered high discharges to the St. Lucie and Caloosahatchee estuaries will be reduced by less than 55% and less than 75% of the dry season Everglades demand target will be delivered to the EPA. A series of options, beyond currently approved projects, to more fully achieve restoration objectives are summarized below.

2. Provide Water Storage and Treatment North of Lake Okeechobee

Conduct a strategic planning exercise to provide additional water storage and treatment north of Lake Okeechobee similar to the ROG Planning Process that was conducted south of the lake. The NEEPP Lake Okeechobee Phase II Technical Plan (LOP2TP) and the ROG Planning Process provide a sound foundation from which to plan, design, and build the additional storage and treatment needed north of Lake Okeechobee. A new strategic planning exercise would necessarily include a regional modeling effort that takes into account lessons learned and information gained since the CERP, NEEPP and ROG planning exercises. Examples of new information gained include the permitting requirements, engineering feasibility and costs, and inter-annual storage benefits associated with Aquifer Storage and Recovery (ASR), deep storage reservoirs, shallow water impoundments and dispersed water management (DWM), as well as the water quality benefits of Stormwater Treatment Areas (STAs) and other treatment technologies. New data gathering efforts and model developments will be required to simulate the cumulative impacts of a regional DWM system north of the lake on the quality, quantity and timing of flows into Lake Okeechobee as a function of climatic conditions, spatial location and density of DWM features on the landscape, and operation of the regional canal system. The Technical Review Team expects that the strategic plan will show that, while DWM on private lands may provide some benefits, DWM will fall short of providing the additional storage and treatment needed, even if fully implemented. Additional land north of Lake Okeechobee will need to be acquired for that purpose (i.e. from approximately 25,000 acres if 300,000 acre-ft is provided by deep storage to approximately 187,500 acres if 750,000 acre-ft is provided by shallow water impoundments).

3. Provide Additional Water Storage, Treatment and Conveyance South of Lake Okeechobee

Develop a strategic plan for the next increment of south-of-lake storage, treatment and conveyance to pursue beyond CEPP to take advantage of new north-of-lake storage and treatment, and more closely meet the performance targets of both the estuaries and the Everglades ecosystems. Independent assessments suggest that an expansive gravity-driven wet flow-way throughout the Everglades Agricultural Area (EAA) may not be feasible or provide maximal benefits to the estuaries. However, the ROG planning process demonstrated that there are several possible options involving combinations of deep and shallow storage, and wet- and dry- flow-ways, coupled with STAs and enhanced conveyance that could provide significant benefit both for the estuaries and the Everglades, far beyond the benefits provided by the Kissimmee River Restoration (KRR), IRL-S, C-43, Restoration Strategies and CEPP projects. Achieving substantial reduction in lake-triggered discharges to the estuaries and substantial improvement toward the dry season Everglades demand target will require between 11,000 and 129,000 acres of additional land between the lake and the EPA, depending on the mix of storage and treatment options. This land could be obtained by purchase of the current U.S. Sugar option lands, purchase of lands from other willing sellers, and/or the use of existing state-owned land (e.g., Holey Land and Rotenberger Wildlife Management Areas (WMAs)).

4. Deep Well Disposal of Excess Flows

Deep well disposal could be part of a long-term solution to reducing damaging discharges from Lake Okeechobee to the St. Lucie and Caloosahatchee estuaries, or it could provide an interim solution until additional water storage, treatment and conveyance capacity can be constructed south of the lake. If sufficient inter-annual storage and treatment north of the lake is determined to be economically or politically infeasible, or the analyses indicate that the captured water cannot be efficiently treated and conveyed south of the lake for use in subsequent dry seasons, the option of constructing a system of large injection wells to permanently dispose of excess flows from Lake Okeechobee in the deep Boulder Zone, rather than discharging to the estuaries, should be explored.

5. Operational Changes

Adjustments within the current Lake Okeechobee regulation schedule (LORS 2008) are unlikely to have a substantive effect on the occurrence of damaging high discharges to the estuaries. However, a substantially revised regulation schedule that provides more storage in the lake might provide those benefits. Developing a new regulation schedule requires completion of the on-going U.S. Army Corps of Engineers (USACE) Dam Safety Modification Study and guidance about the safety of the rehabilitated Herbert Hoover levee and operational structures in light of any new safety standards. The USACE should accelerate completion of the Dam Safety Modification Study so that modification of the Lake Okeechobee regulation schedule, if warranted, can occur as soon as possible. Development of a new regulation schedule will require balancing benefits of holding additional water in the lake for the express purpose of reducing damaging discharges to the estuaries and increasing agricultural, urban and ecosystem water supply versus potential adverse impacts to the lake's ecology.

In the interim, to provide incremental estuarine relief, Lake Okeechobee operations could be modified within the discretionary bands of LORS 2008. Increasing the dynamic range of storage in the lake could allow some additional water to be moved south to the EPA, and also provide increased dry season flows to the Caloosahatchee estuary and EAA. In addition, the regulation schedules of the Holey Land and Rotenberger Water Management Areas (WMAs) could be modified to allow more water storage during both the wet and dry seasons. This modification of the WMA regulation schedules could be in keeping with current goals to restore natural hydroperiods, but will require the inflow/outflow infrastructure be upgraded to allow dynamic water level manipulations.

Future Uncertainties

Failure to draw on information about the range of possible future conditions risks the success of restoration project outcomes. Substantive research indicates clearly that climate change, changes in human demographics, energy costs and land use will affect Florida's future, yet there is little evidence that salient information is being incorporated into restoration project plans. Even if the future of these variables is highly uncertain, the possibility of future changes needs to be acknowledged, effects on restoration outcomes assessed, and flexibility incorporated into projects so that they can have positive outcomes over a broad range of conditions.

Path Forward

Even in the face of uncertainty, many existing plans and projects have been fully vetted and can be expected to yield substantial benefits to the citizens of Florida. Most of the projects are delayed because of a lack of funding. In the interim, the coupled human-ecological system is continuing to degrade in ways that may not be reversible. Monitoring and assessment of system performance is essential to guide projects and to detect and adapt to future surprises. Increased and sustained State and Federal funding is critical to provide additional water storage and treatment before the system becomes so degraded that major attributes reach tipping points that cannot be reversed.

VIII. List of Abbreviations

acre-ft	acre-feet
ASR	Aquifer Storage and Recovery
BiOp	Biological Opinion
bgd	billion gallons per day
BMAP	Basin Management Action Plan
BMP	best management practice
cfs	cubic feet per second
C&SF	Central and Southern Florida Project
CEPP	Central Everglades Planning Project
CERP	Comprehensive Everglades Restoration Plan
CSSS	Cape Sable Seaside Sparrows
CWA	Clean Water Act
DWM	Dispersed Water Management
EAA	Everglades Agricultural Area
EFA	Everglades Forever Act
EIS	Environmental Impact Statement pursuant to NEPA
ENP	Everglades National Park
EPA	Everglades Protection Area
ESA	Endangered Species Act
FAVT	Floating Aquatic Vegetation Treatment
FDACS	Florida Department of Agriculture and Consumer Services
FDEP	Florida Department of Environmental Protection
FEB	Flow Equalization Basin
FWC	Florida Fish and Wildlife Conservation Commission
FWM	flow-weighted mean
FWS	U.S. Fish and Wildlife Service
HLWMA	Holey Land Wildlife Management Area
HWTT	Hybrid Wetland Treatment Technology
IFAS	Institute of Food and Agricultural Sciences
IRL	Indian River Lagoon
IRL-S	Indian River Lagoon-South
ITS	Incidental Take Statement
LOP2TP	Lake Okeechobee Phase II Technical Plan

LORS	Lake Okeechobee Regulation Schedule
LORS 2008	2008 Lake Okeechobee Regulation Schedule
maf	million acre feet
MBTA	Migratory Bird Species Act
mgd	million gallons per day
NEEPP	Northern Everglades and Estuaries Protection Program
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
PIR	Project Implementation Report of USACE
ppb	parts per billion
ROG	River of Grass Planning Process
RPA	Reasonable and Prudent Alternative
RPM	Reasonable and Prudent Measure
RWMA	Rotenberger Wildlife Management Area
SAV	Submerged Aquatic Vegetation
SFER	South Florida Environmental Report
SFWMD	South Florida Water Management District
STA	Stormwater Treatment Area
SWET	Soil and Water Engineering and Technology, Inc.
TN	Total nitrogen
TP	Total phosphorus
UF	University of Florida
US	United States, or U.S.
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WCA	Water Conservation Area
WMA	Wildlife Management Area
WQBEL	Water Quality-Based Effluent Limit
WRP	Wetland Reserve Program
WRDA	Water Resources Development Act

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X. Review Team Biographical Sketches

Wendy D. Graham, Ph.D., is the Carl S. Swisher Eminent Scholar in Water Resources in the Department of Agricultural and Biological Engineering at the University of Florida, and Director of the University of Florida Water Institute. She holds a bachelor's degree from the University of Florida in environmental engineering. Her PhD is in civil and environmental engineering from the Massachusetts Institute of Technology. She conducts research in the areas of coupled hydrologic-water quality modeling; water resources evaluation and remediation; evaluation of impacts of agricultural production on surface and groundwater quality; and evaluation of impacts of climate variability and climate change on water resources. She has served on the National Research Council Committee on Independent Scientific Review of Everglades Restoration Progress, and the Committee on Review of EPA's Economic Analysis of Final Water Quality Standards for Nutrients for Lakes and Flowing Waters in Florida.

Mary Jane Angelo, J.D., is professor and director of the Environmental and Land Use Law Program at the University of Florida. She holds a bachelor's degree in biological sciences from Rutgers University, and a master's degree in entomology and a J.D. in law from the University of Florida. Her academic and teaching focus is in environmental, water, biotechnology, and wildlife protection law, as well as in agricultural policy and the environment. Prior to joining the University of Florida, she practiced as an environmental lawyer for many years. Angelo served in the U.S. Environmental Protection Agency Office of the Administrator and Office of General Counsel in Washington, D.C., and as Senior Assistant General Counsel for the St. Johns River Water Management District in Florida. She has served on the National Research Council Committee on Independent Scientific Review of Everglades Restoration Progress.

Thomas K. Frazer, Ph.D., is a professor of ecology in the fisheries and aquatic sciences program and director of the School of Natural Resources and Environment at the University of Florida. He holds a bachelor's degree in fisheries from Humboldt State University and a master's degree in fisheries from the University of Florida. His Ph.D. is in biological sciences from the University of California, Santa Barbara. The overarching goals of his individual and collaborative research efforts are to develop and transfer into management a mechanistic understanding of the effects of anthropogenic activities on the ecology of both freshwater and marine ecosystems. His research is, by nature, interdisciplinary and involves collaborators from disparate disciplines and is carried across broad space and time scales in order to most effectively address contemporary and emerging environmental issues.

Peter C. Frederick, Ph.D., is a research professor in the Department of Wildlife Ecology and Conservation at the University of Florida. He holds a bachelor's degree in biology from Swarthmore College, and a Ph.D. in zoology from the University of North Carolina, Chapel Hill. His research interests are in the ecology and conservation of wetlands, and particularly of wetland vertebrates. His research lab is focused on understanding wetland processes both for their own sake and as guides to restoration and conservation activities, and much of this work has focused on the Everglades for the past 28 years. Frederick has served on the committees of more than 40 graduate students, and he has authored or co-authored more than 80 publications on wetlands topics.

Karl E. Havens, Ph.D., is a professor of limnology in the fisheries and aquatic sciences program at the University of Florida, and the director of the Florida Sea Grant College Program. He holds a bachelor’s degree from the State University of New York, Buffalo, and a master’s degree and Ph.D. from West Virginia University. He has 30 years of professional experience in aquatic research, education and outreach, and has worked with Florida aquatic ecosystems and the use of objective science in their management for the past 15 years. His area of research specialty is plankton ecology and the eutrophication of lakes and estuaries. At the University of Florida, he has served as chair of the UF Oil Spill Task Force, and currently is chair of the UF Oyster Recovery Team, which is dealing with the collapse of a historic oyster fishery in Apalachicola Bay, Florida.

K. Ramesh Reddy, Ph.D., is graduate research professor and chair of the Department of Soil and Water Science at the University of Florida. He holds a Ph.D. in soil science with specialization in biogeochemistry from Louisiana State University. He conducts research on coupled biogeochemical cycling of nutrients and other contaminants in wetlands and aquatic systems, as related to water quality, carbon sequestration, ecosystem productivity, and restoration. He has worked on Florida’s wetlands and aquatic systems for more than 30 years. He has served on numerous advisory committees at state, national, and international levels. He has served on the National Research Council Committee on Soil Science and the Committee on Independent Scientific Review of Everglades Restoration Progress. He also served on several U.S. Environmental Protection Agency committees including the Science Advisory Board Ecological Effects Committee, Wetland Connectivity Panel, and Lake Erie Phosphorus Objective Panel.