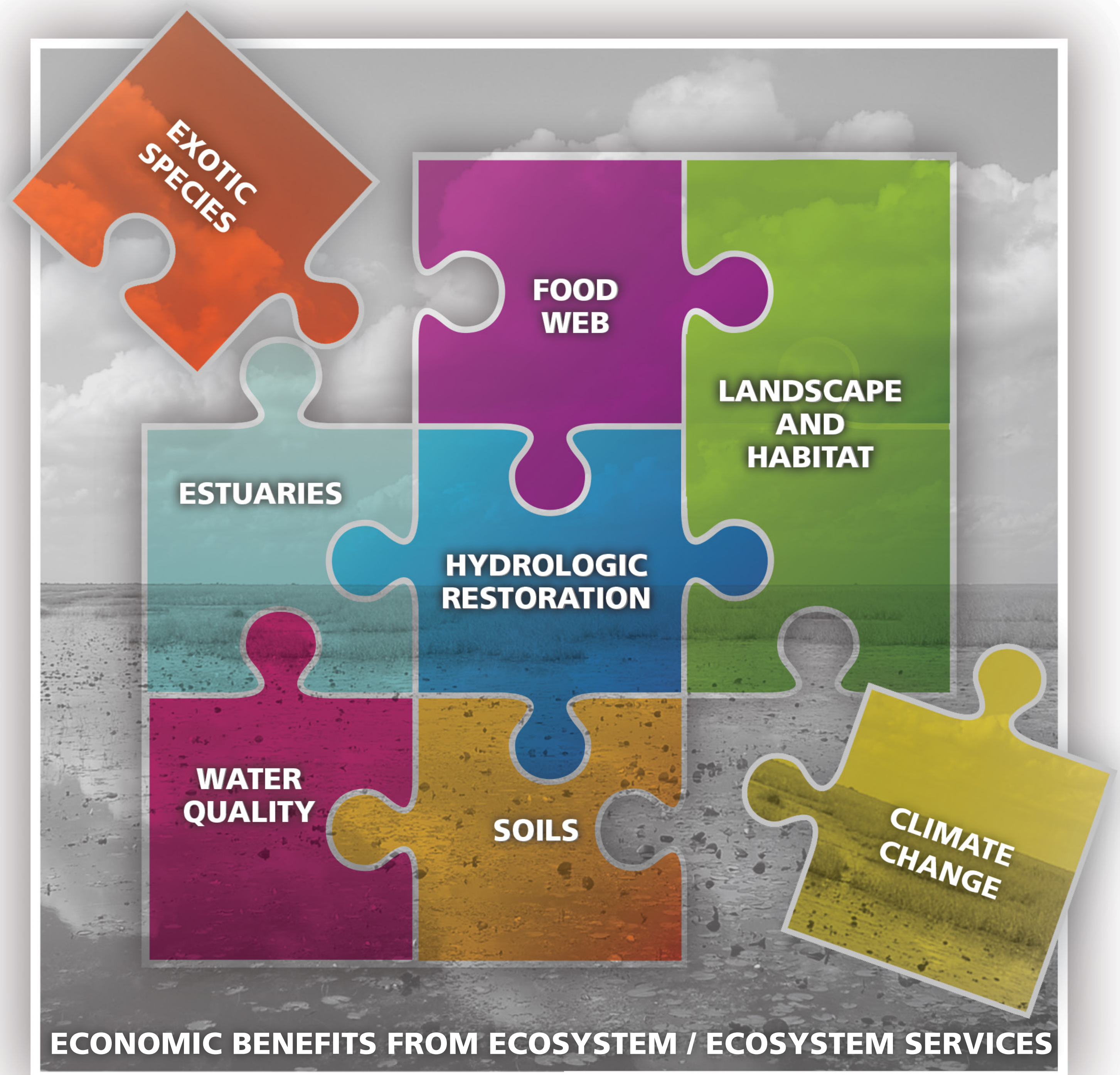
THE SERES PROJECT

Synthesis of Everglades Research and Ecosystem Services

Management-Driven Science Synthesis: An Evaluation of Everglades Restoration Trajectories




Lake Apopka
Orlando
Cocoa Beach
Chain of Lakes
Tampa
St. Petersburg
FLORIDA
Lake Kissimmee
Greater Everglades Ecosystem
Kissimmee River
Ft. Pierce
Port St. Lucie
Atlantic Ocean
Gulf of Mexico
Okeechobee
Lake Okeechobee
St. Lucie River
Port Charlotte
Jupiter
Caloosahatchee River
West Palm Beach
Ft. Myers
A.R.M. Loxahatchee N.W.R.
Everglades Agricultural Area
WCA 2
WCA 3
Naples
Fort Lauderdale
Big Cypress National Preserve
Water Conservation Area 3 (WCA)
Miami
Everglades National Park
Biscayne Bay
Homestead
Flamingo
Key Largo
Florida Bay
The Florida Keys
Key West
20 MILES
LEGEND
Greater Everglades Ecosystem
Current Everglades National Park
Everglades Agricultural Area
Big Cypress Swamp
Major Metro Population Area

TABLE OF CONTENTS

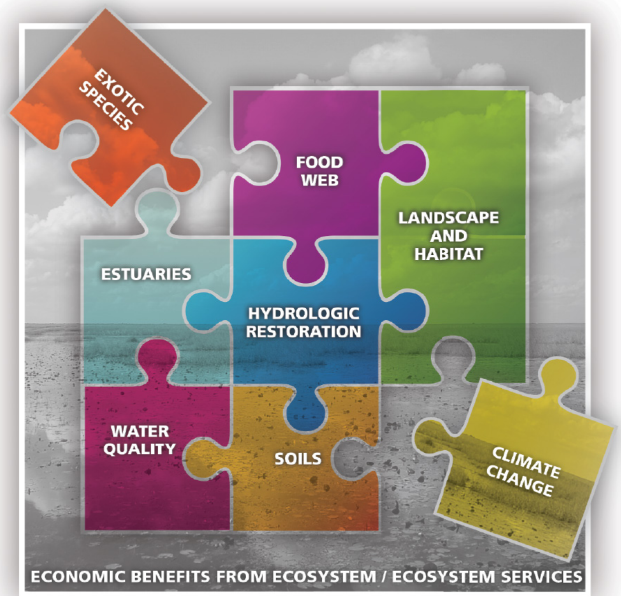
Synthesis of Everglades Research and Ecosystem Services

Suggested citation: SERES Project. 2016. Management-Driven Science Synthesis: An Evaluation of Everglades Restoration Trajectories. 60 pages.

About the Project

The Synthesis of Everglades Restoration and Ecosystem Services (SERES) Project was funded in 2010 by the U.S. Department of Interior (DOI) through the Critical Ecosystem Studies Initiative (CESI) and established to synthesize the ever-growing body of Everglades scientific information with the goal of addressing topics that have hampered restoration since the Comprehensive Everglades Restoration Plan (CERP) was passed in 2000. A distinguishing characteristic of this synthesis effort was that the target end-user was a management/decision-maker audience. Specifically, the aim was to address the questions of the water managers and other decision leaders in a way that would illuminate and inform but not constrain or specify decisions.

Since its inception, the SERES Project has been managed by the Everglades Foundation; however, a core group of scientific experts from agencies, academic institutions, and the private sector have contributed to the project (see list on page 4). We began the project by interviewing key officials, including resource managers, decision-makers, and heads of agencies and environmental organizations. The objective of these interviews was to establish the *Key Science Management Questions* that needed to be addressed in order to advance restoration of the Everglades. The resulting questions led to the organization of project teams focused on Hydrology, Water Quality, Soils, Trophic Dynamics, and Landscape Pattern. In order to establish the technical basis for the project, we conducted in depth reviews of the recent scientific literature, evaluation tools and models, and available data in each of these core areas. Finally, we developed a suite of restoration options that would aid us in addressing the *Key Questions* and evaluated their relative performance from hydrological, ecological, and economic perspectives. General findings of the SERES Project are described in subsequent sections, and technical



At the core of Everglades Restoration, hydrology links other components of the system, ranging from soils to food web dynamics. We illustrate these as pieces to a puzzle that overlay regional ecosystem services and economic benefits.

reviews and results of analyses supporting this document are available in reports on the project website ***(www.everglades-seres.org/Products.html).***

Past, Present, and Future

The pre-drainage Everglades was characterized by a continuum of clean, flowing freshwater from just south of present-day Orlando, down the Kissimmee River, through Lake Okeechobee, across the "River of Grass", and ultimately into Florida Bay and the Gulf of Mexico. Today, the system is highly managed and impacted by a network of pumps, gates, culverts, canals, and levees that comprises the Central and Southern Florida Project (C&SF Project). Major impacts from the C&SF Project are that (1) a huge amount of water storage capacity in South Florida has been lost, (2) the Everglades is no longer connected to Lake Okeechobee, and (3) the ecosystem is highly compartmentalized and therefore no longer flows as a "River of Grass".

The current restoration plan, CERP, was never intended to return the Everglades to a pre-drainage state but rather a state of enhanced functionality by minimizing or removing impacts caused by the operation of the current C&SF infrastructure. One of the biggest restoration problems is water storage and how best to store the quantities of water needed for a healthy Everglades while minimizing harm to other areas such as Lake Okeechobee and the Caloosahatchee and St. Lucie River Estuaries (or Northern Estuaries). Removal of internal barriers to flow (also called decompartmentalization or "decomp") is also needed to restore flow to the "River of Grass" and alleviate ponding of water. In reality, to do this, extraordinary quantities of water storage are needed. The centerpiece of the CERP's storage strategy was aquifer storage and recovery (ASR), particularly around Lake Okeechobee. ASR involves pumping water deep into the ground during high rainfall/flood periods, thus creating a large "bubble" of water belowground, and recovering that water at a later date when needed.

The SERES Team considered options for reducing the amount of storage (the most expensive component in the CERP), and in particular, the reliance on ASR. This necessitated additional flow during wet periods compared to the CERP, and in order to reduce flows to the Northern Estuaries, increased flow through the Everglades was needed. Increased flow necessitates additional decompartmentalization, which, in turn, requires additional storage. We evaluated five Everglades restoration "options", including the "existing condition" (Option A) and the CERP (Option B). See description of each on page 3. We included a scaled-back version of CERP (Option C) with much less overall storage, recognizing that both ASR and Lake Belt Storage, as conceived in the CERP, may be problematic. Replacing that lost storage with an increased above-ground reservoir and enhanced decompartmentalization led to the development and inclusion of Options D and E. Our goal was not to pit one restoration plan against another. Instead, we wanted to provide managers with an array of options, including projected costs and benefits, to consider in regards to the storage problem.

Overall, increased storage and decompartmentalization resulted in deeper water in some areas of WCA 3B, making those local areas unsuitable for ridge and slough landscape and slightly lower overall wading bird populations. However, flows to Florida Bay and to other parts of the Everglades showed great overall benefits, similar in spatial pattern to the benefits modeled in the Central Everglades Planning Project (CEPP).[1] With this document, we provide an overview of these five options, their relative performance in each core area, as well as summarized responses to the Key Questions based in part on SERES project results and best scientific judgment.

SERES Team members and science advisors at initial project meeting.

1 *http://www.saj.usace.army.mil/Missions/Environmental/EcosystemRestoration/CentralEvergladesPlanningProject.aspx*

SERES Restoration Options

OPTION A

Existing Condition ("do nothing" or a future without restoration)

OPTION B

Full implementation of the Comprehensive Everglades Restoration Plan (CERP), including 1000 MGD capacity for aquifer storage and recovery (ASR), Northern and Central Lake Belt storage, Everglades Agricultural Area (EAA) reservoir, Bird Drive Basin storage, and partial decompartmentalization.

OPTION C

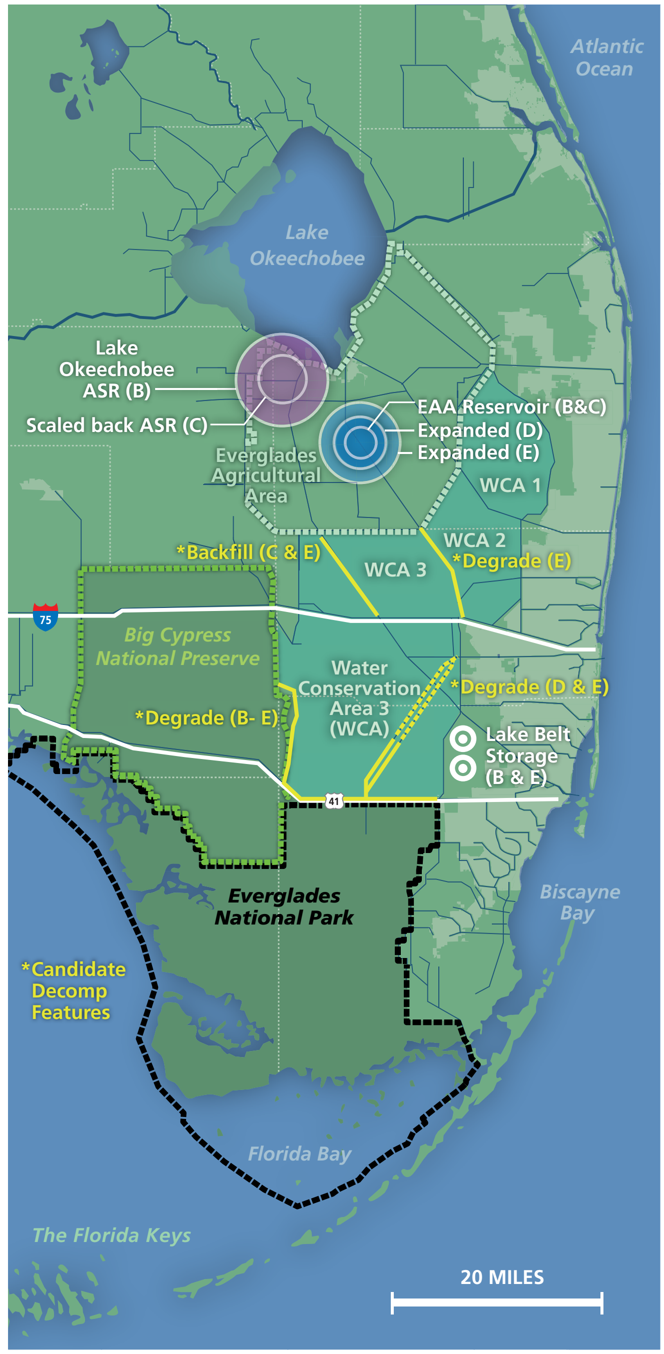
Scaled-back CERP, featuring 250 MGD ASR, no Lake Belt storage, no Bird Drive Basin storage, and partial decompartmentalization (as in Option B).

OPTION D

Expanded storage and decompartmentalization, featuring an expanded EAA reservoir (from 360,000 acre-ft to 1.3 million acre-ft) due to feasibility questions related to ASR and Lake Belt storage (both not included in Option D), increased decompartmentalization between WCA-3A and 3B.

OPTION E

Maximum decompartmentalization, featuring an expanded EAA reservoir (2.5 million acre-ft) to replace loss of ASR, direct connections between WCA-2A and 3A and between WCA-3A and 3B. Option E also includes Lake Belt Storage as conceived in CERP (Option B).



The SERES Team

EVERGLADES FOUNDATION

Stephen E. Davis III

G. Melodie Naja

Thomas Van Lent

SMITH COLLEGE

Paul R. Wetzel

Ibis Ecosystem Associates, Inc.
Environmental Consulting

Steven M. Davis

FIU

Evelyn Gaiser

Michael S. Ross

Jay Sah

Joel C. Trexler

ARIZONA STATE UNIVERSITY

Daniel L. Childers

CLEMSON UNIVERSITY

Bobby McCormick

UF UNIVERSITY of FLORIDA

Rena Borkhataria

Todd Osborne

CETACEAN LOGIC, INC.

Frank Marshall

TEL CONSULTING

Thomas E. Lodge

USGS science for a changing world

James Beerens

Judson Harvey

Jay Choi

ELM ECOLANDMOD, INC.

Carl Fitz

Hiram Henriquez

SERES Team Acknowledgements

We thank the following individuals for their important contributions to the development and management of the SERES project: Laura Bauman, Dr. Victor Engel (USGS), Dr. Fernando Miralles Wilhelm (UMd), Dr. Rosanna Rivero (UGa), Dr. Jerome Krueger (USFS), Felimon Gayanilo (UM-RSMAS), Alicia Logalbo (NPS), Dr. Tylan Dean (NPS), Kevin Kotun (NPS), Dr. Leonard Pearlstine (NPS), Kelly Keefe (USACE), Dr. David Rudnick (NPS), Aida Arik, and Hong Xu. Several key science managers provided critical guidance in Phase I of the project, including Dr. Nick Aumen (USGS), Dr. Fred Sklar (SFWMD), Dr. Garth Redfield (SFWMD), Dr. Susan Gray (SFWMD), and Deb Drum (Martin County). Lastly, numerous past and current resource managers and organization leads provided the Key Science Management Questions that were used as a lens to focus project scenarios and synthesis. These included: Dr. G. Ronnie Best (USGS, ret'd), Greg Knecht (TNC), Dr. Peter Ortner (UM-RSMAS), Don Fox (FWC), Col. Terry Rice (USACE, ret'd), John Adornato (NPCA), Greg May (Task Force, ret'd), Col. Al Pantano (USACE, ret'd), Dennis Duke (U.S. DOI), Eric Draper (Audubon Florida), Dr. Joe Walsh (FWC), Carol Wehle (SFWMD, ret'd), Shannon Estenoz (U.S. DOI), Ray Judah (fmr Lee Co. Commissioner), Nathaniel Reed (Everglades Foundation), Kirk Fordham (Everglades Trust), Paul Souza (USFWS), Charles Dauray (SFWMD, ret'd), Ken Ammon (SFWMD, ret'd), Tommy Strowd (SFWMD, ret'd), Stu Appelbaum (USACE, ret'd), and Eric Eikenberg (Everglades Foundation). Lastly, we thank Robert Johnson (U.S. DOI) and Dr. Carol Mitchell (NPS) for their long-standing support and valuable contributions to the SERES project since its inception. Project funding was provided by the U.S. Department of Interior through the Critical Ecosystem Studies Initiative (CESI).

Fishing in and around the Everglades is an important component of South Florida's tourist-based economy.

PHOTO BY THE EVERGLADES FOUNDATION

Everglades Restoration: It's worth it and it works!

Managers asked about the economics of Everglades restoration, particularly about cost: benefit, jobs creation, and priorities. Everglades Restoration is important from both ecological and economic perspectives. This massive subtropical wetland provides habitat to a unique assemblage of plants such as white water lily, bald cypress, sawgrass, mahogany, gumbo limbo, and ghost orchid and animals such as the American alligator, Roseate spoonbill, Wood stork, Florida panther, and Everglade snail kite. Currently, more than 70 Threatened or Endangered species depend on one or more areas of the Everglades for survival. The Everglades connects National Wildlife Refuges, Big Cypress National Preserve (BCNP) and two National Parks: Biscayne National Park (BNP) and Everglades National Park (ENP), the latter holding global status as a World Heritage Site, a Wetland of International Importance, and an International Biosphere Reserve. Restoration is designed to benefit these landscapes, habitats and species.

> ***"A restored Everglades ecosystem will benefit all these regions and the natural resources and ecosystem services they provide."***

The Greater Everglades Ecosystem also links outstanding communities and beaches with some of the world's best recreational fishing such as Sanibel-Captiva, Jupiter Island, Hobe Sound, Miami, Florida Bay, Islamorada, and Ocean Reef. A 2009 study by Bonefish Tarpon Trust on the *Economic Impact of Recreational Fishing in the Everglades Region*[2] indicated that saltwater and freshwater Everglades fishing accounted for over $1.2 billion of the state's total annual economic output. Valuable indeed. However, during years with polluted water discharge from Lake Okeechobee, as we saw in 2013, economic impact to tourism and real estate values can be disastrous for these communities. A recent study by the Florida Realtors Association[3] showed that polluted lake discharges from 2010 through 2014 had nearly a $1 billion negative impact on residential real estate values in Lee and Martin Counties. This stemmed largely from algae blooms that contributed to odorous or even toxic water conditions and beach closures.

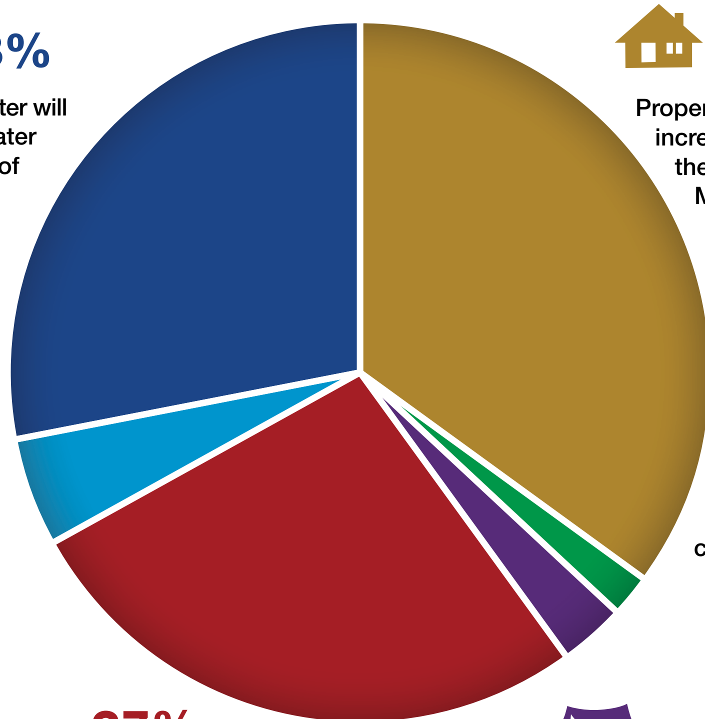
January 2013 photo of Kissimmee River restoration area showing a return to historic meandering flow conditions and an abundance of waterbirds (SFWMD).

CONTINUED ON PAGE 7

2 *Economic Impact of Recreational Fishing in the Everglades Region*, May 2013, Prepared by: Tony Fedler, PhD for Bonefish Tarpon Trust, 27 pages.
3 *The Impact of Water Quality on Florida's Home Values*, March 2015, Florida Realtors Association, 60 pages.

ECONOMIC GAINS BY SECTOR

Economic sectors considered and corresponding proportion of return on investment from Everglades restoration (Mather Economic Study, 2010).



Water Quality: 28%

Enhanced availability of freshwater will protect the region's drinking water supply and cut down on costs of purification methods, such as desalination facilities.

Real Estate: 35%

Property values are expected to increase for all 16 counties within the South Florida Water Management District, due to increased quality of drinking and recreational water.

Fishing: 5%

Recreational and commercial fishing industries will see a significant rebound with the protection of territory and enhanced water quality.

Open Space: 2%

Availability of trees and open space will help offset impacts of sea level rise and global climate change.

Habitat and Hunting: 27%

Restoring the Everglades will provide valuable ecosystem habitat. Native wildlife populations will flourish and lead to increased availability of wildlife viewing and hunting opportunities.

Park Visitation: 3%

Restoration of the Everglades ecosystem will increase wildlife populations and allow for more recreational opportunities during park visitation for residents and tourists.

CONTINUED FROM PAGE 6

A restored Everglades ecosystem will benefit all these regions as well as the natural resources and ecosystem services they provide. Perhaps more important to the economy and viability of South Florida, the Everglades is our water supply. A study by Mather Economics[4] in 2010 showed that Everglades Restoration generates more than 440,000 jobs over a 50-year project timeframe and a conservative 4:1 return on investment with the greatest returns in areas of Water Quality/Supply, Real Estate values, Habitat for animals and recreational hunting, and fishing. Other valuable services such as Carbon sequestration and storm surge protection were not considered in this study but, as indicated in our evaluation of SERES restoration scenarios, are anticipated to respond positively to restoration.

Based on the Mather study, we know Everglades

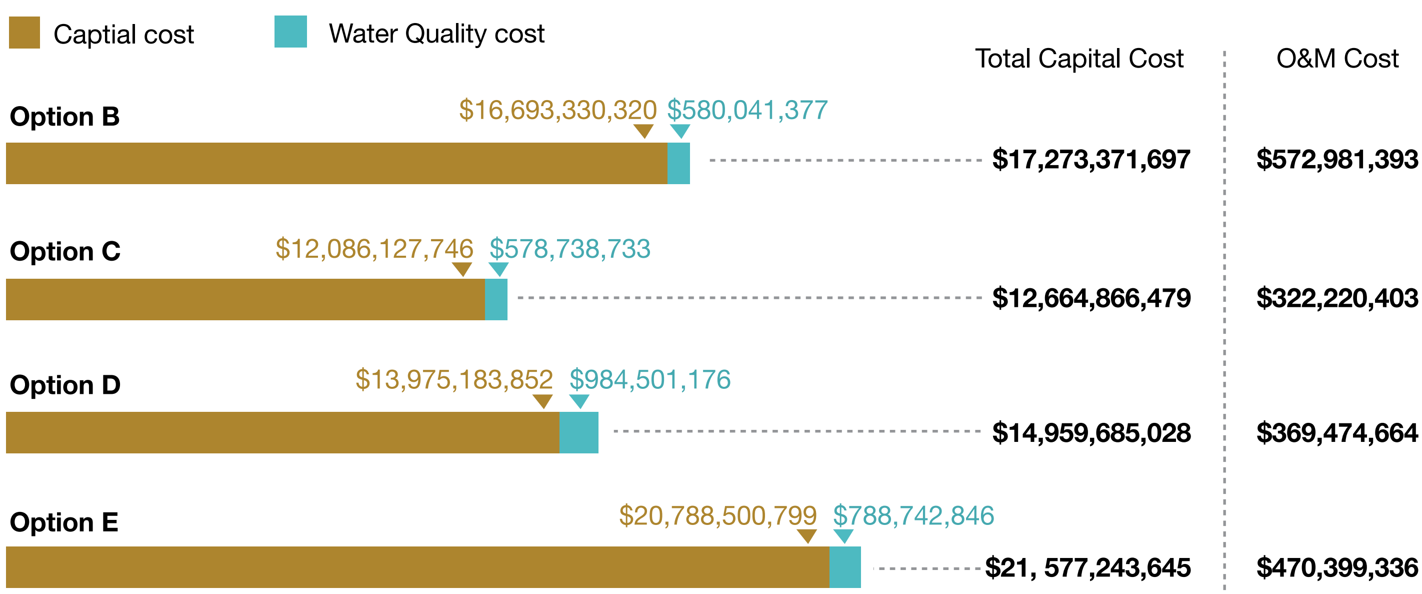
4 *Measuring the Economic Benefit of America's Everglades Restoration*, 2010, Mather Economics, 173 pages.

restoration is worth the investment. However, there are significant costs associated with Everglades Restoration and a long-term commitment to this investment is needed before we can realize the benefits. When it was originally signed into law in 2000, the CERP was estimated to cost between $7 and $8 billion to complete. Those costs have increased considerably over the past 15 years. When the costs of water quality features needed to meet the legally mandated phosphorus standard of 10 parts per billion are included, the cost to restore the flow of freshwater from Lake Okeechobee to the south rises even more. In estimating costs of each of the SERES options (including CERP), we considered capital costs for construction of hydrologic restoration as well as for construction of water quality features needed to meet the phosphorus standard (described on page 18). These costs are included in the table below.

Lastly, we know restoration works. The positive results we have seen in projects such as Kissimmee River Restoration, Picayune Strand, and the Deering Flow-way component of the Biscayne Bay Coastal Wetlands Phase I project all indicate that restoring the quality, quantity, timing, and distribution of freshwater flow back to these environments produces immediate benefits to habitats and wildlife. Further, our predictive tools have been refined over time allowing us to project that benefits from future projects such as the Central Everglades Planning Project (CEPP) will provide 30% habitat improvement to the River of Grass and that we will realize 80% of those projected benefits in areas as far south as Florida Bay within the first 2-5 years of implementation.

COST ESTIMATES FOR EACH OF THE SERES OPTIONS

Estimated capital and annual operations and maintenance (O&M) costs (in 2014 dollars) for flow (brown) and water quality (blue) restoration components of each of the SERES options. Water quality components are additional stormwater treatment areas (STAs) needed to attain the phosphorus standard. O&M values are estimated annual costs over a 50-year project lifespan and are above and beyond current O&M costs.



Montage illustrating valuable recreational wildlife watching and hunting activities in the Florida Everglades.

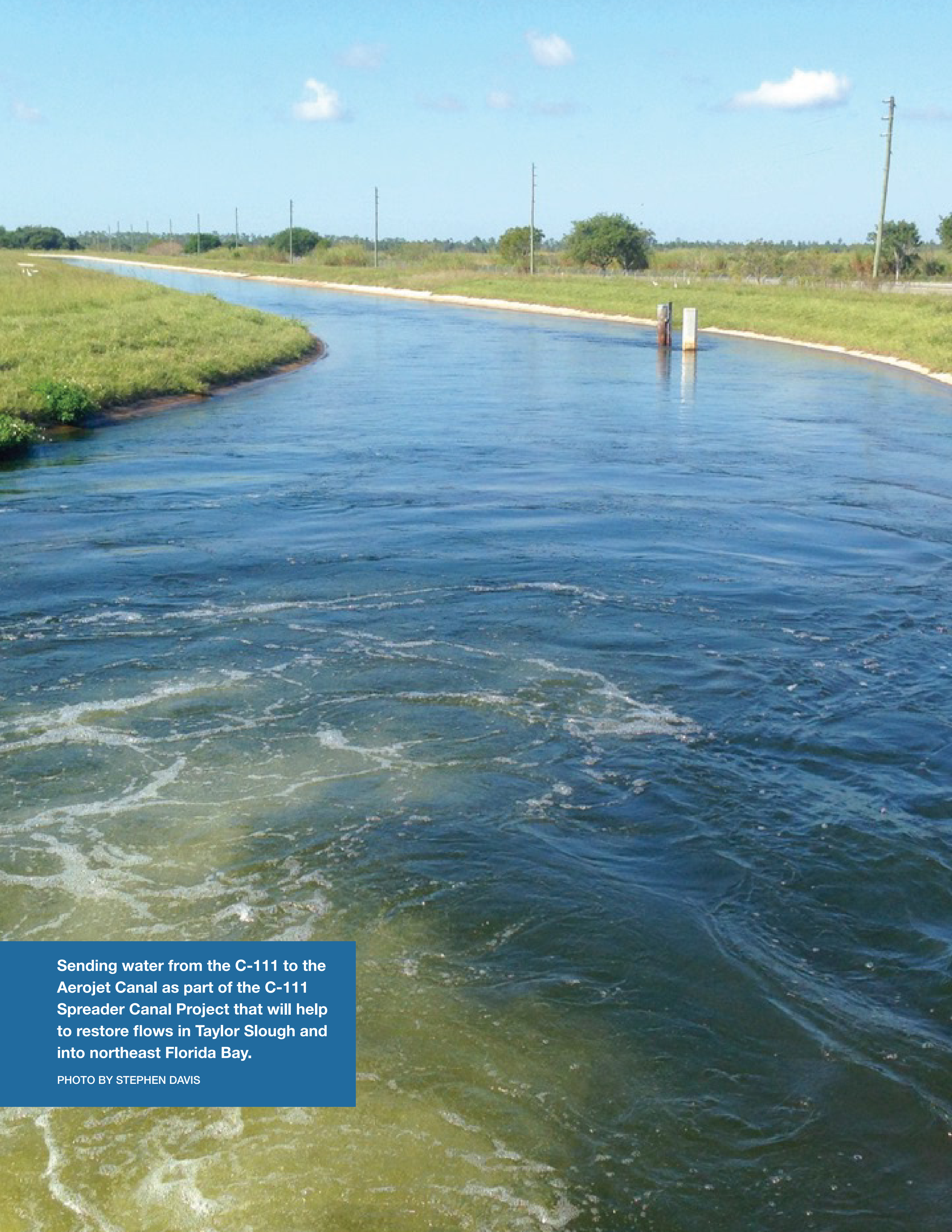
SUMMARY OF ECOSYSTEM SERVICES VALUATION OF EVERGLADES RESTORATION

Table from Mather Economics report (2010) highlighting value of ecosystem services improved by Everglades restoration according to the Comprehensive Everglades Restoration Plan (CERP) over a 50-year timeframe.

Service Benefits	Net Present Value of Restoration Benefits
Real Estate	$16,108,000,000
Groundwater Purification	$13,150,000,000
Wildlife Habitat & Hunting	$12,539,900,000
Recreational Fishing	$2,037,000,000
Park Visitation	$1,311,588,000
Open Space	$830,700,000
Commercial Fishing	$524,100,000
Total Value of Services	**$46,501,288,000**
Initial Investment in Everglades Restoration (2010 Estimate)	**$11,500,000,000**
Benefit-to-Cost Ratio	**4:1**

In addition to their environmental benefits, restoration projects such as the 1-mile Tamiami Trail Bridge create jobs for South Florida.

PHOTO BY STEPHEN DAVIS



Sending water from the C-111 to the Aerojet Canal as part of the C-111 Spreader Canal Project that will help to restore flows in Taylor Slough and into northeast Florida Bay.

PHOTO BY STEPHEN DAVIS

Everglades Hydrology: "Getting the water right"

Hydrologic modification through implementation of the C&SF Project has brought more than a half century of harm to the Everglades ecosystem. Given the importance of the quantity, quality, timing and distribution of water flows in the Everglades, it is no surprise that most management questions focused on aspects of Everglades hydrology and hydrologic restoration. Most managers asked questions about trade-offs and questions that would help prioritize decisions, including *How much water is available? How much do we need to store? How much land do we need for storage and treatment? Where should these storage features be located?*

> ***"Reducing reliance on ASR and still minimizing damaging regulatory discharges requires flowing more water south."***

The most direct answer to these questions is that the CERP spells out the locations and sizes of the reservoirs needed to deliver benefits (see pie chart on page 14). However, the basis for the question could also be recognition or an opinion that CERP storage may not be necessary or possible to implement. While there is a strong desire for a simple volumetric answer, our investigations show that determining the amount of storage needed for restoration is dependent on several factors, and three in particular: *water management strategy, location, and interaction with other infrastructure.*

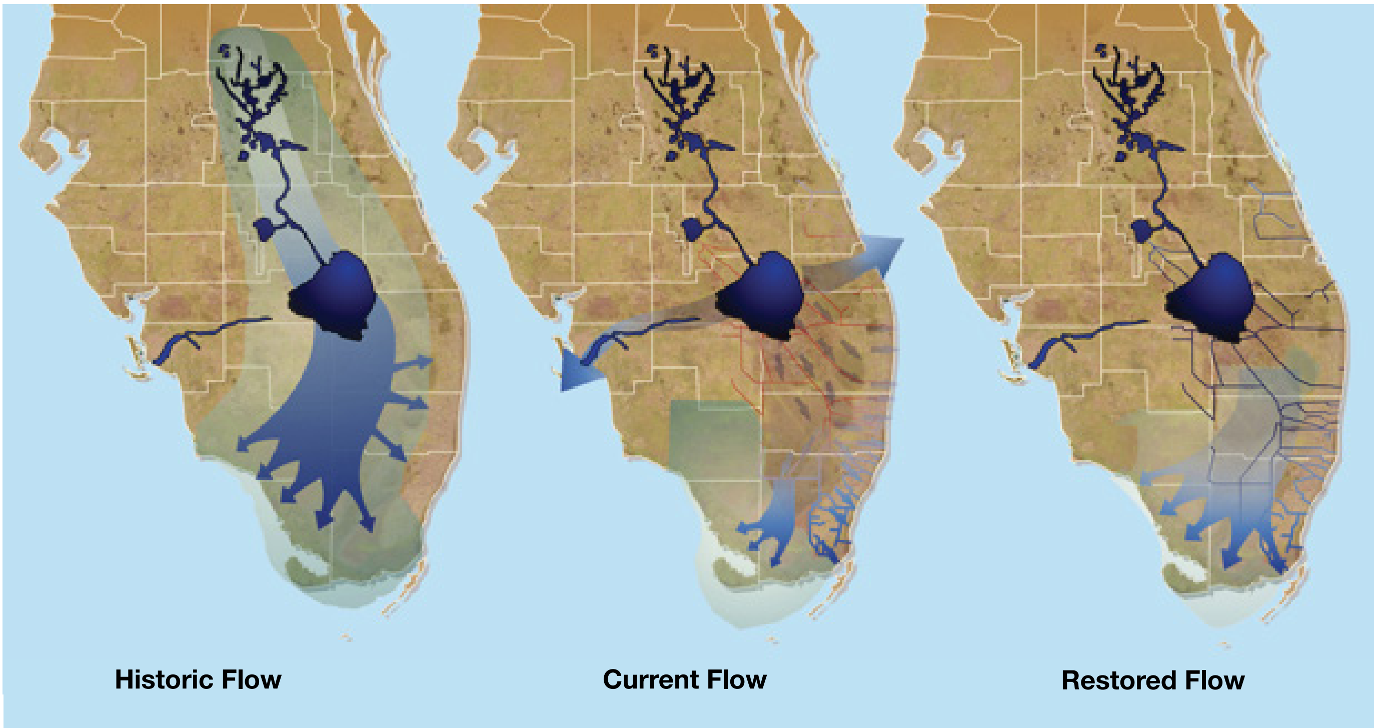
Water management strategies are the most important consideration. The best example of this in the CERP is ASR, where this technology is used to dramatically reduce harmful discharges to the St. Lucie and Caloosahatchee (i.e., Northern) Estuaries while maintaining Lake Okeechobee water levels within desired

CONTINUED ON PAGE 13

WHY IS IT IMPORTANT?

We are currently dumping about 1.7 billion gallons of freshwater per day (on average) to tide. This water used to flow south into the Everglades. In order to restore the Everglades and the northern estuaries as well as provide us with a sustainable water supply for the future, we need to store, clean and re-direct that water back to the Everglades.

The 1-mile bridge along Tamiami Trail will help to restore flow into northeast Shark River Slough of Everglades National Park.



Maps depicting historic flow through the Everglades ecosystem (left), the current showing much of the flow going to the Caloosahatchee and St. Lucie Rivers (center), and the restored state (right). The restored state reflects the intended general pattern and magnitude of flows in the SERES restoration scenarios (Options B through E). National Park Service

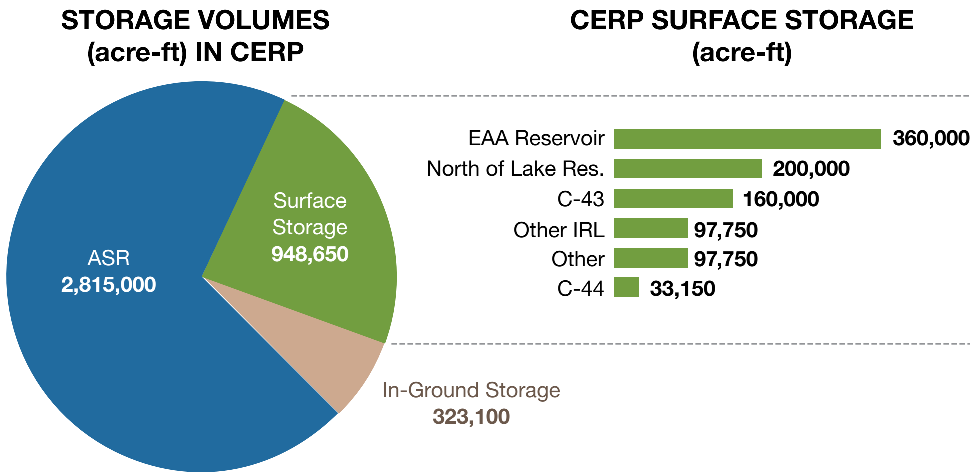
CONTINUED FROM PAGE 12

limits. This is a priority during high rainfall/flood periods and requires an incredibly large storage capacity. For example, the maximum amount of water in the Lake Okeechobee ASR "bubble" as conceived in the CERP is roughly equivalent to the storage in the Lake itself. Despite the magnitude of this volume, full implementation of ASR accounts for only about half of the expected decrease in discharges to the St. Lucie and Caloosahatchee estuaries, cutting total annual discharges from 207,000 acre-ft /year to 106,000 acre-ft/year on average. Lake Okeechobee ASR also aids in controlling Lake Okeechobee stages, and our ability to manage for high water conditions in the lake is directly proportional to ASR capacity.

Location is a second important factor; reservoirs tend to benefit the areas closest to them. The farther away, the more the intervening infrastructure and other features have an effect. The best example is the in-ground reservoirs (i.e., re-purposed rock pits) in the North and Central Lake Belt in CERP. These reservoirs provide water supply to Water Conservation Area 3B, eastern Everglades National Park, Biscayne Bay, and to urban users in Miami-Dade county. The benefits to Everglades National Park during drought are dependent on this reservoir, as is water supply for Miami-Dade County and Biscayne Bay. If these reservoirs are not included in the plan, delivering the same array of benefits in the same magnitude is difficult.

Interaction with other infrastructure is also extremely important. For example, there is a strong relationship between removing the levees/dams in the WCAs and the amount of storage required in the EAA.

A breakdown of total annual storage of the CERP (left) and further breakdown of surface storage (right). The majority of CERP storage is invested in Aquifer Storage and Recovery (ASR), the bulk (approx. 2.4 million acre-ft) of which is Lake Okeechobee ASR.



When the Everglades are impounded, less storage is needed as the WCAs act like reservoirs. A consequence of this is that Everglades National Park, downstream of the WCAs, is too dry. When the dams are removed, more storage and inflow at the top is needed to maintain flows and depths in the marsh. Thus, there are trade-offs with respect to storage capacity. For example, storage can be decreased if flows (both to the Everglades and to the estuaries) are increased. But increased flows also result in deeper water levels in the Everglades.

With these considerations in mind, our analysis suggests that the range of requisite storage is around 2.2 million acre-ft of new storage.

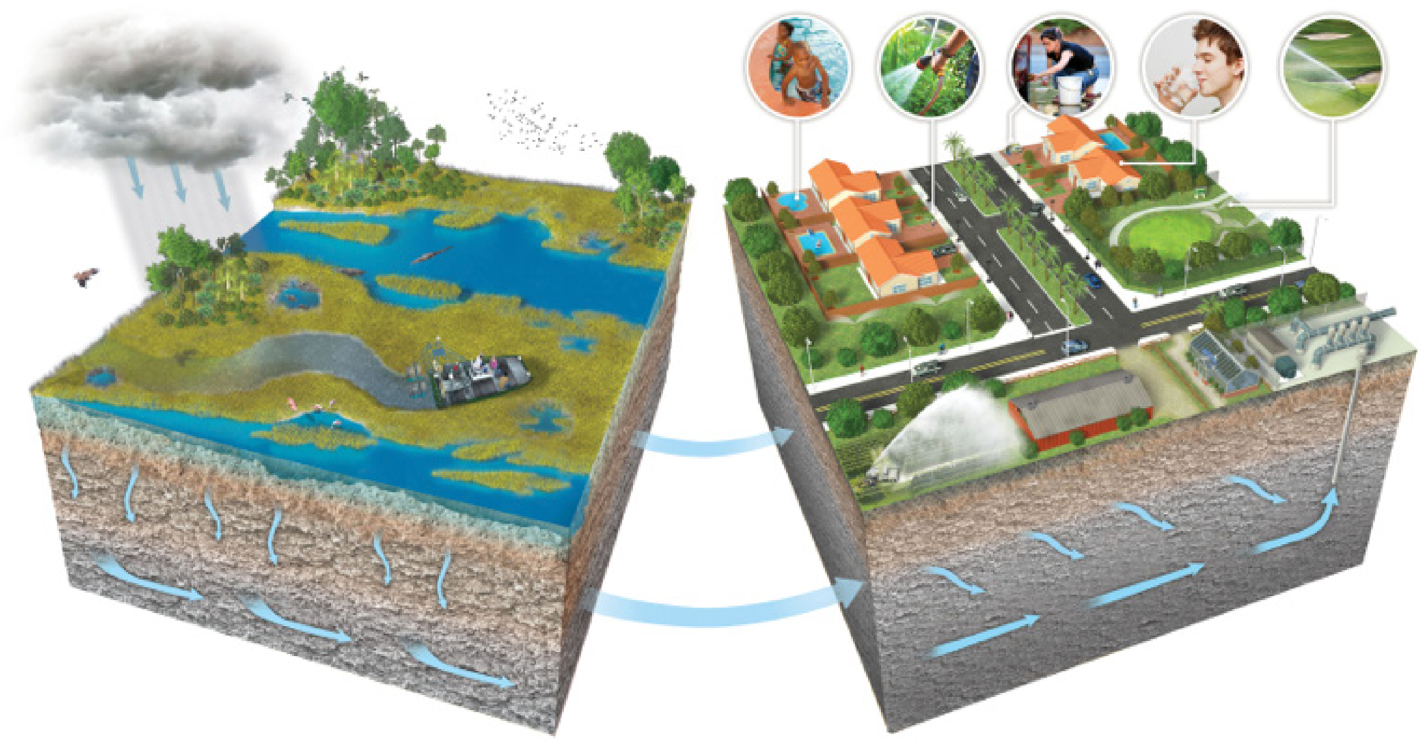
See table on page 16 for a comparison of storage projects and volumes in each of the options we examined. These options looked primarily at the trade-offs between ASR and surface storage. Our hydrological and ecological analyses suggested that additional surface storage, which tended to decrease flows to the Northern Estuaries and deepen water levels in the Everglades, was the preferable direction for restoration when trying to decrease storage needs. There are, however, limits on depths in the Everglades and not all "available" water in Lake Okeechobee can be stored or sent south.

More Tradeoffs: There is no way to meet all the needs of Lake Okeechobee, the Everglades, and the Northern Estuaries while meeting water supply demands. There are many possible configurations and each has drawbacks. Reducing reliance on ASR and still minimizing damaging regulatory discharges requires flowing more water south (i.e., to the Everglades) during wet periods, which increases depths in some parts of the Everglades. Eliminating in-ground reservoirs (i.e., Lake Belt) dramatically decreases overall costs, yet it is difficult to deliver all of the same benefits, especially to Everglades National Park and Biscayne Bay, with a larger reservoir north of the remnant Everglades. However, building storage north of the remnant Everglades and flowing more water through the marsh provides operational flexibility and ecological benefits that extend all the way to Florida Bay.

Managers also asked about the feasibility of ASR. The recent Technical Data Report[5] provides us with a comprehensive perspective. This study concludes that there are no technical issues as to whether ASR will work; however, the CERP was overly optimistic on ASR capacity. It is clear that coupling ASR with surface storage reservoirs greatly improves reservoir efficiency. For example, in the C-43 reservoir, the ASR component accounts for 30% of the reservoir benefits, and the

CONTINUED ON PAGE 15

5 SFWMD and USACE. 2015. *Final Technical Data Report: Aquifer Storage and Recovery Regional Study.* 269 pages.



Rainfall over the Everglades recharges the Biscayne Aquifer that nearly 8 million Floridians depend on for their daily supply of freshwater. Restoring flow back to the Everglades will ensure ample supply of water for a healthy Everglades and our water supply.

CONTINUED FROM PAGE 14

maximum volume stored in the ASR "bubble" actually exceeds the size of the surface reservoir. We included these smaller ASR/reservoir projects in all options. However, we considered Lake Okeechobee ASR — the largest piece of the CERP storage pie — as just one storage option to achieve the water management objectives of moderating Lake Okeechobee stages and reducing flood releases to the Northern Estuaries. The SERES Team also examined the relative costs of ASR and surface storage as part of this investigation and estimated that ASR would cost approximately $205 per acre-ft per year of "effective storage", while surface reservoirs would cost on the order of $150 per acre-ft annually.

We also considered the feasibility of in-ground reservoirs such as the Lake Belt storage features in the CERP. While the smallest component of storage in CERP, modeling tells us that these in-ground reservoirs play a critical role in providing dry season benefits to Everglades National Park and WCA 3B, water supply to Biscayne Bay, and for urban water supply. To date, the Corps and SFWMD have not conducted any studies of their viability. However, we have technologies that can be applied to improve the viability of in-ground reservoirs also allowing us to make some estimate of their cost.

Preliminary modeling shows that an in-ground reservoir is viable if the seepage through the sides and bottom can be controlled. Our calculations indicate that sealing the sides down to the bottom of the rock pit is insufficient; controlling seepage through the bottom is essential. We considered the cost of two methods: (a) sheet-pile along the sides (about 55 feet) of the reservoir and then pavement along the bottom, and (b) sheet pile down through the confining layer (about 120 ft),

CONTINUED ON PAGE 16

CONTINUED FROM PAGE 15

cutting off seepage from the bottom. We found that the latter is likely cheaper, though it costs roughly $225 per acre-ft of storage, significantly more expensive than ASR or surface reservoirs.[6]

We were unable to reproduce the benefits modeled with reservoirs located elsewhere, pointing again to the importance of storage location. Increasing storage north of the Everglades Protection Area and relying on increased in flows did not simulate the dry season and drought-year benefits of the in-ground reservoirs. Seepage losses along the eastern side of WCA 3B were the primary reason. This seepage could be reduced by modifications to seepage control projects in the CERP, but that requires balancing "Savings Clause" concerns and other promised benefits that maintain existing levels of water supply and flood control.

Table of storage components and volumes (acre-ft) considered in SERES Options B through E. Storage features are relative to the CERP (Option B), and storage features and volumes unique to individual options are shaded in brown.

STORAGE COMPONENT	OPTION B	OPTION C	OPTION D	OPTION E
Surface Storage				
EAA Reservoir	360,000	360,000	360,000	360,000
Lake Okeechobee Watershed Reservoir	200,000	200,000	200,000	200,000
C-43	160,000	160,000	160,000	160,000
C-44	33,150	33,150	33,150	33,150
IRL S. Reservoirs	97,000	97,000	97,000	97,000
Central Palm Beach County Reservoir	19,920	19,920	19,920	19,920
Site 1	13,940	13,940	13,940	13,940
Bird Drive Reservoir	11,600	0	0	11,600
C-9	13,800	13,800	13,800	13,800
C-11	13,800	13,800	13,800	13,800
Other Surface Storage	0	0	890,000	2,140,000
ASR				
Lake Okeechobee ASR	2,456,000	822,780	0	0
C-43 ASR	171,700	171,700	171,700	171,700
C-51 ASR	118,800	118,800	118,800	118,800
Site 1 ASR	13,940	13,940	13,940	13,940
Hillsboro ASR	10	10	10	10
CAT ASR	53,900	53,900	53,900	53,900
In-Ground				
North Lakebelt	146,600	0	0	146,600
Central Lake Belt	100,500	0	0	100,500
L-8	76,000	76,000	76,000	76,000
Total Storage (acre-ft) added to Existing Condition	**4,060,660**	**2,168,740**	**2,235,960**	**3,744,660**

6 Costs for ASR, surface reservoirs, and in-ground reservoirs sourced from Lake Okeechobee ASR Pilot Project, Talisman A-1 Flow Equalization Basin, and independent engineering cost estimates, respectively.

Microcystis algae bloom in the C-44 next to S-308, just downstream of eastern Lake Okeechobee (2015).

PHOTO BY DR. PAUL GRAY

Everglades Water Quality: There is no compromise

Although other water quality concerns such as mercury exist in South Florida, phosphorus (P) is the most important in terms of its system-wide impacts in the Everglades. Modeling of our restoration options assumed reaching the State of Florida water quality standard of a 10 parts per billion (ppb) geometric mean of Total Phosphorus (TP) in surface water. Restoring flow from Lake Okeechobee back to the Everglades requires more stormwater treatment areas (STAs), as the current STA system is designed to accommodate existing flows from the Everglades Agricultural Area (EAA). The STA expansions required for the SERES restoration scenarios ranged from 28,500 acres (under a reduced storage Option C) to 47,000 acres (under Option D) and represent a significant cost in addition to decompartmentalization, conveyance and storage infrastructure.

> ***"There is ultimately no trade-off between water quality and quantity when restoration decisions are made."***

Managers often asked whether we could restore flows to the Everglades before water quality standards are met. We concluded that water column concentrations of TP above the 10 ppb "ecological threshold" set off a cascade of ecosystem impacts regardless of whether TP is 20 ppb or 200 ppb. The end point is always a cattail-dominated marsh with high P-containing soils that do not accrete Everglades peat. When water with TP concentrations above 10 ppb enters Everglades wetlands, the speed of the impacts is determined by the magnitude of P load. Ecosystem changes take longest to occur with low volume inflows and TP content only slightly higher than 10 ppb. The most rapid transformation occurs with high flows of water with TP concentrations well

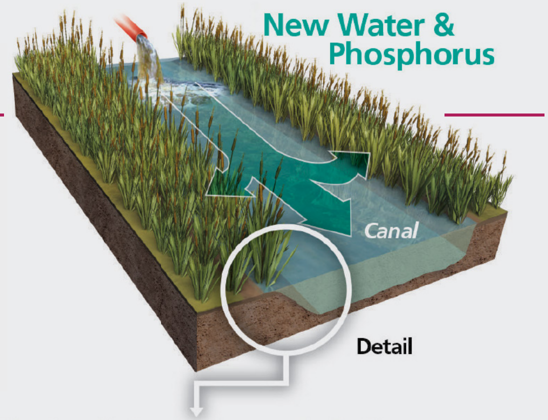
CONTINUED ON PAGE 20

WHY IS IT IMPORTANT?

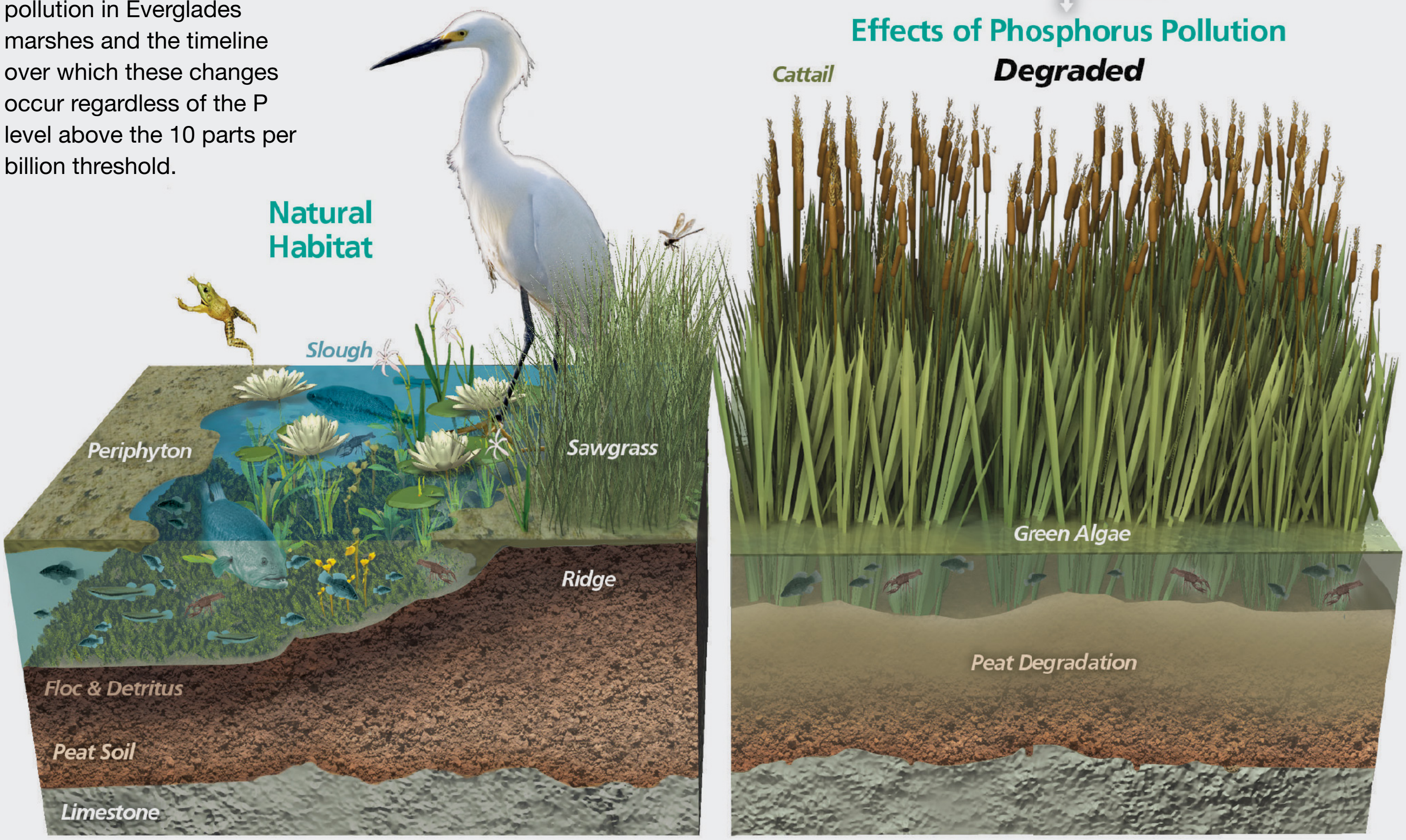
The Everglades developed for thousands of years under extremely low nutrient conditions, especially phosphorus (P). As a result, the ecosystem is highly sensitive to increased availability of P. Phosphorus pollution comes primarily from runoff of EAA fields and results in the loss of periphyton and Everglades habitat. Phosphorus is virtually impossible to remove once it is in the Everglades so we need to do our best to reduce the amount coming into it.

Water polluted with phosphorus discharged from Lake Okeechobee through the S-80 into the St. Lucie River and ultimately into Lower Indian River Lagoon (2013). Photo by Jessica Hodder

Cascading Effects of Phosphorus Pollution

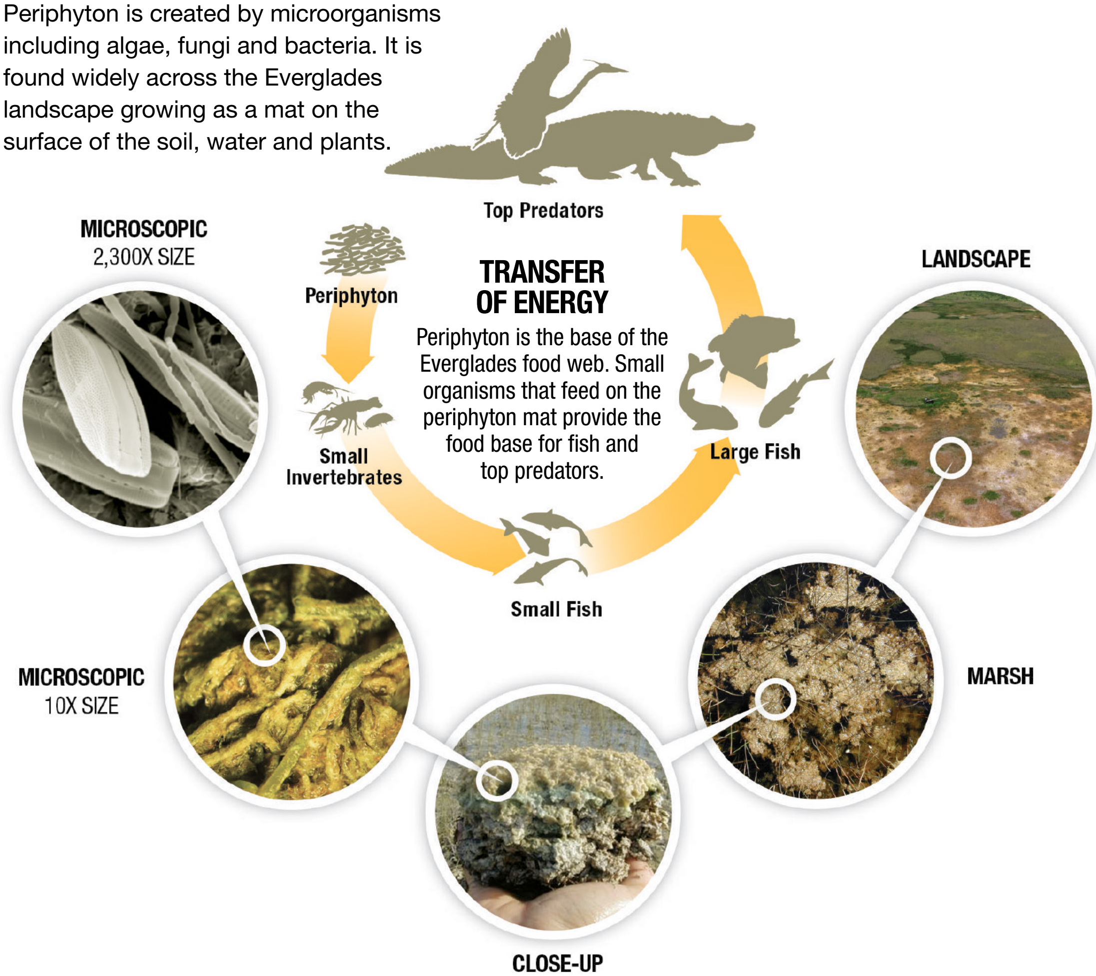


Impacts of phosphorus pollution in Everglades marshes and the timeline over which these changes occur regardless of the P level above the 10 parts per billion threshold.



Periphyton THE BASE OF THE EVERGLADES FOOD WEB

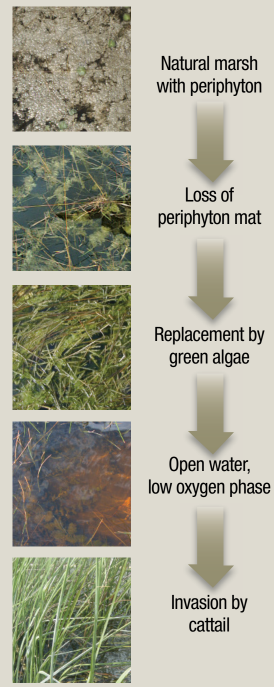
Periphyton is created by microorganisms including algae, fungi and bacteria. It is found widely across the Everglades landscape growing as a mat on the surface of the soil, water and plants.



PERIPHYTON AND PHOSPHORUS POLLUTION

Periphyton is extremely sensitive to changes in water quality. Scientists have shown that when phosphorus concentrations get above 10 parts per billion, periphyton disappears, resulting in changes to the Everglades food web.

CHANGE IN LANDSCAPE OVER TIME



CONTINUED FROM PAGE 18

above the threshold. The only way to maintain a non-impacted Everglades wetland ecosystem is for water entering the system to have TP concentrations at or below 10 ppb. *Thus, both water quality and quantity are needed if we want the Everglades to look and function as it did historically*.

In their questions, managers also wondered whether polluted marshes could be rehabilitated over time with "clean" water (i.e., with TP concentrations at or below 10 ppb). Phosphorus has a very conservative cycle between water, plants, and soil. Once P is in a wetland, it will recycle in place and remain in the marsh or will be slowly transported downstream, often leading to a downstream cascade of impacts. The only real solution may be isolation (capping) or physical removal of high P soils. These engineered solutions would have significant impacts and would change the hydrology of the system. We see no ready solutions to rehabilitating polluted Everglades marshes solely with "clean water" introductions. However, studies such as the Cattail Habitat Improvement Project (CHIP)[6] may shed light on other possible habitat remediation strategies for P-contaminated wetlands in the near-term.

6 *http://soils.ifas.ufl.edu/wetlands/research/chip.pdf*

Everglades estuaries depend on a natural balance of fresh and saltwater. The solution to the problem of too much freshwater in the Northern Estuaries is the same as the solution to the problem of too little fresh-water in Florida Bay.

PHOTO BY BRIAN CALL

Everglades Estuaries: Too much or too little freshwater

Restoring the flow of freshwater to the Everglades will have region-wide benefits. For every increment of water we can send south from Lake Okeechobee to the "River of Grass", we can reduce the polluted regulatory discharges to the Caloosahatchee and St. Lucie River estuaries (a.k.a., the Northern Estuaries). SERES scenarios demonstrated this, with a 66% to 80% reduction in regulatory discharges to both Northern Estuaries. Interestingly, there was no added benefit to the Northern Estuaries of doubling the storage capacity of an aboveground reservoir, as Option D showed the greatest overall reduction in Lake Okeechobee discharges to the Caloosahatchee (82% reduction) and St. Lucie Rivers (79% reduction).

> *"By restoring freshwater flow to the south of Lake Okeechobee, we improve estuarine conditions in Florida Bay."*

Regulatory discharges to the Northern Estuaries impact estuarine conditions necessary to support important fisheries habitat such as oyster reefs and seagrass beds. Because of the high nutrient load associated with Lake Okeechobee water, these discharges also lead to algae blooms that can be toxic and lead to hypoxic conditions. Combined with habitat destruction, these conditions spell disaster for estuarine organisms ranging from recreationally important fish species, to herbivorous manatees, and predators such as dolphins. Lake discharge events also bring economic harm, as was experienced in the summer of 2013 when beaches and waterways were closed to fishing and swimming. A recent study by the Florida Realtors Association[7] showed that lake discharges from 2010 through 2014 had nearly a negative $1 billion negative impact on real estate values in Lee and Martin Counties.

WHY IS IT IMPORTANT?

Estuaries are where rivers meet the sea. As such, they typically exhibit a range of salinity from freshwater (0 parts per thousand or ppt) to marine (35 ppt). The Caloosahatchee River, St. Lucie River, and Florida Bay estuaries are among the most productive in the state of Florida and most valuable in terms of recreational opportunities. However, they are regularly impacted by nutrient pollution and periods of too much or too little freshwater flow as a consequence of the current water management.

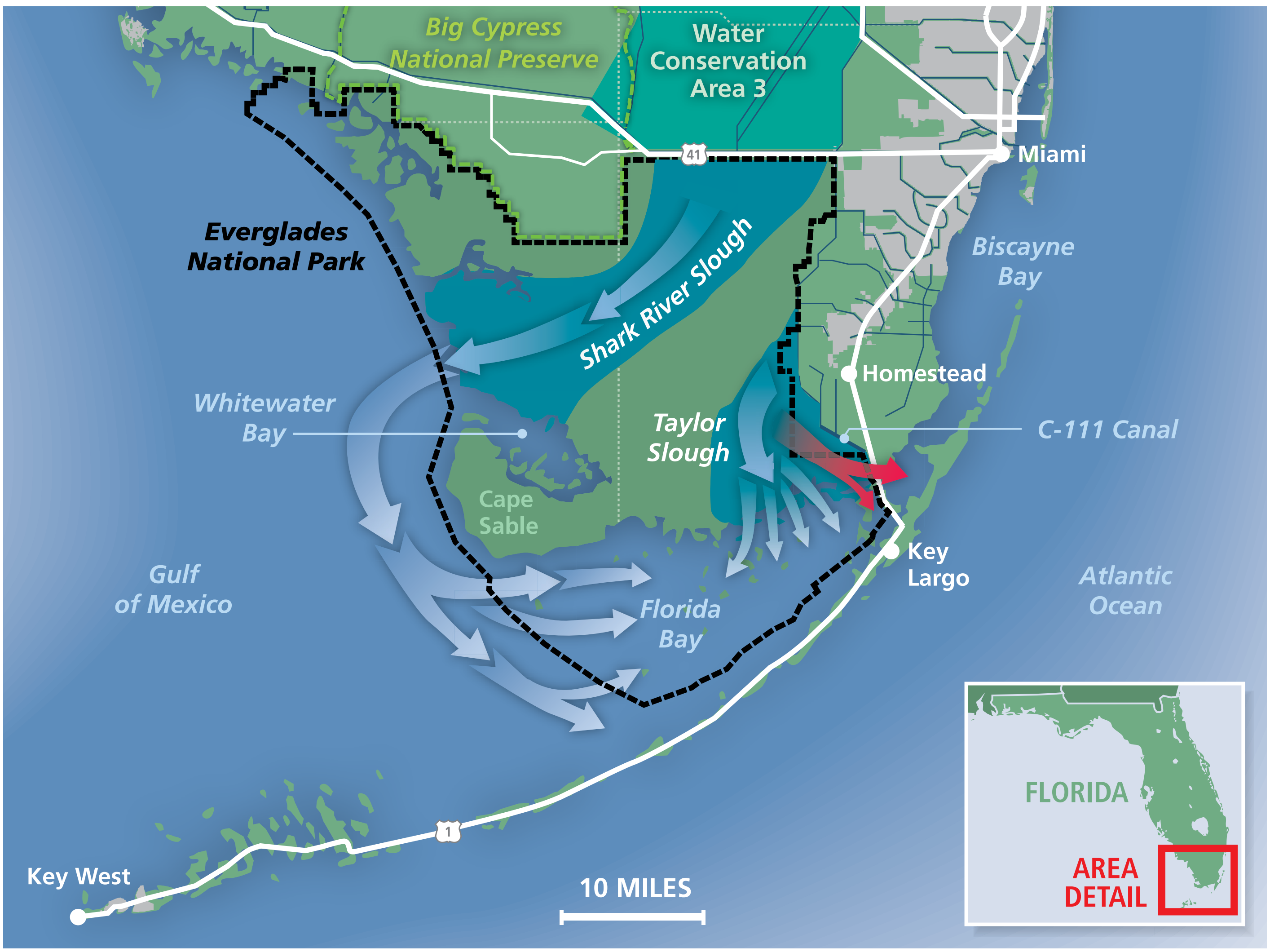
By restoring freshwater flow to the south of Lake Okeechobee, we improve conditions within the Everglades as well as Florida Bay. This is because increased freshwater flow into Everglades National Park will pass into Florida Bay through Shark River Slough and Taylor Slough. Currently, Florida Bay suffers from a lack of freshwater inflow relative to pre-drainage conditions. However, projects such as

CONTINUED ON PAGE 24

7 *The Impact of Water Quality on Florida's Home Values*, March 2015, Florida Realtors Association, 60 pages.

Sanibel-Captiva area of Charlotte Harbor and the Caloosahatchee River Estuary highlights the polluted water plume from Lake Okeechobee during the 2013 discharge event. (Photo from SCCF)

The St. Lucie River Estuary highlights the polluted water plume from Lake Okeechobee during the 2013 discharge event. (Photo by Jacqui Thurlow-Lippisch)



Map showing flow paths to Florida Bay from Shark River Slough and from Taylor Slough. Historic inflows from Taylor Slough in blue, and current modified flows are in red.

CONTINUED FROM PAGE 22

the C-111 Spreader will help to prevent the diversion of water away from Florida Bay. SERES restoration scenarios all showed improved (i.e., reduced) salinity conditions across the bay relative to the existing condition and did not differ significantly from one another. All scenarios showed about a 2 ppt reduction in the bay-wide average salinity, which would improve fish habitat across the bay as well as conditions for estuarine prey fish species essential to supporting sportfish such as snook and spotted seatrout as well as other imperiled species such as the Roseate spoonbill and American crocodile.

Dead seagrass floating on the surface of Florida Bay following a die-off that resulted from inadequate fresh-water inflow in the summer of 2015. **(Photo from FWC-FWRI)**

Illustration showing recreational and aesthetic amenities of a healthy Florida Bay ecosystem.

Early 2015 photo of over-dried peat soil along the periphery of Shark River Slough in Everglades National Park near Pay-Hay-Okee overlook .

PHOTO BY BEN WILSON

Everglades Soil: Restoring peat development

Managers wanted to know how Everglades soils respond to changes in hydrology and water quality and whether the Everglades will continue to be a carbon sink with climate change. Across much of the pre-drainage Everglades, organic-rich peat soil—comprised of dead roots, stems, and leaves of wetland plants—accumulated gradually over hundreds to thousands of years under very wet and low nutrient conditions. Some areas of the Everglades accumulated more peat to relatively high elevations, resulting in shorter duration of flooding that supported tree islands or sawgrass ridges. Other areas were maintained at lower elevations by high sheetflow and therefore had longer periods of flooding and supported deeper water slough habitat. Collectively, these topographic lows and highs contributed to the unique ridge-and-slough landscape pattern of the Everglades. Because of the significant role soils play in the health and function of the Everglades, peat soil conservation, improved water quality, and promoting hydrologic conditions suitable to peat soil accumulation are essential to restoration.

> ***"Until we restore the flow of clean freshwater throughout the Everglades and all the way to Florida Bay, we will continue to lose peat soil and landscape pattern..."***

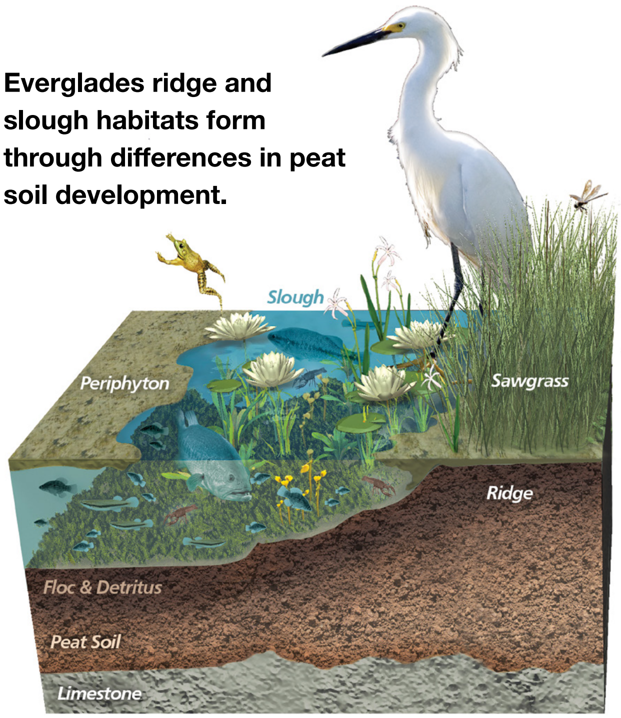
As peat soils develop, they gradually accumulate elements over time and therefore represent reservoirs of carbon (C), nutrients such as Nitrogen (N) and Phosphorus (P), and even low levels of other elements such as iron and mercury. With the drainage of the Everglades over the past century, peat soils have rapidly decomposed. Vast areas of peat soil were lost due to excessively dry conditions or intense fire, resulting in the flattening of the Everglades and the loss of landscape pattern, release of C to the atmosphere and release of N and P to the Everglades. Excess loading of agricultural pollutants — such as P — over the past half century has polluted Everglades sawgrass marsh, replacing it with dense cover of cattail with little habitat value. Although these polluted cattail marshes accumulate soil organic matter at a relatively high rate, it is not Everglades peat soil and does not represent a desirable restoration condition. Further, the agriculturally-derived P in these soils is virtually impossible to remove and the negative impacts of the P will continue into the future.

WHY IS IT IMPORTANT?

Peat soils are the foundation upon which key Everglades habitats exist. These soils develop and are sustained over long periods of time by plants and water. When over-drained or exposed to saltwater, freshwater peat soils undergo rapid decomposition, resulting in the loss of elevation, habitat and the release of their primary constituents (carbon, nitrogen, phosphorus, etc.).

CONTINUED ON PAGE 2 7

Everglades ridge and slough habitats form through differences in peat soil development.



Soil from Everglades slough showing floc and peat layer. **(Photo from Todd Osborne)**

CONTINUED FROM PAGE 26

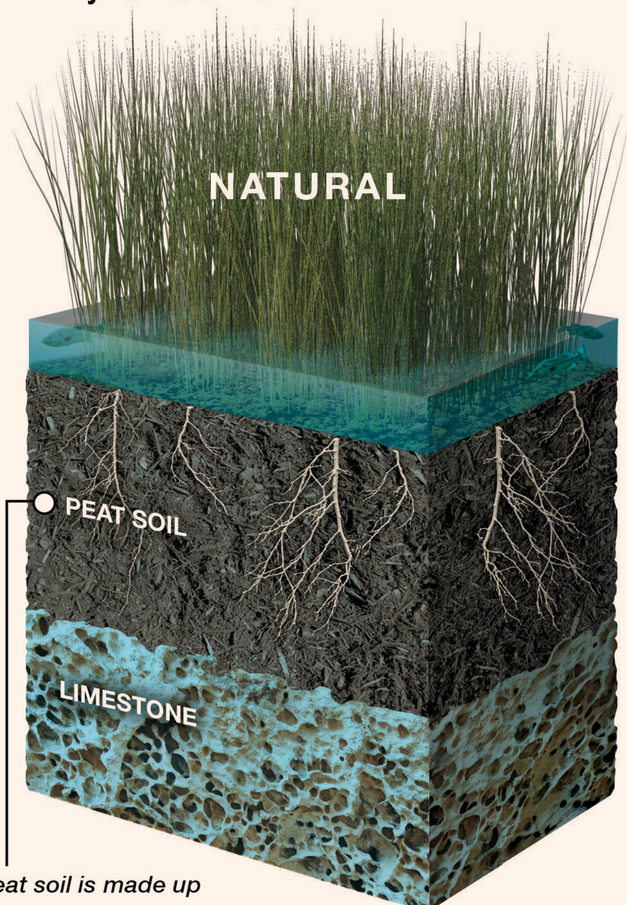
Everglades peat soil accretion improves in all SERES restoration options, with Options D and E resulting in the greatest area of improved soil condition. Soil phosphorus (P) uptake — an indicator of eutrophication — decreases across all options as compared to the existing condition. Until we restore the flow of clean freshwater througout the Everglades and all the way to Florida Bay, we will continue to lose peat soil and landscape pattern — regardless of climate change and sea level rise. However, with climate change, we can expect warmer conditions across south Florida. Projections for rainfall under a future climate are less predictable, but a warmer climate will tip the water balance towards more of a water deficit, exacerbating peat soil loss as described above. It is widely accepted that Everglades Restoration assists with climate change adaptation, as the improved water quality and increased storage capacity will allow us to conserve existing peat soils while promoting development of peat soil in restored areas.

In terms of sea level rise impacts, scientists are beginning to address the impacts of increased saltwater intrusion and inundation on freshwater peat soils near the coast. Documentation of peat collapse with saltwater intrusion has been shown in other coastal wetlands and recent evidence from the Everglades suggests it is an ongoing problem contributing to soil and habitat loss in freshwater marshes near the coast (see Climate Change section on page 38). Restoring the flow of clean freshwater to the Everglades will not stop sea level rise, but it will slow the process of peat collapse. This will allow habitat more time for natural adaptation and succession to other healthy states as opposed to a rapid decline.

Peat Soil Development and Loss

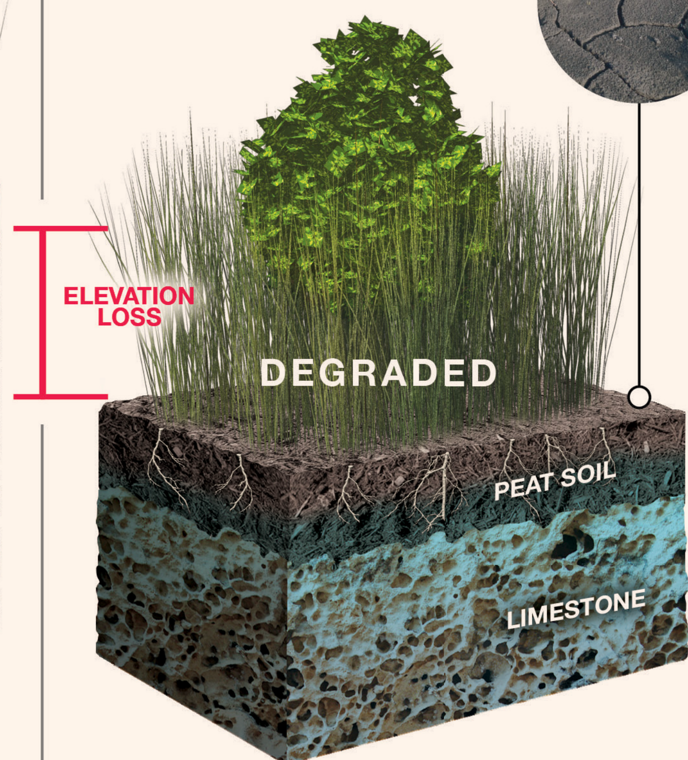
Peat soil, also called muck soil, blankets the limestone bedrock across much of the Everglades and is the foundation upon which key habitats exist.

When drained, peat soil degrades rapidly resulting in elevation loss and habitat change. Peat degradation also releases atmospheric carbon dioxide and polluting nutrients such as nitrogen and phosphorus.



Peat soil is made up of dead and partly decomposed plants and develops very slowly (over centuries to millennia!) in the presence of water.

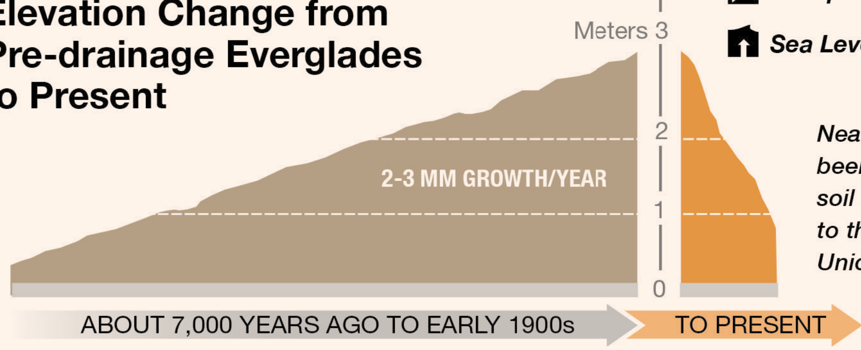
Photo of dried peat soil in Everglades National Park in April 2015.
Photo: Ben Wilson



In addition to the impact of drainage...

- ***Drought** exacerbates peat soil degradation.*
- ***Fire burns** peat soil down to the limestone bedrock.*
- ***Phosphorus Pollution** changes and degrades peat soils.*
- ***Sea Level Rise** catalyzes the rapid collapse of peat soils.*

Peat Soil Development and Elevation Change from Pre-drainage Everglades to Present



Nearly 3.5 billion metric tons of carbon dioxide have been lost to the atmosphere due to Everglades peat soil loss. To put this into perspective, this is similar to the annual CO_2 emissions of the European Union, a population of more than 0.5 billion.

Everglades habitats, including tree islands, sawgrass ridges, and deep water sloughs, are essential in supporting and maintaining a diverse array of fish and wildlife.

PHOTO BY FRANCO TOBIAS

Everglades Landscape Pattern: Ridges, sloughs, and tree islands

Can we restore lost habitats in the Everglades? What are the tradeoffs between flows needed to restore habitats and the needs of wading birds such as the Wood stork and endangered species such as the Cape Sable seaside sparrow? These were the most often-asked management questions related to Everglades landscape pattern that includes tree islands, sawgrass ridges, and deepwater sloughs.

> ***"Everglades ridge and slough landscape will undergo moderate improvement with any of the restoration options."***

Restoration of the patterned landscape of ridges, sloughs and tree islands as well as the adjoining shorter-hydroperiod marl prairie landscape in Everglades National Park (ENP) will require balancing of water deliveries through monitoring and adaptive management once water storage and conveyance infrastructures are in place. Re-directing water from WCA-3A to the east into its natural flow path in Shark River Slough will prevent the extensive marl prairie in western ENP from unnatural flooding, providing much needed relief for the Cape Sable seaside sparrow.

Restoring ridge and slough habitats within the patterned peatland landscape is one of the biggest challenges in Everglades Restoration. Ridge and slough habitats have been lost in ponded areas in southeast WCA-3A and over-drained areas (e.g., northeast Shark River Slough, WCA-3A north, and WCA-3B) where sawgrass has encroached into sloughs. Sawgrass encroachment appears difficult to reverse once sawgrass expands to 60% or more of the ridge and slough habitat because when that happens the ridge is gone and the landscape is flat.

WHY IS IT IMPORTANT?

A patterned ridge and slough wetland is essential for the seasonal hydrologic recession and concentration of small fish and other animals eaten by wading birds across the Everglades landscape. Tree islands are another essential Everglades habitat type and provide a home for many upland species of plants and animals.

The recovery of degraded ridge and slough patterns with restored water depth and flow is uncertain and is an important component of the current Decompartmentalization and Sheetflow Enhancement Physical Model (DPM).[8] However, the modeling of anticipated flows in the SERES evaluation suggests that the Everglades ridge and slough landscape will undergo moderate improvement with any of the restoration options, and ridge and slough sustainability was greater under restoration options that increased decompartmentalization relative to partial or no decompartmentalization.

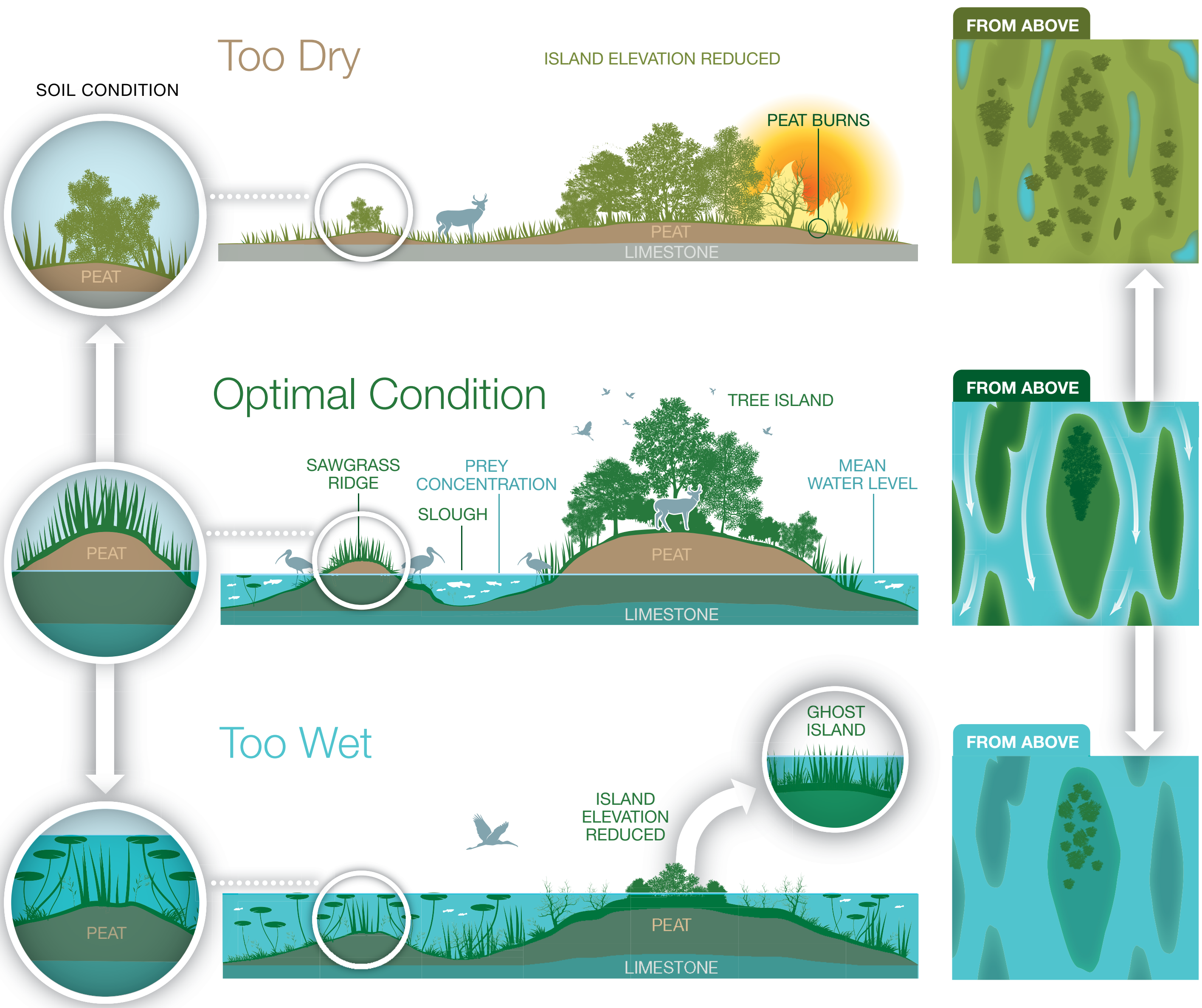
Regarding tree islands, the key to their maintenance is keeping trees alive that can tolerate flooding for only a half month per year while others can be flooded for as much as 9 months of the year. Year-round flooding of tree islands causes trees to die, leading to "ghost

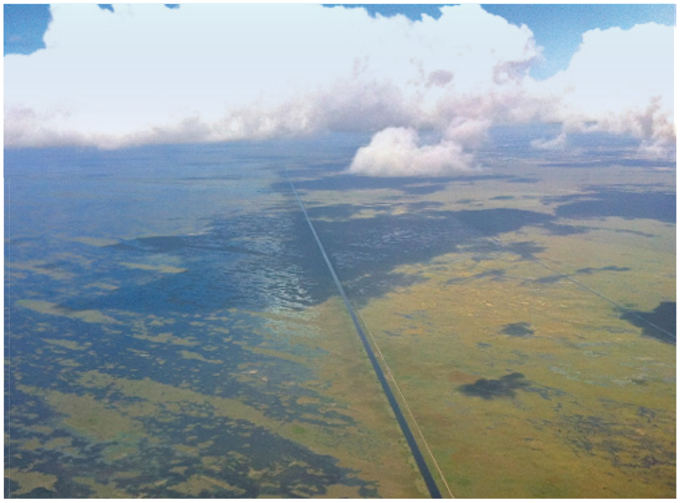
CONTINUED ON PAGE 32

8 *http://www.saj.usace.army.mil/Missions/Environmental/EcosystemRestoration/DecompPhysicalModel(DPM).aspx*

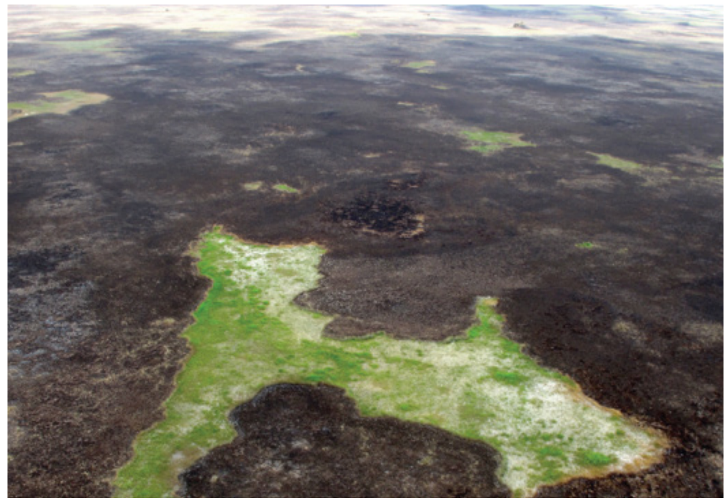
Water Conditions and Habitat Change

Illustration showing the relationship between water level, vegetation, and soil development as described above. The condition that is *too dry* (TOP) leads to a loss of soil elevation and flattening of the landscape that allows for sawgrass to encroach into former slough areas. An example of this is in northern WCA-3A. The *too wet* scenario (BOTTOM) has year-round flooding conditions that result in the conversion of sawgrass ridges to slough and drowning and loss of tree islands. This condition is best exemplified in southeastern WCA-3A. *The optimal condition* (MIDDLE) has a natural, seasonally fluctuating water level that maintains all three habitats.





Aerial photo showing remnant landscape pattern along the L-67A Canal separating WCA-3A from WCA3B. On the dry side, landscape pattern has been lost. **Photo by Stephen Davis**



Aerial photo of a 2011 fire scar in WCA-3B—an area that is currently too dry and has lost a considerable amount of landscape patterning. **Photo by Adam Hines**

CONTINUED FROM PAGE 30

islands" that still show the original outline of the island. A reduced period of flooding in the Everglades favors certain trees and shrubs. However, drier conditions also make tree islands more susceptible to fire that can burn the island edges, or in more intense fires, burn the peat soil of tree islands reducing the overall elevation.

Lowering water levels in ponded areas of WCA-3A will improve conditions for tree islands that are currently being drowned. Re-directing that water to the east into its natural flow path (Shark River Slough) will reduce flooding impacts to a sub-population of the sparrow in the western part of Everglades National Park. However, re-directing water down Shark River Slough will require monitoring and adaptive management to protect marl prairie habitat of the sparrow to the east.

Restored hydroperiods in the scenarios we considered suggest generally positive benefits to tree islands. Everglades restoration will even-out water levels across the landscape and will reduce the ponding of water along levees that currently impacts some tree islands. In over-drained areas, tree islands will experience increased periods of flooding leading to a transition in tree species that prefer wetter conditions. These over-drained islands have probably lost elevation due to soil compaction and the decomposition of organic matter. Tree islands are dynamic and it is expected that given enough time tree islands will have some capacity to adjust to their new water levels and flooding regimes.

We also found that SERES restoration scenarios reduced fire risk in northern WCA-3A relative to the existing condition, thus better protecting existing peat soils, tree islands, and ridge and slough landscape pattern. Using a performance measure developed in the CEPP for predicting fire closure to recreational use in northern WCA-3A, we evaluated the performance of these five scenarios as a relative indication of fire risk. Overall, SERES Options E and B (CERP) reduced fire risk more than the other options, indicating that they do a better job of keeping Everglades habitats wet throughout the year.

Seasonal recession of water level in the Everglades combined with healthy ridge and slough landscape pattern results in prey concentration for foraging wading birds.

PHOTO BY JAMES BEERENS/USGS

Everglades Trophic Dynamics: Restore it and they will come

With regard to how Everglades Restoration will affect the food web, resource managers wanted to know: *How close do we need to get?* and *What are the key metrics?* The Everglades foodweb is based largely on periphyton and detritus. By increasing water depths in areas that are currently too dry, restoration will strengthen the connection between this important foodweb base and invertebrates and small fish. At the same time, restoration will ensure that dry season water depths recede in a natural way across the landscape thus allowing for the concentration of these prey items for wading birds and other top predators.

“Most scientists agree that a restored Everglades should contain the habitats and functionality of the natural Everglades...”

In order to address these questions, we need to acknowledge that 100% recovery of the Everglades in a literal sense, both of hydrology and habitats, is not possible given the extent of development in south Florida. Furthermore, this view of restoration is inconsistent with the goals and objectives of the CERP. Most scientists agree that a restored Everglades should contain the habitats and functionality (e.g., prey concentration) of the natural Everglades and that this requires “getting the water right”.

Everglades habitat restoration targets focus on the protection of degrading habitats rather than aiming for a precise ratio of habitats. The latest Monitoring and Assessment Plan (MAP)[9] for the CERP identifies the defining characteristics of the Everglades that can be used as restoration indicators. The MAP also proposes working hypotheses relating hydrology and ecology for each defining characteristic of the Everglades such as those we looked at in the SERES project. The working hypotheses provide a minimal list of indicators to be monitored as a means to tracking restoration success. Small fish biomass available as prey for wading birds and wading bird nest activity are examples of key restoration indicators. Understanding the connection between hydrology and these indicators has led to the development of robust modeling tools that allow us to forecast changes in these

CONTINUED ON PAGE 35

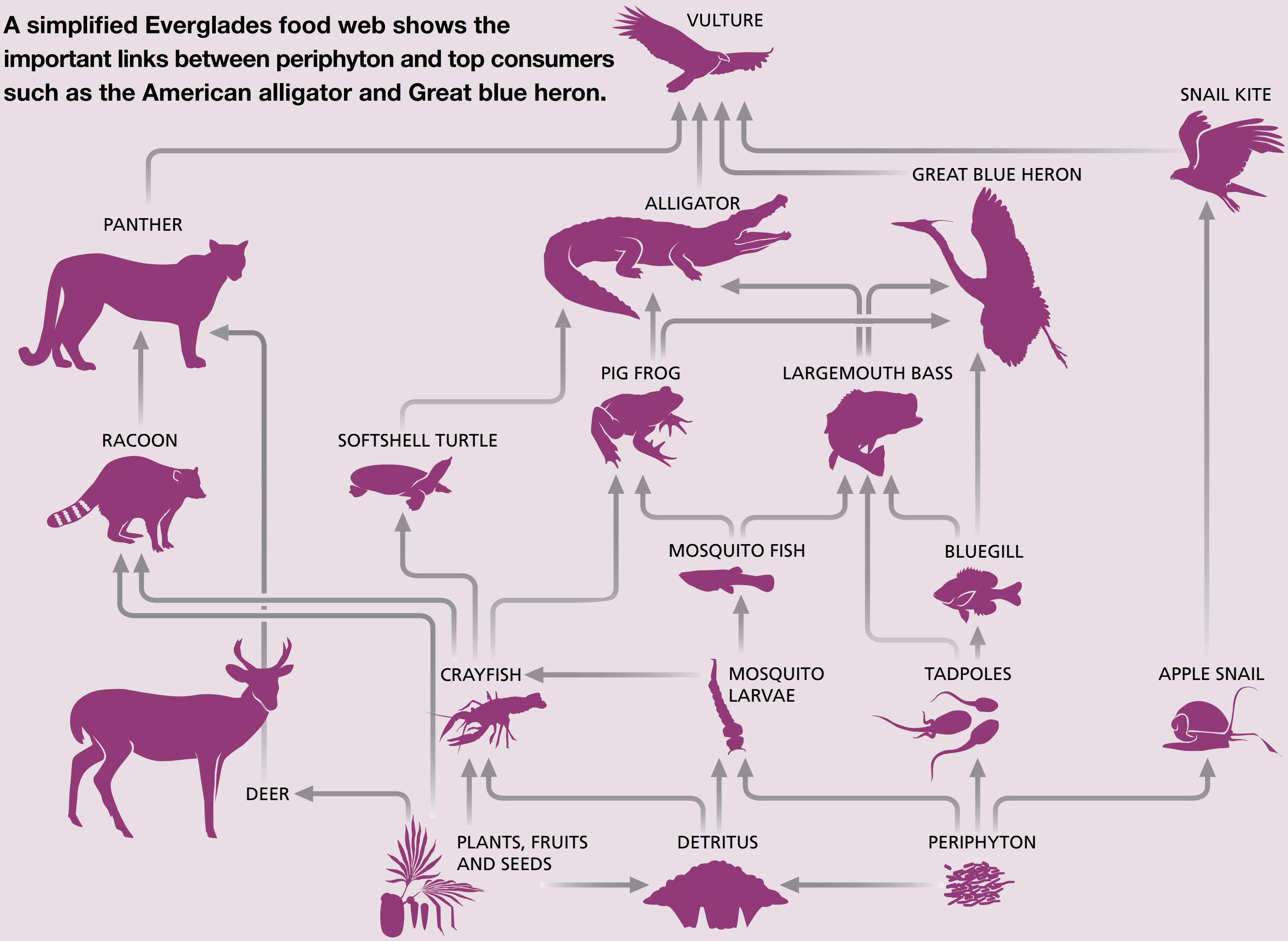
WHY IS IT IMPORTANT?

The pre-drainage Everglades was characterized by extremely low nutrient conditions, a patterned ridge-and-slough landscape, and much more water than at present. Altered hydrology and loss of Everglades habitat has contributed to a 90% reduction in the wading bird population and has contributed to a multi-decadal decline in small fish. A restored hydrology and improved landscape pattern are essential to reestablishing communities of animals associated with the pre-drainage Everglades.

9 *http://141.232.10.32/pm/recover/recover_docs/map_2009/022210_01_map_2009_cover_exec_summary.pdf*

The Everglades Food Web

A simplified Everglades food web shows the important links between periphyton and top consumers such as the American alligator and Great blue heron.



CONTINUED FROM PAGE 34

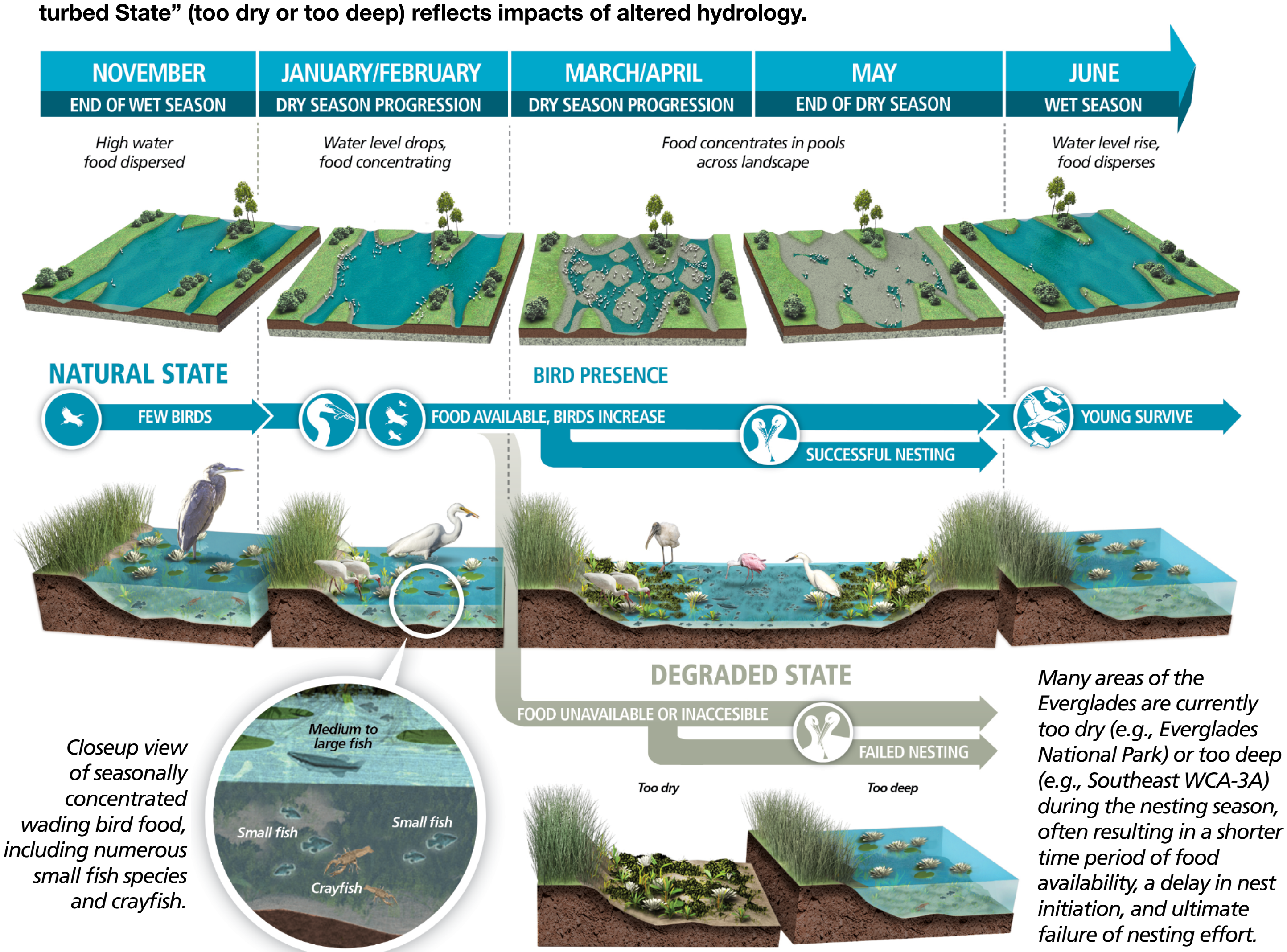
indicators under different restoration scenarios.

By reducing marsh dry-down, all SERES restoration options improve conditions for small fish relative to the existing condition. The biggest improvements were projected for Everglades National Park, especially in Options D and E. With more fish to eat and better foraging habitat, wading bird flock abundance also increased with about an 8% to 10% annual improvement. As another positive response to restoration, largemouth bass populations and sizes are projected to increase due to increased hydroperiods relative to current conditions. This was most notable in WCA-3B, where restoration water depths increased greatly over the current state. Connecting longer-hydroperiod marshes to deep-water habitats in canals such as L-29 (Tamiami Canal) will further benefit largemouth bass populations and should be provided where possible. This directly addresses a stakeholder concern of whether some areas of a restored Everglades could still serve as a fishery for largemouth bass. Currently, canals such as the L-67A that interrupt sheetflow and focus harmful nutrients serve as a recreational fishing hotspot for

Landscape Pattern & Seasonal Water Levels

EFFECTS ON WADING BIRD FOOD AVAILABILITY AND NEST SUCCESS

Timeline of bird presence and activity under the "Natural State" reflects a pre-drainage condition and "Disturbed State" (too dry or too deep) reflects impacts of altered hydrology.



bass. As a tradeoff to this improvement for small fish, wading birds, and largemouth bass, white-tailed deer populations will likely decrease throughout much of the Everglades reverting back to historic levels and distributions.

Restoration actions are generally compatible with recovery of listed species such as the Everglade snail kite and the Cape Sable seaside sparrow. The apple snail is the primary food source for the snail kite. By increasing apple snail abundance across the Everglades, the condition of the snail kite will improve. Our evaluation indicated improved conditions for the apple snail kite and the Cape Sable seaside sparrow — relative to the existing condition — in most areas including northern WCA-3A, WCA-3B, and Everglades National Park. Southern WCA-3A, a current stronghold for apple snails remained as such in all scenarios.

Outside Mahogany Hammock in Everglades National Park showing a saltwater-loving mangrove that has become established in this freshwater marsh—likely brought there by a recent storm surge.

PHOTO BY STEPHEN DAVIS

Climate Change and Sea Level Rise: Restoration is even more important

Managers often asked, *how will climate change affect the Everglades?* This is a complicated question and requires a more specific time-frame or consideration of near-term (the next 20 years) versus long-term (100 years from now). Any response to this question also depends on the status of Everglades restoration and how long it takes to complete.

The effects of climate change are difficult to predict, but our strongest scientific evidence from the Intergovernmental Panel for Climate Change (IPCC) [10] and the National Climate Assessment Report [11] points definitively to increased warming of the earth's surface and likely increased water scarcity. In South Florida, the prediction is that we will see a significant increase in the number of days above 95 degrees Fahrenheit and increased hurricane intensity. Given that the Everglades recharges the water supply for South Florida, solutions that allow us to maintain our water supply and use our water more efficiently for environmental needs are important to consider. This includes consideration of feasible, cost-effective storage solutions for large volumes of water that prevent harmful discharges to the Northern Estuaries, while maximizing flow of freshwater across the Everglades.

"Mangroves and other near-coast habitats have been migrating landward for well over a half-century."

WHY IS IT IMPORTANT?

Increased warming of South Florida, even without changes in rainfall will tip the balance toward drier conditions. Add less rainfall to the equation, and water availability across South Florida may change dramatically. Sea level increased 8 inches over the past century and is projected to rise 2 feet or more by the end of the century. Saltwater intrusion will continue to affect our aquifer and eat away at freshwater habitats around the periphery of the Everglades.

With regard to sea level rise, we are already seeing the impacts in the Everglades. Sea level rise of 8 inches over the past century combined with a reduction in freshwater head has had multiple effects around the South Florida coast. Saltwater is moving landward into our aquifer—not only in developed areas of South Florida but also under the Everglades. Also, we are beginning to see changes in habitats associated with increased exposure to saltwater on

CONTINUED ON PAGE 40

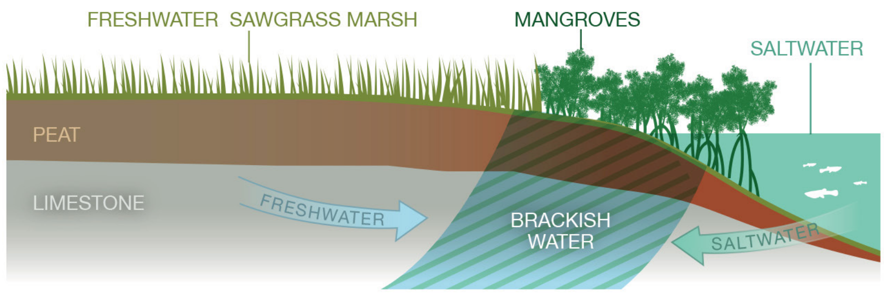
10 *IPCC, 2013: Climate Change 2013: The Physical Science Basis.* Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

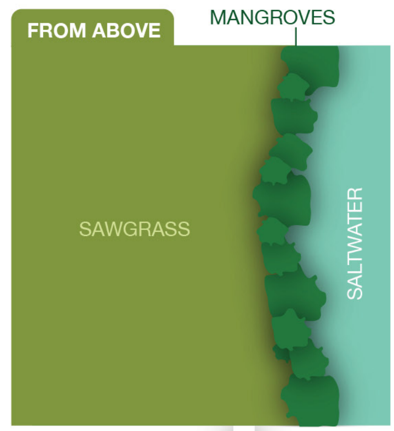
11 Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Highlights of Climate Change Impacts in the United States: The Third National Climate Assessment.* U.S. Global Change Research Program, 148 pp.

The effects of saltwater intrusion into freshwater sawgrass-dominated marsh

1 Current

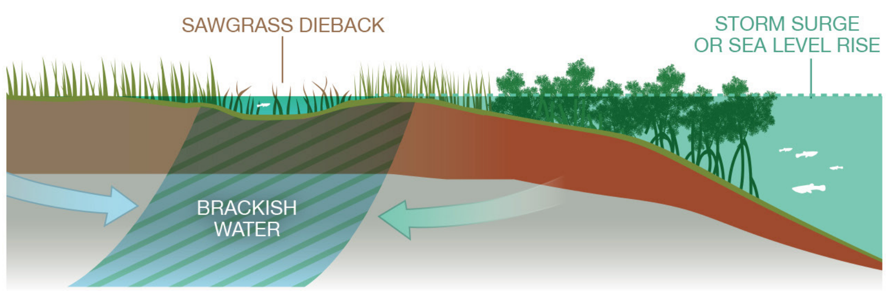
Sawgrass marsh builds peat soil on top of the limestone only in freshwater areas. Mangroves develop peat soil in saline and brackish conditions.

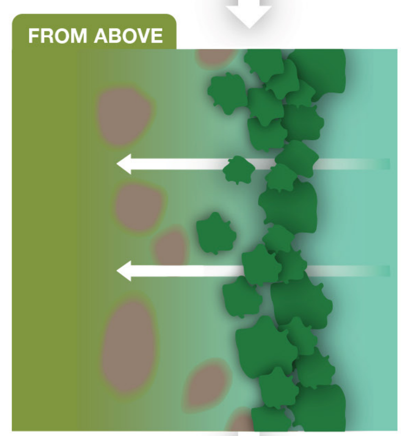




2 Saltwater Intrusion

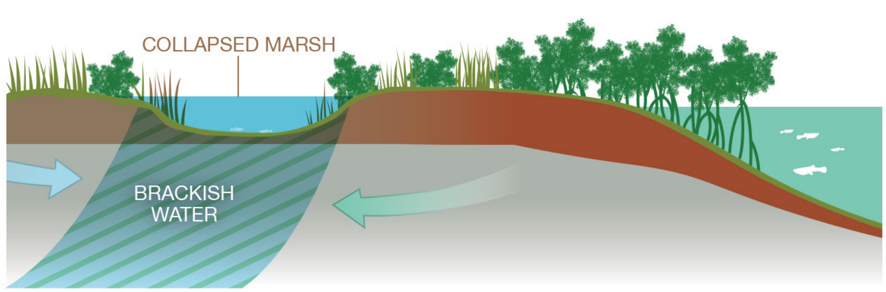
Intrusion of saltwater causes sawgrass dieback and mangrove expansion. Freshwater peat soil begins to degrade with exposure to saltwater.

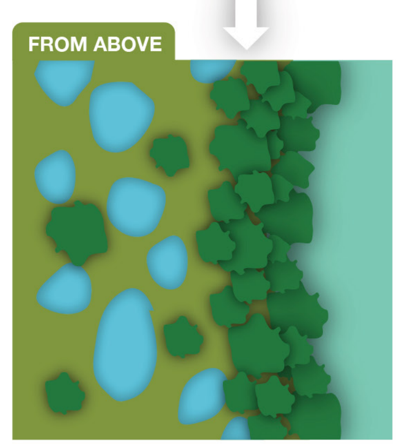




3 Peat Collapse

Freshwater peat collapses and the water is too deep for plants to become established. Mangroves established elsewhere help to re-stabilize soil.





CONTINUED FROM PAGE 38

the surface, as more inland marsh is exposed to hurricane-induced storm surge. Mangroves and other near-coast habitats have been migrating landward for well over a half-century. We have also seen increased evidence of freshwater marsh loss combined with peat collapse and conversion to open water.

Everglades peat collapse was first documented in Cape Sable, where canals dug in the 1920s allowed saltwater to infiltrate freshwater marshes, leading to a dramatic transformation in habitat over a timeframe of 10-20 years. The latest science indicates that the process of peat collapse begins when freshwater marshes and peat soils are exposed to saltwater. A cascade of events then takes place leading to the creation of a "hole" in the landscape. Depending on the duration of exposure, the freshwater plants (e.g., sawgrass) are stressed or dieback increasing the exposure and temperature of the soil. This reduces or stops the production of roots that contribute to the formation of peat soil. Saltwater also provides an enhanced supply of sulfate that increases bacterial activity. The combination of plant dieback and increased bacterial activity tips the peat soil balance towards a rapid breakdown and ultimate collapse of marsh.

The long-term implication of peat collapse is that these habitats do not transition to mangrove forest. They remain as open water and contribute to a *net loss of land.* This is similar to the land loss concept documented in Louisiana; however, the rate of elevation loss (potentially as much as a half foot or more per decade) seems to be more dramatic in the freshwater peat marshes of the Everglades. Another more immediate consequence is that a large amount of nutrients (nitrogen and phosphorus) tied up in the soil and plant biomass is released as the plants dieback and soils collapse. These nutrients can then be transported offshore into Florida Bay and adjacent estuaries, fueling algal blooms and other nearshore impacts.

Some managers also asked *Is Everglades Restoration worthwhile given that sea levels will continue to rise?* The answer to this question is directly taken from

Edge of a collapsed area of sawgrass marsh in Everglades National Park.

Photo by Stephen Davis

the National Academy of Sciences in their 2014 report to Congress: "In the face of climate change, Everglades restoration will increase the resilience of the ecosystem and the water management system and decrease their vulnerability."[12]

Although we did not evaluate the impacts of sea level rise and climate change in our scenarios, the consensus opinion of the Everglades science community is that Everglades restoration will increase ecosystem resilience, reduce the extent of peat soil oxidation and the impacts this has on habitats and water quality, and provide water quantity options and water management flexibility.[12, 13] In the near-term, Everglades Restoration will slow the impacts of sea level rise and mitigate the severity of storm surge from future hurricanes. Both will allow for a more natural landward migration of habitats while minimizing extensive peat collapse and land loss. Restoring flow to the Everglades will also help to mitigate loss of peat soil from drought-enhanced breakdown and will also provide improved conditions for wildlife and fisheries, the benefits of which will improve the economy and quality of life for South Florida.

As was shown in the recent Central Everglades Planning Project, benefits of restoration (both environmental and economic) will be realized in the near-term — in less than 10 years.[14] This will be important in building ecosystem resilience as South Florida environments are gradually shaped by climate change and sea level rise in the future.

12 *CISRERP. 2014. Progress Toward Restoring the Everglades: The Fifth Biennial Review.* National Academies Press. ISBN: 978-0-309-30576-1. 254 pages.

13 *http://www.ces.fau.edu/usgs/pdfs/pecffs-report.pdf*

14 *http://www.saj.usace.army.mil/Missions/Environmental/EcosystemRestoration/CentralEvergladesPlanningProject.aspx*

Old World climbing fern (*Lygodium microphyllum*) growing over a bald-cypress tree in South Florida.
PHOTO BY PEGGY GREB, USDA/AR

Invasive/Nonnative Species: An ounce of prevention...

Several managers asked *How will restoration affect exotics?* While we did not evaluate the interactive effects of exotic species with native communities in the different scenarios of restoration, the team concluded that, in general, Everglades restoration should not make the exotics situation in South Florida any worse. While increasing sheetflow and connectivity could facilitate spread of aquatic invasive exotic species through seed dispersal or through mobilizing floating plants (e.g., water hyacinth), wetter conditions brought about by restoration are not as favorable for some species (e.g., *Casuarina*). Further, nutrient reductions through increased water quality restoration and STA construction will likely benefit native flora (and perhaps fauna) and will reduce the likelihood of invasive plants gaining an advantage.

"Taking an early-detection and rapid-response approach is the best strategy to controlling and eradicating an invasive species."

According to the latest Biennial Review of Everglades Restoration by the National Academy of Sciences Committee on Independent Review of Everglades Restoration Progress (CISRERP),[15] there are approximately 250 nonnative plant species and at least 192 nonnative animal species established in different habitats of the Everglades. Twelve plant species (including Brazilian pepper and *Melaleuca*) and sixteen animal species (including the Burmese python and Red Bay ambrosia beetle) are considered highest priority due to their highly invasive nature, ability to disrupt or displace native communities, and overall impact on the ecosystem structure and function. As an example, it has been estimated that the Burmese python is responsible for a massive reduction in small mammals (e.g., bobcats, raccoons, marsh rabbits, etc.) across the southern Everglades.[16]

While eradication methods have shown promise for

CONTINUED ON PAGE 44

WHY IS IT IMPORTANT?

A mild climate with ample water makes South Florida a haven for invasive species. Several species of invasive plants and animals have already become established within the Everglades and many others continue to be introduced. A few of these have expanded in numbers and range to the point where they have altered the landscape and food web of the Everglades ecosystem.

15 *CISRERP. 2014. Progress Toward Restoring the Everglades: The Fifth Biennial Review.* National Academies Press. ISBN: 978-0-309-30576-1. 254 pages.

16 Dorcas, M.E. et al. 2012. *Severe mammal declines coincide with proliferation of Burmese pythons in Everglades National Park.* Proceedings of the National Academy of Sciences. 109:2418-2422.

Brazilian pepper *(Schinus terebinthifolius)*, a relative of poison ivy, is the probably the most widespread invasive plant in the Everglades and throughout South Florida. **(Photo from National Park Service)**

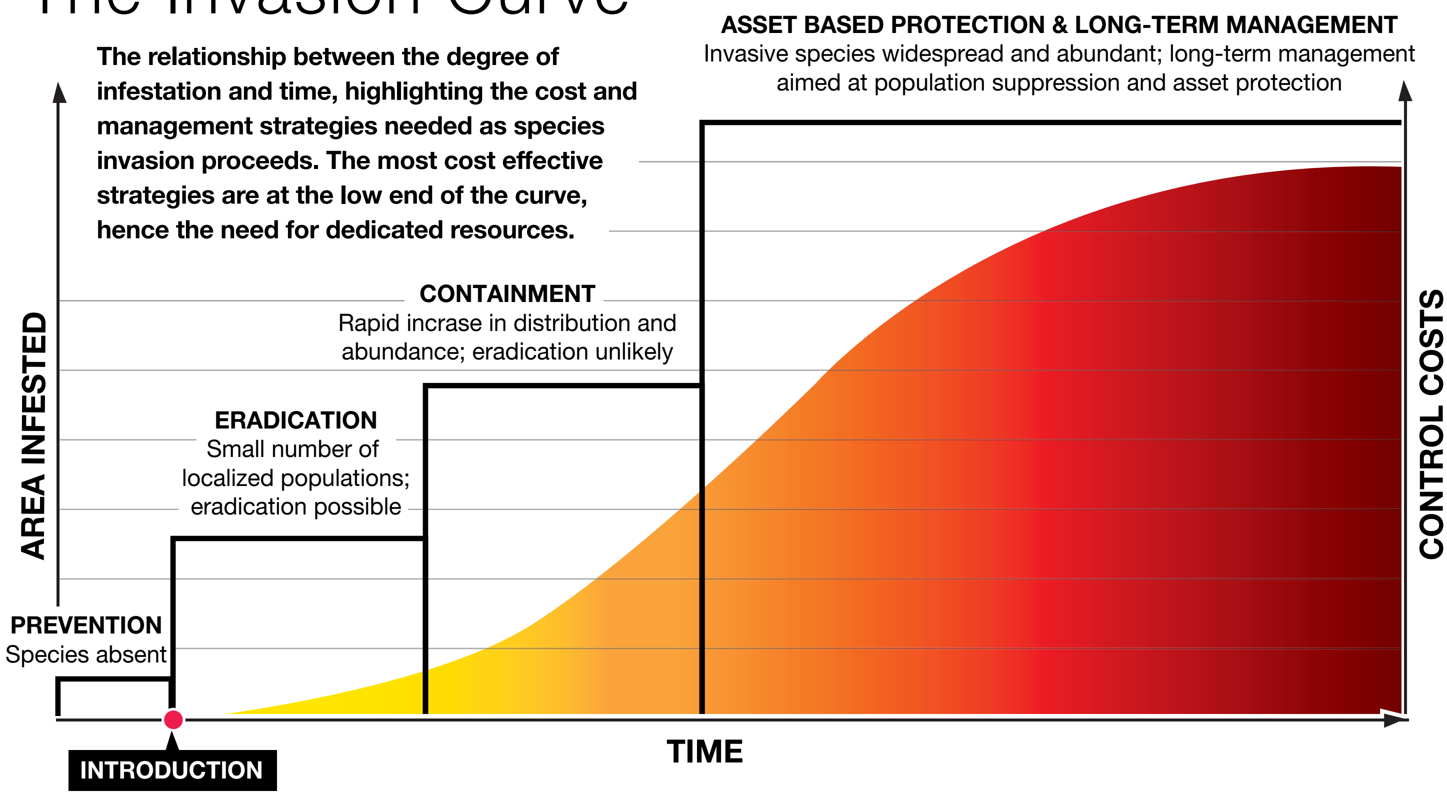
Planted in early efforts to drain the Everglades, Melaleuca *(Melaleuca quinquenervia)* forms dense stands that displace native plants and alter habitat. **(Photo from U.S. Fish and Wildlife Service)**

First discovered near the Everglades in 2008, the Argentine black and white tegu is a prolific and aggressive invader with a wide appetite for plants and animals. **(Photo from Florida Fish and Wildlife Conservation Commission)**

The Burmese python, a cryptic predator of nearly all native wildlife in the Everglades, may number in the tens of thousands across the ecosystem **(Photo from South Florida Water Management District)**

The Invasion Curve

The relationship between the degree of infestation and time, highlighting the cost and management strategies needed as species invasion proceeds. The most cost effective strategies are at the low end of the curve, hence the need for dedicated resources.



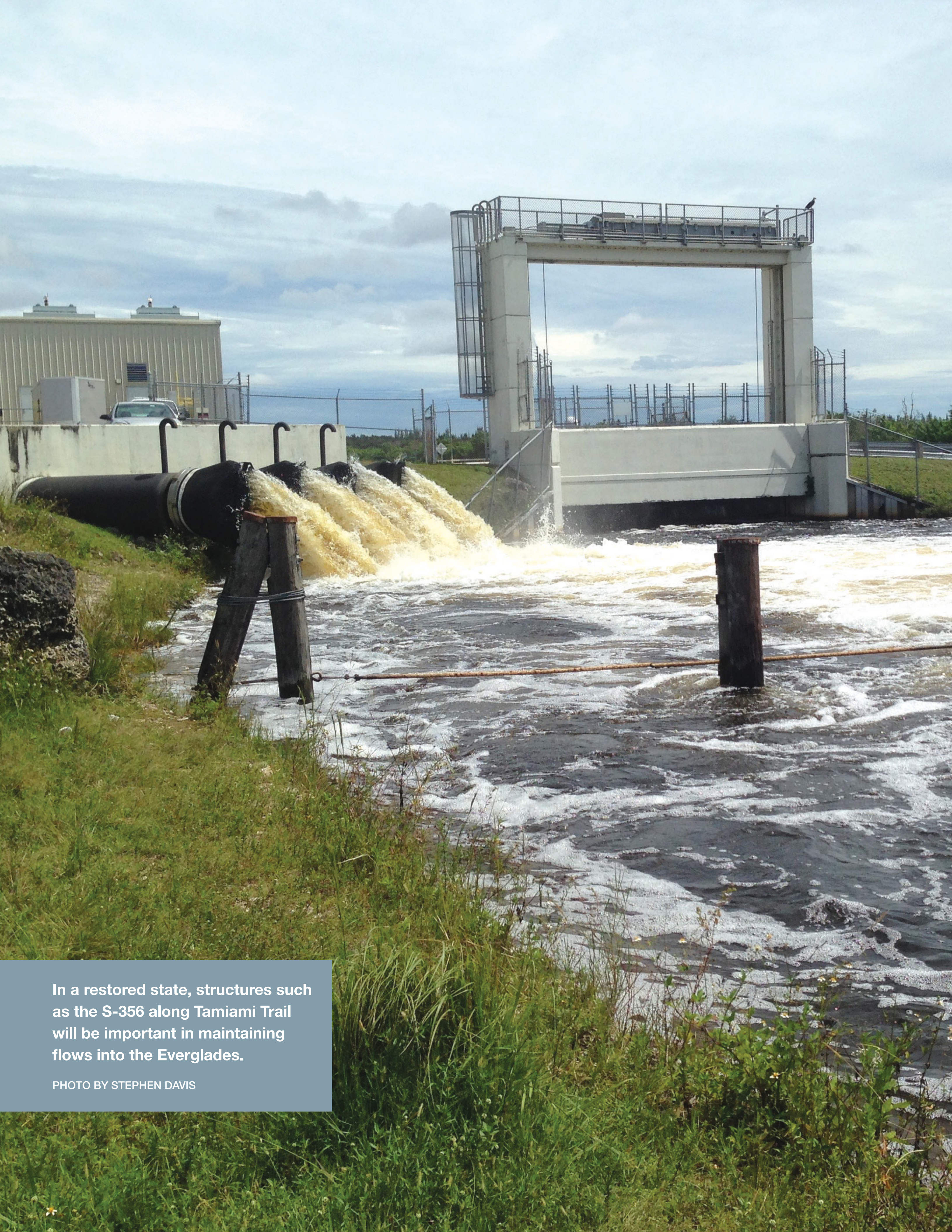
CONTINUED FROM PAGE 42

some established nonnative species (e.g., *Melaleuca*), other established species continue to expand their range and populations despite eradication efforts (e.g., Old-World climbing fern). The challenge of management is also confounded by a continued introduction of new species to the ecosystem. For these nonnative species, preventing introduction is the first step. Once introduced, an early-detection and rapid-response (EDRR) approach is the best strategy to controlling and eradicating an invasive species before it expands.[17] A recent example of EDRR success was the eradication of the sacred ibis, which was discovered breeding in the Everglades in 2005. In order to succeed, EDRR requires sufficient resources to track introductions, coordinate an eradication effort, and ensure no further presence.

The Everglades Cooperative Invasive Species Management Area (CISMA) is a coordinated inter-agency effort to prevent introductions, eradicate introduced species, and contain or manage established species. Despite best efforts of the Everglades CISMA, several species including the Burmese python and Lionfish continue to expand and disrupt native flora and fauna. The CISRERP report makes clear that we lack sufficient resources to solve the nonnative/ invasive species problem in South Florida and that we will be dealing with many established species for decades to come — even in a restored state.

The bigger picture of restoration benefits will not be over-shadowed by nonnative species. Improved control methods and EDRR-like approaches will be important as restoration proceeds.[17] With sufficient resources, mapping and EDRR efforts such as those developed by CISMA have proven that we can eliminate or control some species in areas like Arthur R. Marshall Loxahatchee National Wildlife Refuge (WCA-1). We can be optimistic if sufficient resources are earmarked for management of exotic/invasive species. Restoration needs to be conducted hand-in-hand with control and management of exotic species.

17 *CISRERP. 2014. Progress Toward Restoring the Everglades: The Fifth Biennial Review.* National Academies Press. ISBN: 978-0-309-30576-1. 254 pages.



In a restored state, structures such as the S-356 along Tamiami Trail will be important in maintaining flows into the Everglades.

PHOTO BY STEPHEN DAVIS

Everglades Restored: The end is just the begining

We evaluated four restoration scenarios relative to the existing condition. Our general findings are described in preceding sections, and more detailed technical results are available in project reports.[18] In general, our evaluation of different restoration options revealed that the benefits of ASR could be reproduced — and in some areas improved upon — with increased investment in surface storage beyond that laid out in the CERP. The benefits observed in Options D and E speak to this and depended on decompartmentalization as described earlier but were also limited to some extent by the location of storage options and the feasibility of in-ground storage options in the Lake Belt area.

> *"Expediting restoration of the Everglades will allow us to realize the benefits (ecological, social, and economic) sooner than later."*

The storage that was conceived in Option D provided sufficient flows and ecological benefits relative to Options B (CERP) and E, but Option D was more cost-effective. The scaled-back ASR storage in Option C was estimated to cost less, but it did not provide the same level of benefits. Given the recent conclusions with regard to the reduced capacity of ASR, the large surface storage component in Option D is more feasible. Further, we demonstrate that maximizing decompartmentalization of the Everglades can also strengthen overall ecological benefits.

To illustrate these results, we provide summary maps that highlight change in conditions from the Northern Estuaries all the way to Florida Bay for each Option (B through E, relative to A). These findings represent our best available information and provide a general depiction of what the Everglades may look like in a restored condition. In attempt to distill these results further and allow for comparison across options, we ranked the benefits of each restoration option according to system-wide performance metrics. We then compared these results to ranked costs of each option to determine "cost-beneficial" or "cost-effective" restoration options. The results of this approach are on page 48 and the option maps follow Option A on page 49.

Plugging of canals in vulnerable areas such as Cape Sable (Everglades National Park) is essential to restoring sensitive freshwater marsh habitats. **(Photo from Stephen Davis)**

CONTINUED ON PAGE 47

18 *http://www.everglades-seres.org/Products.html*

Aerial photo looking west towards Everglades National Park Visitor's Center and including the lower portion of the C-111 Spreader Canal going from lower right to upper left. **(Photo from Stephen Davis)**

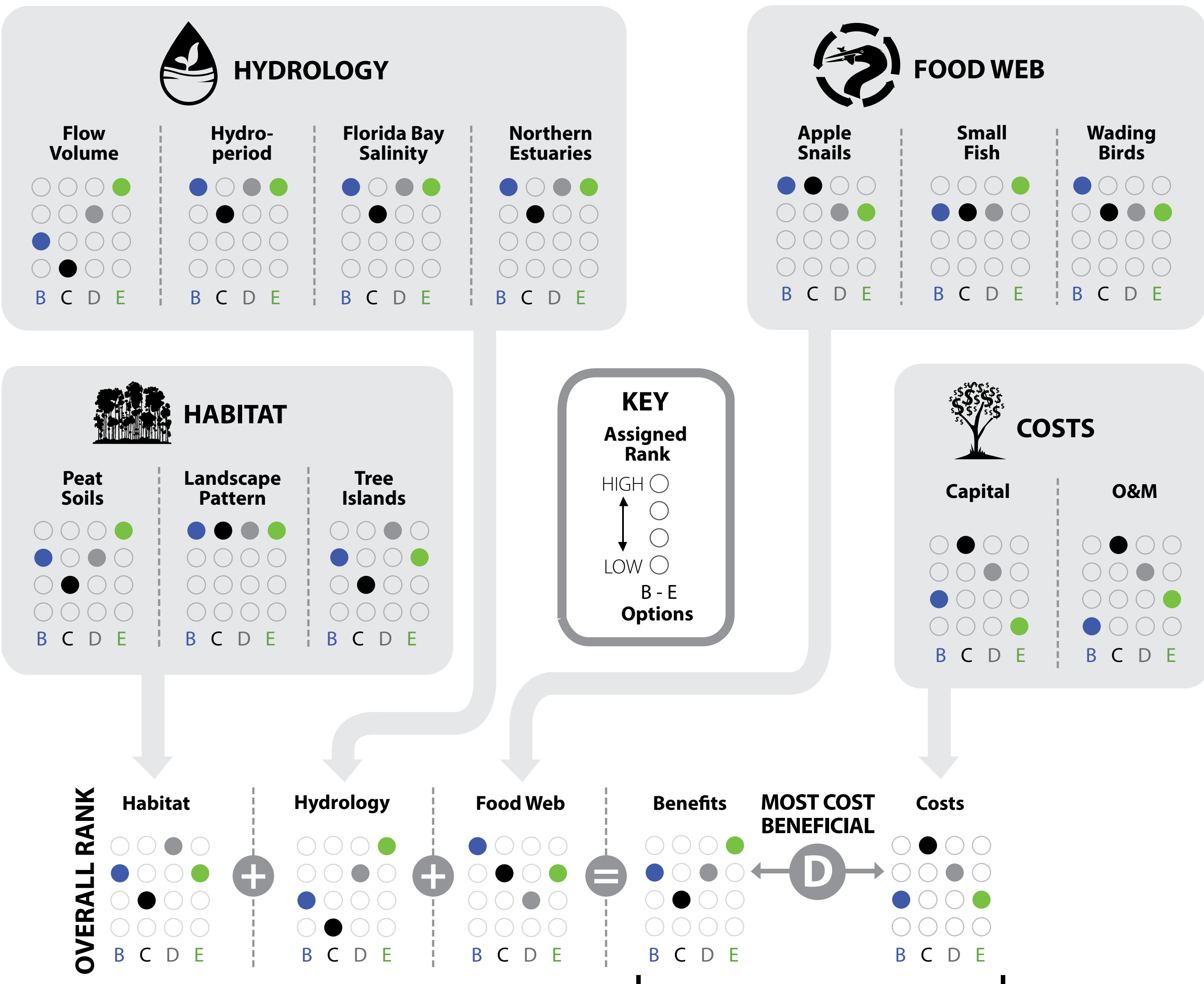
CONTINUED FROM PAGE 46

A final and important management question is, *what will a restored Everglades really look like?* Obviously, it will not look like the original ecosystem. There is much development and millions of people living in South Florida that need flood protection and access to water supply. However, there is sufficient land currently in the Water Conservation Areas, Everglades National Park, Big Cypress National Preserve to restore key aspects and functional attributes of the Everglades. Many believe a restored Everglades should include most if not all of the historical habitats — not necessarily in the original locations or amounts. Further, many believe a restored Everglades should also include key ecosystem attributes and functions such as a low-nutrient/oligotrophic state, a capacity to recharge our aquifer, an ability to maintain and develop peat soils, a patterned landscape, and a capacity to concentrate prey from across the landscape for top predators through an interaction of landscape pattern and hydrology.

From a superficial perspective, a restored Everglades will be wetter and patterned with more alligators and wading birds. There will also be losers in restoration. As examples, WCA-3B will become much wetter and species such as white-tailed deer, that have become more abundant in these over-drained and dried areas of the Everglades will re-locate to more habitable locations. This may include artificial or restored tree islands. As other new technologies and ideas emerge and as we continue to reduce the loading of phosphorus into the Everglades Protection Area, we may also have an ability to reduce the area of cattail-infested marsh across much of the Water Conservation Areas. Finally, all of this will proceed as sea levels continue to rise around, re-shaping our coastline and coastal habitats. Expediting restoration of the Everglades will allow us to realize the benefits (ecological, social, and economic) sooner and is one of our best tools for dealing with the potential impacts of climate change and sea level rise.

Summary of Costs and Benefits for SERES Restoration Options

Hydrological, habitat, and food web performance metrics were compared across all SERES restoration options (B through E) and ranked according to level of performance (See key in center) . These benefits were compared with ranked capital as well as operations and maintenance (O&M) cost estimates to determine the most "cost beneficial" option. Our cost ranking approach assigned lower cost options a higher rank relative to the more expensive options.



COST-BENEFIT RANK

Using a ranking approach, Option E exhibited the best overall ecological performance, followed by Options B and D. A comparison of costs and benefits shows that Option C was the lowest cost but provided the least overall benefits. **Option D was a cost beneficial option**, being ranked second in terms of cost and also second in terms of overall benefits. Options B and E ranked high in benefits but were the most expensive in terms of cost.

EXISTING CONDITIONS » Less than 50% of flows making it to the Gulf of Mexico, requiring nearly 60,000 acres of STA

OPTION A

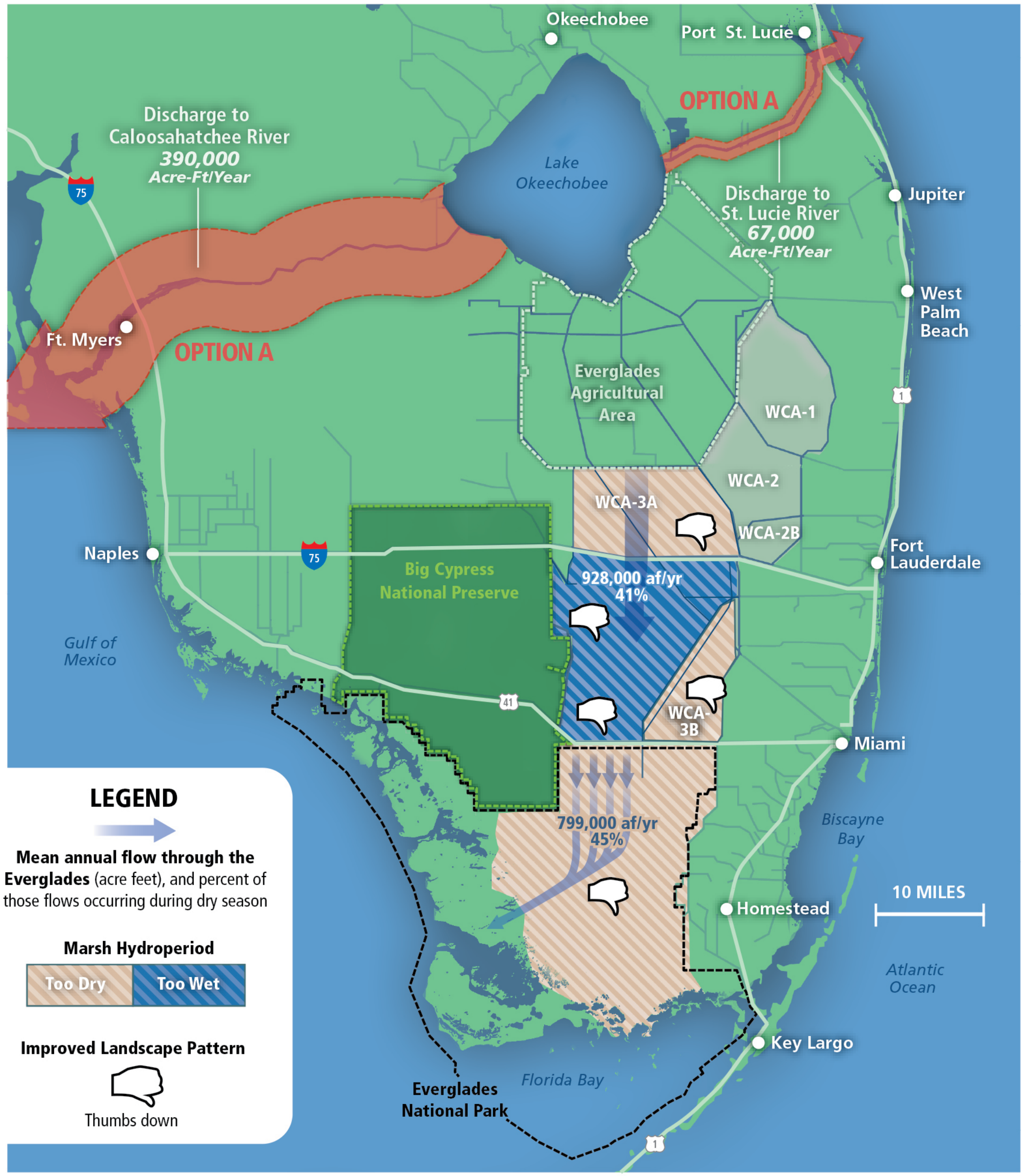
STORAGE UNIQUE TO OPTION A (IN ACRE-FEET/YEAR)

NO STORAGE

0	0	0
Lake Okeechobee ASR	Lake Belt	Surface

125 MILES OF LEVEES

SERVING AS INTERNAL BARRIERS TO FLOW



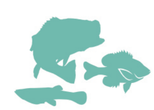
EVERGLADE SNAIL KITE

NEARLY **EXTINCT** DUE TO LACK OF APPLE SNAILS

WADING BIRDS

90% HAVE BEEN **LOST**

FISH DENSITY



SYSTEMWIDE MULTI-DECADAL **DECLINE**

DEGRADED PEAT SOIL CONDITION

1/4 OF EVERGLADES

MARSH POLLUTION

NEARLY 20% OF THE EVERGLADES IS **POLLUTED** BY PHOSPHORUS

FLORIDA BAY

TOO SALTY DUE TO LACK OF FRESHWATER FLOW

RISK OF FIRE

NEARLY EVERY OTHER YEAR

OPTION B

CAPITAL COST
$16.7 billion

STORAGE UNIQUE TO OPTION B… (IN ACRE-FEET/YEAR)

2,456,000

Lake Okeechobee ASR

…OUT OF A TOTAL STORAGE OF 4,060,660

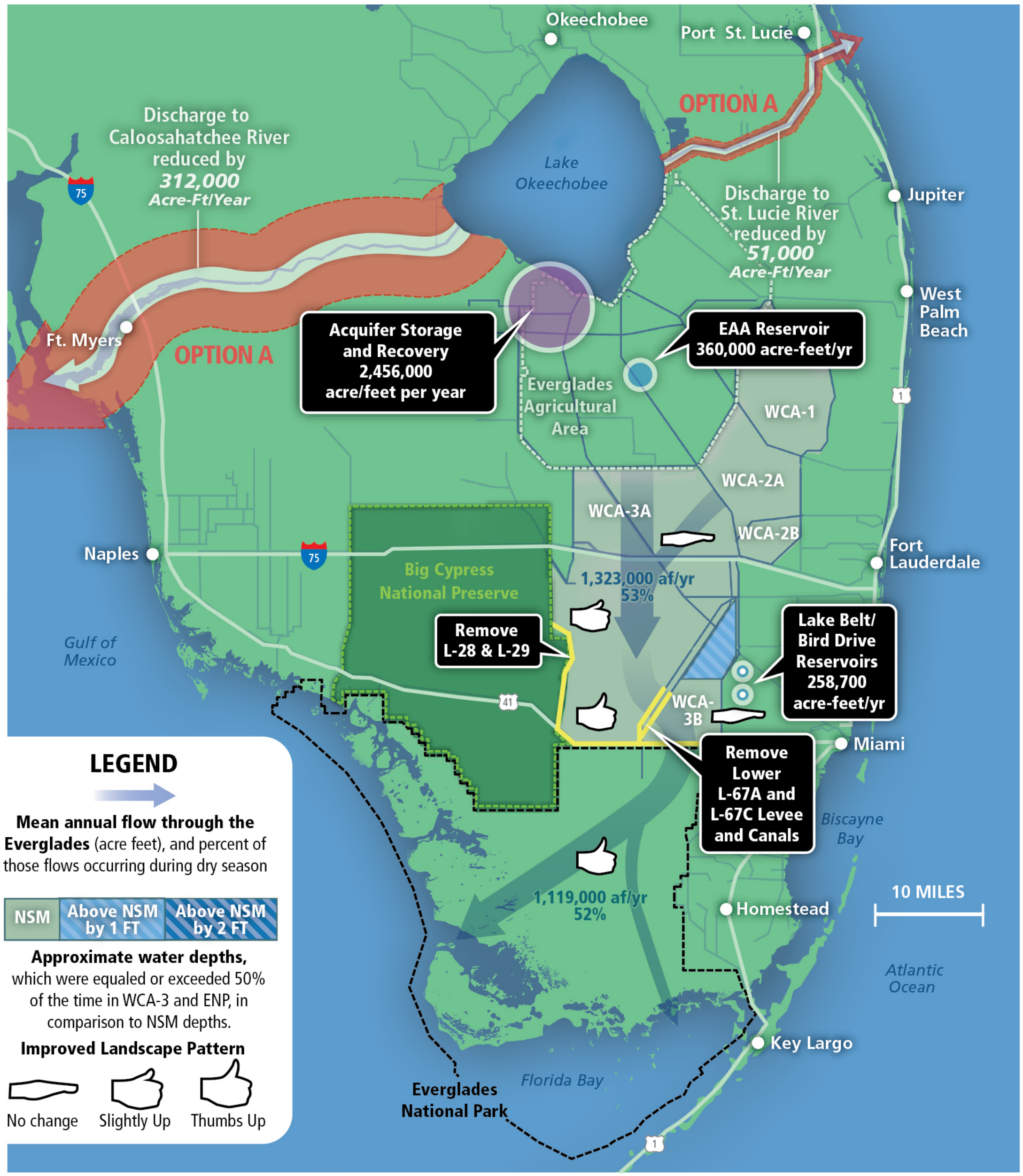
247,100 Lake Belt

11,600 Surface

DECOMPARTMENTALIZATION

54% REDUCTION

IN INTERNAL BARRIERS TO FLOW



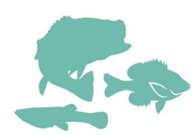
APPLE SNAILS

52% IMPROVEMENT IN HABITAT

WADING BIRD FLOCK ABUNDANCE

10% AVERAGE ANNUAL INCREASE

FISH DENSITY



12% ANNUAL INCREASE

INCREASED AREA OF PEAT SOILS

36,290

FOOTBALL FIELDS

MARSH POLLUTION REDUCTION

39% MODERATE "P" POLLUTION

65% HIGH "P" POLLUTION

FLORIDA BAY SALINITY REDUCTION

50% CLOSER TO TARGET

RISK OF FIRE

78% OVERALL DECREASE

NOTE: Percentage values represent annual averages or overall change in 36-year period of simulation. Refer to detailed appendices for explanations.

PARTIAL CERP » 79% of NSM flows making it to Gulf of Mexico, requiring an additional 28,500 acres of STA

OPTION C

CAPITAL COST
$12.1 billion

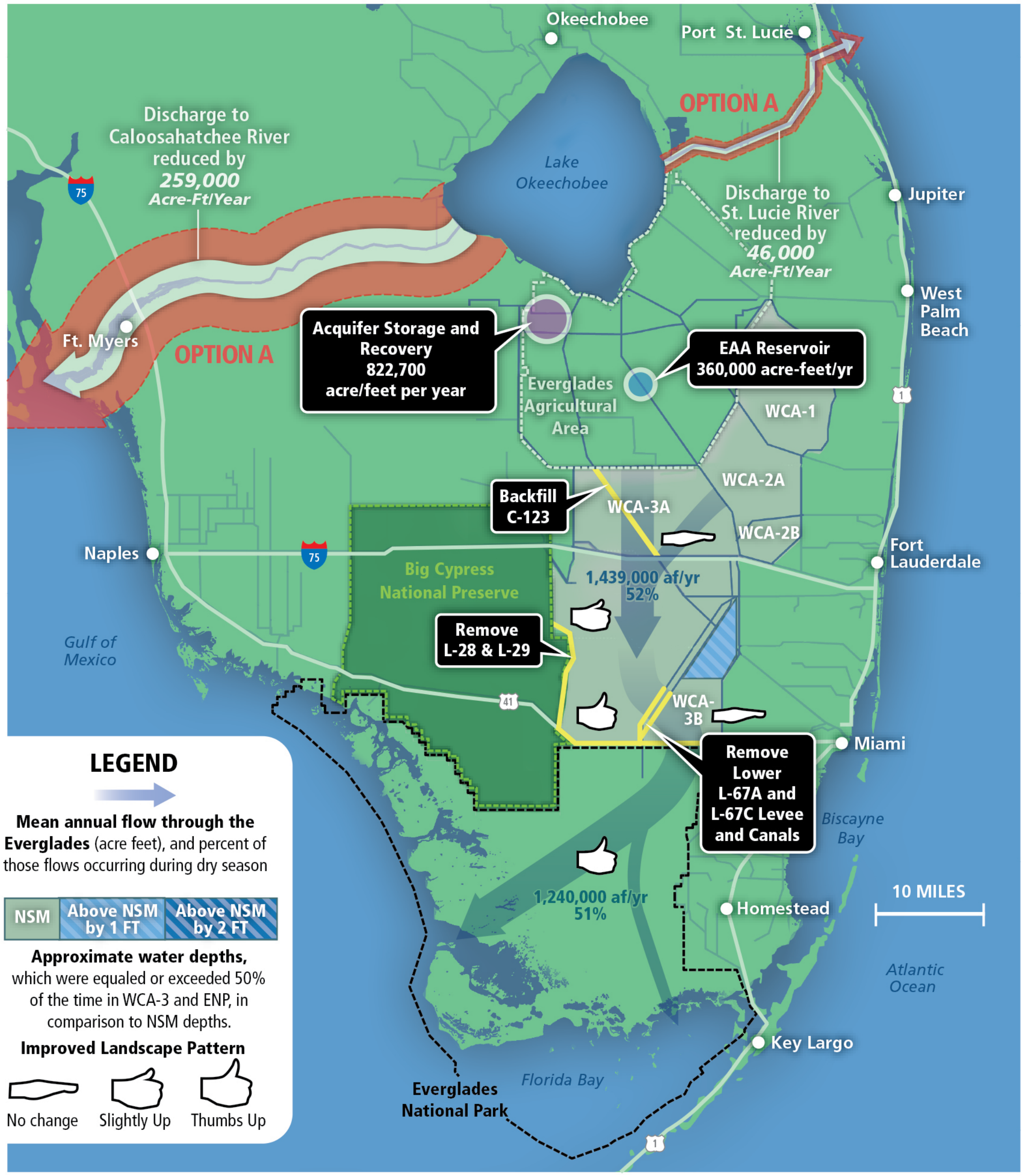
STORAGE UNIQUE TO OPTION C... (IN ACRE-FEET/YEAR)

822,700
Lake Okeechobee ASR

...OUT OF A TOTAL STORAGE OF
2,168,740

0 Lake Belt
0 Surface

DECOMPARTMENTALIZATION
54%
REDUCTION
IN INTERNAL BARRIERS TO FLOW



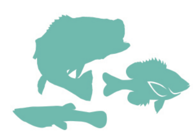
APPLE SNAILS

44%
IMPROVEMENT IN HABITAT

WADING BIRD FLOCK ABUNDANCE

9%
AVERAGE ANNUAL INCREASE

FISH DENSITY



12%
ANNUAL INCREASE

INCREASED AREA OF PEAT SOILS

30,210
FOOTBALL FIELDS

MARSH POLLUTION REDUCTION

40% MODERATE "P" POLLUTION

65% HIGH "P" POLLUTION

FLORIDA BAY SALINITY REDUCTION

25%
CLOSER TO TARGET

RISK OF FIRE

67%
OVERALL DECREASE

NOTE: Percentage values represent annual averages or overall change in 36-year period of simulation. Refer to detailed appendices for explanations.

EXPANDED STORAGE AND DECOMP » 91% of NSM flows making it to Gulf of Mexico, requiring an additional 47,000 acres of STA

OPTION D

CAPITAL COST
$14 billion

STORAGE UNIQUE TO OPTION D... (IN ACRE-FEET/YEAR)

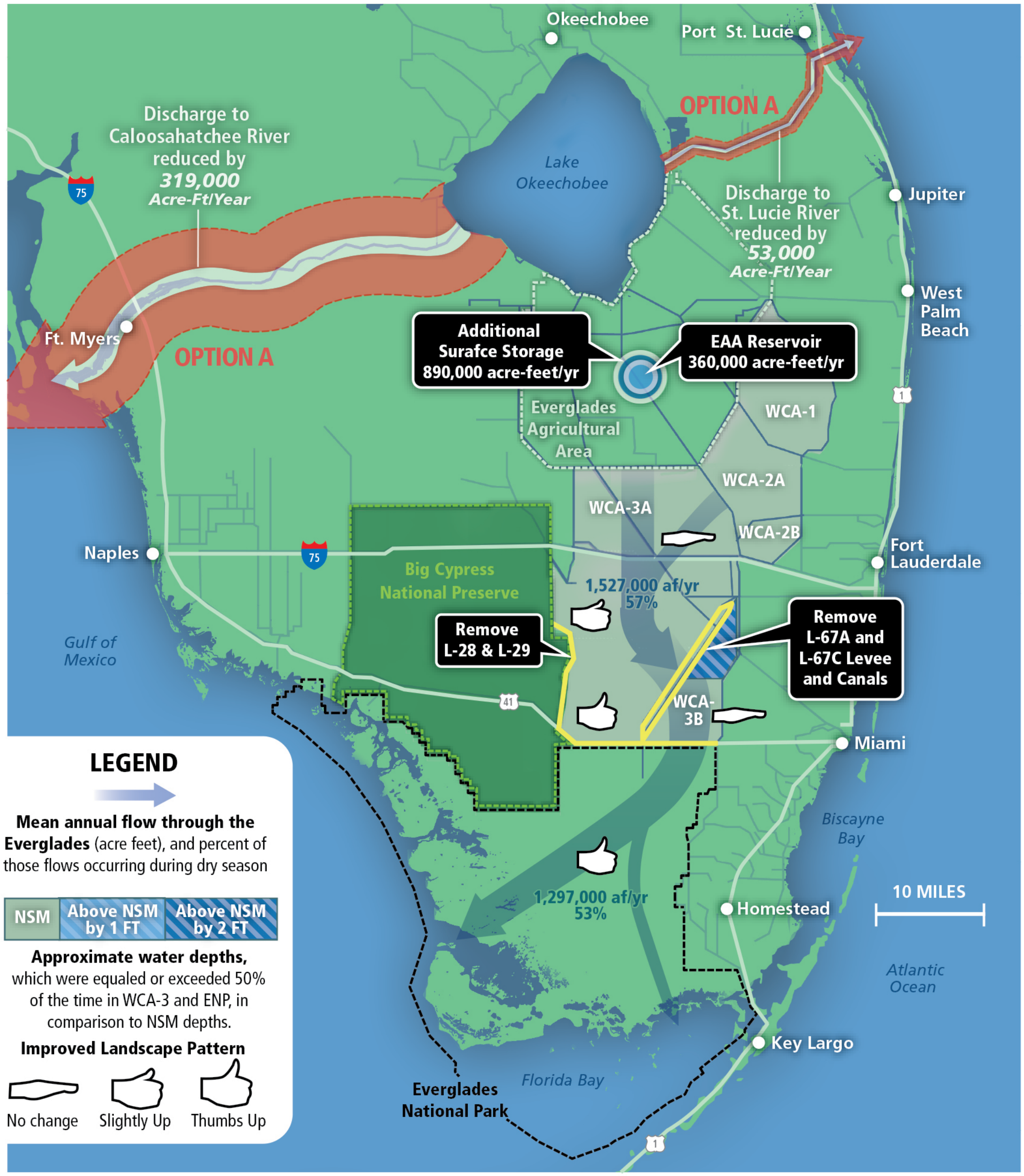
...OUT OF A TOTAL STORAGE OF 2,235,960

Lake Okeechobee ASR	Lake Belt	Surface
0	0	890,000

DECOMPARTMENTALIZATION

69% REDUCTION

IN INTERNAL BARRIERS TO FLOW



APPLE SNAILS

34% IMPROVEMENT IN HABITAT

WADING BIRD FLOCK ABUNDANCE

8% AVERAGE ANNUAL INCREASE

FISH DENSITY

13% ANNUAL INCREASE

INCREASED AREA OF PEAT SOILS

38,285 FOOTBALL FIELDS

MARSH POLLUTION REDUCTION

36% MODERATE "P" POLLUTION

62% HIGH "P" POLLUTION

FLORIDA BAY SALINITY REDUCTION

50% CLOSER TO TARGET

RISK OF FIRE

36% OVERALL DECREASE

NOTE: Percentage values represent annual averages or overall change in 36-year period of simulation. Refer to detailed appendices for explanations.

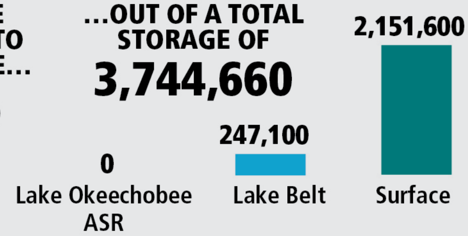
MAXIMUM STORAGE AND DECOMP » 90% of NSM flows making it to Gulf of Mexico, requiring an additional 38,500 acres of STA

OPTION E

CAPITAL COST
$20.8 billion

STORAGE UNIQUE TO OPTION E... (IN ACRE-FEET/YEAR)

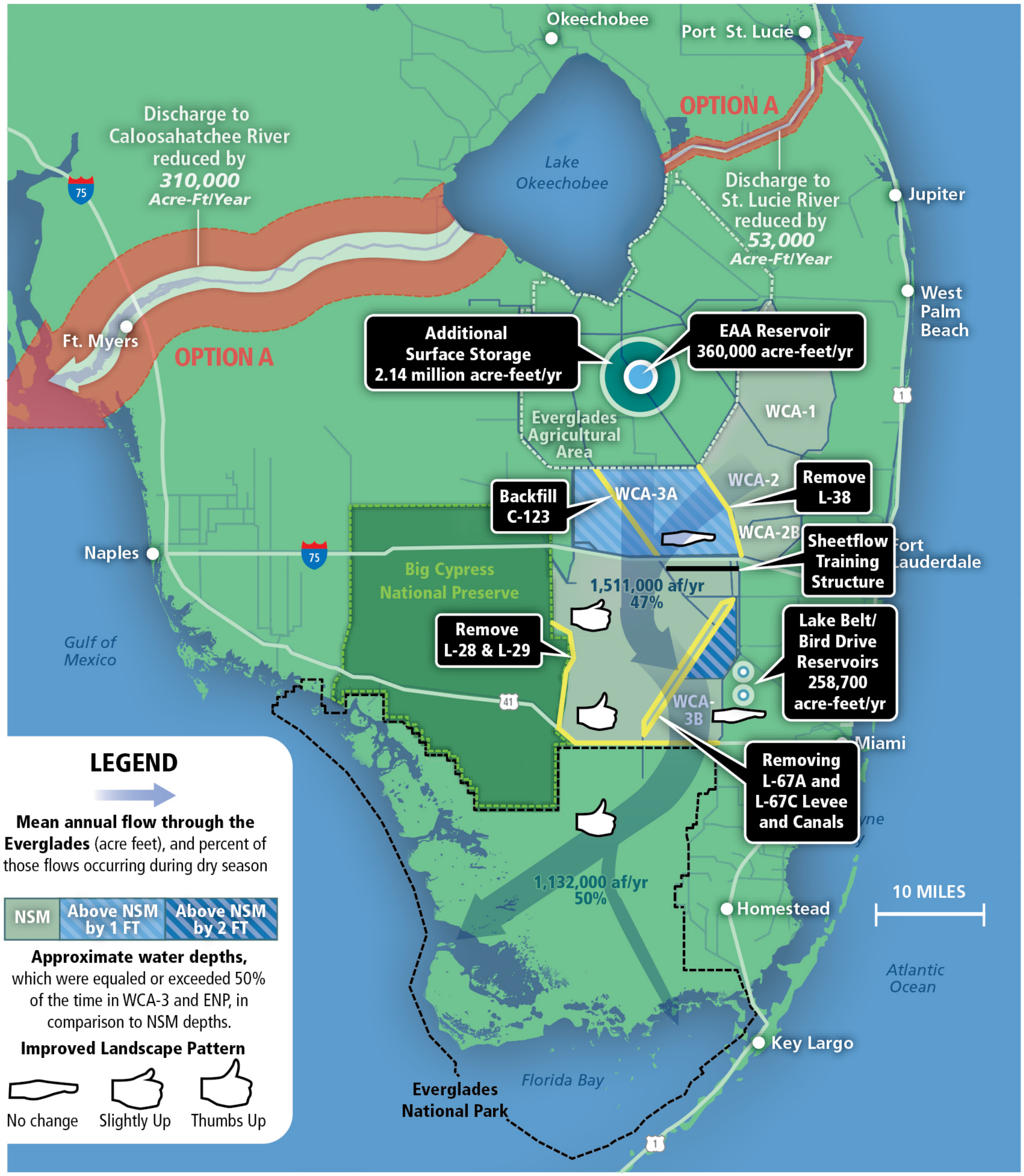
...OUT OF A TOTAL STORAGE OF 3,744,660



DECOMPARTMENTALIZATION

75% REDUCTION

IN INTERNAL BARRIERS TO FLOW



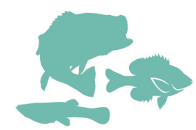
APPLE SNAILS

40%
IMPROVEMENT IN HABITAT

WADING BIRD FLOCK ABUNDANCE

9%
AVERAGE ANNUAL INCREASE

FISH DENSITY



15%
ANNUAL INCREASE

INCREASED AREA OF PEAT SOILS

55,623
FOOTBALL FIELDS

MARSH POLLUTION REDUCTION

26%
MODERATE "P" POLLUTION

61%
HIGH "P" POLLUTION

FLORIDA BAY SALINITY REDUCTION

50%
CLOSER TO TARGET

RISK OF FIRE

89%
OVERALL DECREASE

NOTE: Percentage values represent annual averages or overall change in 36-year period of simulation. Refer to detailed appendices for explanations.

ABBREVIATIONS AND ACRONYMS

Acre-ft - unit of water volume equaling 1 foot of water over an area of 1 acre (equal to 325,851 gallons)

ASR - Aquifer Storage and Recovery

C - Canal (always followed by a number identifying a specific canal, e.g., C-111)

CERP - Comprehensive Everglades Restoration Plan

CEPP - Central Everglades Planning Process

CESI - Critical Ecosystem Studies Initiative

CHIP - Cattail Habitat Improvement Project

CISMA – Cooperative Invasive Species Management Area

CISRERP - Committee on Independent Scientific Review of Everglades Restoration Progress

C&SF - Central and Southern Florida

Decomp - Decompartmentalization

DOI - Department of Interior

DPM - Decomp Physical Model

EAA - Everglades Agricultural Area

EDDR – Early-Detection Rapid-Response

ENP - Everglades National Park

FIU - Florida International University

FWC – Florida Fish and Wildlife Conservation Commission

G - Gate (followed by a number identifying a specific gate, e.g., G-211)

ha – Hectares (1 ha = 2.47 acres)

IPCC – Inter-governmental Panel for Climate Change

L - Levee (followed by a number identifying a specific levee, e.g., L-67)

MAP - Monitoring and Assessment Plan

MGD - Million gallons Per Day

N - Nitrogen

NPCA – National Parks Conservation Association

NPS - National Park Service

NSM - Natural System Model

P - Phosphorus

PPB - Parts Per Billion

PPT - Parts Per Thousand

S - Structure (followed by a number identifying a specific structure, e.g., S-333)

SCCF - Sanibel-Captiva Conservation Foundation

SERES - Synthesis of Everglades Restoration and Ecosystem Services

SFWMD - South Florida Water Management District

STA - Stormwater Treatment Area

TN - Total Nitrogen

TP - Total Phosphorus

UM-RSMAS – University of Miami, Rosenstiel School of Marine and Atmospheric Sciences

USACE - U.S. Army Corps of Engineers

USGS - U.S. Geological Survey

USFWS - U.S. Fish and Wildlife Service

WCA - Water Conservation Area

THE SERES PROJECT

Synthesis of Everglades Research and Ecosystem Services

www.everglades-seres.org/Welcome.html