The ecological–societal underpinnings of Everglades restoration

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The biotic integrity of the Florida Everglades, a wetland of immense international importance, is threatened as a result of decades of human manipulation for drainage and development. Past management of the system only exacerbated the problems associated with nutrient enrichment and disruption of regional hydrology. The Comprehensive Everglades Restoration Plan (CERP) now being implemented by Federal and State governments is an attempt to strike a balance between the needs of the environment with the complex management of water and the seemingly unbridled economic growth of southern Florida. CERP is expected to reverse negative environmental trends by "getting the water right", but successful Everglades restoration will require both geochemical and hydrologic intervention on a massive scale. This will produce ecological trade-offs and will require new and innovative scientific measures to (1) reduce total phosphorus concentrations within the remaining marsh to 10 µg/L or lower; (2) quantify and link ecological benefits to the restoration of depths, hydroperiods, and flow velocities; and (3) compensate for ecological, economic, and hydrologic uncertainties in the CERP through adaptive management.

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Understanding the ecology of the Everglades at all landscape scales, from the ubiquitous mats of calcareous periphyton to the Florida panther, is a tall order, even for an $8.3 billion restoration program (see www.evergladesplan.org). Although most of this money will be used for land acquisition and re-engineering south Florida's vast water management system, $10 million will be spent annually for ecological monitoring and assessment. Everglades restoration is intertwined with both science and public policy (Davis and Ogden 1994). Providing flood control and water supply to urban and agricultural areas competes with the water needs of the environment. As such, the fate of the Everglades is a dramatic case study of a global issue: freshwater allocation. Decision makers from around the world are watching south Florida, to see how wetland restoration will be balanced against economic development and societal demands.

In a nutshell:

- Since 50% of the historic Everglades is gone and cannot be restored, the ecological underpinnings of Everglades restoration will instead establish conservation criteria intended to reverse current negative environmental trends by "getting the water right"
- Restoration plans account for the lack of a coordinated regional effort to regulate future development in southern Florida
- A critical precursor to restoration will be the construction of more than 24 000 ha of treatment wetlands, whose outflow of total phosphorus concentrations will need to approach 10 µg/L
- Restoration will require numerous socioeconomic (eg recreational fishing) and ecological (eg removal of canals) trade-offs
- Flexibility in the design and implementation of Everglades restoration, needed to balance uncertainties and optimize trade-offs, will depend upon the ability of State and Federal agencies to develop an adaptive management approach

Efforts to drain the Everglades first began on a small scale in the 1880s and culminated almost 70 years later with Congressional authorization to build today's complex system of canals and water-control structures (Light and Dineen 1994). Understanding the impact of these events is crucial to understanding Everglades restoration. The drainage projects of the early 20th century uncovered the fertile "black gold" soil for farming by diverting the Everglades' headwaters – Lake Okeechobee – to the Atlantic and Gulf of Mexico, and later by channelizing the Everglades themselves. These initiatives precipitated a 100-year legacy of development and environmental degradation in south Florida.

The economic growth of south Florida is easy to see on a satellite image (Figure 1). Four thousand square kilometers of former marsh have been developed into highly productive farmland and a portion of the cities and towns that are home to more than 6 million people. The environmental damage to the remaining Everglades is not as apparent, but is just as widespread. Between 1880 and 1940, water tables declined by as much as 2.7 m (McVoy

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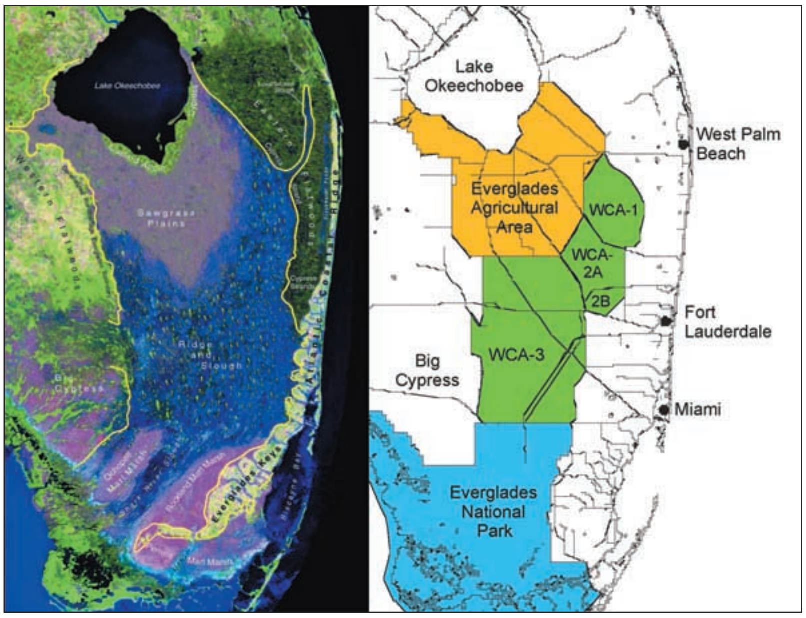

Figure 1. *(a) The Everglades landscape as it is thought to have appeared prior to development compared with (b) today's highly managed, compartmentalized system.*

et al. in press). As a result of drainage, the region's rich organic soils began to subside, due to physical compaction, microbial oxidation, and periodic burning. Over the decades, more than 2 m of soil has been lost in what is now designated the Everglades Agricultural Area (Figure 2), and topographic changes actually reversed the direction of water flow (Davis 1943). Low water tables within the Everglades allowed saltwater intrusion into coastal aquifers and contaminated urban wellfields (Allison 1943).

The problems associated with both flood control and over-drainage prompted Congress to create the Central & South Florida Project in 1948; this authorized the US Army Corps of Engineers (USACOE) to impound the northern Everglades, creating the Water Conservation Areas (WCAs; Figure 1). However, these measures only slowed the rate of environmental damage. The WCAs divided what was a shallow, free-flowing wetland into a series of ponded compartments that operated more as storage reservoirs. These hydrologic changes led to the loss of hundreds of tree islands (Sklar and van der Valk 2002) and altered the characteristic ridge and slough landscape patterning (Science Coordinating Team 2003). In addition, high phosphorus (P) loads in runoff from developed areas have damaged portions of the historically nutrient-poor Everglades (McCormick *et al.* 2002). The goals of Everglades restoration are to restore the region's hydrology and reduce nutrient enrichment to the greatest extent practicable.

Figure 2. *Drainage was especially effective in the Everglades Agricultural Area, where exposure has oxidized much of the original peat soil. The top of the concrete post shown was at ground level when it was driven down to the underlying limestone caprock in the 1920s.*

Plants behaving badly

The encroachment of native cattail (*Typha* spp) into sawgrass (*Cladium* spp) marsh and slough (*Nymphaea, Nuphar, Utricularia,* and *Eleocharis* spp) communities was triggered by alterations in hydrology and nutrient enrichment, and is one of the most visible signs of an Everglades in decline. For example, dense coverage of cattail in WCA–2A increased from 422 ha in 1991 to more than 1643 ha by 1995, an increase of some 350% (Rutchey and Vilchek 1999; Figure 3). Cattail expansion has reduced prey availability for wading birds (Crozier and Gawlik 2002) and altered periphyton (attached algae) productivity, which in cascade fashion contributes to decreased dissolved oxygen (DO) concentrations (McCormick and Laing 2003) and altered food webs. This invasive species is difficult to control since it stores large amounts of P (Miao and Sklar 1998) and is well adapted to present-day water depths and nutrient regimes (Newman *et al.* 1996).

The feedback mechanisms between soil P and cattail growth forecast the fate of the Everglades without restoration. At the far northern end of the Everglades, soil P concentrations are substantially elevated near points where urban and agriculture runoff enters the marsh (Newman *et al.* 1997). Surficial soil P has increased threefold since the 1970s along a nutrient gradient downstream of the WCA-2A inflow structures. In 1998, over 73% of WCA–2A had soil P concentrations >500 mg/kg, as compared to only 48% in 1990 (Figure 3).

The loss of tree islands is another symptom of environmental degradation in the area. These "biodiversity hotspots" are small (1–10 ha) topographic highs within the ridge and slough landscape, and are ecologically important because they provide critical habitat for many plants and animals (Sklar and van der Valk 2002). From 1940 to 1995, WCA–3 experienced a 45% loss in the abundance and a 61% decline in total acreage of tree islands due to frequent peat fires and high water levels. Prolonged submergence of wetland forests inhibits plant growth and regeneration for even the most water-tolerant species (McKelvin *et al.* 1998). A tree island model for WCA–2A suggests that 30 cm of water and 120 days per year of continuous flooding is sufficient to cause physiological stress and eventual replacement of the forest structure by marsh vegetation (Wu *et al* 2002).

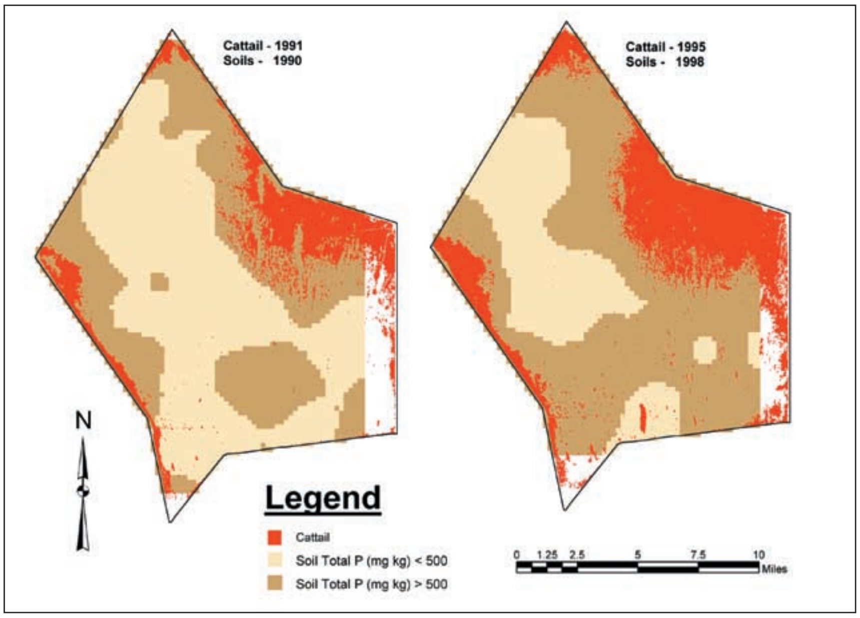

Figure 3. *Temporal and spatial changes in soil total phosphorus content and cattail coverage in WCA–2A in the northern Everglades.*

■ Animals beset with flood and drought

Geographic shifts in nesting patterns and a 90% decline in abundance of wading birds were two early signs of an ecosystem in decline (Ogden 1994). On one hand, reduced flow to Everglades National Park (ENP) led to the reduction of nesting areas for many wading birds during dry years. Conversely, deep water in the WCAs greatly affected species such as ibises, which require a continuous dry down (approximately 0.5 cm/day) during breeding to concentrate prey in depressions (eg sloughs and alligator holes; Gawlik 2002). When water levels increase due to water management or rain, prey disperse, forcing wading birds to abandon their nests (Frederick and Collopy 1989).

Historically, important invertebrate prey, such as the apple snail (*Pomacea paludosa*), were able to survive short periods (5–6 weeks) of desiccation (Darby *et al.* 2002) or, like crayfish (*Procambarus* sp), were able to burrow deep into the soil to find water. However, current Everglades water levels are too low and hydroperiods too short to adequately support these populations (Kitchens *et al.* 1994; Acosta and Perry 2001). Everglades restoration is expected to increase ground-water levels and create more refugia for these species during the dry season.

The dynamic between small fishes and the American alligator (*Alligator mississippiensis*) is another important ecological factor for Everglades restoration. Alligators dig holes that often serve as fish habitat during the dry season. Alligators do so because they need deep, open water for courtship and mating; successful mating and nest building leads to more holes and consequently more fish refugia. However, current compartmentalization of the Everglades can result in abrupt water-depth changes, which can either flood alligator nests or render them vulnerable to predation (Mazzotti and Brandt 1994). To restore successful alligator nesting while creating refugia for fish, it will be necessary to buffer rapid hydrologic changes and mimic the range of pre-drainage water depths.

The 420 animal species native to the Everglades are, to varying degrees, adapted to the pre-drainage hydrology of the region. However, restoring Everglades hydrology may not necessarily meet the long-term requirements of every extant animal. A particular water regime that is beneficial to one species is not always ideal for others. For example, the Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*), a federally endangered species displaced by hydrologic changes in ENP, requires a water depth of around 10 cm to begin breeding because its nests, which are placed at the base of vegetation, are flooded or lost to predators if water depth is too high or too low, respectively (Nott *et al.* 1998). To accommodate the sparrow's breeding cycle, inflow to ENP is reduced early in the dry season, allowing water levels to recede. However, reducing flow through the Park creates ponding stress on tree islands in upstream portions of the Everglades. To deal with this dilemma, and potentially create "trade-offs" (see below), the restoration planners have focused on the water needs of a subset of indicator species, which include lower trophic-level prey organisms such as small (<8 cm) fishes, crayfish, and apple snails, and higher trophic-level predators such as wood storks (*Mycteria americana*), white ibis (*Eudocimus albus*), and alligators (MAP 2004).

■ First, clean the water!

Atmospheric deposition was the primary source of nutrient inputs to the pre-drainage Everglades. The best available science suggests that surface-water P concentrations across most of the Everglades typically ranged from 4 to 10 μg/L and loading rates averaged less than 0.1 g P/m^2 /year

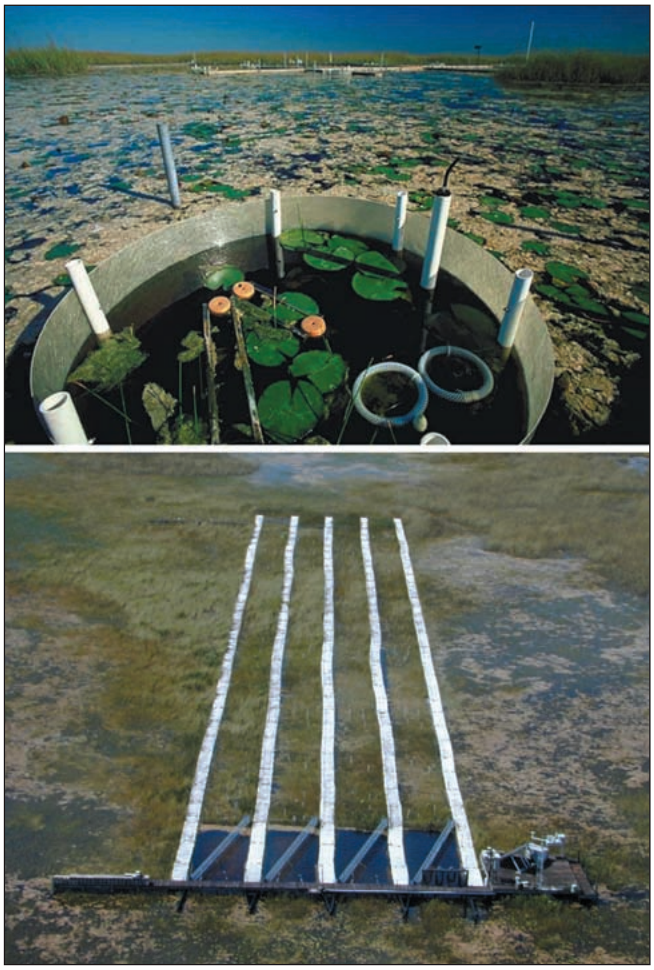

Figure 4. *(a) Floating mats of white periphyton disappear within an experimental mesocosm that is periodically dosed with phosphorus. (b) Sets of four 100-m long flumes evaluate chronic, low P dosing in Everglades National Park (see Gaiser* et al. *in press).*

(McCormick *et al.* 2001). In contrast, total phosphorus (TP) concentrations in drainage canals conveying urban and agricultural runoff to the Everglades have ranged from 100–1000 µg/L over the past three decades.

For restoration of the Everglades to succeed, it will be necessary to reduce nutrient loads, particularly P, entering the landscape from agricultural and urban areas. But how much P is too much? The answer was found along the nutrient gradient in WCA–2A. In addition to the cattail invasion described earlier, an important ecosystem change in nutrient enriched areas was the loss of the once abundant calcareous periphyton mats and an increase in algae, indicative of eutrophication (McCormick and O'Dell 1996). This shift in species resulted in a 6- to 30-fold decrease in areal periphyton productivity in enriched areas. Subsequent reduced DO levels (McCormick and Laing 2003) lead to increased abundance of organisms tolerant of low-oxygen conditions, such as oligochaete worms (Rader and Richardson 1994).

Because other aspects of wetland biogeochemistry and hydrology also vary in the Everglades, the assertion that excess P was the primary cause of ecological changes was tested using enclosed fertilizer plots (eg Craft *et al.* 1995), mesocosms (Figure 4), and flumes (Pan *et al.* 2000; Childers *et al.* 2002). Despite differences in methodology, biotic responses were consistent among experiments and corresponded with many of the ecological changes documented along nutrient gradients. For example, adding P to mesocosms resulted in the loss of the calcareous periphyton mat within several weeks to months, caused a shift from a periphyton-based to a detritus-based system, and increased nitrogen mineralization (Newman *et al.* 2001).

Table 1. Hydrological conditions in the Everglades: then and now*

	NSM v4.5 (Pre-drainage for the remnant Everglades)	*SFWMM v3.5 (Current drainage for the remnant Everglades)*
Average depth (cm)		
Annual	22.6	30.2
Dry season (Nov – May)	19.5	27.5
Wet season (Jun – Oct)	26.5	33.9
Average hydroperiod (days)		
Annual	309	295
Dry season (Nov – May)	172	160
Wet season (Jun – Oct)	138	134
Droughts in Everglades National Park		
# of Events	11	20
Average duration (Weeks)	5	7
Discharge to the Gulf of Mexico (m^3 x 10^6)		
Annual	1932	871
Dry season (Nov – May)	930	323
Wet season (Jun – Oct)	1002	549

NSM = Natural Systems Model; SFWMM = South Florida Water Management Model. Driven by 1965–1995 rainfall patterns, these two models are used to understand how water is currently distributed in the Everglades and how it would have been distributed if all roads, canals, control structures and people were removed from the remnant Everglades.

*The hydrologic goals of Everglades restoration are largely based upon the NSM. The amount of hydrologic change is based upon a comparison of the NSM and SFWMM. The smaller footprint of the remnant Everglades compared to the historic footprint creates a bias towards lower NSM depths when water depths may have been historically greater (McVoy *et al.* in press).

Based on an evaluation of these data, the Florida Department of Environmental Protection (FDEP) determined that key biological changes occurred in the Everglades when water column TP exceeded a mean of 9.8 to 14.7 µg/L (Figure 5). In December 2001, FDEP recommended a TP concentration threshold of 10 µg/L to protect the ecological integrity of the entire system (FDEP 2000).

The question now is: how do

we reduce TP concentrations to a mere 10 µg/L? The answer depends on the adequacy of three approaches: (1) on-farm, best management practices (BMPs); (2) six or more large treatment wetlands, known as Stormwater Treatment Areas (STAs) (Chimney and Goforth 2001; Figure 6); and (3) Advanced Treatment Technologies (ATT), to enhance STA performance. The BMPs, initially expected to reduce the TP load from farms by 25%, have far exceeded their goal. Annual TP loads in agricultural runoff decreased by an average of 54% from 1996 to 2000, compared to a 10-year baseline period (1979–1988). The STAs, designed to achieve an interim outflow TP concentration of 50 µg/L (Walker 1995), have also largely exceeded expectations. With the exception of one STA, mean outflow TP concentrations have ranged from 17 to 47 µg/L.

Three types of ATTs have been investigated: chemical (treatment with aluminum or iron salts), biological (wetlands dominated periphyton or submerged aquatic vegetation [SAV]), and hybrid (combination of chemical and biological approaches) technologies. While chemical treatment achieved outflow TP concentrations at or below 10 µg/L, concerns about high capital and operating costs, disposal of residuals, and the potential impact of the effluent on the Everglades remain unresolved. Because of this uncertainty, chemical treatment was not considered a viable option; instead, research efforts are now focused on optimizing the "green" technologies. One scenario would reconfigure the STAs into treatment trains of sequential cells dominated by emergent macrophytes -> SAV -> periphyton. As currently envisioned, the STAs will encompass more than 24 000 ha when completed, making them the largest complex of constructed wetlands in the world.

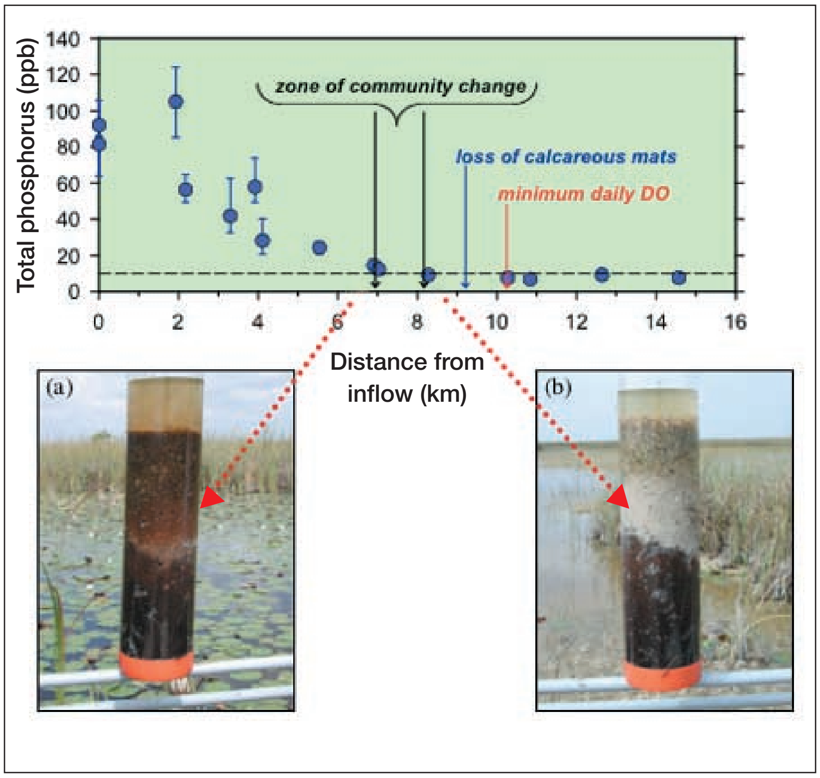

Figure 5. *Change point analysis along the nutrient gradient in WCA–2A. The graph illustrates the decrease in water column total phosphorus concentration with increasing distance from the inflow structures. A sediment core taken from a nutrient enriched area (a) has a dark, highly organic surficial layer, while a core from an unimpacted area (b) shows a characteristic calcareous sediment.*

■ Every restoration plan needs a model (or two)

While researchers have gathered an extensive body of historical information on pre-drainage Everglades hydrology, the synthesis of this material is in progress and the role of flow velocities and direction needs further study (CROGEE 2003). As a result, restoration planning has relied heavily upon a mathematical model, the Natural Systems Model (NSM), to estimate pre-drainage and pre-impoundment water depths, hydroperiods, and, to a lesser extent, flow vectors based on 1965–1995 rainfall patterns. The NSM may be the most important landscape model ever developed for environmental restoration, and yet it cannot be calibrated or "confirmed". Instead, it relies on the calibration of another model, the South Florida Water Management Model (SFWMM), which is similar to the NSM, except that it includes present-day infrastructure (eg canals, levees, etc) and is driven by current (1965–1995) rainfall patterns, soil elevations, and operational rules for flood protection and water supply.

The hydrologic goals of Everglades restoration were derived from a comparison of NSM and SFWMM output (Figure 7). Differences in water depth, hydroperiods and discharge rates (Table 1) were used to help set initial restoration targets. However, the current NSM water depths appear too low and flow directions seem illogical to some (McVoy *et al.* in press). The intent is to return the hydrology of the present-day Everglades to "NSM-like" conditions. However, due to the high uncertainty of NSM, these goals will almost certainly need to be modified through adaptive management (see "Under the underpinnings").

■ Dances with wolves: litigation and legislation

The restoration of the Everglades has been fraught with litigation, beginning with a lawsuit brought by the Federal government in 1988 alleging that the state of Florida was in violation of its own water quality standards for the Everglades. In the ensuing years, numerous other lawsuits and administrative actions were brought by a variety of interested parties (Rizzardi 2001). A settlement

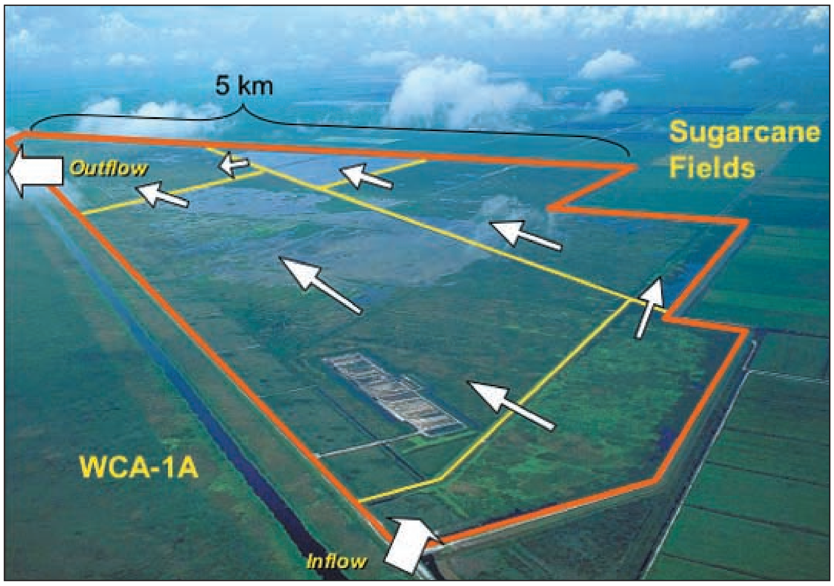

Figure 6. *Oblique photo of a Stormwater Treatment Area (STA) in south Florida. Arrows indicate direction of water flow through the wetland; yellow lines mark interior levees that divide the STA into separate treatment cells.*

to the federal lawsuit included the purchase of large tracts of farmland for conversion into STAs. Never in the history of US wetland science has a conversion of this scale been attempted. The Florida legislature codified the settlement agreement in the 1994 Everglades Forever Act (EFA). The EFA established a taxing mechanism to fund land acquisition and STA construction, at a cost of about $800 million. The EFA also specified that by 2001, the FDEP had to establish a P threshold where, "In no case shall such phosphorus criterion allow waters in the Everglades Protection Area to be altered so as to cause an imbalance in the natural populations of aquatic flora or fauna".

In the event that a P threshold was not adopted by this deadline, a default standard of 10 μg/L would become law. The Florida legislature amended the EFA in 2003, which resulted in moderating provisions and an extension of the time required to achieve long-term water quality goals (the P-rule). Although the P-rule was challenged by both environmental and agricultural interests in 2004, the state won the challenges and therefore a criterion of 10 μg/L is in place and a procedure for assessing compliance is required to be in place by 2006.

The EFA is only half of the legal and legislative story; the Comprehensive Everglades Restoration Plan (CERP) comprises the other. The CERP, authorized by Congress as part of the Water Resources and Development Act of 2000, is a massive hydrologic restoration program for the whole of south Florida. CERP includes some 60 projects to be constructed over the next 30 years, which will extensively modify the existing water management system by removing some infrastructure while adding new components.

In anticipation of a contentious political environment and in recognition of the fact that Everglades restoration is different from most USACOE projects, the following language was incorporated into the Programmatic Regulations that guide the implementation of CERP: (1) Programmatic Regulations will "ensure the protection of the natural system consistent with the goals and purposes of the Plan (CERP), including the establishment of interim goals to provide a means to evaluate success of the Plan"; and (2) CERP will "ensure that new scientific or technical information that is developed through the principles of adaptive management…are integrated into the plan".

The SFWMD, together with the USACOE, are obligated to "ensure that restoration does not diminish current levels of water supply or flood control". Everglades restoration is therefore a two-fold challenge: it must restore hydrologic regimes and clean water while simultaneously devision alternative means of improving regional water management for economic and societal development.

Trade-offs and uncertainties abound

Successful Everglades restoration will ultimately be determined by reconciling society's needs and values with that of the ecosystem. Unlike the cycle of opportunistic growth -> maintenance -> release -> reorganization, as detailed in Holling's (1978) paper on natural succession, the human economic system seems to be one of opportunistic growth -> opportunistic growth -> opportunistic growth. As a result, the re-engineering of the south Florida water management system may conflict with ecological restoration and create issues of social concern that pit dollars against nature.

Despite all the attention, Everglades restoration is not a done deal. In fact, every one of its 60 or so cost-shared projects must be ecologically and economically "justified", using procedures that quantify tax-payer costs against ecological benefits. For very expensive projects, such as the construction of an elevated highway to enhance sheet-flow across the marsh, justification can be very contentious because the uncertainties associated with calculating the benefits greatly exceed the uncertainties for calculating the costs.

These uncertainties become magnified by conflicting interpretations, non-linear feedback mechanisms, slow response times, and a lack of data. As a result, "exact" solutions are not possible; instead, Everglades restoration is challenged by seven major uncertainties:

(1) What will be the structure of the surrounding watershed in 2050? This uncertainty is associated with estimates of population growth and the potential impacts of converting farmland to housing developments or mining operations to maximize economic returns. This will affect both water quantity and water quality. Trade-offs will occur, especially during floods and

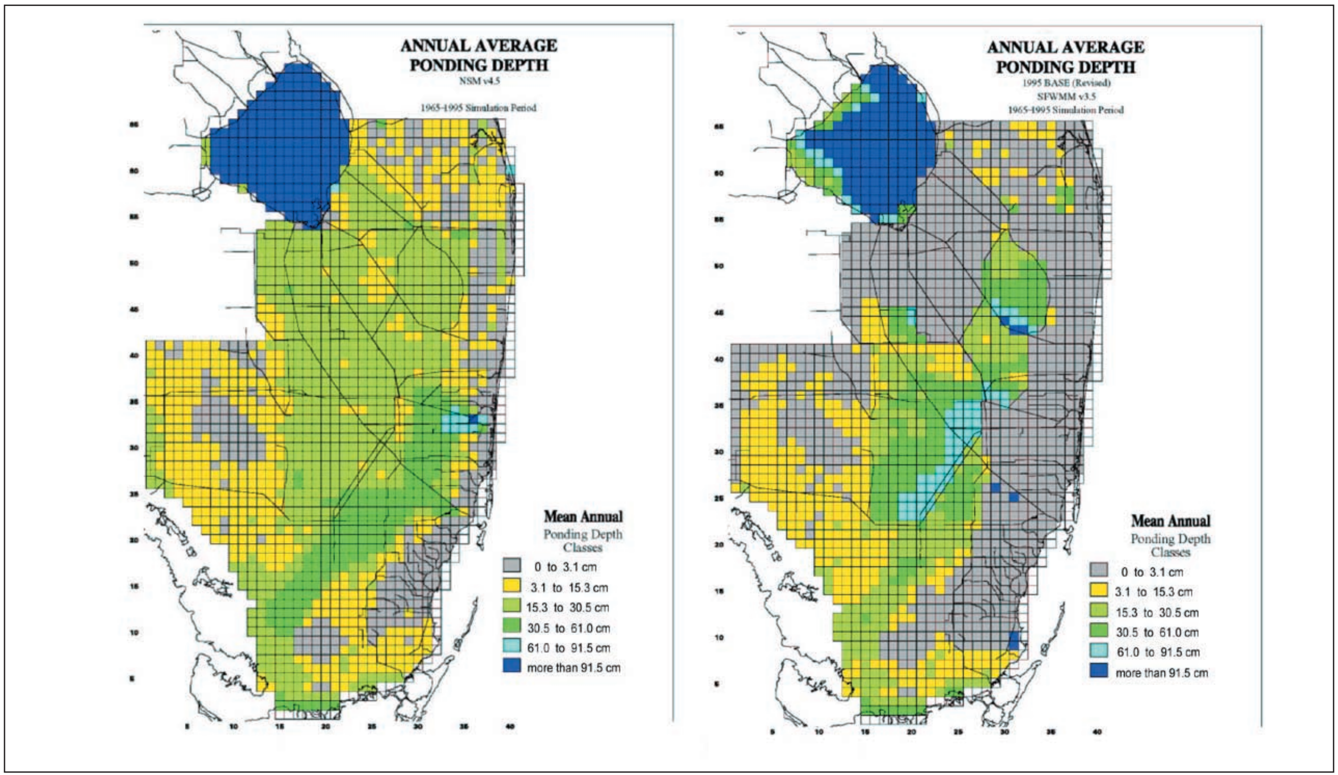

Figure 7. *The difference between (a) the historical extent and (b) the current boundaries of the Everglades is shown here in terms of surface water depths. Much of the historic Shark River Slough (shown as a dark green flow-way) is now east of the existing levee system and outside the current footprint of the Everglades. What remains is approximately 30 cm shallower than historically predicted. At the same time, model simulations indicate that the rest of the Everglades has become deeper.*

droughts when water is diverted to the estuaries or stored belowground in deep Aquifer Storage and Recovery (ASRs) wells, respectively.

(2) How dependent is restoration upon cutting-edge engineering and technology? Some 300 ASR injection wells are proposed to store freshwater and some 20 km of 20–30 m deep curtain walls are suggested as flood protection for urban and agricultural lands. Neither have been implemented at these scales. In the purest sense of restoration, all impediments to flow within the extant Everglades would be removed. However, even with these technologies, if all levees that separate one WCA from another were removed, then according to the SFWMM, water would drain too quickly in some places and not drain at all in others. Since these are very expensive technologies (eg $4 million/km of curtain wall), the trade-offs will be between the ecological benefits of removing all or some structures and the cost of providing flood protection and water supply.

(3) How and where in the Everglades do you measure compliance with a P threshold? This uncertainty is associated with sizing and operating STAs and with soil P dynamics downstream in the marsh. It follows that uncertainty associated with the P threshold in the Everglades will determine land acquistion, at a cost of millions of dollars. It is the precursor to a trade-off between "getting the water right" and "getting the water quality right". If P concentrations delivered to the Everglades exceed the 10 μg/L threshold, then the hydrologic needs of the Everglades landscape may come at the expense of an expanding cattail habitat. Other water quality uncertainties, including the use of runoff elevated in sulfate and its potential effect on the methylation of mercury (Gilmour *et al.* 1998; Bates *et al.* 2002), pesticides, and other contaminants have only begun to be investigated.

(4) What are the freshwater volumes needed for Florida Bay? Too little freshwater inflow from the Everglades to Florida Bay can promote hypersaline events that are detrimental to seagrass beds. However, increasing inflows, if not fully treated, may also increase nutrient loading. The trade-off will be between "getting the salinity right" and "getting the water quality right".

(5) What are the ecological impacts of canals? The canals that were constructed to drain the Everglades are now sport-fishing habitats. However, the complete backfilling of canals will also eliminate deep-draft boating activity. The trade-off will consist of the economic benefits of recreational fishing versus the ecological benefits of sheet-flow.

(6) How do landscape patterns of tree islands, ridges and sloughs maintain their topographic differences? Restoring pre-drainage hydroperiods is expected to prevent peat fires, reverse the impacts of compartmentalization, and create more slough habitat.

Increasing the hydroperiod, however, may stress tree islands that have been losing elevation due to drainage. A return to pre-drainage depths and hydroperiods may cause tree island degradation in some regions.

(7) How do you quantify ecological benefits? The implementation of any USACOE project requires a trade-off between estimated costs and predicted benefits. Models to predict the ecological benefits have considerably greater uncertainty than those used to estimate engineering costs. Furthermore, although there are quantitative valuation techniques for ecosystem services (eg Costanza *et al.* 1993; Howarth and Farber 2002; Kant 2003), they are not easily developed or interpreted, and thus have not yet gained acceptance by government or social institutions.

■ Under the underpinnings

Ecosystem science has clearly documented the environmental impacts associated with the Central & South Florida Project, including over-drainage and excessive nutrient loading. Now, it is a matter of careful design and implementation to correct these problems and compensate for the uncertainties, and therein lies the biggest challenge to Everglades restoration.

Flexibility in the design and execution of CERP, needed to balance modeling and ecological uncertainties, optimize trade-offs, and go beyond just conservation, will depend upon an adaptive management approach (Holling 1978; Walters *et al.* 1992). Adaptive management allows for the utilization of new knowledge as it becomes available and is essential to the success of this long-term project. However, the mechanism for translating new information into new project designs and implementation schedules has yet to be devised. Limitations include the expense of modifying new construction and the long lag times associated with measuring and quantifying ecological benefits. Adaptive management may also be costly and alter benefits to particular stakeholders. Yet these changes will probably be necessary and are in fact the justification for using an adaptive management framework.

Successful adaptive management will require both public and interagency trust. Stakeholders must believe that they will not be short-changed in this process. Unfortunately, due to a long history of accommodation to special interest groups (Douglas 1947; Johnson 1974), there are concerns that social change and shifts in political power may undermine a long-term restoration program that is designed and implemented incrementally. Therefore, the adaptive management approach must contain criteria to reassure stakeholders that the goals of Everglades restoration cannot be compromised. Trust is essential, and will improve as long as the scientific basis for restoration continues to reduce uncertainty. Scientists are currently developing interim goals and a strong monitoring and assessment plan for the Everglades. These efforts will supply the data needed to reduce the ecological and economic risks associated with adaptive restoration, and hopefully provide the framework for the successful restoration of this national treasure.

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