APPENDIX E

DECOMP PHYSICAL MODEL

SCIENCE PLAN

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THE DECOMP PHYSICAL MODEL SCIENCE PLAN

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1.0 EXECUTIVE SUMMARY

Restoration of the south Florida natural system is a massive and complex undertaking with numerous socio-ecological challenges. The ultimate goal is the hydrologic restoration of the quantity, quality, timing, and distribution of water deliveries to the primary landscape features (e.g., cypress forests, sawgrass sloughs, marl prairies, and mangrove estuaries) while maintaining drainage, flood control, water retention, water supply, irrigation, and transportation for the more than 7 million people that inhabit south Florida. There is also a great diversity in how the population of south Florida values the natural system and envisions its restoration. To balance the needs of the ecosystem and society, an adaptive management approach is an integral part of the Comprehensive Everglades Restoration Plan (CERP). This approach utilizes best available science and adaptive assessment for planning, implementation, and modification as more information is obtained. The approach also advocates the use of science to help address socio-ecological uncertainties that are specific or unique to a restoration project.

The Everglades peatland is the keystone of the south Florida natural system. The loss and degradation of this unique ecosystem has been driven by the interruption of sheet flow following hydrologic modifications (canals and levees) aimed to benefit societal needs (e.g., drainage, flood control, water retention, water supply, irrigation, and transportation). Considered by many to be the heart of CERP, the Decomp project (short for decompartmentalization) aims to restore sheet flow to the central (water conservation areas 3A and 3B) and southern Everglades (Everglades National Park) by re-engineering the existing barriers to flow. However, the development of the restoration plan has been influenced by six major socio-ecological uncertainties. Presented here is the Decomp Physical Model (DPM) Science Plan as an effort to use science to address two of the six uncertainties: the ecological need to completely backfill canals and the ecological benefit of sheet flow. The scope of the DPM is to conduct a large-scale field study to address scientific, hydrologic, and water management issues specific to the two uncertainties. DPM utilizes a temporary controllable conveyance feature to assess the hydrologic and ecological impacts associated with depth, hydroperiod, sheet flow, and canal backfilling on the health and sustainability of the ridge & slough landscape and some aspects of wildlife ecology. The project will be undertaken by a multidisciplinary team of scientists and engineers from the South Florida Water Management District, US Army Corp of Engineers, US Geological Survey, and Everglades National Park, who all have significant experience conducting scientific research focused on the hydrology and ecology of the Everglades.

The DPM Science Plan consists of two sections: The first section (2.0 General Introduction) provides a general introduction to the Everglades and its restoration, specifically the Decomp project and the associated socio-ecological uncertainties. The scope, approach, and scale of the DPM are also presented in connection with the anticipated linkages between the results and planning elements. The second section (3.0 The Decomp Physical Model Experimental Design) presents the details of the scientific approach that will be used to address the uncertainties. Testable hypotheses were developed for each uncertainty and an experimental design constructed that utilizes hydrology, sediment transport, vegetation, and wildlife interactions as response variables. It is comprised of four components. Section 3.1 describes the location and features of the DPM, the expectations for the hydrologic conditions that will

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be created by the installation, and the operational schedule. Section 3.2 describes the experimental design to evaluate backfilling options. Section 3.3 describes the experimental design to evaluate the ecological benefits of enhanced sheet flow. Section 3.4 describes the synthesis and reporting the results.

Briefly, the DPM will consist of a 750 cfs culvert on the L-67A levee, a 3000 foot gap in the L-67C levee, and the complete or partial backfilling of two 1000 foot segments of the L-67C canal, adjacent to the L-67C gap. The features are temporary and are planned to be removed at the end of the project. These features will provide a controllable hydrologic connection between WCA-3A and WCA-3B that is predicted to deliver velocities in excess of 3 cm/sec in pulsed events lasting 14 to 40 days. These pulsed flows will be conducted in an operational window that extends from the end of October through January. This window was chosen because the combination of hydrologic gradient, water quality conditions, and other operational constraints are optimal during this period. Pulsed flows above a critical velocity threshold of 3 cm/sec are capable of entraining and redistributing particles, and are far greater than the average flow velocities of < 1 cm/sec currently present in the Everglades. The transport and redistribution of materials by flow is hypothesized to be an important driver regulating the ridge & slough landscape pattern. To address both uncertainties a *before-after-control-impact* (BACI) statistical design will be used. In this approach, the *before* period is defined by *control* measurements made 14-18 months prior to the *impact* and the *after* as the period during and following a pulsed flow event. *Control* areas are not affected by the high flows of the DPM, whereas *impact* areas are present in the DPM flow-way. Hydrology, sediment transport, vegetation, and wildlife interactions and responses will be assessed by coupling state-of-the art tracer technologies with well established vegetation and biogeochemical methods. Further evaluation will be gained by integrating field results with simulation (e.g., Ribbon and Lattice-Boltzmann) and hydrologic models (e.g., South Florida Water Management Model). Results will be reported annually to the Decomp Project Delivery Team as a written document and presentation. The report will be available to the public and all interested parties. In addition, members of the DPM Science Team will attend regularly scheduled PDT meetings to provide project updates and status reports. Members of the DPM Science Team will also be available, as needed, to present project status and results to other parties. It is anticipated that numerous scientifically scholarly articles will be submitted for publication in peer-reviewed journals and regularly presented at annual meetings of national and international scientific professional societies.

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2.0 GENERAL INTRODUCTION

2.1. Introduction

The Everglades was once an expansive subtropical ecosystem comprised of hydrologically interconnected cypress forests, sawgrass sloughs, marl prairies, and mangrove estuaries encompassing more than 3.6 million ha (Davis et al. 1994). These primary landscape features were physically defined by oligotrophic waters, low topographic relief, large spatial extent, seasonally dynamic rainfall and surface-water patterns, hydrologic gradients and sheet flow, and an estuarine system (Fig. 2-1; Ogden et al. 1999). These features supported sizeable populations of animals, whose foraging ranges were tightly coupled with the dynamic hydropatterns.

Over the last century, the Everglades ecosystem has degraded in concert with agricultural and urban development. A vast network of canals, levees, control structures, and conservation areas was created to maintain drainage, flood control, water retention, water supply, irrigation, and transport efforts. The largest of these was the Central and Southern Florida (C&SF) project constructed during the 1950s-1970s (Light and Dineen 1994). Collectively these efforts have significantly altered the natural Everglades hydrology (i.e., quantity, timing, and distribution of water deliveries), resulting in the loss of more than 50% of the Everglades peatland with continuing degradation of the remaining ecosystem (Fig. 2-1). Currently, the Everglades hydropatterns are more spatially and temporally heterogeneous than the pre-drainage (1860) ecosystem. Excessive drainage characterizes the northern reaches of the Water Conservation Areas (WCA) and large portions of Everglades National Park (ENP) and Big Cypress National Preserve whereas excessive ponding is prevalent in the southern regions of the Water Conservation Areas. These discrete geographic regions were once part of a vast contiguous peatland which experienced unconstrained sheet flow. In addition, development has impaired the quality of water throughout the Everglades watershed, leading to additional habitat degradation through eutrophication.

The Everglades is a major component of the complex socio-ecological structure of south Florida. Society has decided that Everglades has national significance and deserves preservation, conservation, and restoration. However, the large population of 7 million people (expected to exceed 8-15 million by 2050) who inhabit the south Florida watershed are directly dependent on water management for flood control, water supply, irrigation, and transportation. More importantly, there is a great diversity of perspectives which define how individual residents value the south Florida natural system. Restoration and management of the system and its resources must therefore strike a balance between the needs of the ecosystem and societal interests; thus, an adaptive management approach is being implemented (Ogden et al. 2005). Key to the plan is the use of “best available science” and “adaptive assessment” which ensures plan flexibility to allow for modification as new information is obtained (Ogden et al. 2003). An “applied science strategy” has also been developed to incorporate science into the planning and implementation of water management (e.g., Ogden et al. 2003; Ogden et al. 2005).

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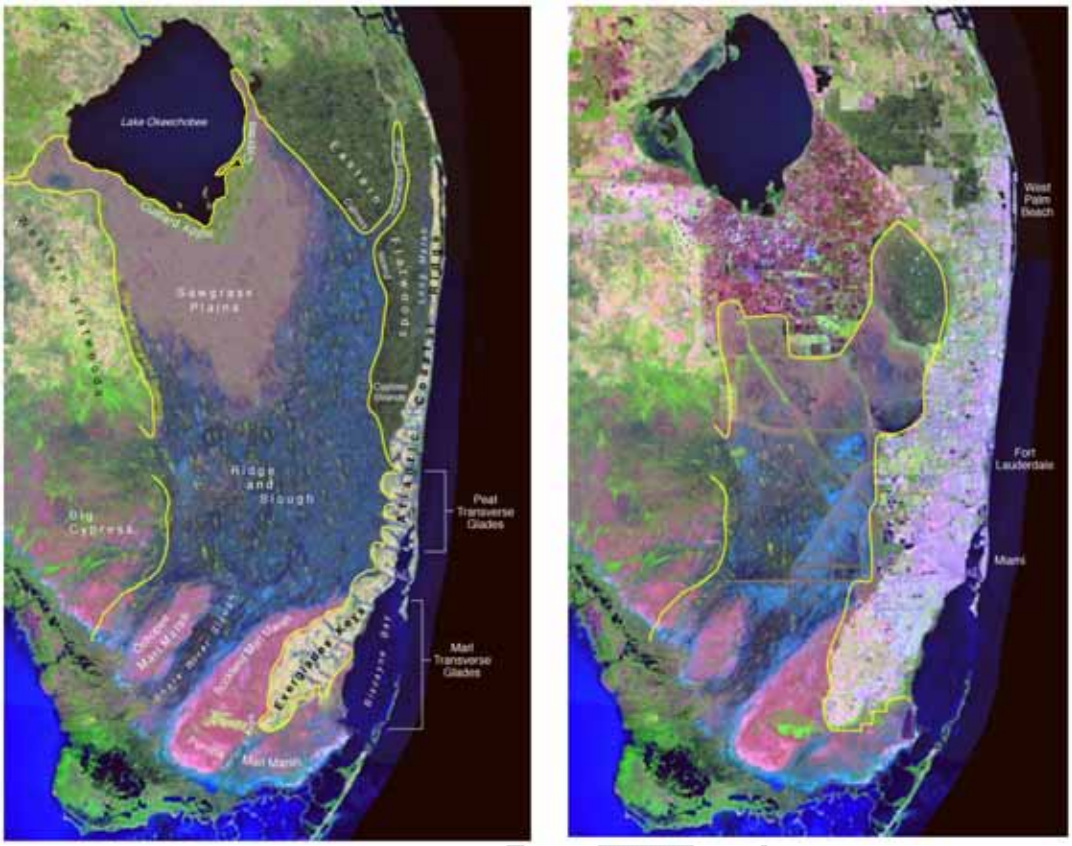

Figure 2-1: Conceptual reconstruction of the pre-drainage and the current south Florida natural system. The ultimate restoration target discussed in this Science Plan is the hydrologic reconnection of water conservation area 3A (WCA-3A), WCA-3B, and Shark River Slough (SRS) by removing or reconfiguring barriers to flow (i.e., canals, levees, and roads). (image by C. McVoy and W. Said).

Over the last three or four decades, a wealth of scientific knowledge has been gained about the Everglades proper and the south Florida natural system. There are hundreds, if not thousands, of published articles, reports, and books about the south Florida and Everglades ecology and restoration (e.g., Davis and Ogden 1994; Porter and Porter 2002; Sklar and van der Valk 2002; Sklar et al. 2005; Trexler et al. 2006; Richardson 2008; McVoy et al. in press; Reddy et al. in review). This information has been synthesized into conceptual models that identify the major anthropogenic drivers and stressors, the ecological effect of these stressors, and the best biological attributes or indicators of these ecological responses for the primary landscape features of south Florida (see Ogden et al. 2005). The primary landscapes types are the Everglades ridge & slough landscape (Ogden 2005), southern marl prairies (Davis et al. 2005a), Everglades mangrove estuaries (Davis et al. 2005b), and Florida Bay (Rudnick et al. 2005). The Everglades ridge & slough conceptual model identifies sheet flow, shortened hydroperiods, and ponding caused by water management practices (driver) that have reduced water storage capacity and increased compartmentalization as key stressors effecting the ecological attributes of the ridge & slough landscape (plant community composition and distribution and abundance of native aquatic animals). The disruption of sheet flow is the

least understood stressor (Science Coordination Team 2003) because there is no modern day analog in which to evaluate how pre-drainage sheet flow influenced nutrient cycling and transport, regulated topography, or primary and secondary production. The absence of sustained flow velocities of historic magnitudes (> 3 cm/sec; Larsen et al. in review) are absent from the current system (< 1cm/sec; Harvey et al., 2009) thereby prohibiting evaluation. This lack of knowledge impacts the downstream landscapes since their restoration is directly dependent on restoring sheet flow to improve freshwater flow volume, duration, and distribution.

Here we describe a large field-scale experiment, the Decomp Physical Model (DPM), to quantify some of the ecological benefits of restoring flow to the Everglades. The project aim is to provide ecological information that can lessen restoration uncertainty. Restoration uncertainty reflects issues in which the outcome is unknown to some degree. Restoration uncertainties that are specific to the south Florida natural system include ecological (attributes required to restore ecosystem structure and function), engineering (construction and operation of features required to restore hydropatterns), and socio-ecological (varied stakeholder interests) unknowns. This project is specifically designed to address uncertainties associated with the Comprehensive Everglades Restoration Plan (CERP) Decomp project, although the information gained will have broader application and relevance.

2.2. CERP and Decomp

The Comprehensive Everglades Restoration Plan (CERP) was authorized by Congress in 2000. The main objective of the plan is hydrologic restoration which will be achieved by increasing water storage capacity and redistributing water to reestablish ecologically desirable patterns of depth, distribution, and flow in the freshwater wetlands and salinity regimes in estuaries (Fig. 2-2; Ogden et al. 2003). CERP contains multiple elements, designed to restore ecosystem function and ensure adequate water supply (storage and distribution) while other efforts are designed to address water quality. Considered by many to be the heart of CERP, the Decomp project aims to reestablish sheet flow in the Everglades by decompartmentalization (i.e., removing barriers to flow). The goal of Decomp is to hydrologically reconnect a significant component of the Everglades peatland: WCA-3A, WCA-3B, and Shark River Slough. This effort will require a significant amount of engineering which will result in dramatic alteration to the ecosystem. The effort entails the removal of levees, the backfilling of canals, and alteration of a major roadway, Tamiami Trail. In addition, there are numerous socio-ecological elements that need to be considered and addressed. Thus, it is not surprising that there are multiple uncertainties and challenges associated with the design of Decomp (DPM Subteam 2009). The DPM is designed specifically to address aspects of the key uncertainties.

2.3. Uncertainties and the Decomp Physical Model

Decomp is faced with six uncertainties that can be addressed scientifically:

1. Is complete backfilling of canals an ecological and hydrologic a necessity for restoration? Are partial backfilling and no backfilling of canals viable options?

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2. What are the quantifiable ecological benefits of sheet flow and ecosystem connectivity?
3. What are the hydrological and ecological effects of levee modifications? Is it necessary for restoration to completely remove levees?
4. What are the water depth and hydroperiod tolerances for ridges, sloughs, and tree islands?
5. What are the effects of water levels in WCA-3B and northeast Shark River Slough on seepage to the Lower East Coast? Will Decomp cause flooding to urban areas?
6. Would the hydrologic models used to evaluate design alternatives benefit from better parameterization (i.e., in situ measurement) of key variables and processes?

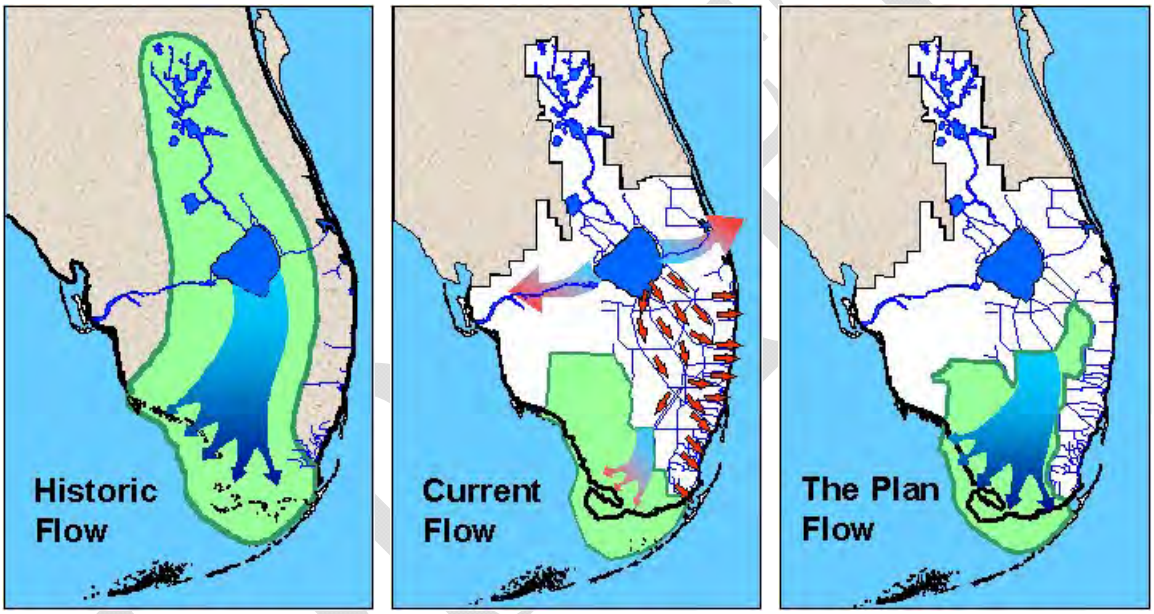

Figure 2-2: Schematic of historic, current, and restored flow patterns in the south Florida natural system.

The scope of the Decomp Physical Model (DPM), as presented here, is to conduct a large-scale field study to address scientific, hydrologic, and water management issues specific to uncertainties 1 and 2. The DPM will address aspects of uncertainties 3-6 to various lesser degrees. It will not address any of the uncertainties completely since this is not a landscape scale experiment. The DPM utilizes a temporary controllable conveyance feature to assess the hydrologic and ecological impacts associated with depth, hydroperiod, sheet flow, and canal backfilling on the health and sustainability of the ridge & slough landscape and some aspects of wildlife ecology. The features are designed to provide flows above a critical velocity threshold of 3 cm/sec capable of entraining and redistributing particles, thought to be an important regulator of the ridge & slough landscape pattern. The hydrology, sediment transport, vegetation and wildlife will be addressed through a *before-after-control-impact*

(BACI) statistical design. The scale and duration of the DPM does not allow for sufficient evaluation of tree island biology or water depth tolerances.

The information obtained by the DPM will be used by the Decomp Project Development Team (PDT) to develop the elements of Decomp Project Implementation Reports (PIR) 2 and 3 that deal specifically with features connecting WCA-3A, WCA-3B, and Shark River Slough. Elements of the DPM are less relevant to PIR 1, backfilling of the Miami Canal, because the DPM addresses features (canals and levees) oriented perpendicular, not parallel, to the direction of flow. Expected benefits of the DPM include:

1. Differentiating the ecological effects for the degradation options of the L-29, L-28, L-67A, and L-67C canals.
2. Information on the extent to which fluctuations in the magnitude and direction of sheet flow affect landscape characteristics of the Everglades.
3. Understanding the hydrologic risk of removing a section of the L-67C levee.
4. Associating water level monitoring with concurrent seepage management efforts for the L31 Canal to more clearly bound the effect of increased water level stages in WCA-3B and northeast Shark River Slough on seepage in northwestern Miami-Dade County.
5. The measurement of input parameters needed to calibrate conceptual and simulation models that will be used to determine the ecological effects of hydrologic modifications outlined in PIRs 2 and 3.

The hydrological and water management uncertainties that the DPM will address indirectly include water budgets and residence times for WCA-3B, minimum flows and levels, water reservations, C&SF system constraints, and operational guidelines and regulation schedules.

The DPM consists of short-term field studies that work <u>within</u> the existing C&SF system water management <u>constraints</u> including the WCA-3B high water stage constraint, L-29 canal stages, G-3273 constraint for 8.5 SMA, and control of seepage across the east coast protective levee and L-31N levee. The goal is to expand the solution space and maximize flexibility under existing conditions of the regulatory regime in WCA-3B to (1) conduct pulsed flow events (14-40 days) to understand the effect of increased velocity and durations on ridge and slough biogeochemistry and (2) determine the effects of complete backfilling, partial backfilling, and no backfilling on hydrology and sediment transport. It is possible that increased flows could increase nutrient loading; thus, water quality responses will be assessed during all phases of installation, operation, and de-installation of the DPM. This will be achieved by the construction of a flow-way that consists of temporary, fully controllable, culverts that convey water from the L-67A canal into a region of marsh called “the pocket” and across a 3000 foot gap in the L-67C levee to convey water from “the pocket” into WCA-3B. The details are provided in Section 3: The Decomp Physical Model Experimental Design.

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3.0 THE DECOMP PHYSICAL MODEL EXPERIMENTAL DESIGN

3.1. Features of the DPM

3.1.1 Introduction

Restoration of historic patterning of Everglades landscape is predicated, in part, on the notion that the existing canal and levee system has significantly reduced the velocity of sheet flow (Science Coordination Team 2003). Thus, restoration must not only include aspects of water quality, quantity, timing, and distribution but must also include a comprehensive understanding of whether these factors will produce the velocities required to shape and maintain landscape patterns. Within the current impounded system, in situ velocities are generally less than 1 cm/sec with occasional pulses exceeding 2 cm/sec and are greater in sloughs than adjacent ridges (Harvey et al. 2009). Based on the principal of best scientific judgment, the velocity for the pre-impoundment Everglades was suggested to be >2 cm/sec (Science Coordination Team 2003). Recent laboratory, modeling, and in situ measurements suggest that velocities >3 cm/sec are required to entrain Everglades bed sediment particles (Larsen et al. 2009a; Hagerthey et al. in prep). Particle entrainment and redistribution of suspended sediment is thought to be a key process for maintaining and restoring the Everglades ridge and slough landscape (Larsen et al. 2007). Given that velocity in the Everglades is typically <1 cm/sec, combined with the great difficulty of knowing when, where, and for how long in situ velocities approach or exceed the historic estimates, it is extremely difficult to evaluate the significance of historic flow velocities in shaping in the Everglades landscape. The Decomp physical model (DPM) is a large-scale experiment designed to test hypotheses about how reintroducing historic flows through the wetland and across canals affect the redistribution of sediments and suspended particles by non-linear particle transport processes. The proposed physical features and operations are designed to provide flow velocities more aligned with historic values in a controlled and predictable manner that will enable scientifically relevant investigations. The information gained from this experiment will provide critical information for 1) assessing various canal backfilling options that will be constructed in the Decomp project proper and 2) determining the ecological role of flow in the Everglades landscape.

3.1.2 DPM Site Location and Features Description

The DPM is situated between WCA-3A and WCA-3B in a region referred to as the pocket (25º51’03’’N; 80º37’10’’W). The pocket is bounded upstream by the L-67A and downstream by the L-67C canal and levee system (Fig. 3-1). The L-67A canal is a conveyance canal (depth = 14.7-19.4 feet; 4.5-5.9 m), receiving waters from the Miami Canal, S-9 pump station, and WCA-3A. It is bounded on the east by the L-67A levee and on the west by a spoil mound. The spoil mound, along with a series of cuts, allows mixing of canal water with WCA-3A marsh water. The L-67C canal (depth 10.9-13.8 feet; 3.3-4.2 m) was constructed to prevent flooding of the communities to the east by controlling seepage and, therefore, does not directly receive discharges from control structures nor is it used for conveyance. It is bounded to the east by a levee and to the west by a small spoil mound. The orthogonal distance between the L-67’s that defines the “pocket” is 1.2 mi (1.9 km). The “pocket” is characterized principally by a slightly degraded ridge & slough habitat and tree

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islands. Degradation resulted from alterations to hydrology and not eutrophication. The DPM will focus it efforts in a region in the pocket referred to as the flow-way (Fig. 3-2). The flow-way is oriented along the historic flow-path, not perpendicular to the existing L-67A and C; thus, the flow-way length is 1.8 mi (2.9km). The flow-way contains several large sloughs and sawgrass ridges but no tree islands, verified by examining aerial photographs of the region acquired in the 1940s.

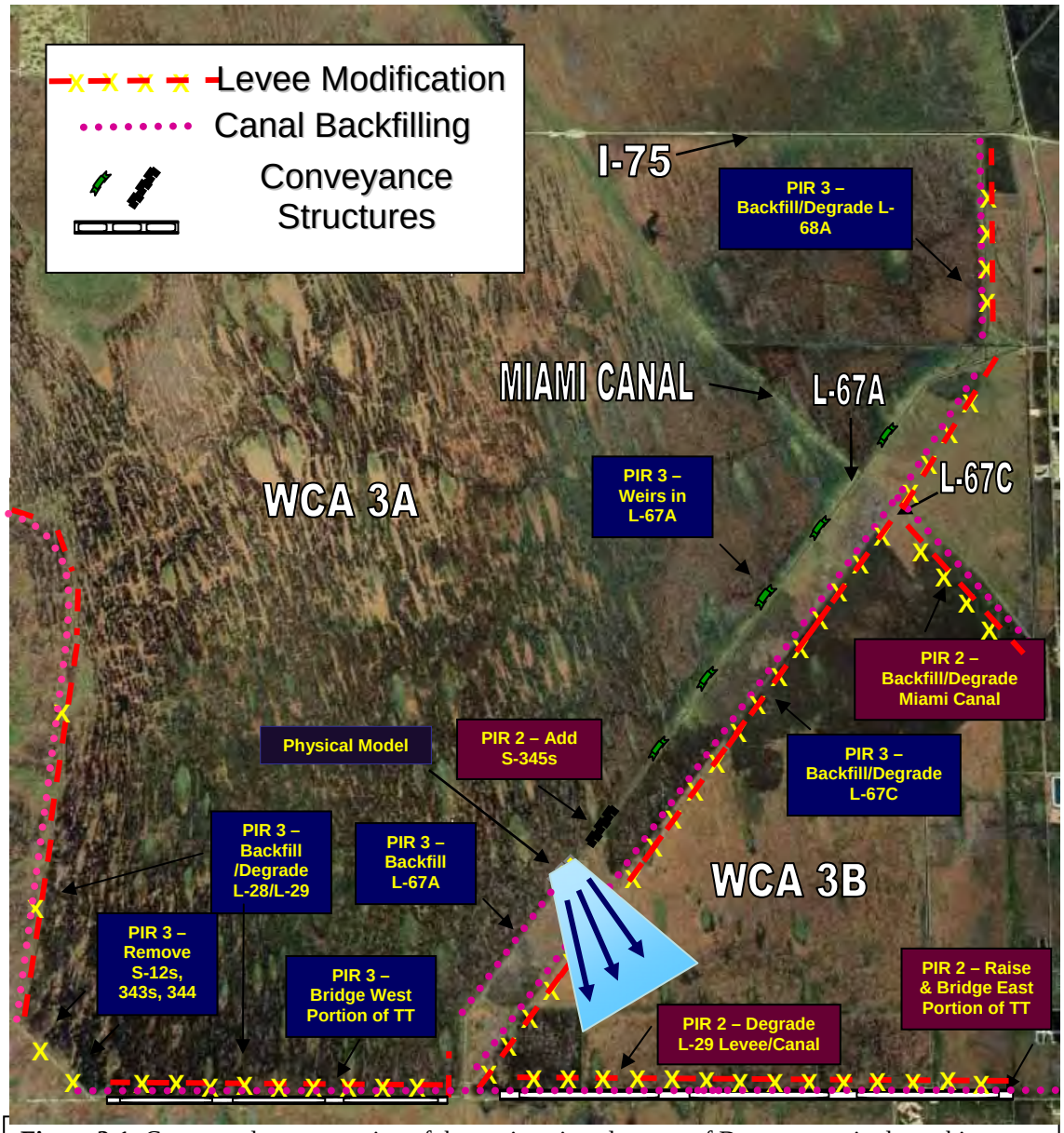

Figure 3-1: Conceptual representation of the engineering elements of Decomp required to achieve hydrologic restoration (USACE and SFWMD 1999). Also represented is the location of the Decomp Physical Model.

The physical features of the DPM are temporary and will be removed at the end of the project. Flow will be manipulated by allowing water to pass from the L-67A canal into the pocket through eight controllable gated 72-inch diameter culverts with a combined maximum flow of 750 cubic feet per second (cfs) (Fig. 3-2; 25º51'51''N; 80º37'15''W). The culverts will discharge into a slough. Head and tail water stages will be continuously monitored as will water quality. To establish sheet flow and to evaluate canal back filling options, a 3000 ft (0.9 km) gap will be created in the L-67C levee (northeast corner 25º50'31''N; 80º36'54''W; southwest corner 25º51'06N; 80º37'12W) downstream of the L-67A culverts (Fig. 3-2). The material from the L-67C levee degrade will be used to construct the adjacent L-67C canal back filling treatments. Levee material will be deposited in the L-67C canal to create a 1000 ft (0.3 km) complete backfill and a 1000 ft (0.3 km) partial backfill. The remaining 1000 ft segment will be left unaltered.

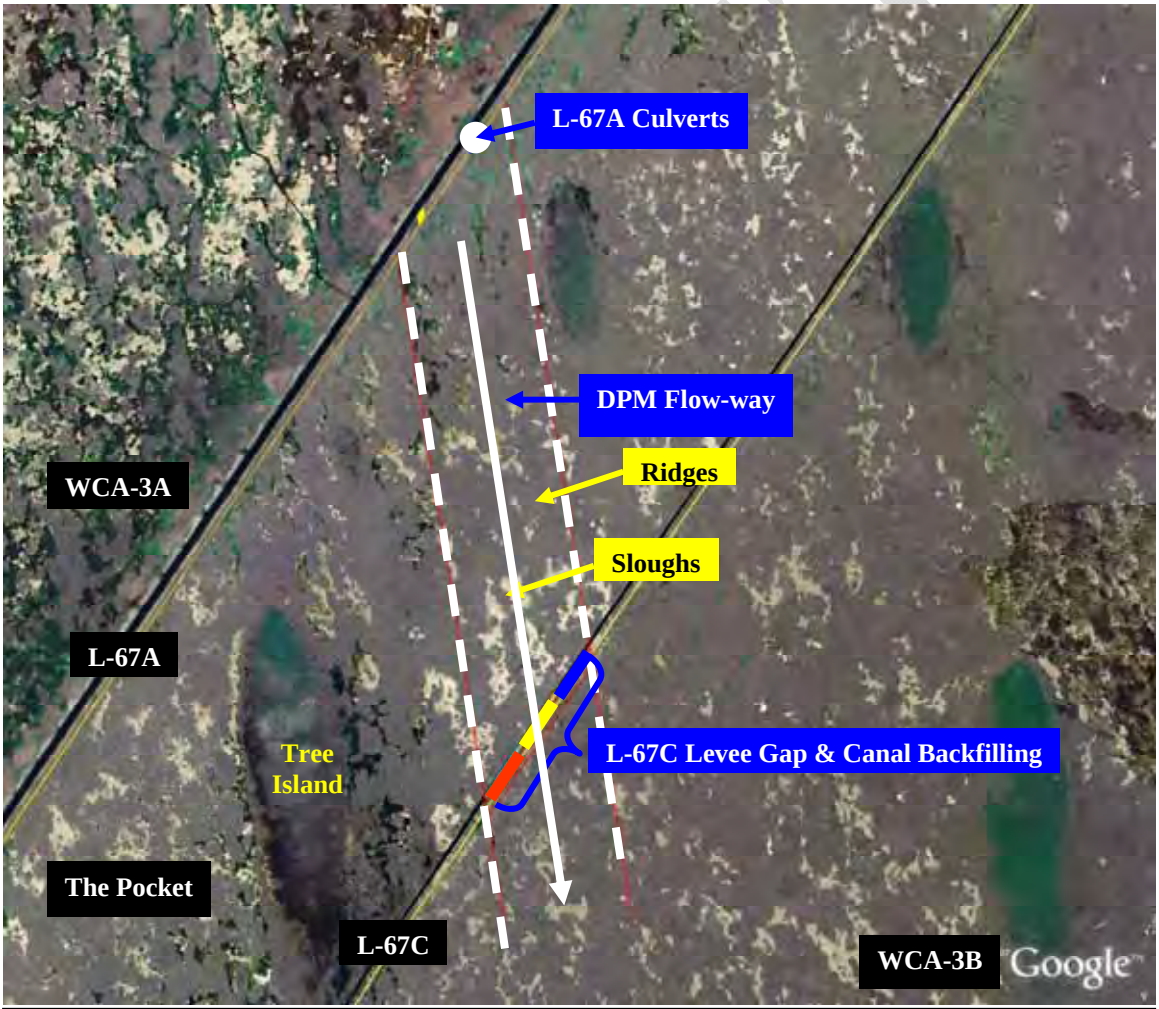

Figure 3-2: Schematic illustrating the features of the DECOMP Physical Model. The major hydrologic elements (L-67A culvert, flow-way, L-67C canal backfilling, and L-67C gap are highlighted in blue, ecological elements (ridges, sloughs, and tree islands) in yellow, and location identifiers in black. The gap in the L-67C is 3000 feet (914 m).

3.1.3 Hydrologic Expectations (sheet flow and velocity patterns)

The culverts and gap are expected to provide velocities >3 cm/sec at the gap in the L-67C levee. A hydrologic model was not available to aid in the design. Instead a weight-of-evidence approach was used to size the DPM features. First, water surface slopes were compared to observed velocities during two L-67 gap tests conducted in the 1990s (USACE, 2009). These tests consisted of 1000 ft (0.3 km) breaches in both the L-67A and C levees which lasted until a stage constraint of 8.5 feet at the 3B-17 gauge in WCA-3B triggered the closing of the L-67A gap (Hagerthey 2005). A second estimate of water velocity was obtained using Kadlec's equation for velocity in open marshes (Equation 1):

$$U = K_f h^{\beta} S^{\lambda} \qquad \textit{(Equation 1)}$$

where: U= velocity
h= depth
S= hydraulic gradient (stage difference between WCA-3A and 3B)
K_f,= 63.53
β= 0.744
λ= 0.775

K_f, β, and λ were determined from non linear regression.

Velocity estimates obtained using the Kadlec equation were related (r^2=0.75) to velocities observed during the gap tests (USACE, 2009). The Kadlec equation was then applied to surface water slopes obtained from a long-term dataset (1991-2008) of WCA-3A and 3B stages to obtain a distribution of monthly estimates of velocities (Fig. 3-3). It should be noted that these values were used to determine periods of time when stage differences would favor high velocities and do not represent velocity estimates associated with DPM operations. From these stages surface water slopes favorable for producing the required velocities were found to occur in October, November, and December.

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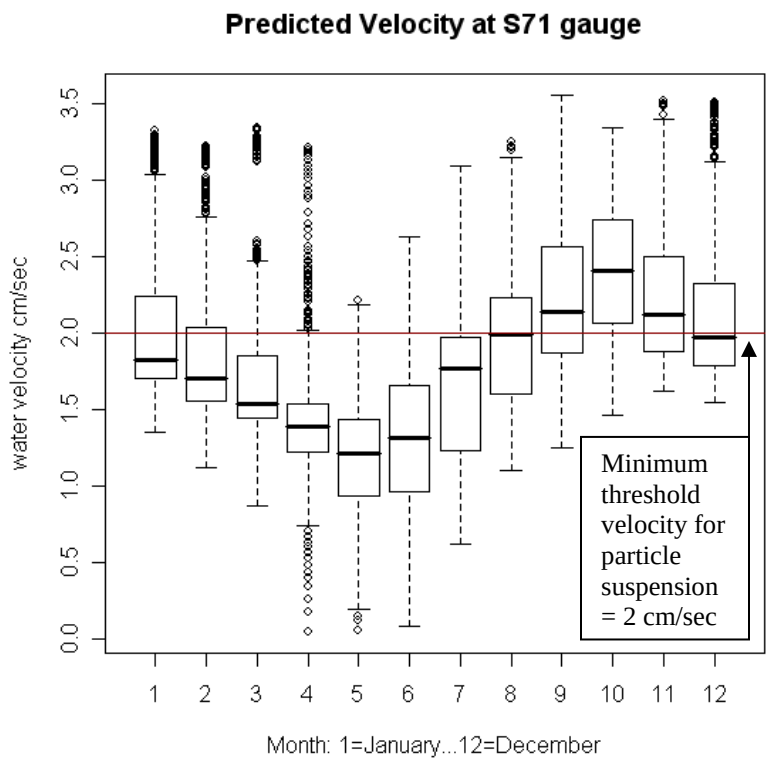

Figure 3-3: Monthly distribution of velocities based on surface water slopes obtained using long-term stage data (Legault 2008). These values were used to determine periods of time when stage differences would favor high velocities and do not represent velocity estimates associated with DPM operations.

The hydrologic analysis (USACE, 2009) further investigated the combination of structural features that would be required to generate these velocities. To generate velocities of 5 cm/sec at the L-67C levee with variable length openings (gaps 500-4000 ft) the L-67A culvert would have to be capable of discharging 124-994 cfs and 248-1988 cfs when water depths were 1 and 2 feet, respectively (Table 3-1). When combined with construction cost constraints, ecological scale, and target velocities, it was concluded that the ideal size of the DPM features would be a 750 cfs culvert structure and a 3000 ft L-67C gap.

Table 3-1- Estimated flow volumes required to generate target velocity at different gap widths.

		Flow Depth (1 ft)				Flow Depth (2 ft)			
Target Velocity		2 cm/sec Discharge		5 cm/sec Discharge		2 cm/sec Discharge		5 cm/sec Discharge	
Gap Length		L-67C*	L-67A	L-67C*	L-67A	L-67C*	L-67A	L-67C*	L-67A
Feet	Meters	cfs	cfs	cfs	cfs	cfs	Cfs	cfs	cfs
500	152	33	50	82	124	66	99	164	248
1000	305	66	99	164	248	131	199	328	497
1500	457	98	149	246	373	197	298	492	745
2000	610	131	199	328	497	262	398	656	994
2500	762	164	248	410	621	328	497	820	1242
3000	914	197	298	492	745	394	596	984	1491
4000	1219	262	398	656	994	525	795	1312	1988

* Assume that 66% of flows through L67A pass through L67C

3.1.4 Operation Schedule (test duration and goals)

The Operational Plan will be developed as part of the water quality permit. This section describes the proposed operational window and duration. The operational window will be between October and January. Several factors led to this determination. First, water managers for the US Army Corp of Engineers and South Florida Water Management District advised against water deliveries to WCA-3B that would increase water depths during hurricane season (June-November). Second, limiting the window to after hurricane season reduces the likelihood of excessive rainfall events that could produce rainfall driven pulses. Third, the L-67A culverts require at least a 0.5 foot head difference between WCA-3A and WCA-3B in order to achieve discharges of 750 cfs (USACE, 2009). Based on long-term records (2000-2008) the average stage differences between WCA-3A and 3B during the operational window are typically greater than 2.5 feet, well above the 0.5 foot criterion. Fourth, during the operational window, the average monthly stages in WCA-3B are below the 8.5 foot (NGVD29) Site-71 stage gauge constraint (Fig. 3-4). Daily stage values are highly variable, especially in October and November, sometimes exceeding the 8.5 foot stage constraint (Fig. 3-5); however, these values were influenced to some degree by the active 2004 and 2005 hurricane seasons. This stage constraint limits how much water can be discharged through the L-67A culverts and sets the theoretical window of how long the culverts can remain open. As water levels in WCA-3B are determined by precipitation and stages in WCA-3A, it is difficult to obtain an accurate estimate of how long a test can be. The simplest calculation sets the windows at 17 to 41 days of continuous operation. This assumes that all of the 750 cfs (~1487 acre ft per day) are delivered to the pocket and WCA-3B, no losses due to evapotranspiration or seepage, or gains from rainfall. It is likely that when these losses are taken into account, the actual operational window will be longer. It is also likely that multiple short duration (e.g., 10 day) tests could be conducted within the operational window. For planning the logistics of field sampling, a 20 day operational duration will be assumed.

Finally, although water quality varies spatial and temporally (Fig. 3-6), water quality in the L-67A canal during this window is optimal. The eight year arithmetic and geometric mean TP concentrations at the S-151 structure located 16 miles upstream of the L-67A structures are close to the 10 µg/L TP numeric criterion (Table 3-2). There is a general consensus that water quality in the L-67A improves with distance from the S-151 because of mixing with surface flow from the low nutrient WCA-3A marsh; thus, we expect that water quality will be better at the L-67A culvert. Tree island impacts are expected to be minimal because the islands in WCA-3B are comprised of flood tolerant species (Engel et al. 2008). The operational window of October through January also takes advantage of being outside the primary nesting season of threatened and endangered species (i.e. snail kite, wood stork, etc.). However, snail kite nesting begins in January in southern WCA-3B.

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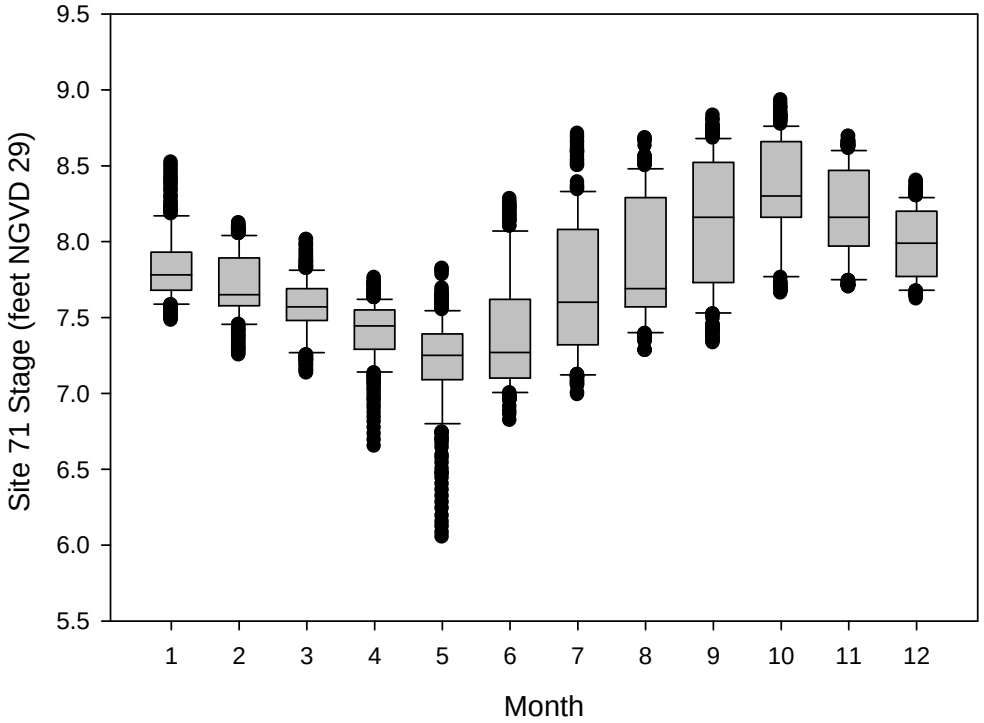

Figure 3-4-Box plots of monthly stage for the Site-71 gauge in WCA-3B between 2000 and 2008. The stage constraint, value that cannot be exceeded is 8.5 feet. The box represents the 25th and 75th percentile, the bar is the median, the error bars the 10th and 90th percentile, and the dots outlying points.

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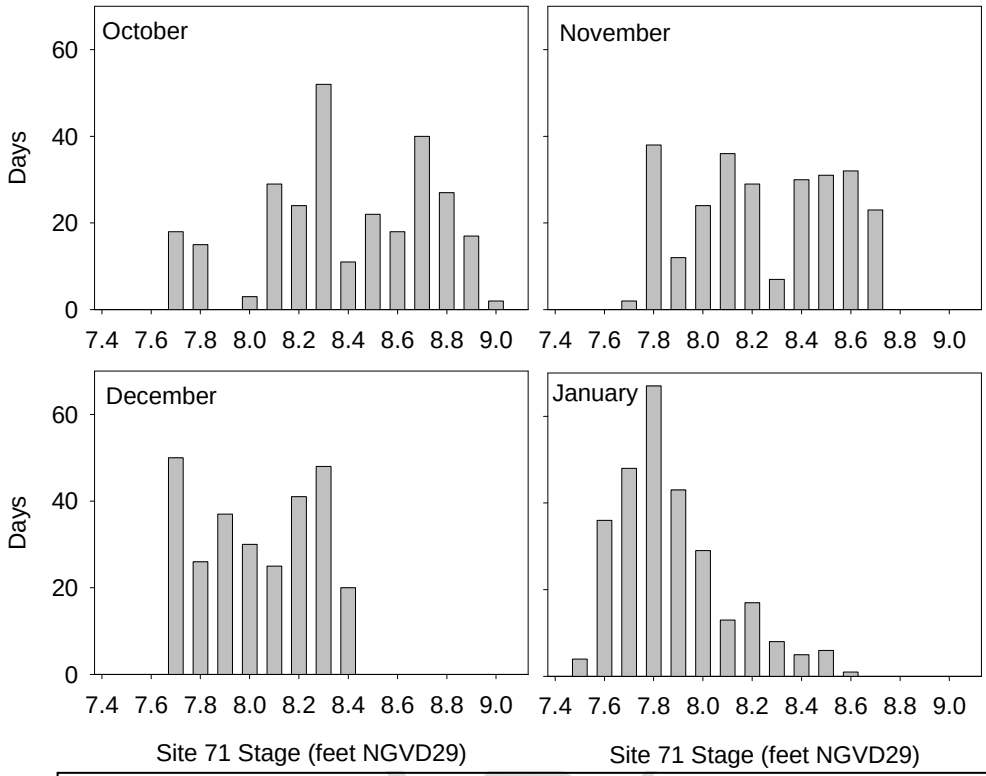

Figure 3-5: Frequency distribution of daily stage at the Site 71 gauge in WCA-3B for the months of October-January. The stage constraint for the site is 8.5 feet (NGVD29).

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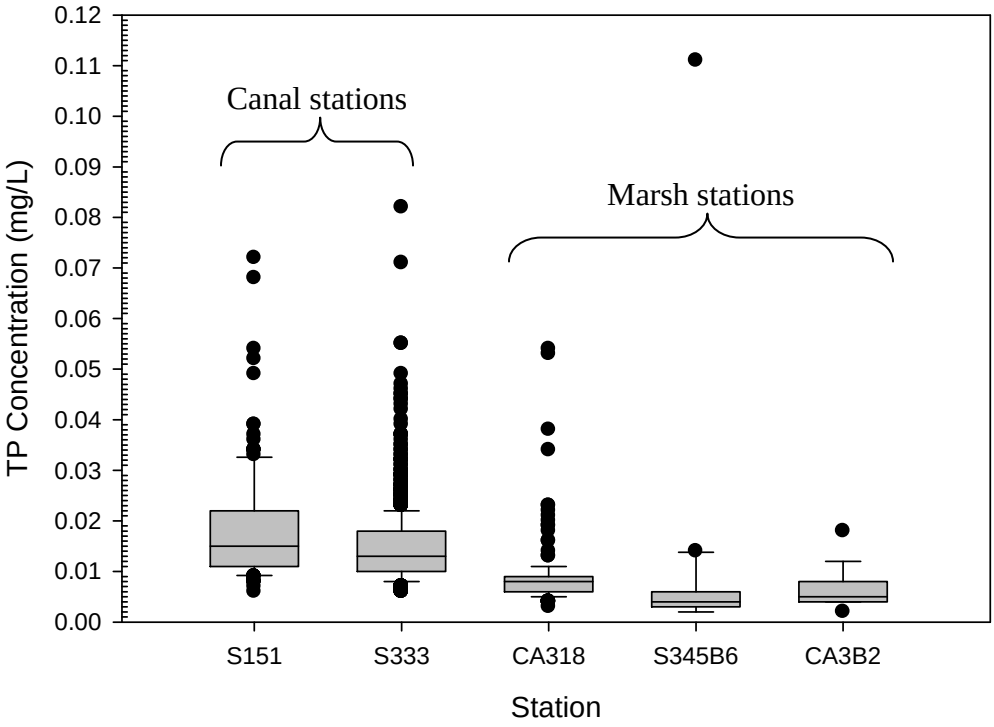

Figure 3-6: Box plots of total phosphorus concentrations in the L-67A canal (S151 and S333), WCA-3A marsh (CA318), and WCA-3B marsh (S345B6 and CA3B2) between 2000 and 2008.

Table 3-2. Eight year (2000-2008) monthly arithmetic and geometric mean TP concentrations at the S-151 structure located approximately 16 miles upstream of the proposed L-67A culverts.

Month	Arithmetic Mean ± sd TP µg/L	Geometric Mean TP µg/L
October	12±3	12
November	11±2	10
December	11±3	10
January	13±3	12
February	14±5	13
March	17±6	16
April	28±17	24
May	30±14	27
June	24±8	22
July	24±11	22
August	16±4	16
September	13±3	12
Overall	18±11	16

3.1.5 The BACI Concept (statistical design)

A before-after-control-impact (BACI) approach will be used to determine if pulsed-flow events impact response variables (Smith et al. 1993; Smith 2002). In this approach, the effects are analyzed by measuring conditions *before* a planned activity (i.e., the opening of

the L-67A culverts) and then comparing the findings to those conditions measured *after* the event. A BACI design also requires the concomitant *before* and *after* measurements of response variables at sites not affected by the impact (i.e., control). For the DPM studies, sites located within the flow-way that extends from the L-67A levee, through the L-67C gap, and into WCA-3B will be considered *impacted* since these sites will experience flow velocities greater than 3 cm/sec when the L-67A culverts are operated. *Control* sites will be located in regions that will experience ambient flow velocities (<1 cm/sec). The control sites were selected to bracket the treatments to account for possible preexisting confounding gradient effects. Assuming operations will begin in November of 2011, the *before* and *after* monitoring periods will consist of 18 and 24 months, respectively. Two *impacts* (pulsed-flow events) are scheduled to begin in October of 2012 and 2013. Because the BACI approach will be applied to both the Backfilling (section 3.2) and Ridge & Slough Sheet flow (section 3.3) experiment designs, the discussion below serves as the statistical details that will be applied to both experiments.

A valuable approach to evaluate the potential of an experimental design to detect effects that are deemed important at the outset of a study is to anticipate analysis of the resulting data and estimate minimum treatment effects that are likely to be detectable (sometimes called a power analysis). Such an analysis assesses the adequacy of the study design and permit design efficiencies; common problems arise by having too few replicates, but is also possible to have more than is necessary. As a first step, an analysis of variance table was produced to document the number of degrees of freedom for each hypothesis test and the minimum effect size required for statistical significance, illustrated by the minimum F-statistic required to reject the null hypothesis of no-treatment-effect with a probability of type I error of 0.05 (Table 3-3). This table illustrates the approximate degrees of freedom for each hypothesis test (the actual numbers will vary with different dependent variables and if samples are missing) with three replicates at each time-space sampling point. Note that the highest F-statistic is for the 'Time' hypothesis, indicating that grand means before and after treatments are applied must differ by over four times more than inter-replicate variability within the time periods (within the *before* period and within the *after* period). Arguably, the key hypothesis test will be for the three-way interaction, which requires a relatively low treatment effect F statistic of 2.18. This indicates that the experimental design with equal replication does not require treatment effects that appear to be especially large *a priori*, however, this is dependent upon the size of the 'error' variance for each dependent variable. Ultimately, these tests will be followed by contrasts comparing specific treatments and that will be similar to simple t-tests (e.g., Tukey-adjusted contrasts).

In addition, the potential to detect treatment effects in this study was also evaluated through a standard power analysis. This uses estimates of inter-replicate variation for representative dependent variables to evaluate if the minimum effects anticipated have the power to determine differences with the proposed sampling effort. These analyses are exploratory since it is assumed that past sampling variance will be representative of the upcoming study. To illustrate this, three variables were considered that may be representative of classes of parameters that will be measured: a physical parameter (dissolved oxygen DO); a biogeochemical parameter (periphyton tissue phosphorus TP); and a population parameter (fish biomass). All comparisons assume a simple two-sample, two-tailed test.

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3.1.5.1 Physical Parameter

Dissolved oxygen was estimated from the water column surface and bottom at three points in the L-67A and three in the L67C canals to evaluate treatment effects on the magnitude of this profile. The power to detect a 10% difference in the mean difference (surface minus bottom: 4.1 mg/L versus 4.5 mg/L) with observed levels of standard deviation (0.6 and 0.58), sample size of 3, and probability of type I error of 5% is 13.2%. It is anticipated that a 13% difference in means (e.g., 4.1 mg/L versus 4.6 mg/L) with observed standard deviation (0.60 and 0.58) will be required to be significant at alpha = 0.05 and power (1-beta) of 20% and proposed sample sizes of 3. The profile magnitude (surface minus bottom) differed between A and C by 2.2 mg/L (C mean = 4.1; A mean = 6.3) on the day it was studied indicating that the proposed sample size would have been sufficient for detection of significant difference.

3.1.5.2 Biogeochemical Parameter

Epiphyton TP content from WCA-3B was used to examine a biotic parameter that is indicative of nutrient dynamics. The power to detect a 10% difference in the mean (477 µg/g versus 430 µg/g) with observed levels of standard deviation (163 and 138), sample size of 3, and probability of type I error of 5% was 6.7%. This suggests that a 65% difference in means (e.g., 477 µg/g versus 180 µg/g) with observed standard deviation (163 and 138) would be required to be significant at alpha = 0.05 and power (1-beta) of 20% with the proposed sample size of 3.

3.1.5.3 Population Parameter

Eastern mosquitofish (*Gambusia holbrooki*) biomass was used as a measure of small fish population standing crop in the study area (density estimates give similar results) with means and standard deviations taken from four years of throw trap estimates collected throughout the Everglades as part of a monitoring and assessment project (RECOVER). The power to detect a 10% difference in the mean (0.84 g/m^2 versus 0.93 g/m^2) with observed levels of standard deviation (0.173 and 0.173), sample size of 3, and probability of type I error of 5% is 9.6%. This indicates that a 30% difference in means (e.g., 0.84 g/m^2 versus 1.2 g/m^2) with observed standard deviation (0.173 and 0.173) will be needed to be as significant with alpha of 0.05 and power (1-beta) of 20% and with the proposed sample size of 3.

3.1.5.4 Summary BACI Power Analysis

The illustrative power analyses demonstrated that the magnitude of treatment effects that are likely to be detected with the proposed sample design will vary among dependent variables in proportion to their inter-sample variability. The DO profile is relatively homogeneous when measured at different places in canals separated by distances similar to those required for this study (within treatment sampling points), while periphyton TP content was more heterogeneous at this scale, and fish biomass was intermediate. DO that is changed by at least 13% by a treatment would be detected as significant with the proposed sampling intensity, while periphyton TP would have to differ by 65% and fish density by 30%.

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Table 3-3: Representative ANOVA table for addressing the backfilling uncertainties. A. Elements of the experimental design. Treatments 1 and 2 (low flow upstream and low flow downstream) are "controls" for this study. The total sample size is assumed to be 90, based on three replicate samples at each space-time combination. B. Anticipatory ANOVA table indicating the number of degrees of freedom (df) for each hypothesis test and the minimum F statistic to reject the null hypothesis of 'no effect' with a probability of type I error of 0.05 (F to beat).

A

	Treatment		Position		Time
1	Control (low flow)	1	Upstream	1	Before
2	Control (low flow)	2	Canal	2	After
3	Complete Backfill	3	Downstream		
4	Partial Backfill				
5	No Backfill				

B

Source	df	F to Beat
Treatment	4	2.61
Position	2	3.23
Time	1	4.08
Position by Treatment	8	2.18
Time by Treatment	4	2.61
Position by Time	2	3.23
Time by Position by Treatment	8	2.18
Error	47	

3.2. Evaluating Canal Backfilling Options

3.2.1 Introduction (statement of problem)

The conceptual proposal for sheet flow restoration in the central Everglades, not including the Miami Canal, calls for the degradation of approximately 75 mi (121 km) of levees and the complete backfilling of 84 mi (135 km) of canals (USACE and SFWMD 1999; Fig. 3-1). While the need for levee degradation to re-establish sheet flow is well founded, there remains much uncertainty and controversy over the need to backfill canals to marsh grade (complete backfill), particularly in canals that are oriented perpendicular to the direction of flow, to minimize hydraulic short-circuiting to marsh flow. This is primarily due to the fact that it is not known if a continuous physical surface connection is an absolute necessity to restore the

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ecological function of the ridge & slough system or ecosystem connectivity. There are two primary reasons (arguments) against completely backfilling the canals thus warranting the investigation of alternatives. First, the existing network of canals supports a highly prized and valued sport fishery. Second, the complete backfill of all the canals may not be economically viable.

Three construction options for backfilling the canals will be evaluated in the DPM. The first option is to fill the canal to the elevation of the marsh surface (complete backfill); however, the adjacent levee lacks the material volume for a complete backfill and will require an external source of material. The second option is to use the volume of adjacent levee material to partially fill the canal (partial backfill). It is estimated that the volume of levee material will fill approximately 40-60 % of the canal. This is an economically viable option because it substantially reduces the distance that material has to be transported. The third option is to remove the levee material but not backfill the adjacent canal (no backfill). There are three possible reasons for not completely backfilling a canal: 1) there are no ecological benefits for the natural system, 2) the sport fishery is adversely affected, and 3) there are economic and ecological benefits to creating a hybrid solution of alternating complete backfill and no backfill along a canal reach.

The ecological rationale for the complete backfilling of canals is based on the hypothesis that the transport and redistribution of materials by flow is an important driver regulating the ridge & slough landscape pattern (Larsen et al. 2007; Larsen et al. in review a). It is hypothesized that without complete backfilling, canals that are oriented perpendicular to the direction of flow will alter the hydrodynamics of sheet flow and the advective transport of material with negative downstream consequences (Fig. 3-7). Canals and levees also reduce the degree of contiguous landscape connectivity that may influence the natural dispersal patterns of flora and fauna or may serve as vectors for the dispersal of exotic, invasive, and nuisance species.

Alternatively, canals provide habitat for many socially important fauna and are refugia for native taxa during the dry-season or extreme droughts. Shifting the hydrologic driver from conveyance, the lateral flow of water through a canal, to sheet flow, perpendicular flow across the canal, may alter the within-canal hydrodynamics. It is not known how these hydrologic modifications will alter the physical (dissolved oxygen and temperature) environment within the canal or if these changes will alter patterns of density, standing crop, and relative abundance of fishes and macroinvertebrates at the local and landscape scale (Figure 3-7). **Therefore, the objective of this study is to evaluate the hydrodynamic and ecological effects of the degree to which canals are backfilled.**

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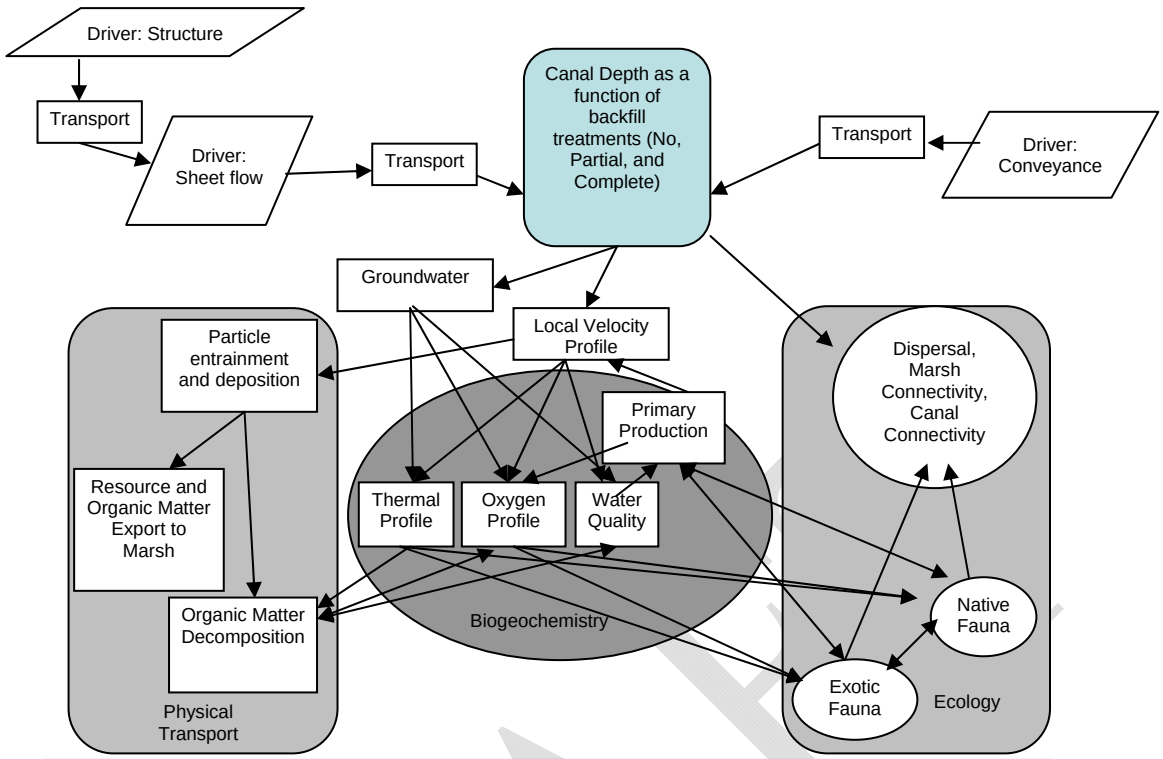

Figure 3-7: Canal backfilling conceptual model of important hydrodynamic, biogeochemical drivers, and ecological drivers

3.2.2 Scientific Hypotheses

The DPM will test nine hypotheses to determine if the differential ecological and hydrological effects of the canal back-filling options and impact of structures (culverts) and features (gaps). There are multiple aspects to each hypothesis and funding constraints which prevents all aspects from being addressed. As this document will be viewed by a broad audience, we present the hypotheses in the null form (H_0) which is a statement of "no difference". If concluded, through statistical tests, H_0 to be false, then it will be interpreted as support for the alternative hypothesis (H_A), meaning there is a "significant difference". Below we list the hypotheses (in bold) and explain the processes and conditions that may lead to rejection of the null hypotheses.

***BH_{01}*: Complete backfilling, partial backfilling, or lack of backfill in canals will not significantly alter water level (stage), sheet flow, or groundwater seepage.** The hydrodynamics of canals that traverse the landscape, even if partially backfilled, will be different than if no canal was present (i.e., a complete hydrologic connection between the upstream and downstream marsh). Canals may be preferential flowpaths; thus, altering the direction of flow. During periods of recession, canals, being the topographic low, may be a hydrologic sink, drawing water from the marsh and delivering it to areas where excessive ponding of water tends to occur. In addition, maintaining canals in the landscape may influence the dynamics of the local and/or regional groundwater system and groundwater/surface water interactions.

***BH_{02}*: Complete backfilling, partial backfilling, or lack of backfill in canals will not significantly alter sediment particle sources, sinks, and transport and will not interfere with downstream topography.** Canals, even if partially backfilled, that traverse the landscape may be more likely to alter hydrodynamics such that suspended particles are not transported downstream but are trapped by the canal. That is, canals may act as suspended sediment sinks, the loss of which may impact downstream landscape features.

***BH_{03}*: The degree of canal backfilling will not alter habitat quality (oxygen and temperature depth profiles).** Independent of sheet flow, the backfilling of canals may alter habitat quality by changing the physicochemical environment. The greater water depths in canals relative to marsh depths may develop different vertical profiles of ecologically important physiochemical constituents (e.g., dissolved oxygen or temperature). Of special concern is the development of waters with low dissolved oxygen concentrations (hypoxia) which could be detrimental to aquatic fauna and affect biogeochemical cycling.

***BH_{04}*: Habitat quality (oxygen and temperature depth profiles) will not differ between canals used for conveyance versus hydrologically modified canals**. Independent of sheet flow, the backfilling of canals may alter habitat quality by changing the physicochemical environment. Canals used to convey water (e.g., L-67A) are more likely to be chemically well mixed whereas hydrologically modified canals that do not convey water (e.g., L-67C) are expected to mix less and develop vertical stratification. Of special concern is the development of waters with low dissolved oxygen concentrations (hypoxia) which could be detrimental to aquatic fauna and affect biogeochemical cycling.

***BH_{05}*: High vegetation densities downstream of structures or features will not inhibit surface flows**. The spatial distribution and density of existing vegetation may be an important factor regulating flow. Thus, flow will be different downstream of structures (i.e., the L-67A culverts) versus features (i.e., the L-67C gap).

***BH_{06}*: Structures and features (gaps and culverts) used to hydrologically reconnect the marsh will not reduce habitat quality by increasing local TP loading and altering oligotrophic species assemblages.** Nutrient loading effects are expected to differ between structures (culverts) and features (canal gaps). Note that nutrient loading can be increased by natural (increasing the supply rate of a low-level nutrient) or anthropogenic means. The oligotrophic floral community that was characteristic of the Everglades historically may shift in species composition and/or local structure (biomass) as a function of nutrient loading. These changes are important for the quality of the local habitat patch as well as the long term hydrodynamics of decompartmentalizing with structures. These structures are likely to create locally intensified areas of nutrient loading immediately surrounding the structure that may cause increases in vegetation density and, by extension, resistance to flow. This feedback loop between structures and the surrounding vegetation is likely to systematically decrease the effectiveness with which the structures pass water through time.

***BH_{07}*: Suspended sediment concentrations and sediment nutrient content will not increase downstream of structures (i.e., L-67A culverts) that concentrate flow and will not propagate downstream over time.** Point source discharges are more likely to be

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regions of concentrated nutrients and velocities. This combination is more likely to increase localized eutrophication with prolonged suspended sediment driven positive feedback loops that allow for the nutrient front to advance downstream with time.

***BH_{08}*: Fish assemblage structure and usage will not differ among backfilling treatments.** Of special interest is the backfilling of canals on the sport fishery, chiefly bass (*Micropterus* spp.), that currently occupies the existing canal network. Canals may serve as valuable habitat for fish, being refuges during periods of high thermal stress or drought. Alternatively, canals may also serve as corridors that enable the spreading and harboring of non-native or exotic species. It is suspected that the canal fisheries are dependent, to some degree, on the marsh, readily moving from one habitat to the other.

***BH_{09}*: Aquatic fauna structure will not differ among backfilling treatments.** Assuming that depth-related physiochemical differences will occur among canal backfilling options, it is likely that pelagic and anaerobic benthic aquatic fauna will be present in the no backfill and partial backfill treatments. These differences may be reflected in spatial and temporal distributions of prey availability for higher trophic levels and trophic cascades.

3.2.3 Experimental Approach

Three backfill options (complete backfill, partial backfill, and no backfill) will be evaluated within the 3000 ft (914 m) L-67C gap. Each treatment will consist of a 1000 ft (304 m) segment within the L-67C canal (Fig. 3-8). Two control sites (no backfill, no sheet flow) will be established in the L-67C canal upstream and downstream of the canal treatments (Fig. 3-8). The location was selected to ensure that each treatment has similar existing and historic ridge & slough habitats (Fig. 3-2). To minimize disturbance, staging and sampling platforms will be constructed at each site. Platforms will consist of aluminum walkways and will be removed at the end of the project. Sites will be accessed by airboats using established routes or by float helicopter.

The BACI experimental design integrates sampling and data collection and will be used to address the nine hypotheses. Two types of measurements, hydrodynamic and ecological, will be made. The hydrodynamic measurements focus on the physics of flow and particle transport. Budget constraints and the short-term pulsed nature of the study limit the type of biological responses that can be measured; thus, the biological measurements will focus on measurements of habitat quality and target species of concern (i.e., fish). However, modeling will be used to predict higher-level biological responses (see section 3.4-Synthesis and Reporting). For example, integration of field measurements of water flow, nutrient load, particle transport, deposition, and metabolism could be used to parameterize and calibrate the Ribbon model for the DPM footprint (Saunders et al. in review). This modeling framework will quantify the seasonal to decadal responses of periphyton P uptake, particle P stocks, water TP responses which have been shown to be sensitive to water mixing and sediment transport (Saunders et al. in review).

To adequately address the hypotheses and support model development requires the accurate and precise measurements of several parameters (e.g., water mass flux, particle entrainment, and particle redistribution) that, until recently, have been difficult to obtain. The DPM

utilizes several methods (described below) developed specifically to study the hydrodynamics in low-flow wetland environments. Each method has been rigorously tested within the Everglades system. Documentation in the form of published articles, articles in press, articles in review, and reports for these methods are available electronically (as PDF) by contacting S. Hagerthey.

Sampling frequencies and locations will vary depending on the parameter. In general, samples will be collected along transects that traverse the canal treatments. The schedule for the study, including the frequency of sampling for each parameter, is provided in Annex 1.

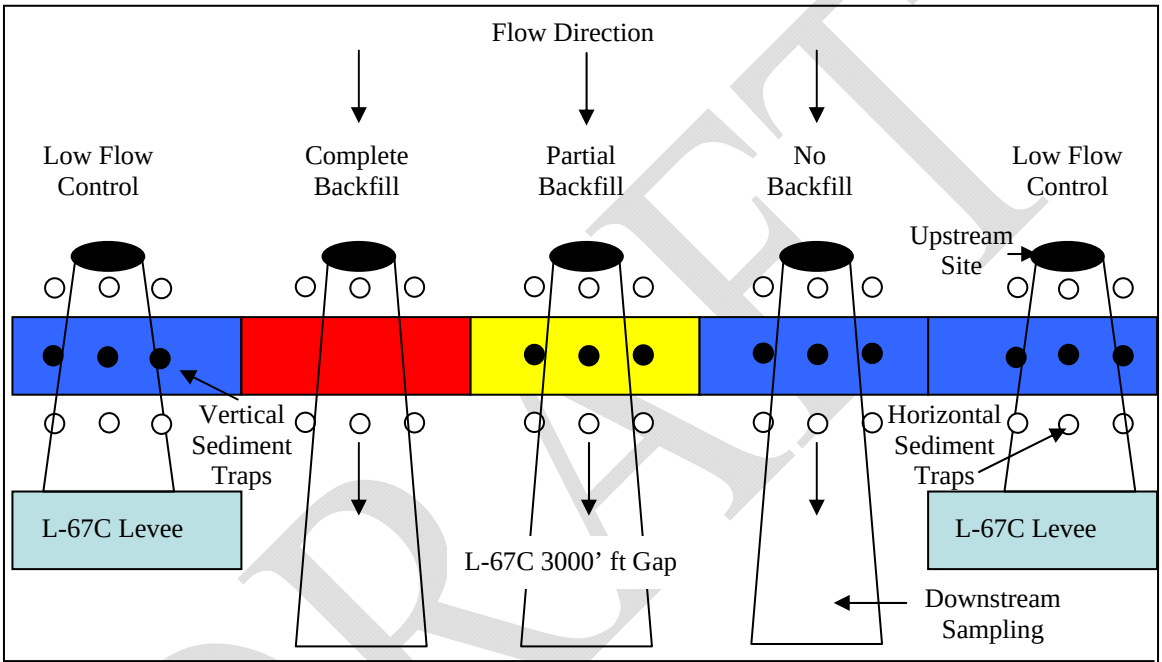

Figure 3-8: Schematic of the sampling regime for the Canal-Backfilling study. The upstream site is the location of the detailed hydrodynamic dye releases, sediment entrainment studies, and tracer drops. Sediment redistribution will be examined in regions extending downstream from the upstream site. Blue indicates no canal backfilling, yellow is partial backfill, and red is complete backfill.

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3.2.4 Materials and Methods

3.2.4.1 Hydrodynamics

The majority of hydrodynamic information for the canal backfilling experiment will be obtained from the DPM hydrodynamic monitoring network. The network is designed to establish the hydraulic gradient within the pocket and WCA-3B by monitoring water depth, velocity, and concentrations of suspended sediment particles. The hydraulic gradient will be expressed as "flow fields" that describe the movement of surface flows. Surface-water flow fields will be defined using a grid (10 stations) of continuous measurements of water level (pressure transducers) and point velocity measurements (Acoustic Doppler Velocimeter, ADV). This network will capture the head/tail water differences for the L-67A culverts and

the L-67C gap. High resolution elevation data (topographic detail of ridges and sloughs) will be obtained for select sites where intensive measurements will be made whereas synoptic surveys will be used to develop elevation information within the entire DPM footprint. Flow directions will be calculated through triangulation for normal experimental conditions. Concomitant with these surveys, vegetation type, biomass, biovolume, and stem density data will be obtained to assess vegetation drag forces (Harvey et al. 2009). Analyses of recent aerial images, combined with the ground surveys, will additionally provide higher spatial resolution of vegetation cover types and canopy height (latter assessed using stereoimages) of the study area. Similar analyses of historic images (ca. 1940) will also provide information on past vegetation changes and the degree to which habitats with a relatively static vegetation composition since 1940 (i.e., sloughs that have not been invaded by sawgrass) are likely to exhibit similar or different hydrodynamics compared to habitats that have changed since 1940. Vegetation cover will be incorporated as a key boundary condition for Ribbon model simulations of P biogeochemistry and Lattice-Boltzmann simulations of sheet flow (discussed in Section 3.4-Synthesis and Reporting).

Tracer studies in the Everglades typically use injections of dissolved constituents to track movement of water (e.g. Harvey et al., 2005). For this study Rhodamine dye will be injected as a pulse and used to quantitatively assess the local effect of backfill treatment on flow during periods of pulsed and no-pulsed flow. Dye will be introduced upstream of canals and aerial observations will be made at regular intervals (hourly) to ascertain flow patterns (Fig. 3-9). In addition, water samples for fluorescence detection will be collected from sentinel sites at 15 minute intervals. To determine if vertical mixing occurs within the complete and partial backfill treatment, water samples will be collected at 0.5 m depth intervals using a Niskin bottle and analyzed for fluorescence. Modeling transient flow simulations using a full 3-dimensional model is an option; however, the budget to support this activity is not presently available.

Figure 3-9: Example of a Rhodamine dye tracer release to study surface flow patterns through sloughs and ridges.

3.2.4.2 Particle Transport

Essential to determining if canals influence the development of the ridge & slough landscape by interfering with the redistribution of entrained sediments is the ability to 1) attain sufficient flow velocities to entrain slough sediments, 2) verify sediment entrainment, and 3) determine the fate of entrained sediments. During operation of the L-67A culverts, the

estimated flow velocities at the L-67C gap, obtained using several independent methods (USACE, 2009), will exceed laboratory and in situ measurements of the critical entrainment velocities (>3 cm/sec) for floc.

Tracer injections of "model" particles (e.g. Saiers et al., 2003; Partrac 2005, 2006, 2008; Huang et al., 2008; Hagerthy et al., in prep) or experiment examining entrainment of natural particles (e.g. Harvey et al., submitted) have been used to observe movement of sediment at field sites in the Everglades. Several methods will be used in the present study to assess the redistribution of particles. The critical entrainment velocity (CEV) and settling velocity of particles in habitats upstream and downstream of each canal treatment will be measured in situ using a portable benthic annular flume (Partrac 2005, 2006, 2008; Hagerthey et al. in prep; Fig. 3-10). When CEV values are combined with in situ ADV measurements of depth-averaged velocities for different habitat types (Harvey et al. 2009), we will be able to accurately assess the spatial and temporal likelihood of particle entrainment. In addition, we will utilize in situ laser particle size analyzers (LISST; Sequoia Scientific; Noe et al. in review), in situ digital floc cameras (Larsen et al. 2009a,b), and direct measurements of water samples to characterize the concentrations, size distribution, and patterns of occurrence of suspended particles across the landscape (Noe et al. 2007). Particle quality (TP, TKN, TOC, etc) will also be assessed following standard methods. Particle origin (i.e., from periphyton, spike rush, floating aquatics, or sawgrass biomass) will be assessed following analyses of biomarkers and macrofossils developed for the Everglades (Saunders et al. 2006; Gao 2007; Gao et al. 2007; Saunders et al. 2008).

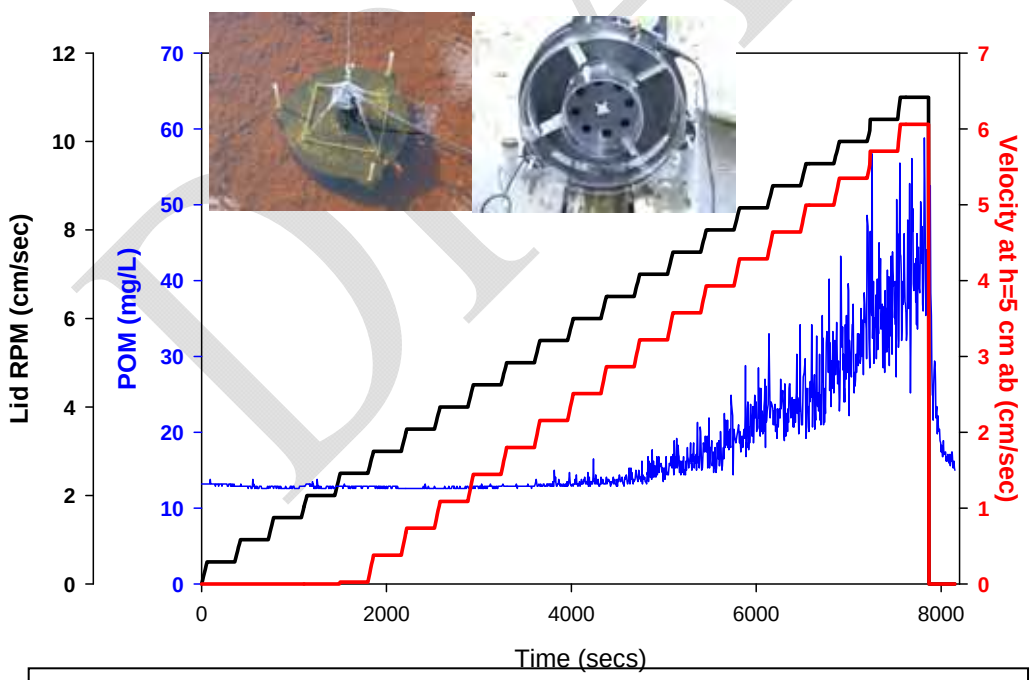

Figure 3-10: In situ Measurement of the Critical Entrainment Velocity (CEV) for floc obtained using a benthic annular flume (insert). Suspended sediment concentration is represented by the blue line, the rotation of the flume lid in black, and the flow velocity (cm/sec) at 5 cm above the bed.

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Particle transport will be evaluated using sediment traps and a dual signature tracer (DST) that is hydraulically matched (i.e., representative) of the mean particle size and settling velocity of particles collected from the study region. Three replicate horizontal sediment traps (Partrac 2005) will be deployed at the sediment-water interface parallel to the direction of flow on immediately adjacent to the canal treatment. Three replicate sets of vertical sediment traps will be suspended 1 m above the sediment-water interface in the complete, partial backfilled, and control canal treatments. A set of vertical sediment traps consists of three vertically oriented tubes with a length to width ratio of 5:1 (Kerfoot et al. 2004). For the shallow water marsh, ridge-slough vertical traps will be deployed at marsh sites (Leonard et al. 2006). Sediment traps will be deployed continuously with collections obtained monthly. Particles will be analyzed for quantity, quality, and size distributions.

The DST particle is made of an inert fluorescent material in which magnetite inclusions are imbedded (Partrac 2005, 2006, 2008; Fig. 3-11). The tracer will be "dropped" as frozen blocks to ensure minimal contamination. A "drop" typically consists of 20-40 kg of tracer per treatment. Tracers of different color (i.e., fluorescent signatures) will be used to distinguish among treatments. Tracer will be retrieved using a sentinel and synoptic design in order to provide adequate temporal and spatial resolution. The tracer will be retrieved using 35,000 gauss magnetic rods with a pole spacing of approximately 1 cm and an effective capture radius of 5 cm (Fig. 3-11 B and C). The sentinel study (moderate spatial but high temporal frequency) will consist of 5 magnets deployed perpendicular to the flow path 3 m for the drop zone. Magnets will be continuously suspended in the water column (Fig. 3-11 D) and visited monthly to collect any tracer adhering to each pole. The tracer will be dried and weighed (g dw/pole) and summed for each magnet (g dw/magnet). Given the 5 cm effective capture radius of the magnet (i.e., any tracer passing within 5 cm of the magnet will be captured), the mass of tracer on each magnet can be expressed per unit area. When combined with the cross-sectional area of the channel (determined from the microtopography measurements), we can estimate the downstream mass flux of tracer (g of tracer/day). Additionally, the vertical distribution of tracer on the magnet provides information on the vertical transport of particles (i.e., whether particles are suspended in the water column or transported as bed load). To assess the redistribution of particles, synoptic maps (high spatial but low temporal frequency) of tracer will be obtained by probing sediment beds, canal bottoms, and vegetation beds with a magnet and determining tracer mass. Synoptic measurements will be made at six month intervals. To aid in the determination of tracer flux and redistribution before (low flow) and after (high flow), two tracer drops of different colors will be scheduled per treatment.

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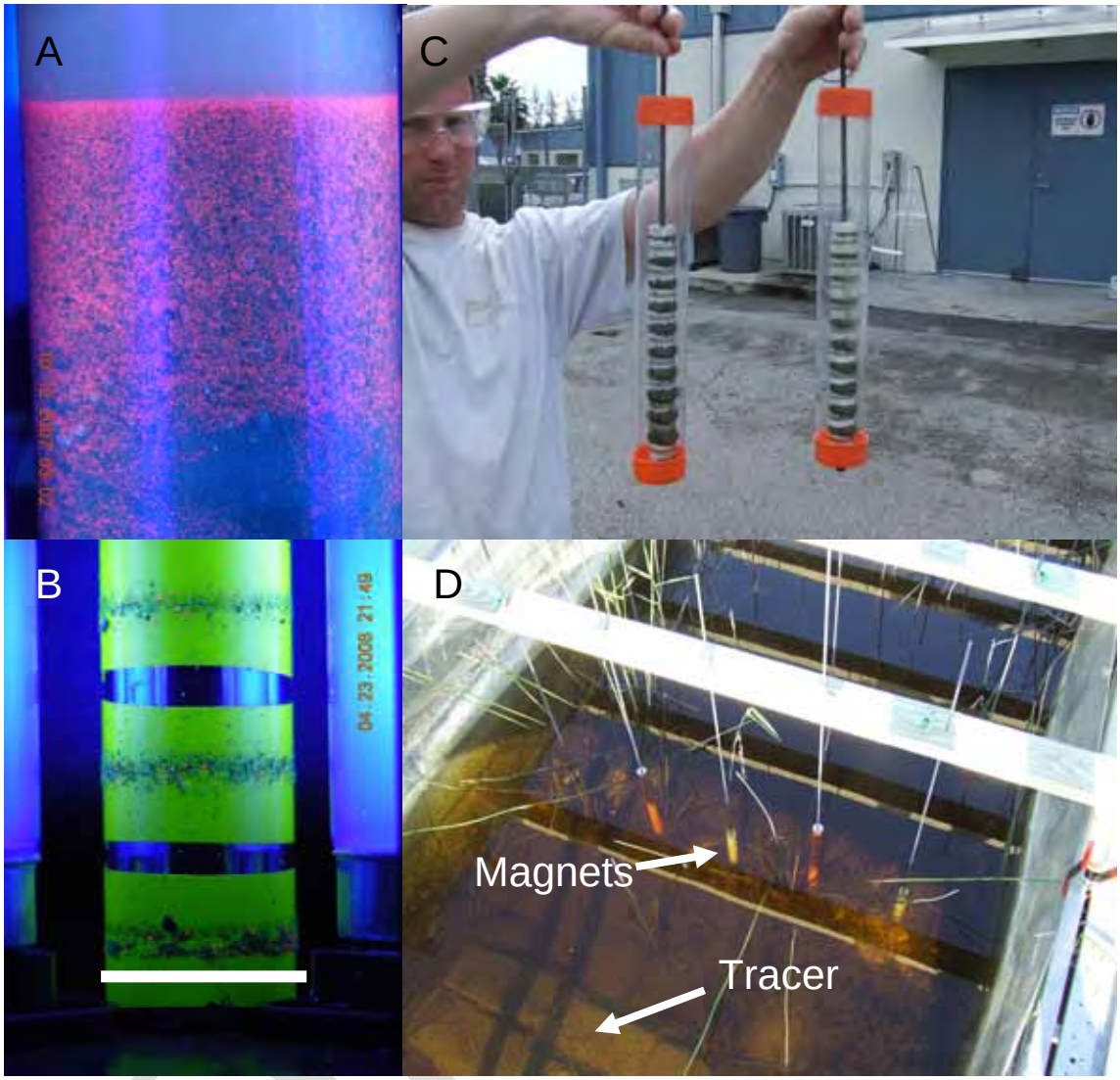

Figure 3-11: Dual signature (fluorescent and magnetic) tracer for studying floc entrainment and redistribution. A) Fluorescent signature of tracer mixed with Everglades floc. B) Fluorescent tracer adhering to the poles of a 35,000 gauss magnet (bar = 2.5 cm). C) Tracer adhering to magnets that were suspended vertically in the water column. D). Magnets suspended vertically in water column and tracer drop zone.

3.2.4.3 Ecology

Physical Environment- Dissolved oxygen and temperature have profound effects on physiological and metabolic processes of aquatic organisms; thus, these parameters provide a relatively simple and inexpensive means to assess habitat quality among canal treatments. Synoptic mapping of surface water dissolved oxygen concentrations, temperature, pH, and specific conductivity will be made monthly using a calibrated Hydrolab sonde. The Hydrolab will also be used to obtain three synoptic depth profiles for the partial backfill, no backfill, and control canals. In addition to the synoptic profile, three continuous temperature profiles per treatment will be obtained using temperature data loggers (Tidbit, Onset Corp) set at 0.5m intervals through the water column. Depth profiles will enable us to characterize

vertical stratification patterns and hypoxia events. Preliminary measurements indicate the possibility of vertical stratification and hypoxia (Table 3-4). To determine how diel patterns differ among treatments and with depth, four hydrolabs per treatment (1 upstream, 1 canal surface, 1 canal bottom, 1 downstream) will be simultaneously deployed in all treatments to record at 30 minute intervals for five consecutive days. Hydrolabs for diel measurements will be deployed monthly. Diel oxygen and temperature profiles will be used to estimate water column metabolism, (i.e., net ecosystem production, gross primary production, and respiration) (Cole et al. 2000; Hagerthey et al. submitted). As the metabolism calculation requires a temperature gas exchange coefficient that varies as a function of wind speed (Cole and Caraco 1998), a meteorological station will be established to measure air temperature, barometric pressure, relative humidity, photosynthetic active radiation (PAR), and wind speed and direction at 30 minute intervals.

Table 3-4: Physiochemical vertical profiles (mean±sd; n=3) for the L-67A and C canals obtained on 18 May 2009. Canal depths were 4.5 m (14.8 feet) and 3.5 m (11.5 feet) for the A and C canals, respectively.

Depth feet (m)	Dissolved Oxygen mg/L	Temperature ºC	pH	Specific Conductivity µS/cm
L67-A Canal				
Surface	8.7±0.3	28.3±0.1	8.1±0.1	789±0.6
3.3 (1)	7.8±0.3	28.2±0.1	8.1±0.1	790±0.6
6.6 (2)	5.4±0.4	27.6±0.1	7.8±0.1	793±0.6
9.8 (3)	2.9±0.5	27.2±0.1	7.7±0.1	791±0.6
13.1 (4)	1.5±0.3	27.0±0.1	7.6±0.1	791±0.1
Bottom Type	Organic Mud			
L67-C Canal				
Surface	5.3±0.2	28.3±0.1	7.7±0.2	645±6.0
3.3 (1)	4.2±0.5	27.9±0.2	7.6±0.1	650±4.0
6.6 (2)	2.3±0.8	27.3±0.2	7.5±0.1	653±6.0
9.8 (3)	1.2±0.6	27.1±0.1	7.4±0.1	654±6.1
Bottom Type	Organic Mud			

The physical environment in the L-67A canal will be assessed using the methods described above. It is important to contrast the L-67A canal with the treatments implemented on the L-67C canal because, under any restoration scenario, canals are no longer used as conveyance features. During the operational period of the DPM, the L-67A will still be an active conveyance canal and its physiochemical structure will be measured to evaluate the effects of eliminating conveyance flows on structuring the physical environment within canals.

3.2.4.4 Animal Responses

To determine if fish assemblage structure differs among canal treatments, each treatment will be surveyed using electro-shocking at least five times per year (Chick et al. 1999; Chick et al. 2004). Because electrofishing is non-destructive, weekly sampling will be conducted immediately before and after flows are manipulated. Concomitant measures of prey availability will be obtained from marshes using sweep net sampling and periphyton cores (Turner and Trexler 1997; Liston and Trexler 2005). To assess fish use of the canal

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treatments and the importance of connectivity, several techniques will be used. To capture fish movement, 20 large fish each of four species (two native, probably largemouth bass and Florida gar, and two non-native, probably Mayan cichlids and either oscars or jaguar guapote) will be tagged with radio transmitters and their positions determined at weekly intervals, again with extra intensity immediately before and after flow manipulations (Winter 1996). Species choices will be determined by data gathered on the relative abundance of species at the collection site. Fish must be large enough that transmitters weigh no more than 5% of the fish mass, setting a minimum size for the target study species. Additionally, dual frequency identification sonar (DIDSON; http://www.soundmetrics.com) will be used to count the number fish crossing the canal-marsh interface (Holmes et al. 2006).

Unlike large fish that can be tracked directly, movement of fish too small for transmitters must be documented by indirect means. Drift fences will be established at three distances from the upstream and downstream section of each canal treatment to capture the directionality and biomass of fishes moving across the landscape. Drift fences will function similarly to fyke nets and will be fitted with traps that sample at two sizes (small and large) to capture both size-class of fishes. Drift fences provide data on the 'encounter rate' of the trap as fishes move across the landscape. These data will be supplemented with density and biomass estimates of small fishes obtained using throw traps (Jordan et al. 1997). Obaza (2009) has recently demonstrated that data from encounter samples, such as drift fences, and density samples, as from drift fences, can be combined to yield estimates of small fish speed and direction. As implied by hypothesis $\boldsymbol{BH}_{08}$, opening connections to canals will alter small fish movement patterns in the wetlands, with implications for ecosystem function in the donor and recipient habitats, for example related to local grazing impacts and food production for higher consumers such as wading birds.

3.2.4.5 Biogeochemistry and Elemental Fluxes (Loads)

Water quality will be routinely monitored at stations near the gap in the L-67C and at the head and tail waters of the L-67A culverts. The constituents of interest are total phosphorus (TP), total dissolved phosphorus (TDP), total particulate phosphorus (TPP), inorganic phosphorus (as soluble reactive phosphorus, SRP), total Kjeldahl nitrogen (TKN), ammonium (NH_4^+), and total nitrogen (TN). Samples will be collected monthly, except during periods of operation when more intensive sampling will take place. During the operational period, considered to be several weeks prior to opening the culverts, the opening of the culverts, and several weeks after closing the culverts, auto samplers will be used to collect composite samples. Nutrient concentrations will be combined with discharge rates to estimate load ($g/m^2/d$) for both the L-67A culvert and L-67C gap. Gap discharges will be rudimentarily calculated using ADV determined flow velocities, water depths, and gap length. Nutrient loading and discharge rates will also be used to provide driving variables (upstream P loading) of the Ribbon model (Saunders et al. in review).

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3.3. Evaluating Ecological Benefits of Enhanced Flow Velocities

3.3.1 Introduction (statement of problem)

The pre-drainage Everglades landscape was a low-gradient, oligotrophic, peatland featuring parallel sawgrass ridges, open-water sloughs, and tree islands shaped, in part, by the flow of water (Science Coordination Team 2003; Larsen et al. 2007). Drainage and compartmentalization efforts have significantly altered flow vectors, stages, seasonal timing, and spatial distribution of water resulting in habitat degradation. Restoration aims to restore hydrology by removing the barriers to flow and re-establishing seasonal distributions. While flow is suspected to be a major driver of the Everglades landscape, there remains an extremely poor understanding of the basic principles, mechanisms, and feedbacks. This was clearly stated in the Science Coordination Team report (2003): "very few research studies have been conducted specifically to determine the role of flow in the Everglades ecosystem". Major obstacles to understanding the importance of flow are that 1) velocities in current ridge & slough landscape are lower than the predicted critical velocity threshold of 3 cm/sec to entrain sediment and restore ridge & slough patterns (Larsen et al. in review a) and 2) the habitats downstream of water delivery structures are degraded. **An objective of the DPM is to build the structural features that will cause a range of surface water velocities to occur in a marginally degraded portion of the natural system in order to verify the critical velocity threshold necessary to entrain and redistribute particles and nutrients in the landscape over a wide range of field conditions. The creation of this "flow field" should allow evaluation of the spatial variability of particle and nutrient transport.**

The short duration of the DPM does not allow for the direct investigation of the relationship between sheet flow and the landscape level changes expected with restoration (i.e., ridge & slough patterning). The DPM instead focuses on the controls that govern landscape morphology and vegetation patterning. The two main drivers of the ridge & slough landscape are hypothesized to be 1) the physical transport of material and 2) biogeochemical processes (e.g., respiration, production, and decomposition). Larsen et al. (2007; in review a) recently synthesized the controlling factors that determine Everglades ridge & slough degradation or sustainability in a conceptual model which indicates that flow induced particle entrainment and deposition is an essential driver of feedbacks between nutrient delivery, vegetation distribution, and differential peat accumulation (Fig. 3-12). These authors argue that the ridge & slough patterning results from the entrainment and redistribution of loosely consolidated particulate matter rather than the peat soils. Particulate matter includes a range of particle sizes that may be derived from various sources, including organic matter from periphyton, macrophytes, and animals, microbial cells, extracellular polymer substances, and geochemical precipitates (such as calcium carbonate). The most common form of loosely consolidated particulate matter is floc, which is a general term describing natural particles with a dominant detrital component in the Everglades that may at times became suspended and transported by flow in the water column given certain hydraulic conditions characteristic of the historic ridge and slough landscape.

Paleoecological evidence suggests that the patterned state of the Everglades ridge & slough landscape was an equilibrium condition for two millennia, prior to excessive anthropogenic influence (Bernhardt and Willard in press). The landscape occupied 55% of the historical

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extent of the Everglades (McVoy et al. in review) and was characterized by elongated peat ridges that were elevated above (by 30-90 cm: Wright 1912; Baldwin and Hawker 1915) and regularly interspersed among lower, more open peat sloughs, all aligned parallel to the dominant flow direction. Ridges were dominated by sawgrass (*Cladium jamaicense*), sloughs by open water or water lilies (*Nymphaea odorata*) with occasional spatterdock (*Nuphar advena*) and likely widespread bladderwort (*Utricularia* spp.) (McVoy et al. in review). Teardrop-shaped tree islands in the central Everglades and circular or cigar-shaped tree islands in the Loxahatchee National Wildlife Refuge contain a diverse assemblage of trees, shrubs, and ferns (Willard et al. 2006).

Over the past century, much of the ridge landscape has undergone rapid conversion to a more homogeneous state under drainage and compartmentalization of the system and changes in flow management (Science Coordination Team 2003). These engineering efforts altered hydroperiods, water depths, and flow directions, diminished flow velocities, and introduced agricultural contaminants into the historically oligotrophic ecosystem (Davis 1994). Concurrent with these changes, large portions of the ridge & slough landscape experienced an expansion of sawgrass into sloughs and a loss of slough connectivity and directionality (Figs. 2-1 and 3-2). These changes hindered fish migration and diminished habitat diversity (Science Coordination Team 2003). Other portions of the landscape upstream of levees that impounded the flow experienced longer hydroperiods and a loss of ridges (Science Coordination Team 2003; Sklar et al. 2005). Restoring the ridge & slough landscape is a goal of the Comprehensive Everglades Restoration Plan, but doing so requires a better understanding of the feedbacks controlling the evolution and stabilization of landscape structure.

Several experiments have begun to test components of the conceptual model for controls on the ridge & slough landscape and provide the informational foundation for the DPM. Harvey et al. (2009) conducted field experiments and dimensional analysis showing that the main controls on flow velocity are water depth, water surface slope, and vegetation architecture. Because emergent vegetation, which resists flow, fully penetrates through the water column, flow velocities are more sensitive to variability in water surface slope rather than variability in water depth. In the present-day system, time-averaged flow velocities, monitored over two wet seasons, were 29% higher in sloughs than in ridges because of the marginally higher vegetative drag in ridges. However, because of the greater water depths, sloughs provide 86% of the total discharge through the landscape (Harvey et al. 2009). Vertical profiles of flow velocity vary non-logarithmically with depth (Harvey et al., 2005) but can be accurately predicted using estimates of water surface slope, vegetation frontal area profiles, with a velocity measurement at a single depth serving to calibrate the model. Still, flow velocities in sloughs are not typically high enough to entrain flocculent bed floc (Larsen et al. 2009a, Noe et al. in review), which requires a critical bed shear stress of at least 0.01 Pa (Larsen et al. 2009a), typically achieved at velocities near 3 cm/sec (Larsen et al. in review a; Hagerthey et al. in prep).

The expected benefits of the sheet flow study are to evaluate surface flows, vegetation interactions, and particle entrainment and redistribution along a spatial and temporal gradient of surface flow velocities.

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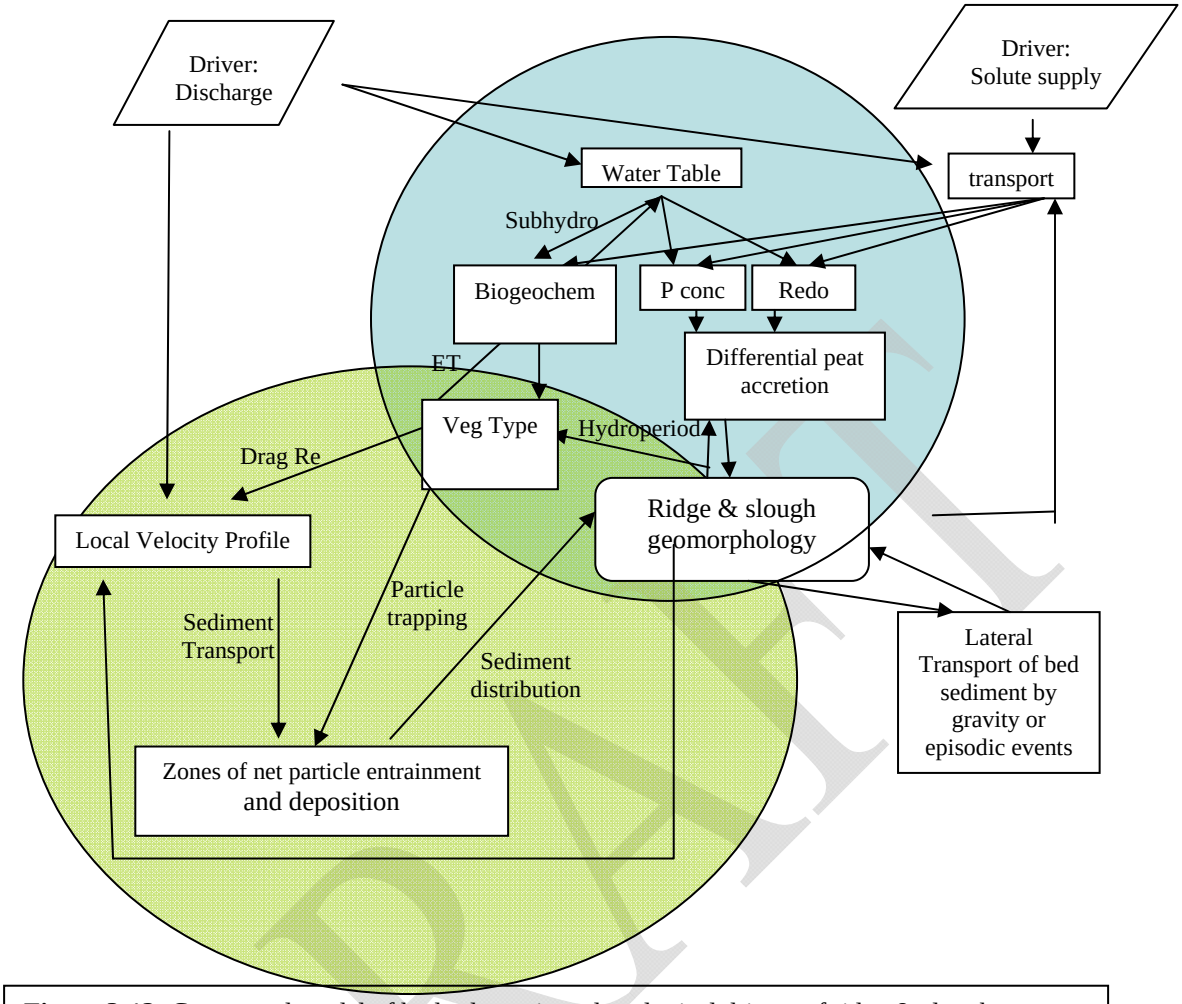

Figure 3-12: Conceptual model of hydrodynamic and ecological drivers of ridge & slough patterning. After Larsen et al. (2007).

3.3.2 Scientific Hypotheses

The DPM will, to some degree, test 13 sheet flow hypotheses to determine the role of flow in structuring and maintaining the ridge & slough pattern. $\boldsymbol{SH_{01}}$ through $\boldsymbol{SH_{03}}$ address the physics of particle transport. $\boldsymbol{SH_{04}}$ through $\boldsymbol{SH_{09}}$ explore in greater detail the elements of $\boldsymbol{SH_{03}}$ focusing on transport processes role in the ridge & slough landscape. $\boldsymbol{SH_{10}}$ through $\boldsymbol{SH_{13}}$ address landscape scale issues and restoration. Splitting the problem into so many hypotheses is indicative of problem complexity and an orderly approach towards solutions. These hypotheses are presented in the null form (H_0) which is a statement of "no difference". If concluded, through statistical tests, H_0 to be false, then this will be interpreted as support for the alternative hypothesis (H_A), meaning there is a "significant difference". Here we present the null hypotheses (bold), followed by a brief discussion of the expectation of the science team.

3.3.2.1 Physics of Transport Hypotheses

***SH_{01}*: A flow regime that exceeds a critical flow velocity and bed shear stress is not necessary to entrain sediment**. It is expected that sustained periods (days to weeks) of flow velocities exceeding a threshold of 3 cm/sec are required to entrain and redistribute a quantity of sediment particles. The long-term cumulative effect of these flow events will result in the restoration and maintenance of the historic ridge & slough landscape.

***SH_{02}*: Increasing flow will not enhance the transport of bed particles, periphyton-derived particles (algae), and water column-derived particles. In addition, the critical erosion threshold (velocities and shear stresses) required for transport of bed particles are not different than epiphyton-derived particles, and water column-derived particles.** It is expected that the velocity required to entrain and transport a particle will vary as a function of the origin and characteristics of particles. Furthermore, the erosion characteristics (i.e., the thresholds for the critical entrainment velocity and critical erosion) will be unique for different particles. Thus, the erosion and transport of particles at the landscape scale will be a function of spatial and temporal variations in flow velocities and the hydrodynamic nature (e.g., size distribution, particle density, settling velocity, etc.) of source particles.

***SH_{03}*: There is no net movement of sediment from sloughs to ridges.** It is expected that velocities and depths will be greater in sloughs than ridges due primarily to lower vegetative hydraulic resistance. Thus, sediment erosion is also expected to be greater. Ridges, since they have a greater vegetative hydraulic resistance, are expected to be depositional zones, resulting in a net redistribution of sediments from sloughs to ridges.

3.3.2.2 Transport and Ridge & Slough Development Hypotheses

***SH_{04}*: Deep water areas that are relatively free of vegetation will not exhibit higher rates of flow nor sediment transport and are not necessary to restore and maintain ridge & slough topography**. It is expected that vegetation density regulates flow velocities through increased drag, which will result in higher flow velocities and correspondingly higher sediment transport rates in deep zones that are sparsely vegetated.

***SH_{05}*: Elevated ridges do not direct flow preferentially into deeper water zones, leading to higher velocities and increased sediment transport.** If vegetation density increases drag (i.e., hydraulic resistance), then flows should be directed preferentially to regions of lower hydraulic resistance (i.e., sloughs).

***SH_{06}*: The capture of suspended particles through filtration does not vary among vegetation types (i.e., emergent, floating, or submersed). In addition, particle settling due to velocities falling below the critical entrainment velocity is not a greater sink for suspended sediment than capture by vegetation.** It is expected that vegetation type and density have a fundamental role in regulating the fate of entrained particles.

***SH_{07}*: Bed particles (e.g., floc) are not a more important contributor to long term ridge & slough elevation differences than fine suspended particles entrained from periphyton**

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on floating plants and emergent macrophytes. The long-term maintenance of the ridge & slough landscape is likely controlled, in part, by the erosion of and deposition of relatively refractory particles emanating from the bed of sloughs. However, transport of more biogeochemically reactive fine particles has received little attention and must also be considered.

***SH_{08}*: Sheet flow and sediment redistribution does not maintain organic soil accretion or loss in a state of dynamic equilibrium.** It is expected that the differential rates of erosion and deposition of sediment in slough and ridge and differential rates of biological processes (i.e., decomposition and organic matter production) balance such that the elevation difference between ridges and sloughs remains constant when the system is in equilibrium. A partially degraded landscape, such as that found in the area where the experimental flow-field will be applied should begin to increase net elevation differences as a consequence of high velocity pulse-flow events which redistribute flocculent material.

***SH_{09}*: The magnitude and duration of pulsed, high-water levels, and resulting flow velocities will not be more strongly related to restoration success (i.e., maintaining distinct ridges and sloughs) than average water depths and flow velocities.** It is not known what type of flow conditions (pulsed flow or steady flow) are required for the long-term sustainability of the ridge & slough landscape. It is anticipated that results from the DPM, a pulsed flow experiment, will provide information that can be used to address this hypothesis in greater detail, possibly through model development (see Section 3.4).

3.3.2.3 Landscape Hypotheses

***SH_{10}*: Sheet flow patterns in partially compartmentalized areas will not be directed preferentially between the inflow and outflow structures, characterized by regions of highly focused flow and large "backwater" zones.** Barriers to flow, whether canals or levees, will inhibit the development of sheet flow. Canals may serve as preferential flowpaths that redirect flow away from the historic flowpath. Alternatively, a system of gaps and levees may develop backwaters (stagnation points) as water is focused towards gaps in the levee. This could result in higher velocities near the gap and lower velocities near levees.

***SH_{011}*: Restoration of parallel ridge & slough communities does not require a combination of sheet flow and water depth fluctuations. S**heet flow and resulting sediment redistribution are required to maintain the parallel-drainage patterning of the ridge & slough landscape and prevent ridges from expanding into sloughs, while an appropriate range of water depths (through its control on net peat production) will be needed to maintain vertical differentiation between ridge & slough. This hypothesis may be addressed through model based inference.

***SH_{012}*: The difficulty of restoring and slough topography will not increase with the degree of ecosystem degradation currently in an area.** This hypothesis recognizes that the existing degraded landscape may have a high degree of ecological resistance (e.g., in sloughs that have been invaded by emergent vegetation have high vegetative resistance that reduces flow and sediment transport) that prohibits or limits restoration success. Simply put, the restoration of the abiotic driver, in this case variable but higher-than-present flow velocities,

may not be enough to restore the ecosystem. This hypothesis may be addressed through model based inference, or the duplication, of a DPM type approach across a range of degraded habitats.

***SH_{013}*: Within the current degraded landscape, an active management approach, in addition to flow, is not required to accelerate the restoration of the ridge & slough landscape.** This hypothesis recognizes that restoration may require actions beyond restoring pre-drainage flow to restore the degraded landscape (i.e., lower the ecological resilience of the degraded system). This is likely accomplished by dramatically altering abiotic drivers and biotic drivers (e.g., reductions in plant density), such that ecologically important feedbacks are altered (e.g., nutrient cycling). Although the DPM does not explicitly test this, the information gained from this study could be used to assess and recommend whether additional management actions may be required to restore the ridge & slough landscape.

3.3.3 Experimental Approach

Three representative ridge & slough habitats will be selected for detailed measurements within the flow-way where surface flow velocities will at times exceed 3 cm/sec. A fourth site located outside of the flow-way will serve as a low-velocity control site. To minimize disturbance, a network of aluminum walkways and staging platforms will be constructed to access sampling sites. Sites will be accessed by airboats using established routes or by a float helicopter.

Two types of measurements, hydrodynamic and ecological, will be made. The hydrodynamic measurements focus on the physics of flow and particle transport. Ecological measurements will focus on biological attributes that affect hydrodynamics as well as those that respond to increased nutrient supply associated with increased flow. Many of the same methods described for the evaluation of canal backfilling options (Section 3.2.4) will be used.

Sampling frequencies and locations will vary depending on the parameter (Fig. 3-13). The schedule for the study, including the frequency of sampling for each parameter, is provided in Annex 1.

3.3.4 Materials and Methods

3.3.4.1 Hydrodynamics

The majority of hydrodynamic information for the ridge & slough experiment will be obtained from the DPM hydrodynamic monitoring network described in Section 3.2.4.1. Briefly, the network is designed to establish the hydraulic gradient within the pocket and WCA-3B by monitoring water depth, velocity, and concentrations of suspended sediment particles. High resolution elevation data and vegetation type, biomass, biovolume, and stem density data will also be obtained (see Section 3.2.4.1). Comparisons of the present day landscape patterns in the study area will be compared with historic imagery.

The large-scale hydrodynamics of surface water flows between the L-67A and L-67C will primarily be investigated using an SF_6 tracer methodology modified for the low-gradient

Everglades (Ho et al. 2009; Variano et al. in press). Four SF_6 tracer studies (1 per year, 2 *before*, 2 *after*) will be conducted in the operational window of October through January. The tracer will be released immediately downstream of the L-67A culverts and the daily fate of the plume followed by making continuous measurements of SF_6 concentrations using a GC mounted to an airboat (Fig. 3-14). The plume will be followed for 5-10 days depending on dispersal rates. The results of the tracer tests, in combination with aerial photography to delineate landscape features, will be integrated with a Lattice-Boltzmann modeling procedure to develop fine-scale simulations of flow dynamics within the ridge & slough landscape, including vegetation interactions (see Section 3.4-Synthesis and Reporting).

Rhodamine dye will be used to complement the SF_6 tracer studies to study the short-term local flow dynamics in ridges and sloughs. Dye will be introduced to 5-10 sloughs and sawgrass ridges in both the flow-way and control ridges and aerial observations will be made at regular intervals (hourly) to ascertain flow patterns (Fig. 3-9). In addition, water samples for fluorescence detection will be collected from sentinel sites at 15 minute intervals.

3.3.4.2 Particle Transport

To determine if particle transport is essential for the development and maintenance of the ridge & slough landscape by redistributing entrained sediments, a variety of parameters will be measured to characterize sediment properties and trace particle movement. Critical erosion thresholds (CEV) and settling velocities will be measured in situ using a portable benthic annular flume prior to flow enhancements (Fig. 3-10; Partrac 2005, 2006, 2008; Hagerthey et al. in prep). When these experimental CEV values are combined with in situ monitoring of the relationship between flow and suspended sediment abundance, an accurate assessment of the spatial and temporal likelihood of particle entrainment will be attained. ADV measurements of depth-averaged velocities will be made for different habitat types (Harvey et al. 2009). In addition, in situ laser particle size analyzers will be utilized (LISST; Sequoia Scientific) and direct measurements of water samples to characterize the size distribution, mass, and biogeochemical quality of suspended particles (Noe et al. 2007; Noe et al. in review). Measurements made using a digital floc camera will complement those of the LISST by providing a record of concentrations and shape characteristics (e.g., fractal dimension) of opaque floc particles ranging in size from 40 μm to several cm in diameter (Larsen et al., 2009a). Particle origins will be assessed further using standard biomarker and macrofossil methods developed for the Everglades (Saunders et al., 2006; Gao, 2007; Gao et al., 2007; Saunders et al., 2008).

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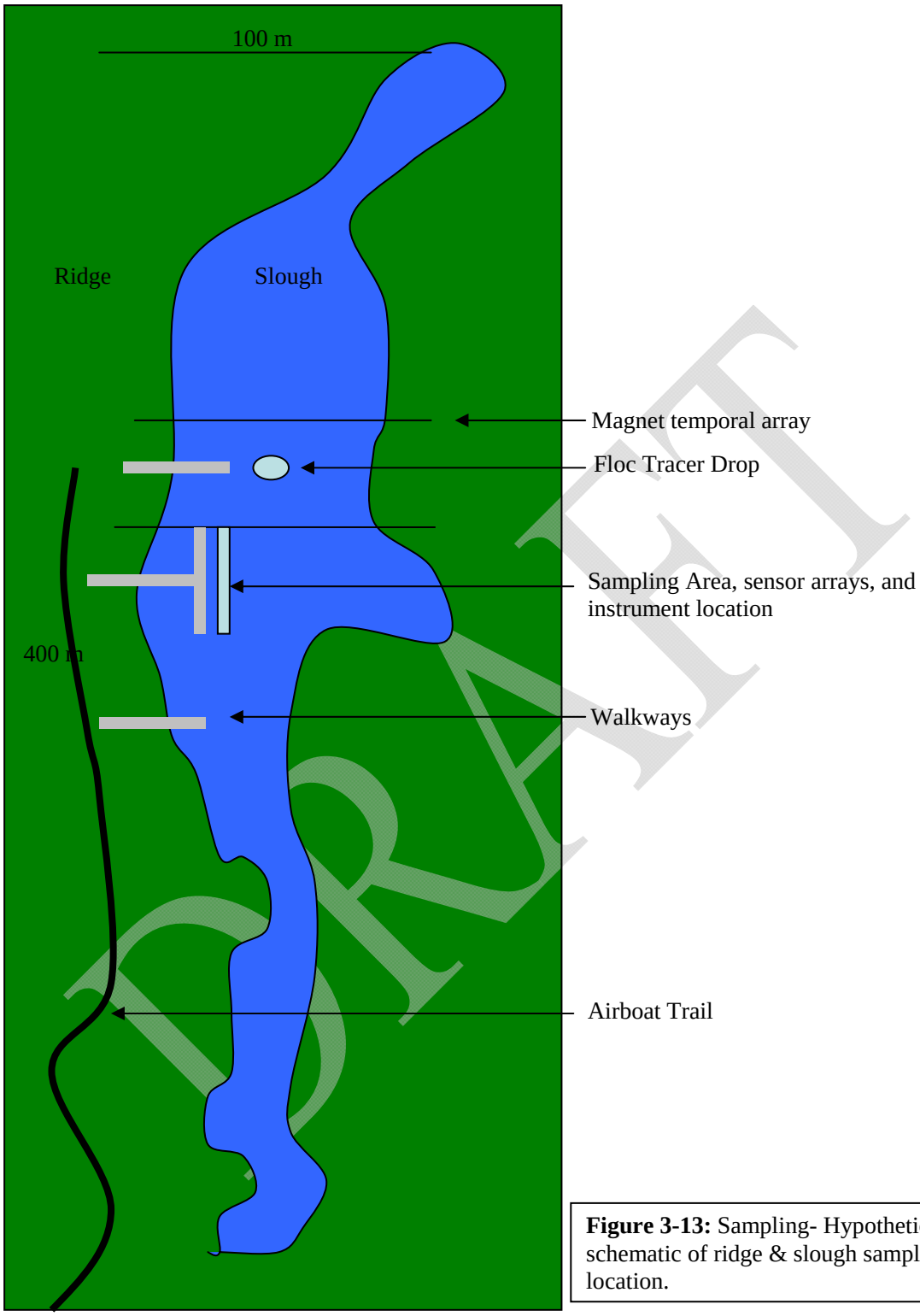

Figure 3-13: Sampling- Hypothetical schematic of ridge & slough sampling location.

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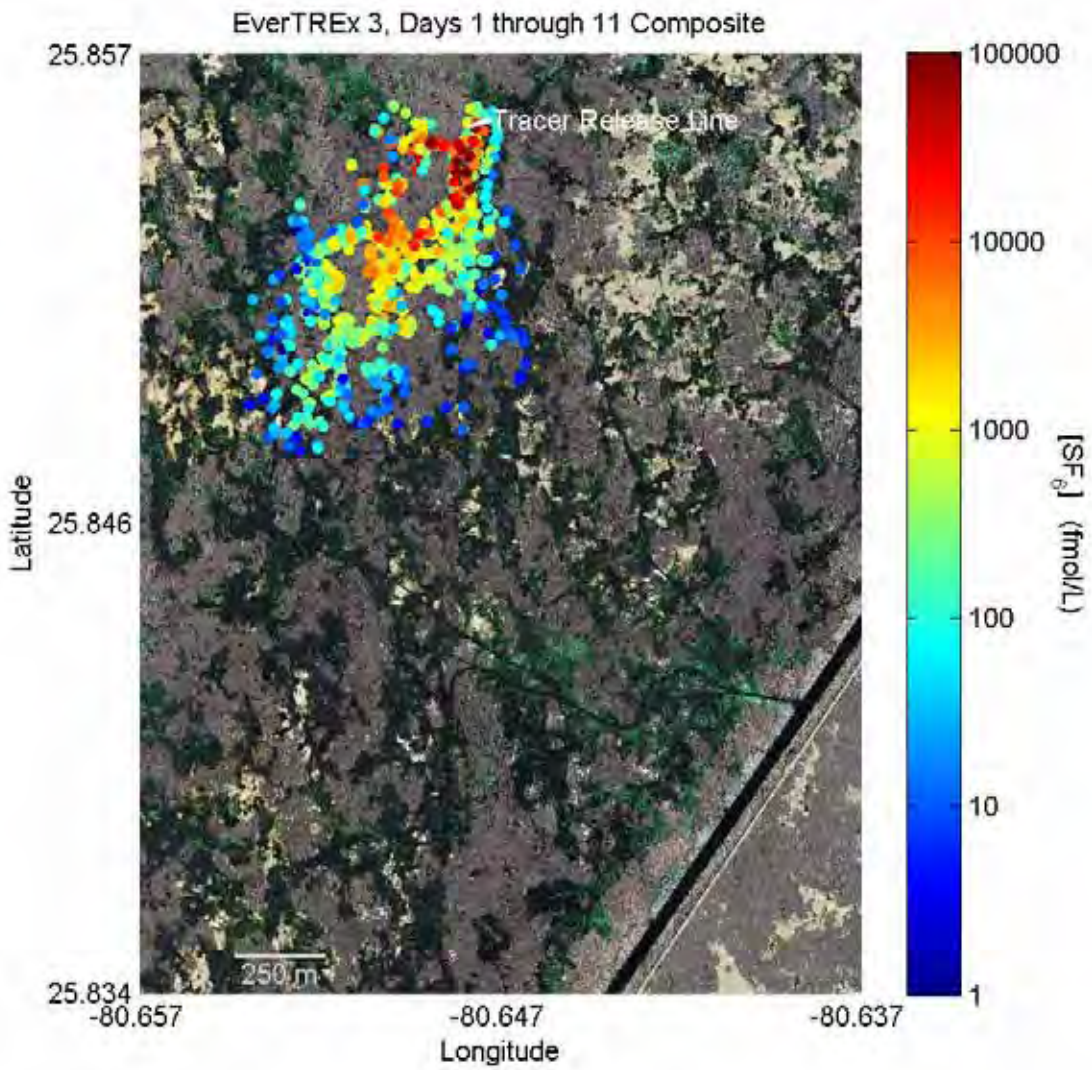

Figure 3-14: Eleven day composite map of surface flow in the Everglades ridge & slough landscape obtained by following the release of the tracer SF_6.

Particle transport will be evaluated using sediment traps and a dual signature artificial tracer (DST) that is hydraulically matched (i.e., representative) of the mean particle size and settling velocity of sediment collected from the study region. Three replicate horizontal (Partrac 2005) and vertical (Leonard et al. 2006) sediment traps will be deployed at the sediment-water interface perpendicular to the direction of flow, from the slough transition to ridge. Sediment traps will be deployed continuously with collections obtained monthly. Particles will be analyzed for quality and size distributions. The DST particle is made of an inert fluorescent material in which magnetite inclusions are imbedded (Partrac 2005, 2006, 2008; Fig. 3-11A). The tracer will be "dropped" as frozen blocks to ensure minimal contamination. A "drop" typically consists of 20-40 kg of tracer with a unique fluorescent signature per treatment. Tracer will be retrieved using magnetic rods (Fig. 3-11B and C) in a

sentinel and synoptic design in order to provide adequate temporal and spatial resolution. The sentinel study (moderate spatial but high temporal frequency) will consist of 5 magnets deployed perpendicular to the flow path 3 m downstream and upstream from the drop zone. Magnets will be continuously suspended in the water column and visited monthly to collect any adhering tracer. The tracer will be dried and weighed (g dw/pole) and summed for each magnet (g dw/magnet). Given the 5 cm effective capture radius of the magnet (i.e., any tracer passing within 5 cm of the magnet will be captured), the mass of tracer on each magnet can be expressed per unit area. When combined with the cross-sectional area of the channel (determined from the microtopography measurements), we can estimate the downstream mass flux of tracer (g of tracer/day). Additionally, the vertical distribution of tracer on the magnet provides information of the vertical transport of particles (i.e., are particles suspended in the water column or transported as bed load). To assess the redistribution of particles, synoptic maps (high spatial but low temporal frequency) of tracer will be obtained by probing sediment beds and vegetation beds with a magnet and determining tracer mass. Synoptic measurements will be made at six month intervals. To aid in the determination of tracer flux and redistribution before (low flow) and after (high flow), two tracer drops of different color will be scheduled per treatment.

Biomarker and macrofossil analyses of particles will also provide "natural" tracers to compare the relative importance of upstream sources versus local sources of particulate matter under high-flow versus low-flow conditions. Biomarker and macrofossil analyses will be performed on suspended particles, particles captured in vertical and horizontal sediment traps (described above), and bed sediments sites located upstream, and 10-m or 20-m downstream (Fig. 3-15). Previous biomarker and macrofossil analyses of bed sediments indicate organic matter may be deposited 20-m downstream from the point of origin (Colin Saunders personal communication). Significant differences between ridges and sloughs in the relative importance of upstream sources on particles collected in sediment traps will indicate the degree to which entrained particles are preferentially transported between ridges and sloughs and how those fluxes differ between high and low flow conditions. To the extent possible, these natural tracer studies will be co-located with monitoring sites designated for artificial tracer drops (described above).

3.3.4.3 Biological Measurements

Many of the sheet flow hypotheses indicate that vegetation community structure is an important factor affecting the shape of velocity profiles and determining the distribution of velocities close to the bed (Larsen et al. in review a); therefore, vegetation community composition, biomass, biovolume, and stem densities will be determined. Within the four intensive study sites, vegetation in 0.25 m^2 quadrates will be characterized in a stratified random strategy along transects from each slough, transition, and adjacent ridge locations at the four focal slough sites. In addition to the intensive site collection, the same vegetation parameters will be collected from 5-10 sites within the flow-way to obtain a more holistic perspective of near-surface frontal areas, near-bed frontal areas, and vegetation drag coefficients. Vegetation sampling will be collected during the wet and dry seasons.

Characterization of the biological sources of suspended particles requires the measurement of the abundance of particulate matter sources (periphyton and sediments) during periods of low

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flow and before and after high flow pulses. A stratified random sampling design implemented within the four intensive study sites will characterize the mass of periphyton per unit area and volume in 0.25 m^2 quadrates along transects that traverse a slough, transition zone, and adjacent ridge. Bed particles (i.e., the floc layer) will also be collected along the transects using 4" butyrate cores and analyzed for particle size distribution, mass, settling velocity, and biogeochemical characteristics.

Fig. 3-15: Hypothetical schematic of natural tracer ridge & slough sampling locations. Analyses of biomarkers and macrofossils will be performed on particulate sources (upstream and downstream sites) and from horizontal and vertical sediment traps (downstream sites only).

Increasing flow from background to 3 cm/sec will increase loading of nutrients to the downstream system. In this phosphorus limited ecosystem, it is particularly important to assess whether we see a change in how phosphorus is processed and whether this is expected to have long-term consequences that are linked to other biological processes and ultimately species composition and carbon cycling, all of which are necessary to sustain a ridge & slough landscape. Given the short-term nature of the pulses, dramatic vegetation shifts are not expected; instead indicators of change will be used to predict future responses. Tissue nutrient contents are a more sensitive measure than water quality concentrations when examining biological responses (e.g., Gaiser et al. 2004). Therefore, nutrient concentrations of the surficial floc/periphyton community, and tissue nutrients of key macrophytes/periphyton will be used to track biological changes. Studies have shown that enzyme activity can be used to indicate the relative degree of phosphorus limitation by measuring phosphatase activity (Newman et al. 2003). This low cost and sensitive measure may be the most effective means to establish a phosphorus supply versus biological response

relationship. Phosphatase activity will be measured in the surface water and in floc and periphyton samples to assess a switch in phosphorus availability (i.e., supply) using a standardized substrate: methyl umbelliferone phosphate. To ensure that the periphyton community is of known age, periphyton phosphatase activity and biomass will be determined from periphyton that is allowed to colonize acrylic dowels suspended within the water column. Data will be expressed per unit area (Newman et al. 2003). Enzyme activity has been shown to respond within 2-3 weeks of phosphorus enrichment (Newman et al. 2003) and thus will work well within the pulsed timeframe of DPM.

To compare decomposition rates between ridges and sloughs during low and high flow conditions, short-term decomposition studies will be conducted using a standard cotton strip substrate (Newman et al. 2001). Two 12 cm (wide) by 31 cm (long) cotton strips (Shirley Institute, Manchester, England), will be attached to a stainless steel frame (6 mm) that supports the strips vertically, and deployed into the soil encompassing the water, floc and soil interfaces. The location of the two interfaces will be recorded and after two weeks, the strips will be retrieved and loss in tensile strength determined at 2 cm increments using a Chatillon TCD-200 tensiometer, equipped with a digital force gauge (DFIS 200, Chatillon, Greensboro, North Carolina). All data will be linearized and presented as annual cotton rotting rates to correct for non-linear changes over time (Hill et al. 1985).

3.4. Synthesis and Reporting

3.4.1 Synthesis

The DPM is the first study to evaluate the hydrologic and ecological aspects of flow in the Everglades. The incorporation of these results, parameter estimates, into hydrological and ecological simulation models greatly enhances the ability to synthesize and infer ecosystem responses to different restoration scenarios. The following simulation models will benefit from DPM.

3.4.1.1 Integration with Hydrologic Models

The results of the DPM will allow the Decomp project to evaluate alternative designs and extents for the backfilling of the L-67A and L-67C levees and removal of the L-29 levee because these results will “fine-tune” hydrological modeling parameters associated with WCA-3B lag times, roughness coefficients, directional flow, retention times and seepage that are in the current SFWMM (South Florida Water Management Model; www.sfwmd.gov) as well as the still-developing, more refined, RSM (Regional Simulation Model; www.sfwmd.gov). These models are critical tools for calculating volumes of water that traverse a wetland and the DPM will be measuring volumes of water across an intensely monitored wetland at a resolution never before accomplished in the Everglades. Despite the rather coarse resolution of the SFWMM it is still the most significant planning tool ever devised for restoration (Sklar et al. 2005) and since both the SFWMM and the DPM are sensitive to all water balance components (ET, rain, flow, and seepage), the physical model will supply very exact hydrologic response curves that can then be used (e.g., to calibrate) by the SFWMM or RSM.

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The most important DPM hydrologic response, relative to RSM and SFWMM dynamics, will be the rate of water level increase in WCA-3B as a function of inflow volumes. Since the inflows and the stage responses will be carefully monitored as part of the DPM, mass balance calculations, especially those associated with infiltration, seepage and percolation can then be easily extracted. In this part of the Everglades Protection Area (EPA), these groundwater recharge elements are significant to both society and restoration. The synthesis of the DPM findings will include working with SFWMD modelers and providing them with water table responses in the saturated and unsaturated zones at the three USGS stage gauges in WCA-3B.

Other important DPM results, especially relative to RSM, include flow field dynamics as a function of vegetation structure and sediment distribution as a function of velocity. Frictional coefficients at the fine scale of ridge and slough need to be clearly defined in the RSM if the planning for Decomp is going to include the hydrodynamic characteristics of sheet flow and velocity.

Other models that will use DPM results include EDEN (Everglades Depth Estimation Network), the SFWDAT (South Florida Water Depth Assessment Tool), and the ELM (Everglades Landscape Model). EDEN (http://sofia.usgs.gov/eden/) and SFWDAT are daily spatial interpolations of stages to calculate water depths. Depths are the basis for structure openings and closing, and since the refined depth network associated with the DPM will improve EDEN and the SFWDAT, the synthesis will be a more optimized Decomp operation manual. The ELM (Fitz et al. 2004) is a dynamic ecological simulation, which Decomp plans to use to evaluate the ecological benefits of sheet flow. This model has a state variable not found in any other model, but critical to Everglades structure and function, and measured extensively in the DPM: floc. The ELM developers discovered that it was not possible to capture realistic accretion rates and phosphorus accumulation rates in the model unless floc was modeled separately from soil. As a result, ELM calibration and validation is linked to all of the DPM sheet flow hypotheses, and ELM evaluations can be used to scale up the DPM findings to all of WCA-3A and 3B.

3.4.1.2 The RASCAL Model

RASCAL (Ridge and Slough Cellular Automata Landscape) is a numerical model developed at the USGS (Larsen and Harvey, in review b) to simulate flow/vegetation/sediment transport feedbacks at a 5-m resolution. Inputs to the model are water level and water-surface slope during flow pulses and a peat topography DEM. The model produces predictions of the quasi-3D flow velocity field, bed shear stress distribution, floc redistribution, and peat aggradation or degradation due to floc redistribution and autogenic processes. Drag coefficients in the model were calibrated in the field (Harvey et al. 2009), and predictions of flow velocities and bed shear stresses were validated under present conditions (Larsen et al. in review c). The DPM will provide the opportunity to validate model predictions over a wider range in flow conditions and to refine uncertain components of the model (e.g., the proportion of floc that is conservatively converted to peat). RASCAL in turn will provide a means by which findings from the DPM can be scaled up and used to predict long-term evolution of ridge and slough topography and vegetation patterning under different management scenarios.

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3.4.1.3 The Ribbon Model

The Ribbon model (Saunders et al. in review) simulates major ecosystem P stocks (plants, consumers, detritus, floc and soil), P fluxes (ecosystem P retention and cycling rates) and water TP for unit models of sawgrass, wet prairie and moderately P enriched sawgrass and wet prairie communities. This model has been parameterized with *in situ* measurements (from 2000 to present) of plant community composition, above- and below-ground biomass and production, periphyton uptake, detritus decomposition, nutrient mineralization/ immobilization, sedimentation, water residence, and floc metabolism provided through the Florida Coastal Everglades Long-term Ecological Research (FCE LTER) program. Previous applications of the Ribbon model in oligotrophic and canal-impacted wetlands of Shark Slough showed the highest sensitivity of water TP and ecosystem P stocks and fluxes to two processes: habitat exchanges of water P and floc P. Incorporating short-term results from the DPM (mainly between habitat exchanges of waterborne P, floc transport, periphyton and floc metabolism) into the Ribbon model provides a unique opportunity to explore ramifications of increasing water flow on the dynamics of the major ecosystem P stocks and fluxes over a time span of multi-years to decades.

3.4.1.4 The Lattice-Boltzmann Model

Lattice-Boltzmann model (LBM; Sukop and Thorne 2006) is a high-resolution (1-m) hydrologic model that investigates flow patterns in Everglades landscapes and determines velocity fields for nutrient (solute and particulate) transport in the ridge and slough landscape based on regional hydraulic gradients and water management. The model spatial domain is easily adapted to the DPM using digitized aerial imagery of marsh habitats and structures in the DPM footprint. The model is calibrated with SF_6 tracer data (to be conducted as part of the DPM) in conjunction with a state-of-the-art optimization scheme PEST (Parameter ESTimation, Doherty 2005). Previous work integrating LBM with SF_6 tracer data (in WCA3A and 3B) clearly identifies preferential flow paths on the landscape including landscape patterning and man-made structures, including levees, canals – thus, it is an important tool for understanding canal-backfilling treatment effects on landscape flow paths. SF_6 tracer experiments planned for the DPM will be used by the LBM to calculate resistances of different vegetation types, thus allowing for simulations in areas without tracer tests, and the LBM provides additional improved information on flow resistance terms used in regional modes such as the SFWMM. Lastly, the LBM can help address questions related to ecological connectivity in degraded and well-preserved landscapes, by constraining hydrologic and particle transport inputs required for ecological models such as ELM and the Ribbon model.

3.4.2 Reporting

Results from the DPM will be formally reported annually to the Decomp Project Delivery Team in both a written document and a presentation. The report will be available to the public and all interested parties. In addition, members of the DPM Science Team will attend regular scheduled PDT meetings to provide project updates and status reports. Members of the DPM Science Team will also be available, as needed, to present project status and results to other parties. It is also anticipated that numerous scientifically scholarly articles will be

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submitted for publication in peer-reviewed journals and regularly presented at annual meetings of national and international scientific professional societies.

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WWW.SFWMD.GOV (portal location for the RSM: http://www.sfwmd.gov/portal/page?_pageid=1314,2555966,1314_2554338&_dad=portal&_schema=PORTAL&navpage=rsm)

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5.0 ANNEXES

Annex 1-The Decomp Physical Model data collection and synthesis schedule.

Annex 2-Supporting documents used in the development of the Decomp Physical Model. 1) Decomp Physical Model: Risks, Constraints, and Assumptions. 2) Tree island composition, elevation, and hydrologic tolerances of the dominant species: Implications for the Decomp physical model. 3) Predicting water velocity from stage conditions during the L-67 gap test. 4) An analysis of the biological and water quality benefits and impacts in Water Conservation Area 3B associated with 1998 opening of the L-67A levee. 5) Water surface slope and phosphorus concentrations interact to determine the DPM operational window.

Annex 3-Curriculum Vitae: Contributing Authors and Principal Investigators

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ANNEX 1

DECOMP PHYSICAL MODEL

DATA COLLECTION AND SYNTHESIS SCHEDULE

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Annex 1: Schedule for data collection and synthesis for the Decomp Physical Model. BACI Period: yellow represents the Before Impact and purple the After Impact. Orange and Red indicate preoperational and operation periods, respectively. Dots represent point measurments whereas dashes are continouous (i.e., data loggers). Lead Agency reflects responsible party for collection and analysis oversight.

Construction Begins March 31, 2011

Levee Degrade

Sampling Year		2010	2011												2012												2013												2014			
BACI Period			BEFORE IMPACT MONITORING																								AFTER IMPACT MONITORING															
Month		J F M A M J J A S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Event			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
			Pre-Ops Window												Pre-Ops Window												Ops Window												Ops Window							
●=Point Measurement																																														
▬= Continuous Measurement	**Agency Lead**																																													
Backfilling Uncertainity																																														
Hydrodynamic																																														
L-67A Water Quality	SFWMD		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	–	–	–	–	–	–	–	•	•	•	•	•	–	–	–	–	–	–	–	•	•	•	•
Water Quality	SFWMD		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Stages (pressure tranducers)	USGS		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Flow velocity and direction (ADV)	USGS		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Synoptic Water Depths	USGS		•	•	•										•	•	•										•	•	•										•	•	•					
Synoptic Flow Velocity	USGS		•	•	•										•	•	•										•	•	•										•	•	•					
Particle Size Analysis (LISST)	USGS		•	•	•										•	•	•										•	•	•										•	•	•					
Digital Floc Camera	USGS		•	•	•										•	•	•										•	•	•										•	•	•					
Synoptic Particle Size and Characterization	USGS		•	•	•										•	•	•										•	•	•										•	•	•					
Particle Origin Analysis (Biomarkers)	SFWMD		•	•	•										•	•	•										•	•	•										•	•	•					
Rhodamine Dye Tracer Study	SFWMD		•												•												•												•							
High Resolution Topgraphy	USGS											•	•	•										•	•	•									•	•	•								
Vegetation Surveys (type, biomass, biovolume, and stem density	USGS											•	•	•										•	•	•									•	•	•								
Benthic Annular Flume (sediment properties)	SFWMD											•	•	•										•	•	•									•	•	•								
Floc Tracer Drops	SFWMD									•																•																				
Sentinal Tracer Retrieval	SFWMD		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Synoptic Tracer Retrieval	SFWMD			•						•						•						•				•							•						•						•
Aerial Image Interpretation	SFWMD																		•	•	•	•									•	•	•	•									•	•	•	•
Ecological																																														
Ecosystem Metabolism- NEP, GPP, R (Hydrolabs)	SFWMD		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Vertical Temperature and Dissolved Oxygen Canal Profiles (Hydrolabs)	SFWMD		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Metrological Measurements (Air temp, water temp, baro press, PAR, rel humidity, wind speed)	SFWMD		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Canal Temperature (Tidbits)	SFWMD		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Fish Surveys	Trexler		•		•						•		•		•		•		•				•		•		•		•		•					•		•		•		•		
Prey Surveys	Trexler		•		•						•		•		•		•		•				•		•		•		•		•					•		•		•		•		
Fish Tracking	Trexler		•	•	•									•	•	•	•									•	•	•	•									•	•	•	•				
Ridge & Slough Uncertainity																																														
Hydrodynamic																																														
Stages (pressure tranducers)			–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Flow velocity and direction (ADV)			–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Synoptic Water Depths			•	•	•										•	•	•										•	•	•										•	•	•					
Synoptic Flow Velocity			•	•	•										•	•	•										•	•	•										•	•	•					
Particle Size Analysis (LISST)	USGS		•	•	•										•	•	•										•	•	•										•	•	•					
Digital Floc Camera	USGS		•	•	•										•	•	•										•	•	•										•	•	•					
Synoptic Particle Size and Characterization	USGS		•	•	•										•	•	•										•	•	•										•	•	•					
Particle Origin Analysis (Biomarkers)	SFWMD		•	•	•										•	•	•										•	•	•										•	•	•					
SF6 Tracer Surface Water	ENP		•												•												•												•							
Rhodamine Dye Tracer Study	SFWMD		•												•												•												•							
High Resolution Topgraphy	USGS											•	•	•										•	•	•									•	•	•								
Benthic Annular Flume (sediment properties)	SFWMD											•	•	•										•	•	•									•	•	•								
Floc Tracer Drops										•																•																				
Sentinal Tracer Retrieval			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Synoptic Tracer Retrieval				•						•						•						•				•							•						•						•
Aerial Image Interpretation	SFWMD																		•	•	•	•									•	•	•	•									•	•	•	•
Biological																																														
Ecosystem Metabolism- NEP, GPP, R (Hydrolabs)	SFWMD		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Vegetation Surveys (type, biomass, biovolume, and stem density	USGS											•	•	•										•	•	•									•	•	•								
Biological characterization of source particles	USGS		•	•	•									•	•	•	•									•	•	•	•									•	•	•	•				
Biological Responses (nutrient enzymes)	SFWMD		•	•	•									•	•	•	•									•	•	•	•									•	•	•	•				
Decomposition	SFWMD		•	•	•									•	•	•	•									•	•	•	•									•	•	•	•				
Synthesis and Reporting																																														
DPM Report to PDT	SFWMD																				•												•											•	
Synthesis	ALL																																										•	•	•	•

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ANNEX 2

DECOMP PHYSICAL MODEL SCIENCE PLAN

SUPPORTING DOCUMENTS

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SECTION 5- Water surface slope and phosphorus concentrations interact to determine the DPM operational window

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SECTION 1

The Decomp Physical Model: Risks, Constraints, and Assumptions

The Decomp Physical Model Subteam (February 2009)

DPM RISKS

The DPM could be perceived by the public as a delay and lack of commitment to the full-scale Decomp project by the Corps and the SFWMD. Concerned citizens may perceive that the Corps and SFWMD "already know enough" and that the Corps and SFWMD can proceed with Decomp "by just restoring the natural hydrology." However, as noted, there are many uncertainties and risks that are high with this approach without further study of the unique Everglades environment. This is why it must be made clear to the public and other agencies that the DPM is designed to accelerate ecological benefits by addressing current landscape uncertainties and to reduce risks.

A second risk of the DPM is potential misuse and misinterpretation of short-term results from the 5-year physical model. The DPM is being implemented in an environment that still includes significant constraints on hydrologic parameters such as flow and stage. Therefore, interpretation of the results of the DPM needs to take into account the known constraints of the environment. Furthermore, as has been suggested for all CERP restoration projects, alterations to the system may produce initial negative environmental impacts while moving toward hydrologic and ecological restoration. Additional science, supplied by the DPM, will help to explain these kinds of patterns if they occur, and allow RECOVER to better understand the mechanisms that will in fact, restore the functional attributes of the Everglades.

DPM CONSTRAINTS

The constraints associated with the DPM are listed under Section 3.3 of the Decomp Project Management Plan. Additional details needed to further define each of these constraints are documented within this section.

1) Protect cultural, archeological, and environmental resources, including vegetation, tree islands, and wildlife.

   - Coordination is on-going with the Florida State Historic Preservation Office (SHPO) to determine presence of cultural and archeological resources. At this point of the planning process, there do not appear to be any cultural or archeological resources within the DPM footprint that would be impacted by the project. Should such resources be identified (during the planning, construction, or monitoring phases), project activities would cease until further coordination with SHPO determines a proper course of action.

   - Constraints that may need to be implemented for vegetation and wildlife were considered, especially related to seasonal operational constraints for wading bird foraging and nesting. Water levels in WCA 3B have been unsuitable for nesting. The increased

water levels due to the DPM may actually improve suitability. It is anticipated the hydrologic operational constraints, discussed further below, would be met before any adverse impacts would occur to the vegetation and wildlife.

- Tree islands that inhabit the Everglades show evidence of a wide range of tolerances to fluctuating water levels. Most of the tree islands are dominated by flood-tolerant species. During a normal rainfall year, the hydrologic conditions on the tree islands show significant local variation, even among islands in close proximity. The islands in WCA 3B are significantly drier than the islands in WCA 3A. There is an abrupt reduction in inundation patterns in WCA 3B as compared to WCA 3A due to L-67A and L-67C preventing flows from entering WCA 3B. The average annual hydroperiods on the heads of many of the tree islands in WCA 3B are significantly lower than what is typical in the rest of the Everglades. Thus, the average annual hydroperiod could be increased significantly while still maintaining hydrologic conditions within the known tolerances of the islands' dominant species. An analysis on tree islands within WCA 3B of average annual hydroperiod, species assemblages, and elevations suggests that the average annual hydroperiod could be increased from 50 to 261 days, depending on the island, while still maintaining hydrologic conditions favorable to the dominant species. This is an estimate of the extent to which average annual hydrologic conditions in WCA 3B could change before population- and community-level responses on the islands could be expected. The analysis does not attempt to predict changes in tree island communities, but only to identify the thresholds of the existing communities, such that implementation of the DPM does not cause harm to the tree islands.

2) Preserve the capacity of water supply deliveries to the Lower East Coast.

3) Maintain current level of flood protection east of the L-30 and L-31N levees.

- Closure or restriction of the DPM structures in L-67A will be considered if WCA 3B stages at Site 71 rise to 8.5 feet NGVD (1929), in order to control potential impacts caused by increased seepage to the east and manage potential risks to the integrity of the protective levee system. Alternative or additional WCA 3B reference gage(s) for operational constraints may need to be considered, depending on the final location of the DPM (SRS-1 and S-355A & B headwater gages represent potential gages already in place).

- Closure criteria for the DPM structures in L-67A may situationally be raised above 8.5 feet NGVD, based on an assessment of system-wide conditions (including WCA 3A, Northeast Shark River Slough, and the South Dade Conveyance System). In order to maintain higher stages within WCA 3B, the South Dade Conveyance System (SDCS) must have available capacity to effectively manage the increased seepage volume. Due to the intra-annual variability of water levels within WCA 3, increased operational flexibility may be expected during the dry season and following the end of the hurricane season.

4) Ensure quality of water. At a minimum, no further degradation and meet federal, state and tribal water quality standards for discharges to the WCAs and ENP.

The DPM will include control measures to ensure quality of water. At a minimum, no further degradation will be allowed and the test must meet federal and state quality standards for discharges to the WCA 3B and ENP. Impacts to the water quality of Tribal lands are not expected from this test. If there is any indication that that is happening or may happen, the test will be adjusted to address that matter.

The discharge from the L-67A canal into the L-67 pocket resulting from the physical model test will have a total phosphorus compliance limit (i.e., water quality based effluent limit (WQBEL)) of 17 ppb expressed as an annual flow-weighted mean TP concentration. The 17 ppb flow-weighted mean WQBEL was determined by the FDEP to be equivalent to the phosphorus criterion which is expressed as a long-term geometric mean of 10 ppb in the marsh.

The State of Florida is conducting all monitoring required to access compliance with the phosphorus criterion in the marsh and will continue the necessary monitoring independent of activities of this project.

Since each culvert may be operated independently, an autosampler must be placed immediately upstream of each culvert. A two-week maintenance interval is the current proposed cycle to collect samples from and conduct maintenance on the autosamplers. The exact sampling regime (frequency and type of samples collect, i.e. discrete or composite) for the autosamplers will be determined by the Water Quality Sub-team. Adjustments to the number and placement of the autosamplers may take place if the Water Quality Sub-team determines change is appropriate based on the data collected. Any changes to the total phosphorus sampling regime must be approved by the FDEP to ensure adequate compliance monitoring is being achieved. Only total phosphorus will be analyzed from the autosampler aliquots.

The flows through each culvert during this test needs to be measured in order to allow the flow weighted concentration to be determined.

Physical parameters (DO, pH, conductivity and temperature) will be measured every two weeks immediately upstream of each culvert. Metals are not required to be sampled. The Corps will include TN and sulfate to the parameters to be sampled as grabs every two weeks when discharges are occurring. Nitrogen is a parameter of interest and sulfate is closely linked to mercury methylation. Mercury methylation in this general canal location is of great interest but will not be analyzed in the water column. Grabs for total phosphorus will also be taken each time and at each autosampler location when the autosamplers are serviced if flow is occurring through the culverts

Routine meetings will be held by the Water Quality Sub-team to discuss the results of the phosphorus monitoring for the physical model testing discharges. The frequency of these meetings will be determined by the Water Quality Sub-team. These meetings may result in recommendations as to the timing of the different testing events for the physical model in order to meet the phosphorus discharge limit.

The results of the required water quality monitoring would need to be presented, summarized, and discussed in a separate report. The report format will be coordinated with the FDEP to ensure the compliance monitoring needs are adequately addressed.

Any discharges from the S-355 A and B structures will continue to be monitored in accordance with the FDEP monitoring requirements. It is expected that this test will include operation of the S-355 A and B structures to some degree. The currently FDEP approved monitoring regime for these structures is presented below.

Water Quality Monitoring For S-355 A and B

	UNIT
TEMPERATURE WATER	DEG C
DISSOLVED OXYGEN	MG/L
SPECIFIC CONDUCTANCE, FIELD	µMHOS/cm
pH, FIELD	STD UNITS
TURBIDITY, FIELD	NTU
TOTAL SUSPENDED SOLIDS	MG/L
AMMONIA	MG/L
NITROGEN TOTAL KJELDAHL	MG/L
TOTAL NITROGEN	MG/L
ORTHOPHOSPHATE, DISSOLVED	MG/L
PHOSPHORUS TOTAL	MG/L
NITRITE-NITRATE	MG/L
CHLORIDES	MG/L
CALCIUM	MG/L
SULFATE	MG/L

Frequency: Discrete samples shall be taken at each structure every two weeks during flowing conditions (structure(s) open) and monthly discrete samples taken at each structure during non-flowing conditions (structure(s) closed)

Location: Sampling shall be taken upstream (WCA 3B side) of the structures

5) Comply with applicable federal, state and local laws and regulations.

6) Ensure that the Tamiami Trail transportation corridor remains functional during construction and operation of the DPM. The high water constraint for the Tamiami Trail L-29 Borrow Canal will remain consistent with current IOP operations for the duration of the DPM.

   - Under IOP, per request from the Florida Department of Transportation, S-333 discharges are typically discontinued if L-29 Canal levels exceed approximately 7.5 feet NGVD.

   - The 7.5 feet NGVD high water constraint for the L-29 Canal may be exceeded periodically with prior agreement from the FDOT.

- If the L-29 high water constraint is modified prior to implementation of the DPM, the modified constraint would remain in affect during the DPM.

7) The Interim Operational Plan (IOP) is the authorized regional Water Control Plan that will be in effect during the DPM experiment. IOP includes the WCA 3A Regulation Schedule and South Dade Conveyance System (SDCS) operations.

8) The current WCA 3A regulation schedule will continue to be used to determined surface water deliveries to the Everglades National Park (ENP), including Western Shark River Slough (WSS) and Northeast Shark River Slough (NESRS), during the DPM. The current WCA 3A regulation schedule relies on the Rainfall Plan for determining the amount, timing, and distribution of surface water flows from WCA 3A to SRS. Total surface water deliveries to NESRS and ENP during the DPM are anticipated to remain approximately the same as they would under current (non-DPM) IOP operations, although additional deliveries may be considered if allowable given consideration of system-wide conditions.

   - During the DPM, operation of the S-355A and S-355B structures are anticipated to be used to the maximum extent practicable for providing the surface water deliveries to NESRS specified by the Rainfall Plan, by discharging water from WCA 3B into the L-29 borrow canal. Operation of the S-355A and S-355B structures are included within the IOP operations, although the operation of these structures has not been previously permitted for more than short-term, temporary operations.

   - Additional considerations for operational constraints for the S-355 structures are specified below:

     - When the combined S-355 discharge capacity is not adequate to pass the desired 55 percent of the Rainfall Plan computed deliveries to NESRS, S-333 would be used to supplement the flows, as necessary.
     - The S-355s would remain closed when there is no head or a reverse head across the S-355 structures during the DPM.
     - Continued operation of the S-355s will be assessed under conditions when DPM constraints require closure of the DPM structures in L-67A. Closure of the S-355s will be considered.
     - Closure of the S-355s would be expected during high water conditions in WCA 3A, to ensure maximum required regulatory releases from S-333.
     - During periods of WCA 3A regulatory releases to the SDCS, the capability to continue operation of the S-355s will be assessed.
     - Permits will need to be obtained for operation of the S-355 structures during the DPM, in order to provide WCA 3B outlet capacity to control potential high water levels within WCA 3B.

9) The G-3273 constraint will not be modified from the current IOP for the duration of the DPM.

- During IOP Column 1 operations, S-333 discharges to the L-29 canal are discontinued if the stage at G-3273 exceeds 6.8 feet NGVD.

- During IOP Column 2 operations, S-333 discharge is matched by S-334 discharge if the stage at G-3273 exceeds 6.8 feet NGVD.

- If the G-3273 is modified prior to implementation of the DPM, the modified constraint would remain in affect during the DPM.

DPM ASSUMPTIONS

Legal issues will not delay project planning and implementation.

A three-PIR approach will be used for completion of the Decomp project. The first PIR will focus on the Miami Canal and North New River. The second PIR will focus on the remaining features of Decomp, Part 1 components as outlined in the Yellow Book. The third PIR will focus on Decomp, Part 2 as outlined in the Yellow Book. During each PMP update and at key milestones throughout PIR completion, the adaptive management and DPM implementation strategy will be reviewed and revised as necessary.

The DPM is the heart of the adaptive management approach for Decomp. The adaptive management implementation tasks are described in Appendix V. The DPM will allow the PDT to examine different design alternatives, gather data to improve evaluation tools, and answer key uncertainties associated with distinguishing meaningful differences among restoration options. With sufficient information gathered from the DPM, it would then be used in the formulation and evaluation of alternatives, and could possibly be used to address similar uncertainties in other regional projects.

Assumptions for Cost Estimates

The following budget items are proposed:

- Experimental design that produce a conceptual model and final science plan.
- Engineering designs, plans and specs and site-specific survey.
- Project Management.
- NEPA document preparation.
- Pre- and post-construction monitoring.
- Physical model construction and deconstruction.
- Placement of primary sampling platforms at structures and within the BACI flow-way.
- Permitting and any associated monitoring during construction.
- Total costs shall not exceed $10,300,000.

SECTION 2

Tree island composition, elevation, and hydrologic tolerances of the dominant species: Implications for the Decomp physical model

Vic Engel, Ph.D, and Amy Renshaw, Everglades National Park
Michael Ross, Ph.D. and Jay Sah Ph.D., Florida International University
Carlos Coronado, Ph.D. and Jennifer Mellein, South Florida Water Management District

1/20/09

INTRODUCTION

The tree species that inhabit the Everglades tree islands exhibit a wide range of tolerances to fluctuating water levels. For instance tree species, such as *Bursera simaruba* (Gumbo Limbo) and *Eugenia axillaris* (White Stopper) do not tolerate high water levels and long hydroperiod; therefore they are typically found in areas that are inundated only infrequently. On the other hand, species such as *Salix caroliniana* (Willow) and *Annona glabra* (Pond Apple) may tolerate high water levels and long hydroperiods; therefore they are found in areas that may be flooded for more than 10 months a year. With the possible exception of some tropical species found in the highest elevations in ENP, all of the tree species found on the Everglades tree islands exhibits some tolerance to flooding. In general, the species that are the most flood-tolerant also exhibit the greatest tolerance to fluctuating water levels. In other words, the species that are adapted to the wettest conditions also occur over relatively wider ranges of hydrologic conditions compared to less flood-tolerant species.

The degree to which hydrologic conditions on tree islands change with water levels is dictated in large part by the elevation of the island relative to the surrounding marsh. For example, with modest increases in surrounding water levels, elevated tree islands are likely to experience relatively less hydrologic impact compared to low-lying islands. Over longer time periods, the changes in tree island plant communities that may be expected to occur with projects like the DPM will also depend on the hydrologic tolerances of the species that currently inhabit the islands. Moreover if hydrologic conditions on an island are altered for extended periods beyond the tolerances of the extant species, then it is expected that these species will lose their competitive advantage, resulting eventually in their disappearance and replacement by more suitable species. In the case of extended flooding, herbaceous species adapted to longer hydroperiod may replace the tree and shrub species.. For regularly-flooded islands that experience a decrease in hydroperiod, the flood-tolerant species such as *Salix*, *Annona* and *Persea* may be replaced by species that currently occupy more elevated hardwood hammocks. The time required for shifts in tree island communities in response to altered hydrology is unknown. Other factors such as past anthropogenic disturbance, the presence of exotics, seed banks, and fire regimes will all play a role in determining how tree communities will respond to altered hydrology. Short term responses may differ from those occurring over decadal time scales due, in part, to soil processes. In this sense, more research is needed to develop predictive models of tree island succession in response to altered hydrology, including droughts.

Recently, several extensive surveys of tree island elevations and community composition were completed in WCA 3 and Everglades National Park (ENP). In these surveys, the elevation of the highest points on the tree island, and the relative dominance and basal area of the

dominant tree species were determined. Since 2005, over 100 islands in WCA 3 and ENP have been surveyed by two groups – one at the SFWMD headed by Dr. Carlos Coronado, and one at FIU headed by Dr. Michael Ross. These surveys indicate that across the Everglades, tree islands exhibit a wide range of elevations and species composition. The data show that even neighboring islands may differ significantly in elevation relative to the surrounding marsh. Species dominance also varies dramatically among islands in relatively close proximity. Based on these results, it is clear that the response of the tree communities on these islands to changing water levels will differ.

This report summarizes briefly the results of the elevation and community surveys of islands in WCA 3 and ENP. Water level data collected for the last seven years through the USGS EDEN network are used to calculate the hydrologic patterns on the islands. The elevation and community characteristics of the tree islands in WCA 3B are then analyzed in more detail. While the focus of the report is on the islands in WCA 3B, the survey results from the other areas are also provided in order to place the results in the context of landscape-scale patterns. The results indicate that the islands in WCA 3B are significantly drier than the islands in WCA 3A; however, most of the islands are dominated by flood-tolerant species. This suggests that the average annual hydroperiod on the islands in WCA 3B could be increased significantly above the values reported for these islands over the last seven years, while still maintaining hydrologic conditions within the known tolerances of their dominant species.

METHODS

Weighted-averaging (WA) regression is used to determine hydrological niches of tree species found in tree islands in the Everglades (**Table 1**). The concept behind WA regression is that tree species whose hydrologic "optima" are close to conditions experienced on a given island would tend to be the most abundant taxa there and on islands of similar hydrology (see Birks et al. 1990 for analogy). Therefore, hydrologic optima and tolerances, which is an expression of dispersion around the optimum of a taxon, were calculated from species abundances across the islands for which hydrological variables were known. This work expands on the analyses presented in Sah (2004), in which the hydroperiod (number of days per year when water level was above the ground surface) and water depth tolerances were calculated using data collected at multiple locations on three large islands in Shark Slough. In the current study, the hydrologic tolerances of tree species are calculated using data from the most elevated locations on 73 islands. In calculating species "optima" and "tolerances" for hydroperiod and water depth, the C2 program of Juggins (2003) was applied to data from the vegetation surveys

Vegetation data from the Ross lab at FIU were pooled from five different vegetation surveys conducted on tree islands within ENP and WCA3B. These studies were conducted on three islands in central Shark Slough (TI_PH1) in 2000-2001, on 72 "extensive" islands (TI_EXT) visited once, on 16 "intensive" islands (TI_INT) visited repeatedly between 2005-2008, on 6 "resource" islands studied for vegetation-soil nutrient relations by Erin Hanan (TI_RES) in 2006-2007, and on 6 "woody plant" islands (TI_WPP) in 2006-2007. The TI_WPP islands were surveyed as part of a study investigating woody plant invasion into the marl prairies. When the hammocks on the TI_EXT islands had obvious 'gaps', particularly due to anthropogenic disturbance and with no or very few trees, they were excluded from the analysis. There were 5 islands which had vegetation data, but did not have complete elevation data and therefore were excluded from the analysis. Among the 75 remaining islands for which vegetation

and hydrology data were completed, two were identified as outliers in the course of analysis, resulting in 73 islands to be used in WA regression. The names, locations and elevations of the islands surveyed and used for this study by the Ross lab are shown in **Table 2**.

Species dominance

For both the FIU and SFWMD datasets, the Importance Value (IV) of the dominant tree species on each island was calculated using the following equation:

$$IV = (\text{Relative dominance} + \text{Relative density})/2 \qquad \textbf{Equation 1}$$

Relative Dominance was generally based on basal area, but in a few cases it was based on cover estimates. When density information was not available, species Importance Values equated simply to their Relative Dominance.

Tree Island Hydroperiods

Except for the TI_EXT islands, plots in the tree islands visited by FIU were surveyed from nearby bench mark with known elevation. Plots in TI_EXT islands were first surveyed for relative elevation in reference to water level on the edge of islands or in adjacent marsh. Later, the mean daily water elevation data obtained from Everglades Depth Estimation Network (EDEN) (http://sofia.usgs.gov/eden/models/watersurfacemod.php) was used to calculate mean absolute ground elevation of vegetation plots established in each island. To calculate annual mean hydroperiod and water depth, we used mean ground elevation of these plots and EDEN water elevation data over the last seven years. However, for bayhead and bayhead swamp plots surveyed in 2000-2001 in Gumbo Limbo, Satinleaf and Black Hammock, water level data from three stage recorders (NP-203, P-33 and G-620, respectively) were used to calculate mean hydroperiod and water depth for seven years prior to vegetation sampling

The methods used to survey the islands in WCA 3 by the Coronado lab at SFWMD were slightly different. For all islands, the elevation of the highest point was measured relative to a set of 31 First order benchmarks installed in the marsh 2-3 miles away from any surveyed tree island. On islands where the water level was below the soil surface at the time of sampling, a shallow well was excavated and depth to the water table reflected in the well was measured the following day. This value was added to the elevation of surface water derived from the EDEN network spatial model, yielding ground surface elevation. Seven-year time series of EDEN water levels relative to island elevation were used to calculate mean annual hydroperiod and other hydrologic parameters. The results of the SFWMD field surveys are presented in **Table 3**.

The average annual hydroperiod for tree islands in WCA 3B was predicted using an inverse WA analysis. In this method, the IV and the known hydrologic "optima" and "tolerances" for the dominant species were used to infer the expected average annual hydroperiod on the islands in WCA 3B. In other words, the species assemblages found on the islands in WCA 3B, along with the known hydrologic tolerances of these species, were used to predict (i.e. "back-calculate) the average annual hydroperiod expected on these islands.

$$TI_HYDRO_pred = \sum_{i=1,n} (Opt_HYDRO_i * IV_i / Tol_Hydro) / \sum (IV_i / Tol_Hydro) \qquad \textbf{Equation 2}$$

where, Opt_HYDRO is the optimum hydroperiod and Tol_Hydro is the hydroperiod tolerance for species *i*, and IV_i is its importance value on a particular tree island. The results are presented in **Table 4**.

A large set of islands in WCA 3 were surveyed for elevation according to the methods above but the available vegetation data were of a qualitative nature only. The hydrologic conditions on these islands over the last seven years were determined from the EDEN data and are presented below.

RESULTS

Hydrologic tolerance of Everglade tree species

Figure 1 shows the mean annual hydroperiod optima (± tolerances) of 16 dominant tree species on Everglades tree islands. The list also includes *Taxodium distichum*, even though it was recorded on only one island (WPP-D). In addition, two species, *Sideroxylon salicifolium* (SIDSAL) and *Myrsine floridana* (MYRFLO), which were co-dominant with other hammock species in many islands, are also included. A list of the species and the 6 letter abbreviations can be found in Table 1.

Tree island characteristics in the WCA 3 and ENP

Data collected by the SFWMD show that tree islands in WCA 3A and WCA 3B are generally colonized by flood tolerant species (**Figure 2 and 3**). The data provided by the Ross lab at FIU show similar results for WCA 3B (**Figure 4**) but also show that the highest elevations of islands in ENP (**Figure 5**) are inhabited by less flood tolerant species.

Hydrologic conditions for an average rainfall year (2005) and a low rainfall year (2007) on a large set of islands in WCA 3 are shown in **Figures 6 and 7**. The results indicate that during a normal rainfall year, the hydrologic conditions on the islands shows significant local variation even among islands in relative close proximity. This variation reflects the differences in island elevations relative to the surrounding marshes and the larger-scale hydropatterns across the WCA 3. At the landscape level, inundation periods on the islands generally increase with ponding depths in the marsh from north to south in WCA 3A. In comparison, the islands in WCA 3B show significantly reduced hydroperiods, resembling the values observed on the islands in ENP. This decrease in tree island inundation periods in WCA 3B compared to WCA 3A reflects the abrupt shift to drier hydrologic conditions from NW to SE across the L67 A and C levees.

CONCLUSIONS

Implications for the DPM

A very large dataset of baseline conditions for tree islands in WCA 3 and ENP has now been produced through the dedication of groups from FIU, FAU, the SFWMD, and ENP. This information will be invaluable in the upcoming DPM experiments and for the DECOMP adaptive management, since it will allow for a thorough analysis of tree island plant community responses to hydrologic management. It is anticipated that this baseline data, along with the information gathered during the

DPM, will also allow for the generation of robust ecological models and tree island performance measures to be applied across all CERP projects.

The results of the extensive surveys presented above show that the islands in WCA 3B are generally inhabited by flood-tolerant tree species. Similarly, the data also indicate that the average annual hydroperiods on the heads of many of the islands in WCA 3B are significantly lower than the hydroperiods in which many of these species are typically found in other areas of the Everglades. In other words, the woody species that dominate the relatively "dry" islands in WCA 3B are also known to inhabit much wetter environments in WCA 3A and in ENP. These results suggest that many of the islands in WCA 3B may have been, historically, inundated for longer periods than have been typical over the last seven years while still maintaining the species composition and forest structure that characterize longer hydroperiod conditions.

The average annual hydroperiods from 2000-2007 for the islands in WCA 3B (TI_Hydro_obs) were significantly less than the hydroperiods predicted from the species assemblages (TI_HYDRO_pred) that might be expected given the dominant species on these islands (Table 4). Subtracting these values suggests that the average annual hydroperiods on the islands in WCA 3B may be increased from 50 to 261 days, depending on the island, while still maintaining hydrologic conditions favorable to the dominant species. However, while results of this report are based on an extensive dataset, the ability to predict changes in tree island communities using this measure has not been evaluated. The ability of this measure to provide information on tree island responses to individual flooding (i.e. pulse) events such as those which might be generated by the DPM has also not been defined. Therefore, the differences between these two measures should be considered only as an estimate of the extent to which *average annual* hydrologic conditions in WCA 3B may change before both population-level and community-level responses on the islands can be expected.

In conclusion, there is currently no model or performance measures capable of predicting how community dynamics on the tree islands in WCA 3B may be affected by changing water levels controlled by the DPM. The rate and extent of changes to an island community that may be caused by short term hydrologic manipulations cannot be precisely determined from the data presented above. Consequently, these data should not be used to set hydrologic restoration targets for tree islands. Instead, these data should be considered only as a rough comparison between the hydrologic conditions present on islands in WCA 3B and the known hydrologic tolerances of the dominant species on these islands. The comparisons above suggest the hydroperiods present on the islands in WCA 3B over the last seven years are significantly less than the values that may be expected given the species assemblages. More complex models of community dynamics, which include processes such as competition, seedling recruitment, physiological responses, and natural disturbances, are necessary to more accurately forecast the developmental trajectories these islands may take with changing water levels. Information on soils and belowground processes, and more data on the structure and function of the low-lying island "tails" are also necessary. It therefore is suggested that a detailed monitoring program be established to monitor the responses of these islands to changing water levels and increased flow velocities anticipated with the DPM. This information, in turn, will be useful for more rigorous analyses of potential impacts and benefits of the full DECOMP project on islands across the Greater Everglades, including those in WCA 3A and ENP.

Table 1 The hydroperiod (HYDRO) and water depth (WD) optima and tolerance values for tree species in the Everglades (See Figures 1 and 2)

Species name	SPPCODE	Opt_HYDRO	Tol_HYDRO
Magnolia virginiana	MAGVIR	217	65
Salix caroliniana	SALCAR	215	139
Annona glabra	ANNGLA	209	102
Myrica cerifera	MYRCER	137	89
Persea borbonia	PERBOR	90	62
Ilex cassine	ILECAS	74	123
Taxodium distichum	TAXDIS	66	
Chrysobalanus icaco	CHRICA	55	98
Sabal palmetto	SABPAL	44	46
Schinus terebinthifolius	SCHTER	39	81
Myrsine floridana	MYRFLO	35	40
Ficus aurea	FICAUR	29	72
Sideroxylon salicifolium	SIDSAL	24	21
Sambucus canadensis	SAMCAN	12	122
Quercus virginiana	QUEVIR	12	28
Metopium toxiferum	METTOX	8	24
Psidium guajava	PSIGUA	3	1
Coccoloba diversifolia	COCDIV	2	12
Celtis laevigata	CELLAE	2	4
Nectandra coriacea	NECCOR	2	15
Ardisia escallonioides	ARDESC	2	6
Eugenia axillaris	EUGAXI	1	4
Bursera simaruba	BURSIM	1	4
Chrysophyllum oliviforme	CHROLI	1	3
Carica papaya	CARPAP	0	1
Sideroxylon foetidissimum	SIDFOE	0	1
Calyptranthes pallens	CALPAL	0	0
Citrus sp.	CITXXX	0	0
Delonix regia	DELREG	0	0
Exothea paniculata	EXOPAN	0	0
Ficus citrifolia	FICCIT	0	0
Morus rubra	MORRUB	0	0
Myrcianthes fragrans	MYRFRA	0	0
Schoepfia chrysophylloides	SCHCHR	0	0
Simarouba glauca	SIMGLA	0	0
Solanum erianthum	SOLERI	0	0
Trema micranthum	TREMIC	0	0
Zanthoxylum fagara	ZANFAG	0	0

Table 2 Locations of tree islands in Shark Slough (SS), ENP, and WCA 3 surveyed by Mike Ross (FIU) and the 7 year mean hydroperiod (TI_HYDRO_obs) and water depth (TI_ WD_obs) conditions on the islands as determined by EDEN..

Dataset	Island	X_NAD83	Y_NAD83	Elev (cm)	TI_HYDRO_obs (days)	TI_ WD_obs (cm)
TI_EXT	SS-05	529172	2830138	202.84	0	-67.6
TI_EXT	SS-06	527369	2828237	188.85	0	-65.6
TI_EXT	SS-07	523786	2824300	157.54	0	-60.8
TI_EXT	SS-10	519020	2817037	77.84	5	-37.6
TI_EXT	SS-13	516465	2818797	84.17	0	-48.2
TI_EXT	SS-14	516316	2818894	84.14	0	-48.0
TI_EXT	SS-20	514319	2820483	72.09	2	-36.0
TI_EXT	SS-23	515262	2821070	98.79	0	-56.1
TI_EXT	SS-27	517479	2822788	125.63	0	-63.8
TI_EXT	SS-34	519958	2825571	153.59	0	-66.2
TI_EXT	SS-36	518542	2826094	138.20	0	-53.6
TI_EXT	SS-38	519472	2829364	171.33	0	-70.8
TI_EXT	SS-45	524650	2830617	177.56	0	-52.1
TI_EXT	SS-47	523094	2832475	175.27	0	-48.2
TI_EXT	SS-48	522686	2833691	192.22	0	-60.8
TI_EXT	SS-50	524862	2836175	212.49	0	-64.7
TI_EXT	SS-52	528250	2834668	220.60	0	-70.7
TI_EXT	SS-54	526249	2840075	211.90	2	-45.5
TI_EXT	SS-56	526827	2846410	257.58	1	-58.5
TI_EXT	SS-59	529151	2844990	253.99	0	-65.6
TI_EXT	SS-61	527922	2841278	238.07	0	-65.6
TI_EXT	SS-63	529384	2840559	241.60	0	-70.7
TI_EXT	SS-67	531814	2844694	255.38	0	-70.6
TI_EXT	SS-69	535878	2846166	276.58	0	-104.3
TI_EXT	SS-82	519189	2829568	175.17	0	-76.4
TI_EXT	SS-83	528182	2845768	258.91	0	-66.1
TI_EXT	SS-84	528354	2845755	247.43	1	-54.6
TI_EXT	SS-85	526131	2843841	252.71	0	-71.1
TI_EXT	SS-86	526354	2843678	262.81	0	-81.2
TI_EXT	SS-92	533158	2837385	231.03	0	-69.3
TI_EXT	SS-93	535151	2848529	305.53	0	-135.6
TI_EXT	SS-95	536537	2838972	239.20	0	-79.4
TI_EXT	WCA3B-02	548177	2851906	215.09	0	-53.6
TI_EXT	WCA3B-03	543455	2850814	203.14	3	-31.8
TI_EXT	WCA3B-04	541964	2849836	228.10	0	-59.3
TI_EXT	WCA3B-05	538088	2851244	198.45	38	-19.2
TI_EXT	WCA3B-07	537540	2856111	202.37	47	-14.7
TI_EXT	WCA3B-10	544470	2854119	162.83	278	11.3
TI_EXT	WCA3B12A	546326	2857361	166.47	224	5.6
TI_EXT	WCA3B-20	546983	2868871	281.36	0	-88.7
TI_EXT	WCA3B-24	537033	2858402	224.53	3	-30.5
TI_EXT	WCA3B-25	550888	2861124	216.33	0	-77.5
TI_EXT	WCA3B-26	551374	2858049	205.19	0	-69.3
TI_INT	Black	531295	2832630	225.50	0	-78.3
TI_INT	Chekika	534372	2847485	254.33	0	-79.1
TI_INT	E-4200	529566	2819857	116.55	39	-25.6

TI_INT	FicusINT	517701	2806030	31.80	21	-25.1
TI_INT	Grossman	541819	2833205	217.17	0	-87.4
TI_INT	Gumbo	525999	2834793	205.85	0	-61.7
TI_INT	Irongrape	533651	2836523	233.56	0	-74.2
TI_INT	Manatee	518560	2820117	119.03	0	-63.8
TI_INT	Mosquito	520271	2804429	89.17	0	-79.0
TI_INT	Panther	524189	2828472	178.90	0	-63.4
TI_INT	Satin	524499	2838019	219.65	0	-63.4
TI_INT	SS-37INT	518488	2826245	142.80	0	-57.5
TI_INT	SS-81INT	547639	2848113	187.88	9	-25.3
TI_INT	Vulture	528918	2841667	266.26	0	-92.8
TI_PH1	BH-BH	531295	2832630	157.22	180	-2.0
TI_PH1	BH-BS	531295	2832630	144.97	254	10.2
TI_PH1	GL-BH	525999	2834793	149.85	198	0.3
TI_PH1	GL-BS	525999	2834793	124.36	327	26.4
TI_PH1	SL-BH	524499	2838019	156.40	206	4.2
TI_PH1	SL-BS	524499	2838019	145.63	283	17.6
TI_RES	ET1	538883	2815267	130.86	62	-37.3
TI_RES	ET2	538786	2815071	120.79	95	-28.2
TI_RES	ET3	520627	2823621	78.27	242	8.0
TI_RES	ET4	519422	2822329	74.46	172	-2.5
TI_RES	ET5	541087	2824620	135.19	149	-17.1
TI_RES	ET6	540586	2825826	151.45	84	-31.1
TI_RES	ET7	527929	2835187	138.00	263	13.7
TI_RES	ET8	527436	2835512	139.90	256	12.6
TI_WPP	WPP-A	507220	2831791	51.36	152	-8.56
TI_WPP	WPP-B	519738	2804574	40.24	26	-31.20
TI_WPP	WPP-D	544664	2802649	29.20	66	-15.80
TI_WPP	WPP-E	530689	2820365	115.75	115	-17.99

Table 3 Locations of tree islands in WCA 3A and 3B surveyed by Carlos Coronado (SFWMD) and the 7 year mean hydroperiod (TI_HYDRO_obs) and water depth (TI_ WD_obs) conditions on the islands as determined by EDEN.

Island	X_NAD83	Y_NAD83	Elevation (cm)	TI_HYDRO_obs (days)	TI_ WD_obs (cm)
3A13 HEAD	530186	2861455	239.6	236	-3.6
3A13 NT	530176	2861399			
3A14 HEAD	530356	2857524	247.9	182	-65.9
3A14 NT	530366	2857325			
3A15 HEAD	531672	2864249	232.9	263	30.1
3A15 NT	531723	2863884			
3AS16 HEAD	534704	2861809	253	167	-86
3AS16 NT	534735	2861521			
3AS1 HEAD	523029	2874918	270.7	117	-153.7
3AS1 NT	523029	2874918			
3AS2 HEAD	518549	2865420	292.8	28	-264.8
3AS2 NT	518549	2865420			
3AS3 HEAD	523056	2859812	279.6	37	-242.6
3AS3 NT	523056	2859812			
3AS4 HEAD	525673	2853549	272.7	36	-236.7
3AS4 NT	525673	2853549			
3AS5 HEAD	531717	2862555	234	258	24
3AS5 NT	531717	2862555			
3B01 HEAD	546982	2868869	295.8	0	-111.05
3B01 NT	546992	2868769			
3B02 HEAD	545763	2865033	266.5	0	-76.02
3B02 NT	545824	2864889			
3B03 HEAD	546341	2857393	279.9	0	-108.59
3B03 NT	546331	2857316			
3B04 HEAD	546763	2854305	230.8	0	-63.78
3B04 NT	546744	2854050			
3B05 HEAD	548165	2851918	222.8	0	-62.26
3B07 HEAD	542552	2857624	188.7	110	-7.34
3B07 NT	542583	2857436			
3B08 HEAD	544458	2854120	214.2	0	-40.82
3B08 NT	544418	2853998			
3B09 HEAD	540686	2858161	185	161	-0.35
3B09 NT	540646	2858083			
3B10 HEAD	537525	2856103	211.7	14	-24.68
3B10 NT	537516	2855970			
3B11 HEAD	537490	2854596			
3B11 NT	537540	2854298			
3B12 HEAD	540858	2854429	187.5	118	-6.18
3B12 NT	540849	2854252			
3BS1 NT	549050	2851246			
3BS2 HEAD	543875	2863487	192.9	166	0.18
3BS2 NT	543875	2863487			

Table 4 Comparison of existing average annual hydroperiods (TI_HYDRO_obs) on tree islands in WCA 3B with the hydroperiod predicted given species assemblages (TI_HYDRO_pred).The values for TI_HYDRO_pred were derived from the known hydrologic tolerances of the dominant species on these islands weighted by their Importance Values (see Equation 2). Marsh elevations were derived from the EDEN DEM at the tree island location. The island Elev Diff is the tree island elevation minus the marsh elevation.

Island	TI_ HYDRO_pred (days)	TI_HYDRO_obs (days)	Island Elevation (cm)	Marsh Elevation (cm)	Island-Marsh Elev Diff (cm)
3B01 HEAD	99	0	295.80	153.97	141.83
3B02 HEAD	279	0	266.50	150.93	115.57
3B03 HEAD	138	0	279.90	137.70	142.20
3B04 HEAD	266	0	230.80	138.20	92.60
3B05 HEAD	133	0	222.80	135.74	87.06
3B07 HEAD	181	110	188.70	146.43	42.27
3B08 HEAD	215	0	214.20	141.50	72.70
3B09 HEAD	169	161	185.00	150.39	34.61
3B10 HEAD	180	14	211.70	163.72	47.98
3B12 HEAD	264	118	187.50	143.77	43.73
3BS2 HEAD	282	166	192.90	147.08	45.82

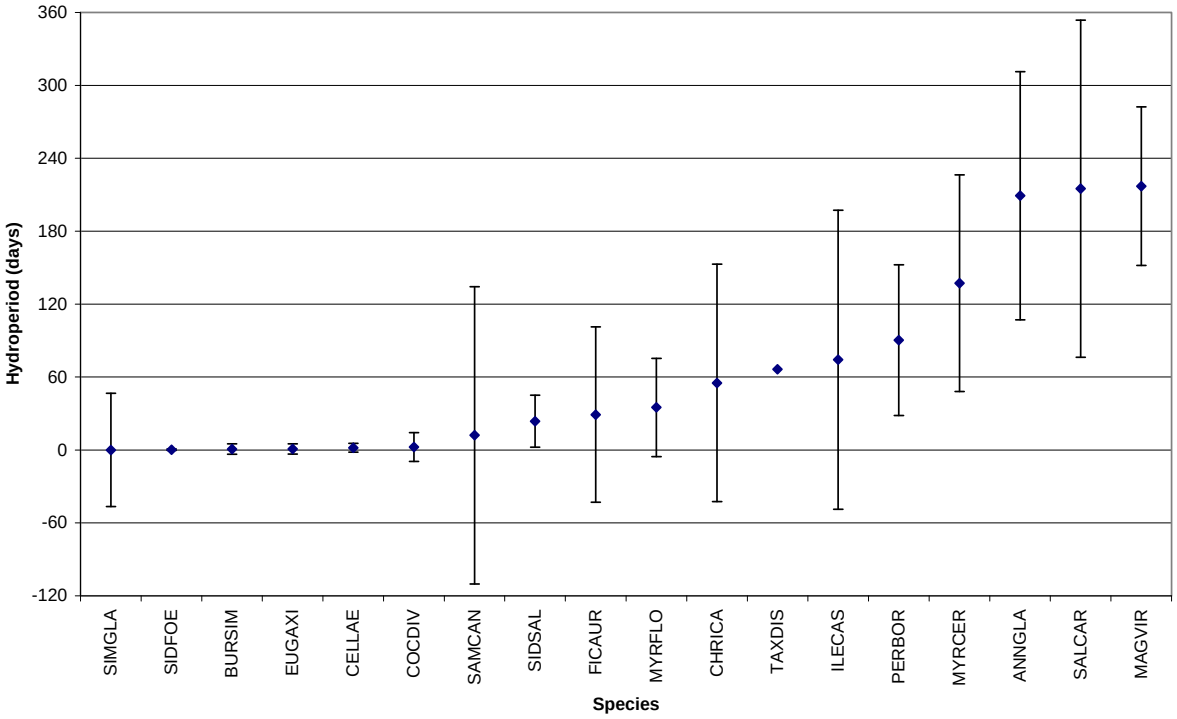


Figure 1 The mean annual and range of hydroperiods in which a species is found can be considered to represent the "optima" and "tolerance" of the species to these hydrologic conditions. Sixteen of the most common tree species in the Everglades are presented here. Negative values result from the subtraction of a large tolerance value from a smaller mean and should be ignored. In general, the species that are found in the wettest environments also exhibit the largest tolerances to variable hydrologic conditions. *Taxodium distichum* was found on only one island.

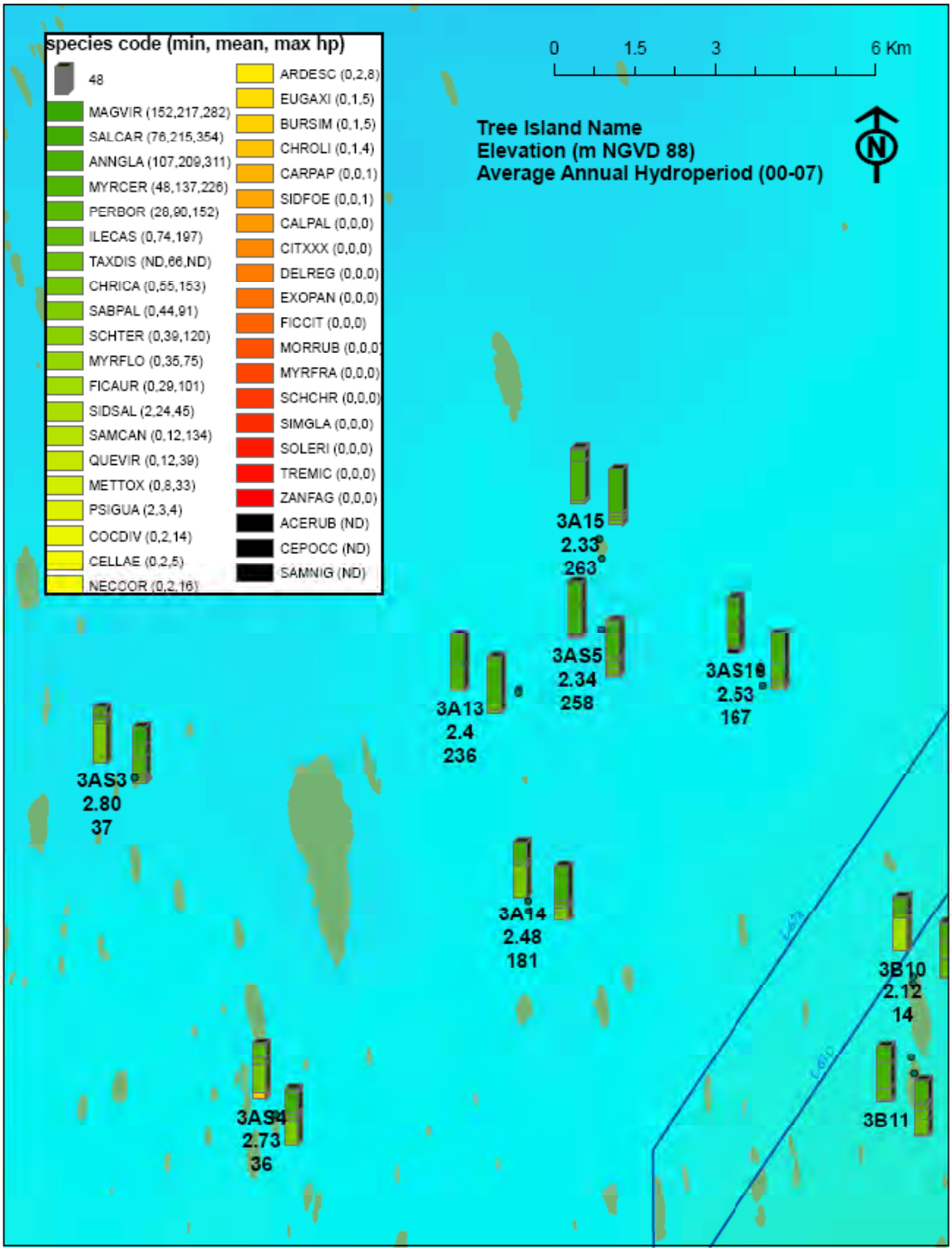


Figure 2 Tree islands in WCA 3A surveyed by the SFWMD. The color codes on the stack graphs correspond to the hydrologic tolerance of the dominant tree species on the island (shown in the legend), and the height corresponds to their relative Importance Value (IV). Individual graphs for the island heads and tails are shown. The island elevation and the mean annual hydroperiod 2000-2007 derived from EDEN are shown next to each island.

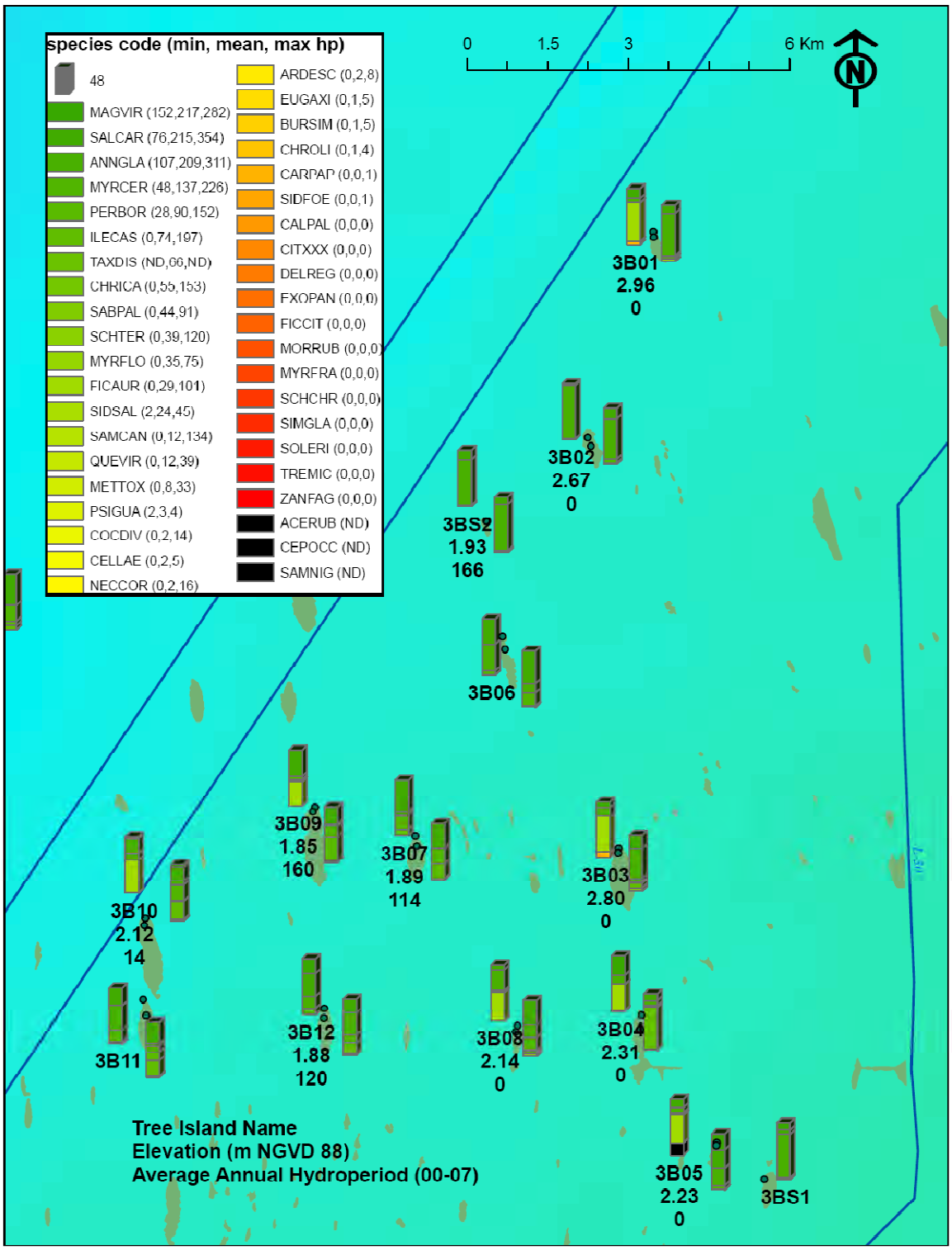


Figure 3 Tree islands in WCA 3B surveyed by the SFWMD. The color codes on the stack graphs correspond to the hydrologic tolerance of the dominant tree species on the island (shown in the legend), and the height corresponds to their relative Importance Value (IV). Individual graphs for the island heads and tails are shown. The island elevation and the mean annual hydroperiod 2000-2007 derived from EDEN are shown next to each island.

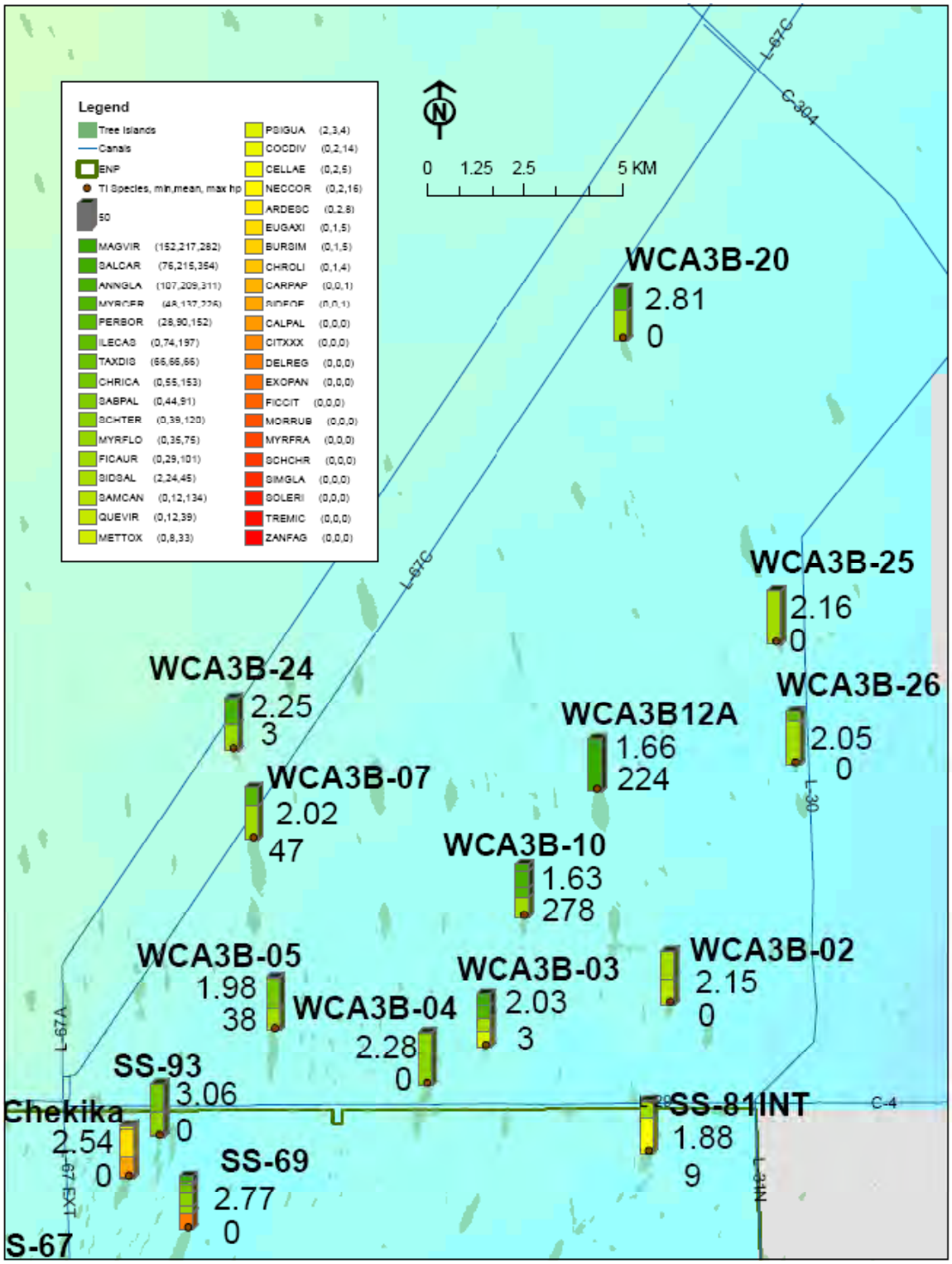


Figure 4 Tree islands in WCA 3B surveyed by FIU. The color codes on the stack graphs correspond to the hydrologic tolerance of the dominant tree species on the island (shown in the legend), and the height corresponds to their relative Importance Value (IV). The island elevation and the mean annual hydroperiod 2000-2007 derived from EDEN are shown next to each island.

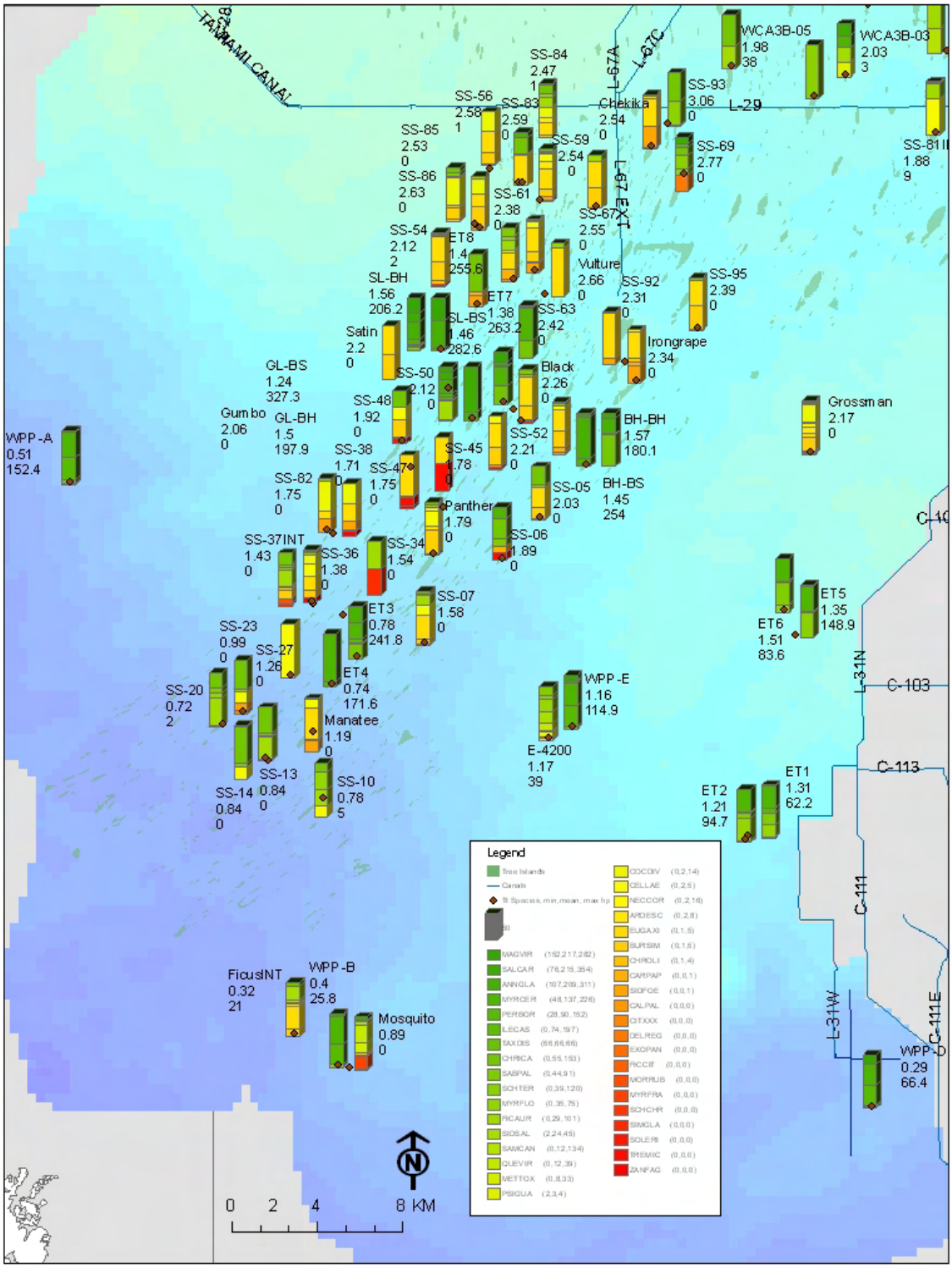
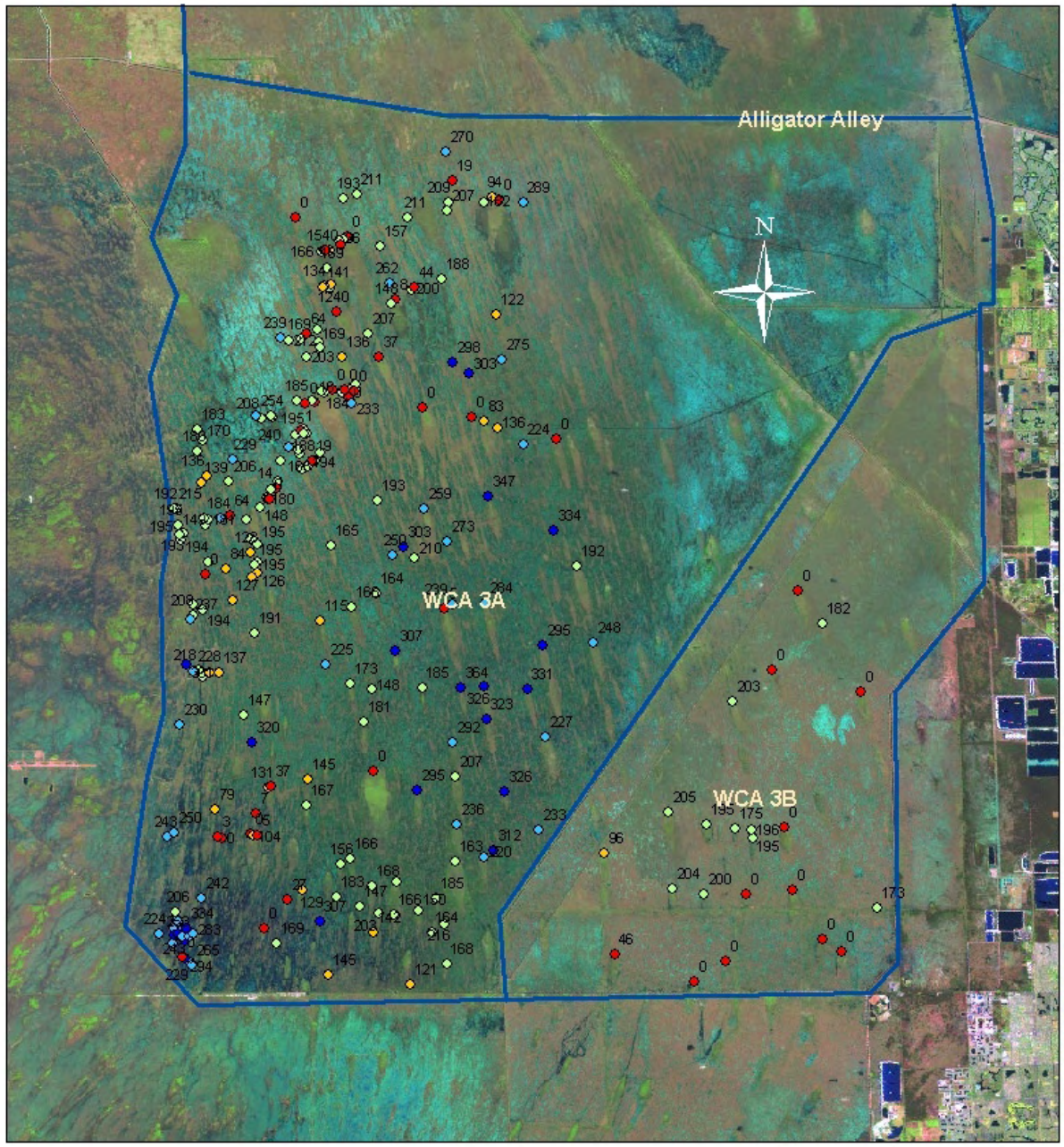


Figure 5 Tree islands in ENP surveyed by FIU. The color codes on the stack graphs correspond to the hydrologic tolerance of the dominant tree species on the island (shown in the legend), and the height corresponds to their relative Importance Value (IV). The island elevation and the mean annual hydroperiod 2000-2007 derived from EDEN are shown next to each island.



Number of Days Inundated

YR2005

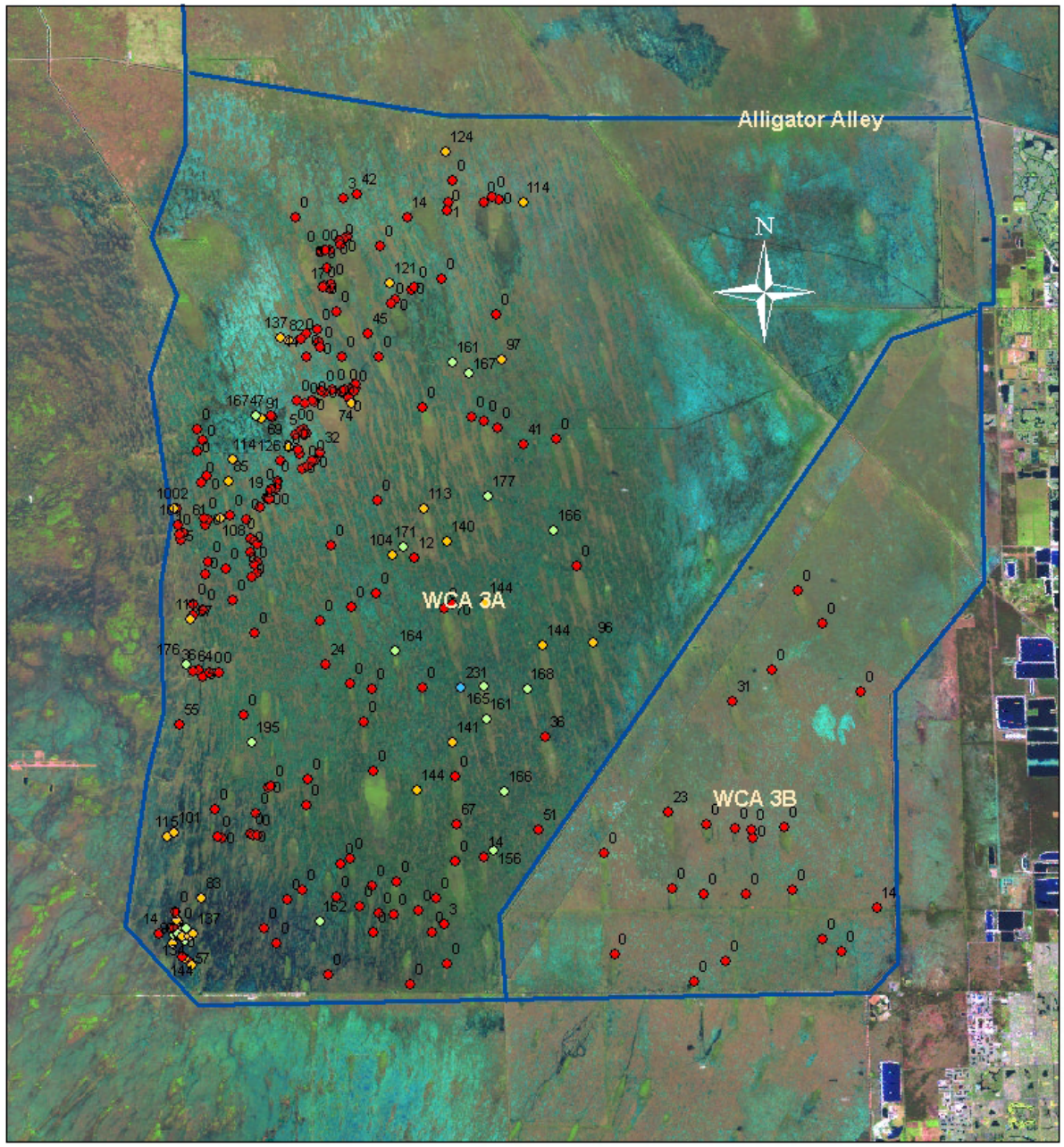
- 0 - 73
- 74 - 146
- 147 - 219
- 220 - 292
- 293 - 365

Each island displays the number of days it's maximum elevation point was inundated during the year 2005. Water level data was aquired from the EDEN Network online database for each island.

Kilometers

0 1.5 3 6 9 12

Figure 6



Number of Days Inundated

YR2007

- 0 - 73
- 74 - 146
- 147 - 219
- 220 - 292
- 293 - 365

Each island displays the number of days it's maximum elevation point was inundated during the year 2007. Water level data was aquired from the EDEN Network online database for each island.

Kilometers

0 1.5 3 6 9 12

Figure 7

References:

Birks H.J.B, J.M. Line, S. Juggins, A.C. Stevenson and C.J.F. ter Braak. 1990. Diatoms and pH reconstruction. Philosophical Transactions of the Royal Society of London (Series B) 327: 263-278.

Juggins. S. 2003. C2 User Guide: Software for Ecological and Palaeoecological Data Analysis and Visualization. University of Newcastle, Newcastle upon Tyne, UK.

Sah, J. P. 2004. Vegetation Structure and Composition in Relation to the Hydrological and Soil Environments in Tree Islands of Shark Slough. In: Ross, M.S. and Jones, D.T. (Eds.) *Tree Islands in the Shark Slough Landscape: Interactions of Vegetation, Hydrology and Soils.* pp: 85-114. A final report submitted to Everglades National Park, National Park Service, U.S. Department of the Interior.

SECTION 3

PREDICTING WATER VELOCITY FROM STAGE CONDITIONS DURING THE L-67 GAP TEST JANUARY 2009

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PREDICTING WATER VELOCITY FROM STAGE CONDITIONS DURING THE L-67 GAP TEST JANUARY 2009

Introduction

To better assess expected flows and velocities for the DPM pilot study, an analysis of measurements and monitoring data in the vicinity of the existing gap in the L67C levee was conducted. The objective of this report was to determine the optimal window of operation that would capitalize on seasonal hydrologic and meteorological conditions that would provide the highest probability of attaining target velocity magnitudes required to successfully measure suspend sediment transport over the DPM pilot study. The reader is referred to the L67 Gap Pilot Test Draft Pilot Summary for an overview of the Test. The reader is also referred to "An Analysis of the Biological and Water Quality Benefits and Impacts in Water Conservation Area 3B Associated with 1998 Opening of the L-67A Levee" (*Hagerthey, 2005*)

The L67 Gap Pilot Test consisted of degrading 1000' of levee in the L67A and L67C levees to allow sheet flow to pass unimpeded from WCA3A to WCA3B. The L67C gap to the east was opened on June 23, 1994 and the L-67A gap to the west was first opened on July 12, 1994. Because of high water stages at the Site 71 gauge, the L67A gap was closed on September 24, 1994 after two months of testing. The L67A gap was reopened January 14, 1998 and was closed again on September 1, 1999. Flow data was collected by the USGS and water quality analyses were conducted (see: *Hagerthey, 2005*).

This document first presents an overview of WCA3A hydraulics in the vicinity of the existing L-67C gap and across WCA3A to the L30 and L29 canals. Local water stages and surface gradients were examined using water surface estimates from the USGS EDEN network. The reader is referred to *http://sofia.usgs.gov/eden/publications.php* for publications regarding the Network and interpolation methods to develop water surface estimates from real-time water-level monitoring gages. Next, stage data from the South Florida Water Management District's corporate environmental DBHYDRO database [*https://my.sfwmd.gov*] and flow data from the L67 Gap Pilot Test were examined to determine trends between local water stages and gradients during the L67A and L67C levee openings. Predictions of velocity magnitude at the existing L67C Gap are made from 1998 through 2007 with existing stage measurements.

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Overview of WCA3A Hydraulics

To understand the effect of local hydraulic gradients and potential sinks for flow, water slopes across the "pocket" (the area between L67A and L67C), the existing Gap in the L67C, and WCA3B were examined *during wet conditions that typically occur seasonally in October*, which corresponds with the time period over which it is expected that measurements will be made for the DPM pilot study. Using surface estimates generated using the EDEN Transect Plotter we examined *the local directional gradient of flows* across the pocket and in WCA3B.
(*http://sofia.usgs.gov/eden/edenapps/transectplotter.php*)

Harvey et al. (in press) found good agreement between Transects Plotted in EDEN and surface water surface slopes. Transects were specified (fig. 1) across the Pocket to the existing gap in the L67C (Trans 1); continuing across to the L30 (Trans 2); through Site71 to L30 (Trans 3); to the S334 (Trans 4); to the 355B (Trans 5); to the culvert G67 (Trans 6) and to the 355A (Trans 7).

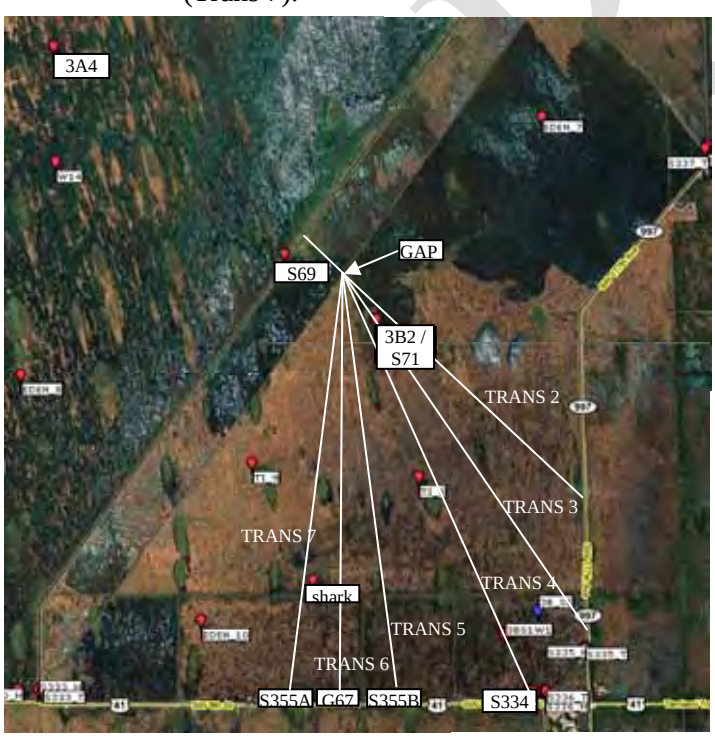

Figure 1: Transects used for EDEN Transect Plotter; Along-transect spacing = 500m.

Individual Easting, Northing points were specified along each Transect at 500m intervals as input parameters for the EDEN Transect Plotter. All available data from the EDEN Network were used from 2000 to 2008.Surface Stage Elevations decreased toward the southeast with stages at their lowest adjacent to the L30 and the S334 (figs 2, 4, 5 and 6). Stages were higher along the western sections of the L29, including in the vicinity of the S355B. In general, Local Surface Gradients were greatest at the existing gap in the L67C and approximately 4000m (2 miles) from the L30 Canal and from the S334 Structure (figs. 3, 4, 5, 6). Associated surface stages are presented in Figure 7.

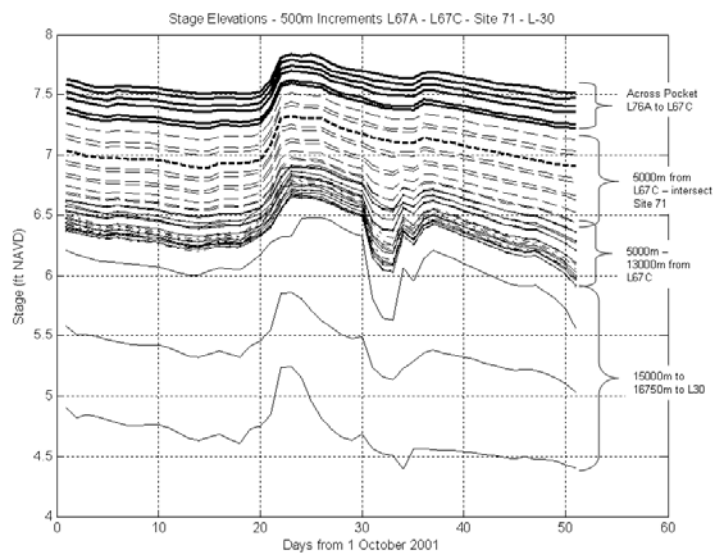

Figure 2: Typical Stage Elevations for Transect 3 which crosses Site 71 and ends at the L30 Canal.

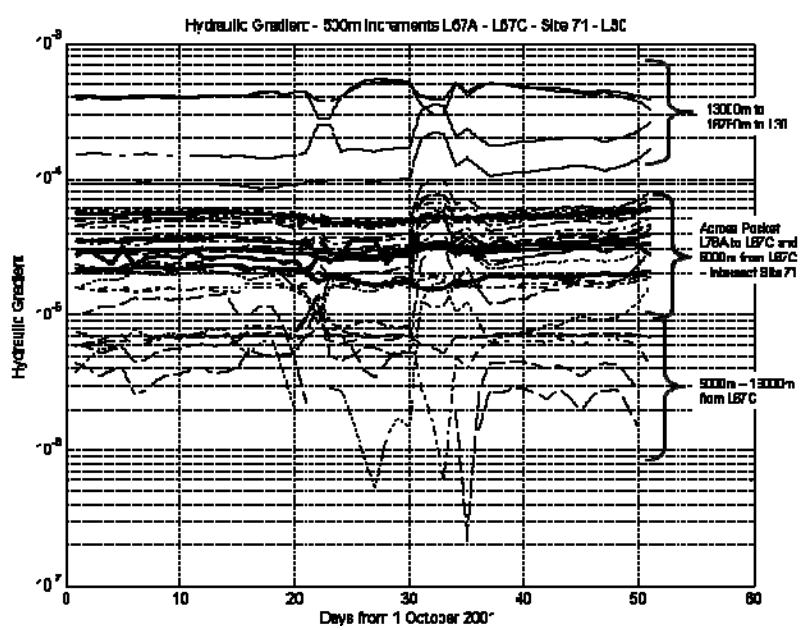

Figure 3: Typical Hydraulic Gradients for Transect 3 which crosses Site 71 (3B2) and ends at the L30 Canal; the Gradient increases over the last 4000m of the transect, at the L30 Canal.

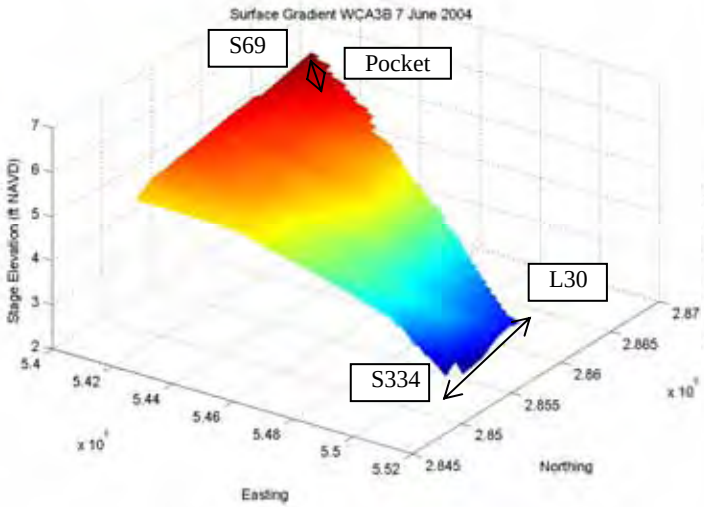

Figure 4: Surface Stages for 7 June 2004 [max stage = 6.2' NAVD]

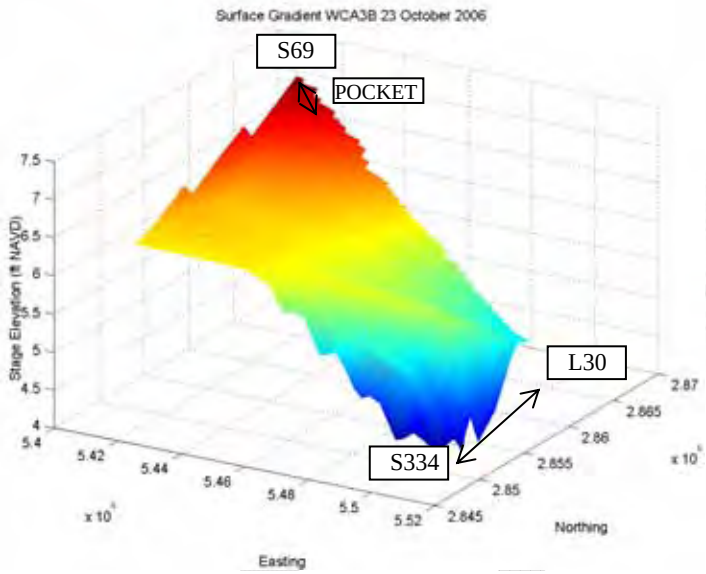

Figure 5: Surface Stages for 23 October 2006; Stages decrease distinctly at the L30 and the S334.

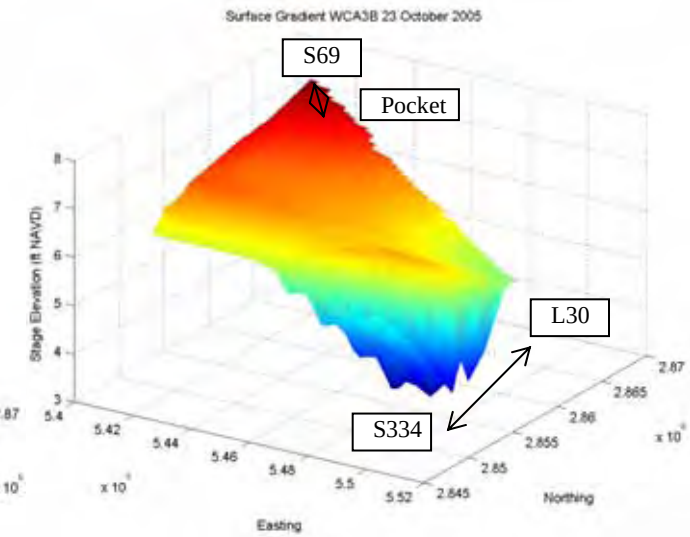

Figure 6: Surface Stages for 23 October 2005; Stages are high, but decrease distinctly at the L30 and the S334. [max stage = 7.8' NAVD]

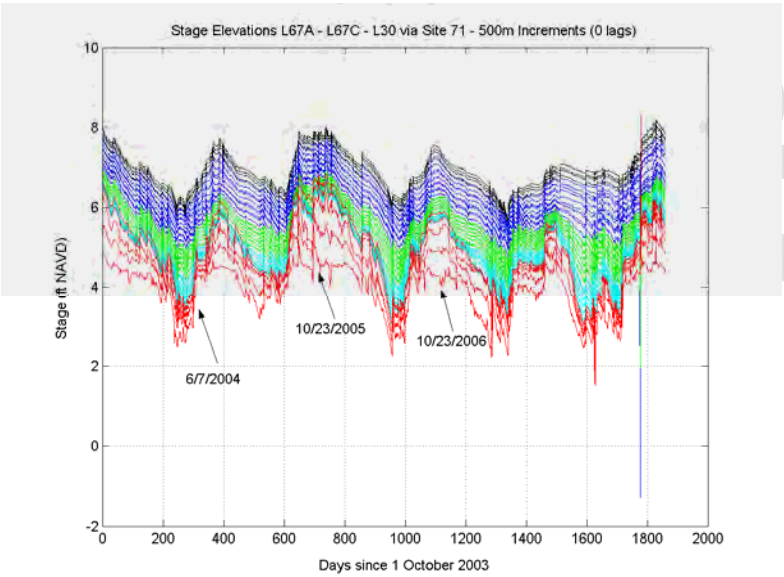

Figure 7: Surface Stages Transect 3 crossing Site 71 (3B2).

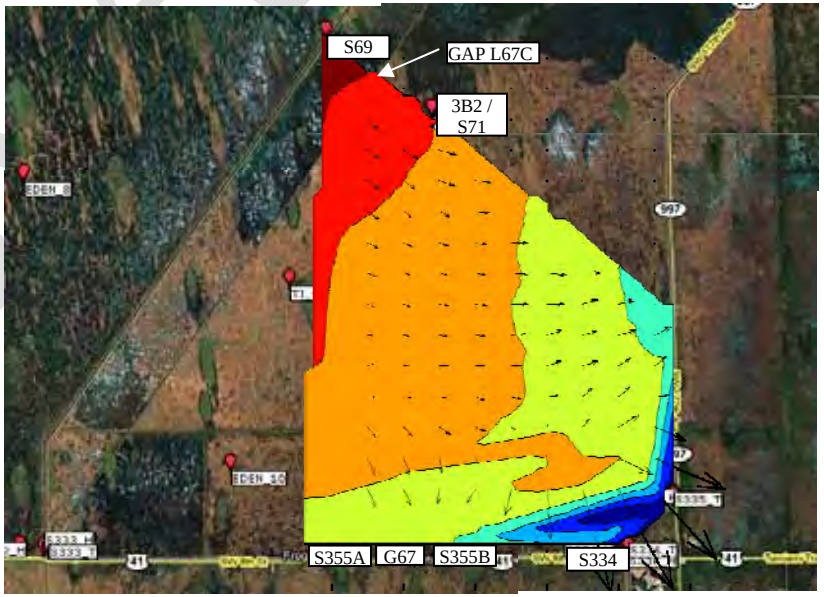

Figure 8: Surface Gradient (ft NAVD) for 23 October 2005; Surface Gradient direction Average = 95°; s.d. = 21°

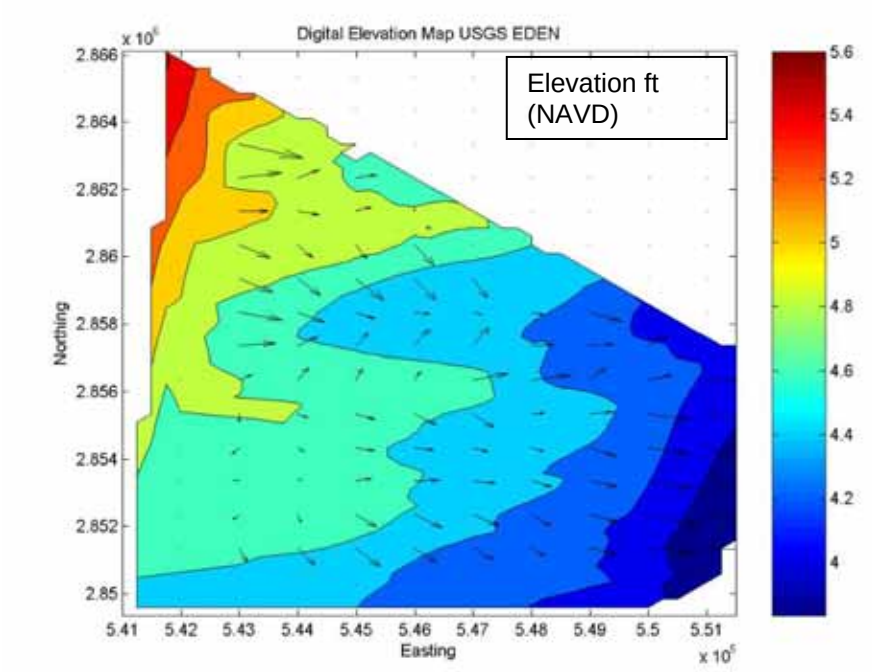

*Figure 9: Surface Topography and topographic gradient for transects plotted in Figure 1 estimated from Digital Elevation Model [USGS EDEN (*http://sofia.usgs.gov/eden/edenapps/transectplotter.php*)*

Analyses of the EDEN surface stage data along Transects 1-7 show that *differences* in local hydraulic gradients (along-gradient scale O 4,000m) exist across the pocket, in the vicinity of L67C and in regions approaching the L30 canal and S334 structure. The directional gradient integrated over the *entire* hydraulic surface was approximately 95 ^{o} to the ESE on 23 October 2005 (fig. 8). Directional gradients through the pocket are toward the SE (150° +/- 8°) (*Variano et al., in press*). Directional gradients over hydraulic surfaces tend to be more toward the ESE than those gradients over the topographic surface especially in the vicinity of the L30 Canal and the 334 structure (figs. 8 & 9).

Average Directional Gradients calculated *at each node* specified from the EDEN Network for the *entire hydraulic surface* derived from the EDEN network for the hydraulic surfaces on 7 June 20004 and 23 October 2006 were approximately 100 +/- 6 degrees. Surface flow directions at the *L67C gap* were 150° on 7 June 2004, and 158 ^{o} on 23 October 2005, and 146° on 23 October 2006. Surface flow tracers during the EverTREx Experiment (*Variano et al., in press*) found a tracer heading of 131° +/- 2° as flows traveled through sawgrass and was aligned with the direction of surface water flowing through the L67C Gap. Comparison between calculated surface flow directions from the EDEN network and those measured during the EverTREx Experiment were reasonable. The topography in the region slopes toward the southeast, and in general hydraulic gradients follow the topography; however, local deviations toward the south do exist, especially for high water conditions (23 October 2005), for regions in the vicinity of the L67C Gap and directly adjacent to the southern and eastern sections of the L30 and L29 canals, respectively (figs 8 and 9).

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Stage and Flows L67 Gap Pilot Test

Stage and flow data from the L67 Gap Pilot Test were examined to determine trends between local water stages and gradients during the L67A and L67C levee openings. Stage and flow data from the 1994 and 1998 Gap Test are presented in Table 1. Observations were made by the USGS during the 1994 and 1998 openings in the summer of 1994 and generally in the winter of 1998. Stages were measured at the L67A Canal and at the Gap in the Levee at the L67C. Stages from the gauge at Site 69_E sited in the pocket directly adjacent to the L67A were extracted from the DBHYDRO data base for the time period over which measurements were made. Similarly, stages at Site 71 were also extracted from DBHYDRO. The hydraulic gradient was calculated over the distance from Site 69_E (2865450N, 541208E UTM) and Site 71 (2863003N, 544405E). The percentage of flow through the L67C Gap relative to the total flow at the L67A opening was calculated from average flows reported by the USGS. A comparison of measured depths at the levee gap in the L67C and calculated depth at the Site 71 show that depths were greater at the levee gap by approximately 1-foot. This difference is most likely due to a change in the local topography due to construction activities during the degradation of the L67C levee. Measured velocities used to calculate the total flow through the L67C Gap are reported.

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TABLE 1: Stage and Flow Data from 1994 / 1998 L67C Gap Test

Observation during 1994 and 1998 experiments **Date**	Stage at L67A (ft NGVD) *(USGS meas)*	Stage at L67C (ft NGVD) *(USGS meas)*	Stage at Pocket (ft NGVD) from the 69_E Gauge *(DBHYDRO)*	Stage at Site 71 (ft NGVD) from the Site71 Gauge *(DBHYDRO)*	Hydraulic gradient from S69_E to Site 71 derived from stage data	L67A Flow (cfs) (approx) *(USGS meas)*	L67C Flow (cfs) (approx) *(USGS meas)*	Flow at L67C relative to flow @ L67A	Depth at L67C (ft) *(USGS meas)*	Depth at Site 71 (ft)	Velocity at L67C (cms^{-1}) *(USGS meas)*	EQUATION (1) expected velocity at L67C using Kadlec's equation calibrated with with depth Site 71 and gradient between S69_E (cms^{-1})* K_f =63.53 β=0.744 λ=0.775
7/21/1994		8.82	8.81	7.61	9.09E-05		146.00		2.00	0.97	2.44	1.89
7/21/1994		8.82	8.81	7.61	9.09E-05		136.00		2.00	0.97	2.13	1.89
7/28/1994		8.88	8.93	7.69	9.39E-05		136.90		2.08	1.05	2.13	2.05
8/18/1994		9.29	9.32	8.11	9.16E-05		170.00		2.59	1.47	2.13	2.59
8/31/1994		9.5	9.53	8.32	9.16E-05		228.00		2.84	1.68	2.44	2.86
9/19/1994		9.86	9.89	8.69	9.09E-05	767.00	279.00	36%	3.05	2.05	3.05	3.29
1/24/1998	10.65	9.96	9.66	8.56	8.33E-05	281.00	271.00	96%	2.78	1.92	3.05	2.93
2/9/1998	10.89	10.14	9.85	8.73	8.48E-05	400.00	318.00	80%	2.93	2.09	3.35	3.17
2/21/1998	10.85	10.14	9.86	8.72	8.63E-05	500.00	366.00	73%	3.01	2.08		3.20
3/10/1998	10.66	10.16	9.89	8.72	8.86E-05	559.00	358.00	64%	3.11	2.08	3.66	3.27
3/21/1998	10.82	10.19	9.91	8.72	9.01E-05	618.35	277.00	45%	3.11	2.08	2.74	3.31
7/1/1998	10.88	8.36	8.16	7.37	5.98E-05		36.00		1.21	0.73	0.91	1.10

** Depth is (Stage minus Elevation) at Site 71*

**Gradient from Station 69_E to Site 71*

6.64 ft (NGVD) ground surface elevation at Site 71

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Stages and Gradients: Stage data for WCA3A (Site 3A4), Site 69_W (L67A Canal), Site 69_E (Pocket), Site 71, Shark 1 and Site 3BSE from 1991 through 2008 were plotted to examine changes in water level stage before, during and after the L67 Gap Pilot Test (fig. 10). During test periods, the minimum stage at Station 3BSE remained above 6' NAVD.

Similarly, the hydraulic gradient was calculated between Stations 3A4, Site 69_W (L67A Canal), Site 69_E (Pocket), Site 71, Shark 1, and Site 3BSE from 1991 through 2008 were plotted to examine the difference in the hydraulic gradient between WCA3A, the Pocket and WCA3B before, during and after the Pilot Test (fig.11). Site locations and distances between them are listed in Table 2.

An offset in hydraulic gradient of approximately $3x10^{-5}$ between the Pocket and WCA3B is noticeable after the Gap in the L67C Levee was constructed when comparing pre- and post- Pilot Test data (fig. 12). During times when the L67A Gap was opened, the hydraulic gradient between WCA3A and the Pocket was consistently low. During the 1998 test, hydraulic gradients varied by $5x10^{-5}$ from a maximum of approximately $1x10^{-4}$ (similar to pre-Test conditions when the levee was intact) to a minimum of about $5x10^{-5}$ between the Pocket and WCA3B.

TABLE 2: SITE LOCATION AND DISTANCES

Station	E (UTM)	N (UTM)	Distance (mi)
3A4	533109	2873028	
69_E	541208	2865450	
L67C GAP	543176	2865107	
Site 71	544405	2863003	
(WCA3A – Pocket) Distance from 3A4 to S69_E			6.89
Distance from S69_E to L67C GAP			1.24
Distance from L67C GAP to Site 71			1.51
(Pocket – WCA3B) Distance from S69_E to Site 71			2.50
(WCA3A – WCA3B) Distance from 3A4 to Site 71			9.38

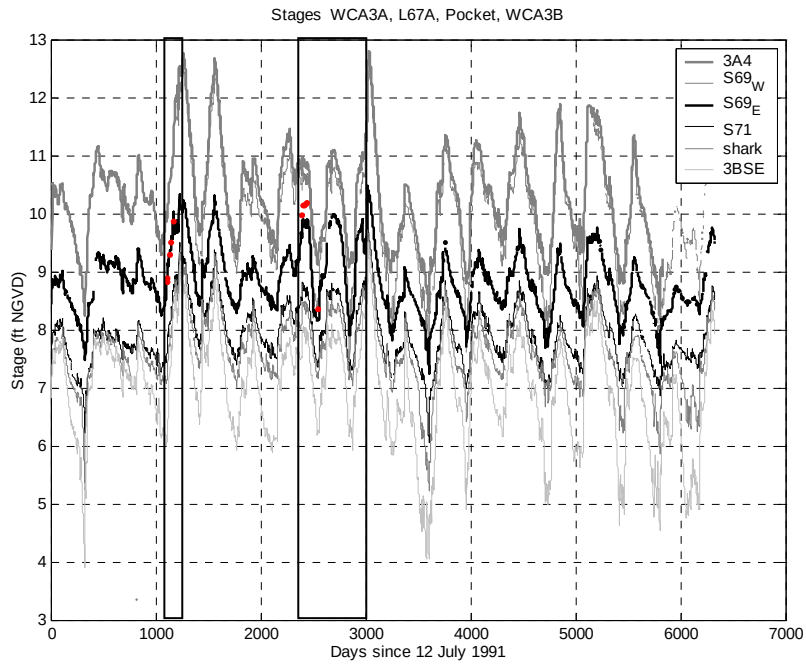

Figure 10: Stage data from DBHYDRO database. Black lines are sites S69_E (in pocket) and at Site 71 (3B2). Red circles denote elevations measured at L67C (USGS) and are < 0.2 ft different than the S69_E gauge stage. Boxes denote test periods.

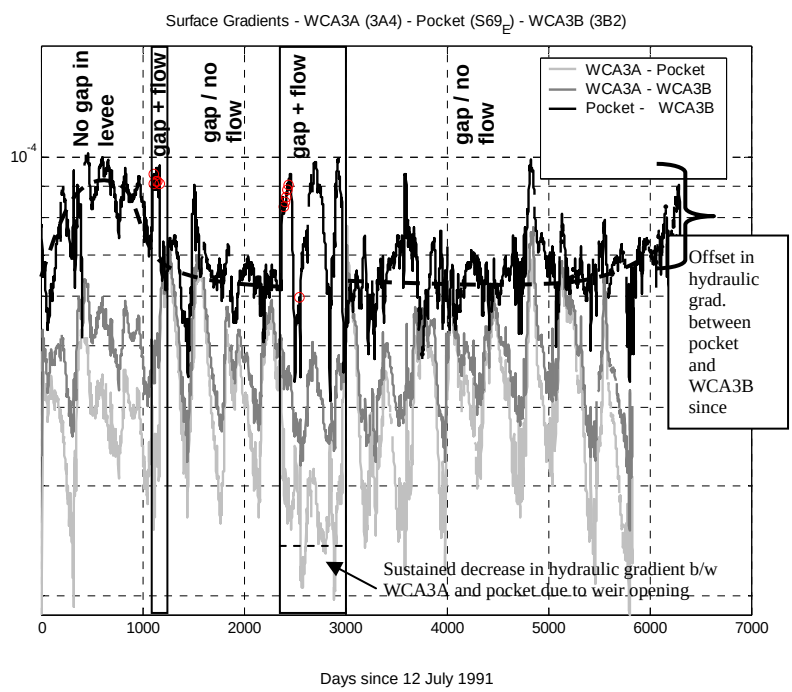

Figure 11: Hydraulic Gradient calculated from DBHYDRO database. Black is gradient from S69_E to Site 71(3B2). Grey line is from 3A4 to Site 71 (3B2). Light Grey is from is from 3A4 to Site 71 (3B2). Red circles denote days over which stage measurements were taken (TABLE 1). Boxes denote test periods.

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Expected Velocities: Expected velocity magnitudes at L67C Levee Gap were calculated using Kadlec's equation for velocity in an open marsh (fig. 12):

$$U = K_f h^{\beta} S^{\lambda} \qquad (1)$$

where:

U= velocity (cm/s)
h= depth (ft)
S= hydraulic gradient

where K_f *(cm/s·ft)*, β and λ are parameters determined from non linear regression.

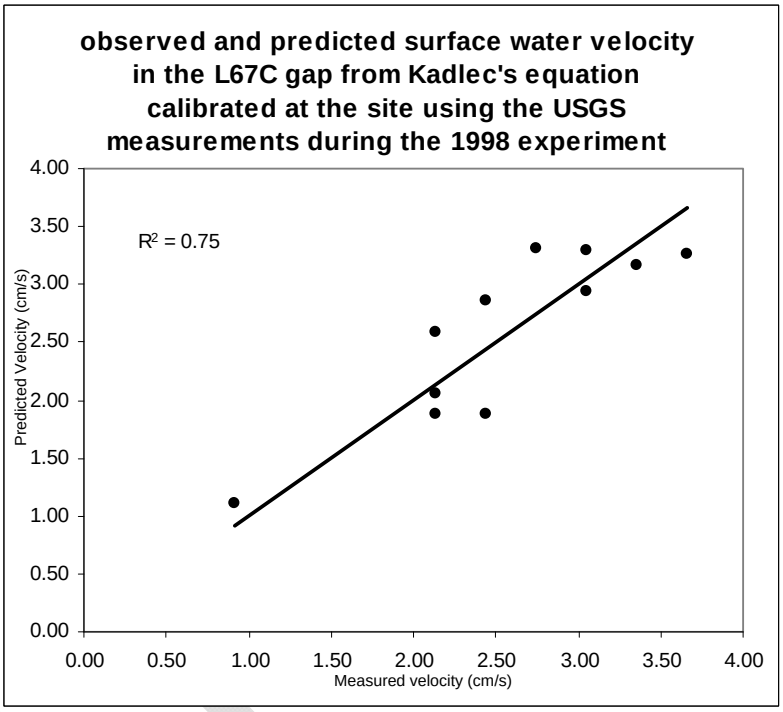

Figure 12: Linear Fit for Equation 1. This parameterization produced R^2 values of 0.75. Equation 1 will be used for the prediction of velocities at the L67C gap using stages from Site 69_E and stages at Site 71 (3B2).

Observations of *U* provided by the USGS at the L-67C gap, *h* at Site 71 calculated by subtracting the elevation of Site 71 (6.64 ft NGVD) from stage data at Site 71, and *S*, the hydraulic gradient calculated over he distance from Site 69_E to Site 71 were used to calculate K_f, β and λ. Resulting Equation 1 is presented below:

$$U = 63.53 h^{0.744} S^{0.775}$$

Calculating expected velocities using *Equation 1* made possible the calculation of expected velocities over an extended data set (limited by the available period-of-record, POR, from 12 July 1991 through November 2008) using stages at Site 69_E and Site 71 (fig. 13).Velocity estimates obtained using the *Equation 1* were related (r^2=0.75) to velocities observed during the gap tests.

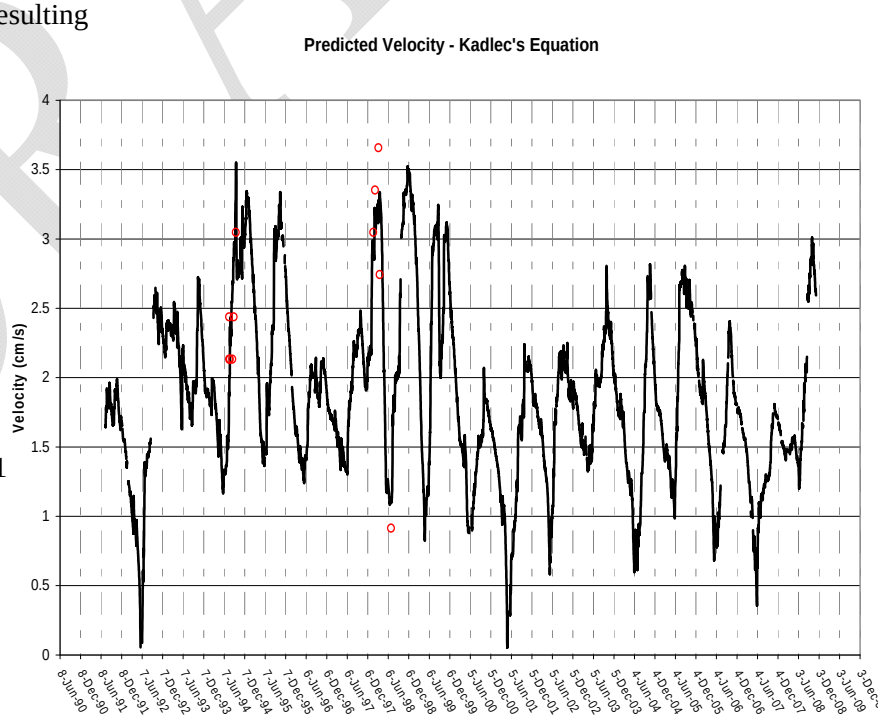

Figure 13: Predicted velocity at existing Gap in L67C using Kadlec's Equation calibrated with 1994 and 1998 velocity measurements. Red circles are measured velocities.

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Water stages and gradients were plotted for Site 71 (bold line) (figs. 14 and 15) to examine water stages and gradients necessary to support water velocities at the existing gap in the L67C of at least 2 cms^{-1} (fig. 14). During the1998 Pilot Test, and for periods after 1998, when stages exceed approximately 8 feet NGVD at Site 71, flows at the L67C Gap will exceed 2 cms^{-1}. A clear relationship between velocities exceeding 2 cms^{-1} and surface gradients between the Pocket and WCA3B is not as apparent (fig. 15), however, it can be noted that in 13, when stages were slightly less than 8' NAVD, the gradient was approaching $1x10^{-4}$, and velocities exceeded 2 cms^{-1}.

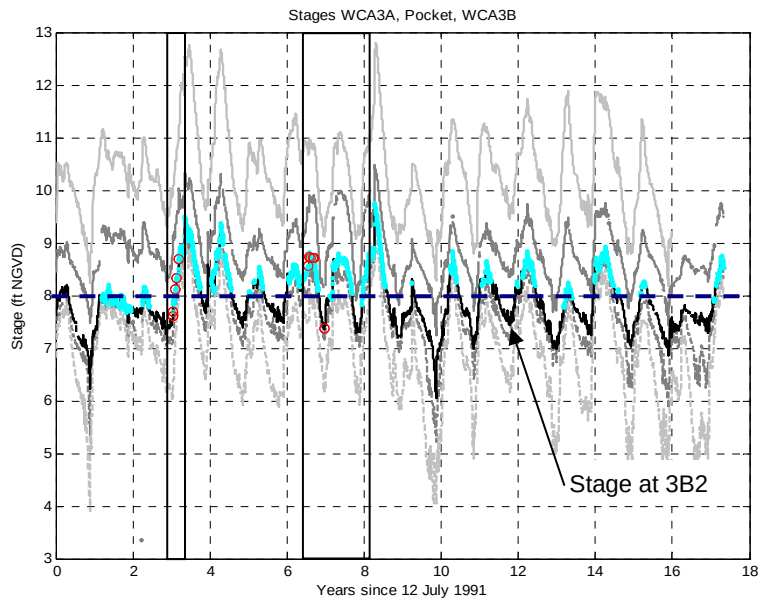

Figure 14: Surface Water Stages from DBHYDRO database. Dark black line is Site 71(3B2). Red circles denote days over which measurements were taken (TABLE 1). Boxes denote test periods. Cyan dots denote periods for which predicted velocities are greater than 2 cm/s through the existing gap in the L67C levee.

It is clear from Figures 14 and 15 is that, for given stages and gradients present in the vicinity of the L67C Gap after the 1998 Pilot Test (Years 8 – 18), there are annual periods when velocity magnitudes can be expected to exceed 2 cms^{-1} without additional flow inputs from WCA3A via weir or culvert. Velocities during this period, however, were not expected to exceed 2.75 cms^{-1} (fig. 14).

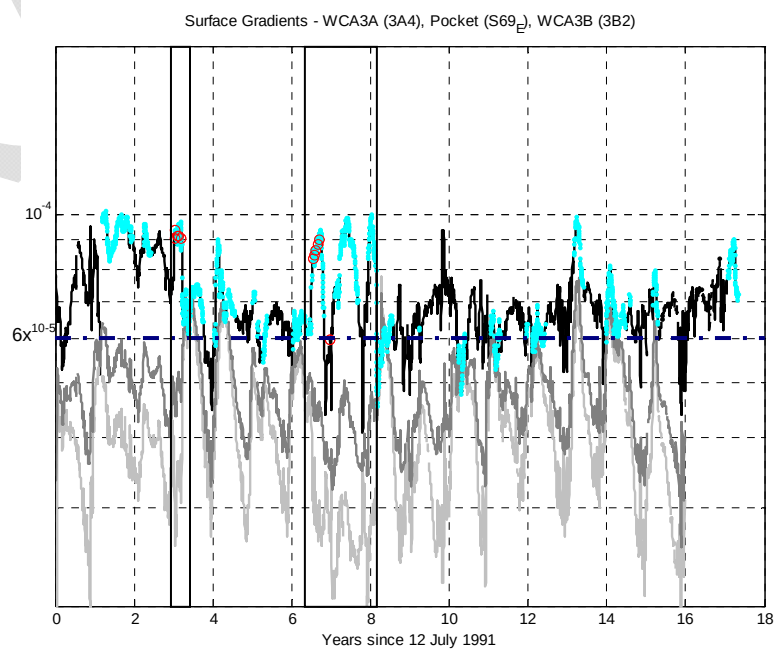

Figure 15: Hydraulic Gradient calculated from DBHYDRO database. Black is gradient from S69_E to Site 71(3B2). Grey line is from 3A4 to Site 71 (3B2). Light Grey is from is from 3A4 to Site 71 (3B2). Red circles denote days over which measurements were taken (TABLE 1). Boxes denote test periods. Cyan dots denote periods for which predicted velocities are greater than 2 cm/s through the existing gap in the L67C levee.

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Design Discharges: DPM structures for the L67A Canal were sized to pass the design discharge with 0.6 ft of head. Figure 16 shows the stage difference over the time period from 1994 to 2008 for Stations L69_W at the L67A Canal (POR 1994-2008) and L69_E in the Pocket (POR 1991-2008). The exceedance plot (fig. 17) indicates that approximately 85% of the time, the head differential between the L67A Canal and the Pocket will exceed 0.6 ft of head, and will therefore, pass the design discharge into the Pocket.

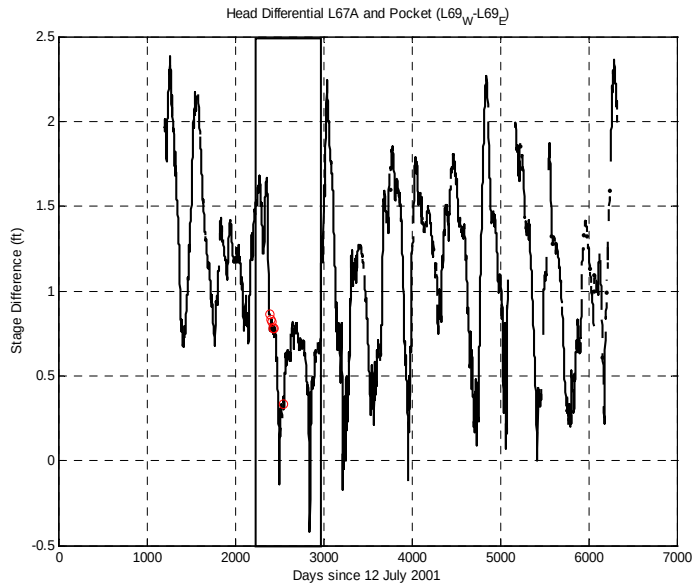

Figure 16: Head Differential calculated from DBHYDRO database. Black is gradient from S69_W (L67A) to S69_E (Pocket). Red circles denote days over which measurements were taken (TABLE 1).

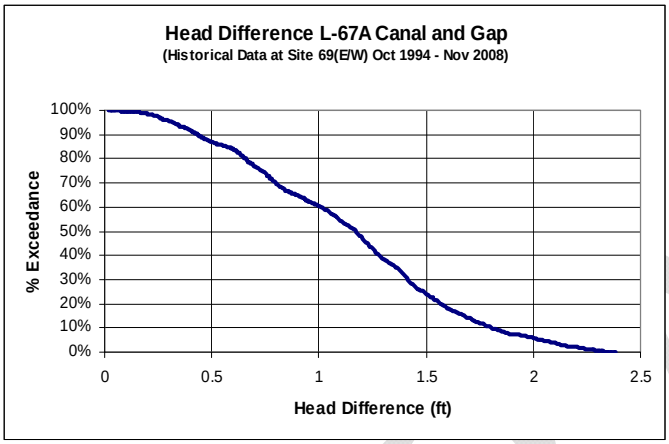

Figure 17: Probability density function for Head Differential calculated from DBHYDRO database. Black is gradient from S69_W (L67A) to S69 E (Pocket).

Examination of Table 1 shows that on average, the discharge through the Gap at the L67C levee were 66% of the flows passed from L67A Canal. The analysis of expected velocities at Site 71 (fig. 13) described previously demonstrates that for given stages in WCA3A, the Pocket and WCA3B and associated gradients, there are specific times of each year that measured velocities in WCA3B can

Table 3. Flow (cfs) through gaps based upon 1998 L67 Gap Pilot Test

		2 cm per second 0.07 feet per second		**5 cm per second 0.16 feet per second**		**2 cm per second 0.07 feet per second**		**5 cm per second 0.16 feet per second**	
Gap Length *(feet)*	**Gap Length *(meters)***	**Discharge L67C *(cfs)***	**Discharge L67A *(cfs)***	**Discharge L67C *(cfs)***	**Discharge L67A *(cfs)***	**Discharge L67C *(cfs)***	**Discharge L67A *(cfs)***	**Discharge L67C *(cfs)***	**Discharge L67A *(cfs)***
				Flow Depth of 1.0 feet (30.5 cm)				Flow Depth of 2.0 feet (30.5 cm)	
500	152	33	50	82	124	66	99	164	248
1000	305	66	99	164	248	131	199	***328***	***497***
1500	457	98	149	246	373	197	298	***492***	***745***
2000	610	131	199	328	497	262	398	***656***	***994***
2500	762	164	248	***410***	***621***	328	497	820	1242
3000	914	197	298	***492***	***745***	***394***	***596***	984	1491
4000	1219	262	398	656	994	***525***	***795***	1312	1988
Assume that 66% of flows through L67A are passed through L67C									

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be expected to exceed 2 cms^{-1} *based upon the historical gradients and depths between WCA3A and WCA3B*. Calculated velocities during this period, however, did not exceed 3.0 cms^{-1}, and additional flow inputs would be necessary to increase velocities to a range greater than 3.0 cms^{-1}. Table 3 was developed to determine the discharge requirements at the L67A based on a conservation of volume analysis to provide velocities downstream of the L67C gap that would approach 5 cms^{-1}. Using the average depths at Site 71 and assuming that 66% of flows passed through the structures at the L67A will be passed through the Gap at the L67C, discharge requirements were estimated for a range of expected depths at Site 71 and a velocity range of 2-5 cms^{-1} at L67C (Table 3). The numbers in bold represent those flows that would approach the target velocity desired for the Decomp Physical Model.

Conclusions

Flows and velocities in WCA3B are a strong function of water depth and hydraulic gradient. During the 1998 Pilot Gap Test, hydraulic gradients varied greatly, but approached pre-Gap conditions ($1x10^{-4}$) periodically. This gradient, combined with a decrease in friction with increased water depths, yielded flows of 3 cms^{-1}. Calculated velocities show that flow speeds in the existing L67C Gap could exceed 2 cms^{-1} without additional flow inputs from L67A. Table 3 demonstrates flows between L67A/L67C and expected velocities. If 750 cfs is achieved at the L67A Canal (which will occur 85% of the time), then approximately 500 cfs can be expected at the L67C Levee Gap. Finally, as the eastern portion of the L29 and as the L30 Canals are approached, local hydraulic gradients will increase to values greater than $1x10^{-4}$ and local velocities will increase in these regions. Flow directions will be directed by the L67C Gap orientation, local topography and vegetation and the L29 and L30 Canals.

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SECTION 4

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5 January 2005

An Analysis of the Biological and Water Quality Benefits and Impacts in Water Conservation Area 3B Associated with 1998 Opening the L-67A Levee

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SUMMARY

The purpose of this report is to determine if there were quantifiable biological and water quality benefits or impacts associated with increased flows into Water Conservation Area 3B (WCA-3B) when a gap was made in the L-67A levee. The results are:

The main conclusions of this report are: 1) Biological and water quality benefits or impacts of flow associated with the opening of the L-67A levee could not be discerned. 2) Although periphyton composition differed among years, similar interannual differences have been observed throughout the Everglades suggesting a regional climate factor was more likely responsible for the observed difference. 3) Overall water quality was not influenced by the gap and was indicative of pristine Everglades P limiting conditions. However, an opening in the levee does subject WCA-3B to a greater probability of pulsed nutrient delivery from the L-67A canal.

Key Findings

- Four open-water sloughs in WCA-3B have been regularly monitored for water quality, periphyton composition, and periphyton tissue nutrient content since September 1997.
- A 1000 foot gap was opened in the L-67A levee from January 1998 until September 1999 that established a surface water connection between WCA-3A, L-67A, and WCA-3B.
- Minimal flow data is available during the period when the levee was open; thus, precluding a direct cause and effect analysis.
- Hydroperiod differed between pre and post closure of the gap. When the gap was open, mean water depths were deeper and the periods of maximum inundation were greater. In contrast, when closed, precipitation regulated hydroperiod and was therefore more variable.
- Water quality, both when the gap was open and closed, was indicative of oligotrophic conditions. TP averaged less than 0.01 mg/L. However, mean TP and TKN were greater during the gap opening due to pulses of nutrient enriched water into the marsh. These pulses coincided with discharges into the L-67 canal immediately following the opening of the S340.
- Periphyton community structure differed between the period of time when the gap was open and closed. However, the same algal taxa dominated both periods and differences were primarily due a few taxa. The dominant taxa were indicative of pristine Everglades periphyton. The taxa present only during the gap opening are indicators of nutrient enrichment.
- Periphyton tissue nutrients were not influenced by the opening of the levee. Tissue nutrients did differ among periphyton types in the following order: total phosphorus = epipelon > epiphyton > metaphyton; total nitrogen = epipelon > epiphyton > metaphyton; total carbon = epipelon > epiphyton > metaphyton; total calcium = epiphyton > epipelon = metaphyton.

INTRODUCTION

The Comprehensive Everglades Restoration Plan (CERP) aims to restore natural hydrological patterns by modifying current hydrologic units in the Everglades. This includes Water Conservation Area 3B (WCA-3B), which currently functions as a healthy, precipitation driven, marl-forming, periphyton marsh. One major proposed modification is to improve the hydrologic connection between WCA-3A and WCA-3B by allowing flow through the L-67 levees. The quality of additional water entering WCA-3B will likely reflect the upstream influence of agricultural and urban runoff such that hydrologic modifications may be accompanied by undesirable water quality changes. Environmental monitoring in WCA-3B, Shark River Slough, and Taylor slough began in August of 1997 as part of the Experimental Program of Modified Water Deliveries to Everglades National Park. Monitoring began in association with the Test Iteration 7 of this program to 1) obtain baseline information on ecological conditions; 2) to quantify benefits and impacts of hydropattern alterations (increased flows); 3) quantify potential water quality impacts associated with hydrologic manipulations.

The study described here provides an assessment of the impacts and benefits resulting from the opening of the L67 levees to distinguish the effects of changing hydropatterns and water quality on the marsh ecosystem in WCA-3B. To improve the hydrologic connection between WCA-3A and WCA-3B, a 1000 ft gap (opening) was created in the L-67A and L-67C on 12 July 1994 and 23 June 1994, respectively. The L-67A gap was subsequently closed on 24 September 1994 but the L-67C gap has remained open. The L-67A gap was reopened on 14 January 1998 for the Sparrow Emergency Operations. The gap was closed on 1 September 1999. No environmental monitoring data was collected during the gap openings in 1994.

The purpose of this report is to determine if there were quantifiable biological and water quality benefits or impacts associated with increased flows when the levees were open. Since no monitoring program was in place in 1994, this report focuses on the period between August 1997 and February 2004 and is associated with the reopening and closure of the L-67A levee. Pre-opening data is limited as monitoring began approximately four months before the levee was opened; thus, comparisons will generally center on the periods when the gap was open (January 1998 -September 1999) and closed (September 1999 – December 2001).

MONITORING PROGRAM

Study Sites

Four sites in WCA-3B have been monitored since August 1997. The sites are positioned on two north-south transects (Fig. 1). Sites S345B2 (25°53.11”N; 80°34.00”W) and S345C2 (25°50.68”N; 80°35.52”W) are 2 km from the L-67C levee whereas sites S345B6 (25°51.20”N; 80°32.94”W) and S345C6 (25°48.63”N; 80°35.19”W) are 6 km from the levee. Each site is located in a slough.

Parameters

Sites were monitored for water quality and biological properties. Water quality was assessed bimonthly by measuring surface water total phosphorus (TP) and total Kjeldahl nitrogen (TKN). Chemical analyses were performed by the Florida Department of Environmental Protection (FDEP). Further water quality assessments were made using Hydrolab® Data Sondes. Sondes were deployed quarterly and measured temperature, pH, specific conductivity, and dissolved

oxygen at 30 minute intervals over a period of five days. The biological status of each site was assessed using periphyton. Periphytometers were deployed bimonthly. Taxonomic composition was used as biological indicators of water quality within the two month deployment interval. Natural substrate periphyton was collected biannually to assess the long-term (6 month) cumulative biological response to water quality and hydrology. Natural substrate samples consisted of epipelon (algae attached to sediments), metaphyton (floating algal mats), and epiphyton (algae attached to plants). Taxonomic analysis of periphyton and natural substrate samples were performed by the Biological Lab of FDEP. The total nitrogen (TN), total phosphorus (TP), total carbon (TC), and total calcium (TCa) tissue nutrient content of natural substrate periphyton was determined biannually. These analyses were performed by DB Labs.

RESULTS

Hydrology

With the closure of the gap in the L-67A levee, hydrology in WCA-3B is driven by precipitation. When the levee was open, flow into WCA-3B was a function of discharges from the S340 and S9 and releases from the S151 and S333. The S151, when open, reduces the amount of water entering L-67A as this conveys water east into the C-304. The S333 is the primary discharge structure for the L-67A. When operational, this structure removes water from the canal and WCA-3A.

Limited flow data are available for when the L-67A gap was open. Flow rates in the L-67A and L-67C gaps were made by the US Geological Survey between January and March 1998 (Table 1). Within that time frame, the majority of water entering the L-67A canal was from the S340 with minor inputs from the S-9 (Table 1). Flows through the S151 and S333 were minimal (Table 1). Because of the limited data, direct comparison between flow and environmental variables cannot be made.

Daily water depths for each site were calculated using a regression equation developed from measured water depths at the time of sample collection and the SHARK.1_H or 3-71 stage recorders. The regression coefficient (r^2) for both equations was greater than 0.91 indicating a strong relationship between measured water depths and stage gages. Measured and predicted water depths varied little among sites (Fig. 2). In general, water depths varied annually between 20 and 60 cm and the sites remained inundated throughout the year. During the opening of the L-67A, hydroperiods were less variable and remained deeper longer than the period following the closure of the levee. Following closure of the gap, hydropatterns were more stochastic as a result of variable precipitation. Maximum water depths occurred in 2000 when Hurricane Irene made landfall. Minimum water depths occurred in 2001 when severe drought resulted in complete dry-down at all four sites. The major difference associated with the opening of the gap was a more managed and less stochastic hydroperiod.

Table 1- Flow rates (cfs) measured in the L-67A and L-67C gaps by the US Geological Survey. Three replicate measurements were made at the L-67A (mean±SD) whereas only one measurement was made at the L-67C. Corresponding rates are provided for structures that discharge water to (S340 and S9) and from (S151 and S333) the L-67A.

Date	Flow (cfs)	Canal Inflow	Canal Outflow

		Structure	Flow (cfs)	Structure	Flow (cfs)
L-67A					
24 Jan 98	281±17	S340	1170	S151	0
		S9	0	S333	352
7 Feb 98	400±60	S340	1024	S151	0
		S9	372	S333	0
21 Feb 98	500±35	S340	1190	S151	0
		S9	444	S333	0
7 Mar 98	559±74	S340	514	S151	100
		S9	0	S333	0
L-67C					
24 Jan 98	271	S340	1170	S340	0
		S9	0	S9	352
9 Feb 98	318	S340	1049	S340	0
		S9	490	S9	0
21 Feb 98	366	S340	1190	S340	0
		S9	444	S9	0
10 Mar 98	358	S340	539	S340	99
		S9	439	S9	0

Water Quality

TP and TKN varied seasonal and were similar among sites (Figs. 3 & 4) and no downstream gradient was observed. TP and TKN were typically less than 0.01 and 1.5 mg/L, respectively. Geometric mean TP concentrations were generally 0.001 to 0.003 mg/L greater when the gap was open compared to other periods (Table 2); however, only values for S345B6 were significantly different. Similar higher concentrations were observed for TKN (Table 2). Significant differences were detected for S345B2 and S345B6 only. The higher geometric means for TP and TKN during the pre-closure period were due to greater variability in nutrient concentrations. Two pulses in TP and TKN were recorded at sites when the levee was open. These pulses were associated with discharges from the S340 structure.

Mean temperature varied seasonally (range 15 to 30 °C) but not among sites (Fig. 5). Values for pH at each site ranged between 7.0 and 8.0 and were not influenced by the gap (Fig. 5). Mean specific conductance values were indicative of moderately mineral enriched water (range 300-700 µS/cm). There was a tendency for sites closer to the gap (B2 and C2) to have higher values than sites B6 and C6 (Fig. 5). This may indicate canal water intruded into the marsh. Mean dissolved oxygen concentration varied between 2 and 7 mg/L (Fig. 5). These concentrations were indicative of high primary production and were reflective of oligotrophic conditions found elsewhere in the Everglades

Table 2- Geometric mean TP and TKN concentrations (mg/L) for four monitoring sites in WCA-3B during the pre and post closure of the L-67A gap. Sites were compared using one-way ANOVA. An * indicates concentrations that are significant greater than other periods.

	P	Gap Open 1998-1999	Gap Closed 1999-2001	Gap Closed 2001-2004

Site		TP (mg/L)	TP (mg/L)	TP (mg/L)
S345B2	0.2850	0.007	0.005	0.006
S345B6	0.0085	0.008*	0.005	0.006
S345C2	0.1244	0.007	0.005	0.007
S345C6	0.0549	0.008	0.006	0.006
		n=11	n=9	n=15
Site		TKN (mg/L)	TKN (mg/L)	TKN (mg/L)
S345B2	0.0062	1.29*	0.94	1.02
S345B6	0.0352	1.26*	0.94	0.97
S345C2	0.2975	1.29	1.05	1.08
S345C6	0.4233	1.13	0.98	0.97
		n=10	n=9	n=15

Periphyton

Periphytometers- A total of 181 taxa were identified whose relative abundance exceeded 5%. Periphytometer species composition was similar among sites; however, composition varied temporally (Fig. 6). Analysis of Similarity (ANOSIM) was conducted to determine if the assemblages differed in conjunction with the gap. Groups were defined as prior to the opening of the L-67A gap (P1), when the gap was open (O1), the period from the closure of the gap until the 2001 drought (C1), and post 2001 drought (C2). The degree of similarity between groups was assessed using the statistic R, which measures the separation between groups. Values close to 1 indicate no similarity whereas 0 indicate that the samples are indistinguishable. Composition differed among the four groups (Global R=0.659). Species composition prior to the opening of the L-67A (P1) overlapped but were different from samples collected during the period when the gap was open (O1) (ANOSIM R=0.706). Samples collected after the gap closure but before the 2001 drought (C1) separated from those from when the gap was open. However, the low R value (0.498) indicates little separation between the two groups. This is due to the inclusion of samples collected in October 1999 into the C1 group. This set of samples spanned the opening and closing of the gap and thus is more likely to reflect the gap opening. The R value increases to 0.675 when the October 1999 samples are included with the O1 group. Samples collected after the 2001 drought (C2) were more similar to those collected after the gap closure (C1) (R=0.495) then those collected when the gap was open O1 (R=0.922).

The species composition among groups was very similar (Appendix 1). The data reported here is restricted to the period when the levee was open (O1) and the period after closure (C1). Taxa common between O1 and C1 assemblages included the diatoms *Brachysira vitrea*, *Encyonema evergladianum*, *Gomphonema gracile*, *Fragilaria synegrotesca*, *Mastogloia* sp, and *Mastogloia smithii*, the filamentous cyanobacteria *Anabaena* sp. and *Lyngbya* sp and the green algae *Chlorella* sp. and *Mougeotia* sp. These taxa are generally indicators of low TP and moderate conductivity (McCormick and O'Dell 1996; McCormick et al. 1996; McCormick et al. 2001). In addition, average cell densities were greater for the C1 than O1 samples. The major difference among groups was a greater relative abundance of araphid diatoms and filamentous cyanobacteria in the C1 group (Fig. 7). Taxa associated with the closure of the gap included the filamentous cyanobacteria *Cyanobium parvum* and *Cyanobium plancticum*, diatoms belonging to the family Fragilariaceae, and several *Gomphonema* species. Taxa associated with the opening (O1) included diatoms belonging to the family Bacillariophyceae, the diatoms *Brachysira*

serians, *Encyonema minutum* var. *pseudogracilis*, the coccoid cyanobacteria *Chroococcus* sp., *Chroococcus minutus*, and *Synechococcus* sp, the green algae *Gloeocystis* sp. These taxa tend to have higher optimal nutrient concentrations (e.g., TP and TKN); thus, their presence suggests that the differences in assemblage structure may be due to higher nutrient concentrations or loadings.

Grab Samples- The relative abundance of species for epipelic, metaphytic, and epiphytic did not differ significantly within a site or among sites for a given date. In addition, the structure of periphyton assemblages was similar when the gap was open and when it was closed (data not shown). The taxa comprising periphyton mats was similar to those identified from the periphytometers, both with respect to identification and abundance. The species identified are reflective of algae associated with pristine Everglades periphyton.

Although differences in periphyton structure were observed, the differences may not be associated with whether the gap was open or closed. Preliminary analysis of species composition of periphytometers collected throughout the Everglades system has shown a similar interannual variation. In other words, similar variation in species composition have been observed among samples collected 1998-1999, 2000-2001, 2002-2004 for a given site regardless of trophic status. Similar variation has been observed for natural substrate periphyton samples and for invertebrates. This suggests that regional climate patterns may impart a strong influence on biological communities. A strong El Nino event occurred between 1997 and 1999 which resulted in a wetter than normal dry season. A severe drought occurred in 2001. Normal or average climate conditions persisted in 2000-2001 and 2002-2004. This variation should be taken into account when monitoring biological responses to structure or management effects.

Tissue Nutrients

No discernable patterns were observed for the tissue nutrient concentrations of epipelon, metaphyton, and epiphyton among sites or between periods when the levee was open and closed (Figs. 8, 9, & 10). In general, TP, TN, and TC content of epipelon and epiphyton were greater than metaphyton. In contrast, calcium concentrations were generally higher for metaphyton. TP concentrations for all periphyton types varied among dates. Concentrations for metaphyton were typically less than 200 mg/kg suggestive of little to no enrichment by surface waters. Concentrations of epipelon and epiphyton were generally less than 500 mg/kg indicative of moderate to little enrichment. Similar patterns and concentrations have been observed in pristine regions of WCA-2A (McCormick et al. 2001; Scinto and Reddy 2003).

CONCLUSIONS

Biological or water quality benefits or impacts of flow associated with the opening of the L-67A levee could not be discerned. Although periphyton composition differed among years, similar differences have been observed during the same time period throughout the Everglades suggesting a regional climate factor was more likely responsible for the observed difference. Overall water quality was not affected by the opening of the levee and was indicative of pristine Everglades P limiting conditions. However, opening in the levee does subject WCA-3B to a greater probability of pulsed nutrient delivery from the L-67A canal.

RECOMMENDATIONS

Monitoring programs need to be designed to properly evaluate the benefits or impacts of a specific project. Three components need to be carefully addressed prior to the beginning of the study. First, considerable thought must be given to the hypotheses to be tested and to the statistical design. This includes which statistical procedures will be used to test project specific hypotheses. The identification of statistical methods will ensure that the correct type and quantity of data is collected. In this study, the question of interest centered on the effects of increased flow; however, the limited flow data precluded the direct establishment of cause and effect. Second, related to the statistical design is the establishment of a proper control. In this study, it appears that flow influenced periphyton composition; however, similar composition differences were observed throughout the Everglades ecosystem during the same periods. This suggests that the differences between 1998-1999, 2000-2001, and 2002-2003 may be a function of regional climate differences and not related to a project. Thus, it is essential that sites be selected that will not be affected by the project to account for other factors. Third, biological and water quality monitoring stations need to be located closer (<0.5 km) to the project. Recent studies indicate that biological and chemical gradients in the southern Everglades are relatively short, spanning a distance of less than 2 km (Raschke 1993; Childers et al. 2003; Gaiser et al. 2004); thus, within the scope of most projects (1-2 years) it is highly unlikely that a site 2 km from the project will be show benefits or impacts of the project. As always, reference sites should also be included on the project design.

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FIGURE LIST

Figure 1- Location of study sites S345B2, S345B6, S345C2, and S345C6 in Water Conservation Area 3B. Latitude and longitude coordinates are listed in the text. Sites B2 and C2 are located approximately 2 km south of the L-67C. Sites B6 and C6 are located approximately 6 km south of the L-67C.

Figure 2- Measured (circles) and predicted (line) water depths (cm) for four sites in WCA-3B. Predicted depths were calculated using regression analysis of measured depths and stage recorders (see text for details).

Figure 3- Total Phosphorus (TP) time-series for four sites in WCA-3B. Sites B2 and C2 are 2 km from the L-67C levee. Sites B6 and C6 are 6 km from the L-67C levee. The box indicates the period when the L-67A gap was open.

Figure 4- Total Kjeldahl Nitrogen (TKN) time-series for four sites in WCA-3B. Sites B2 and C2 are 2 km from the L-67C levee. Sites B6 and C6 are 6 km from the L-67C levee. The box indicates the period when the L-67A gap was open.

Figure 5- Time-series of temperature, pH, specific conductance, and dissolved oxygen for four sites in WCA-3B. Parameters were collected using Hydrolabs. Values are average of the daily means collected over a 5 day deployment period.

Figure 6- Log-transformed cell densities for each taxon were used as the variables in the Non-Metric Dimensional Analysis (NMDS). NMDS is a multivariate statistical method which uses a Bray-Curtis similarity index to determine the similarity among samples. Samples that occur close together in ordination space are more similar than those that are distant.

Figure 7- Relative abundance of selected periphyton functional groups: Araphid Diatoms, Biraphid Diatoms, Coccoid Cyanobacteria, and Filamentous Cyanobacteria. Shaded boxes indicate the period when the L-67A gap was open.

Figure 8- Epipelic tissue nutrient concentrations for four sites in WCA-3B. TP = total phosphorus, TN = total nitrogen, TC = total carbon, TCa = total calcium. All values are in mg/kg.

Figure 9- Metaphytic tissue nutrient concentrations for four sites in WCA-3B. TP = total phosphorus, TN = total nitrogen, TC = total carbon, TCa = total calcium. All values are in mg/kg.

Figure 10- Epiphytic tissue nutrient concentrations for four sites in WCA-3B. TP = total phosphorus, TN = total nitrogen, TC = total carbon, TCa = total calcium. All values are in mg/kg.

Figure 1

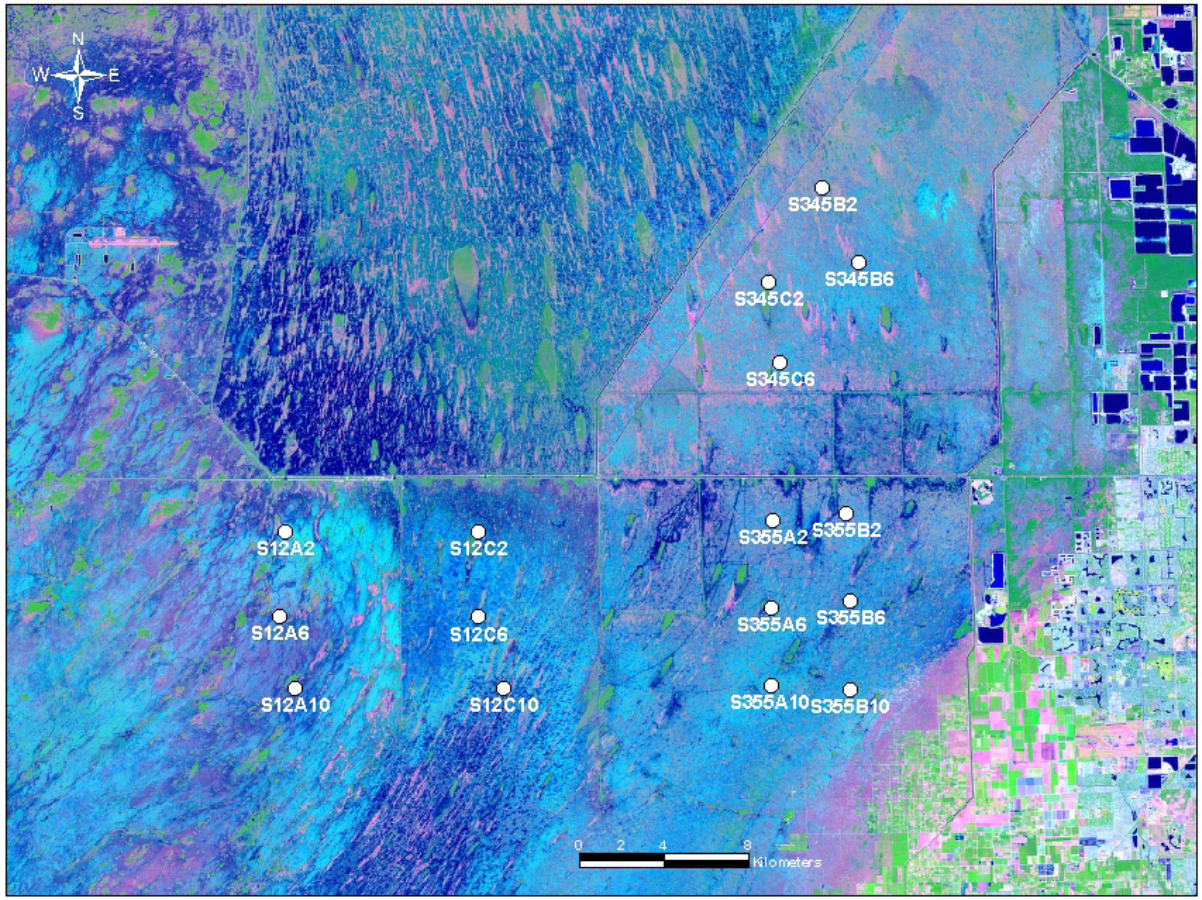

N
W
E
S
S345B2
S345B6
S345C2
S345C6
S12A2
S12C2
S355A2
S355B2
S12A6
S12C6
S355A6
S355B6
S12A10
S12C10
S355A10
S355B10
0 2 4 8
Kilometers

Figure 2

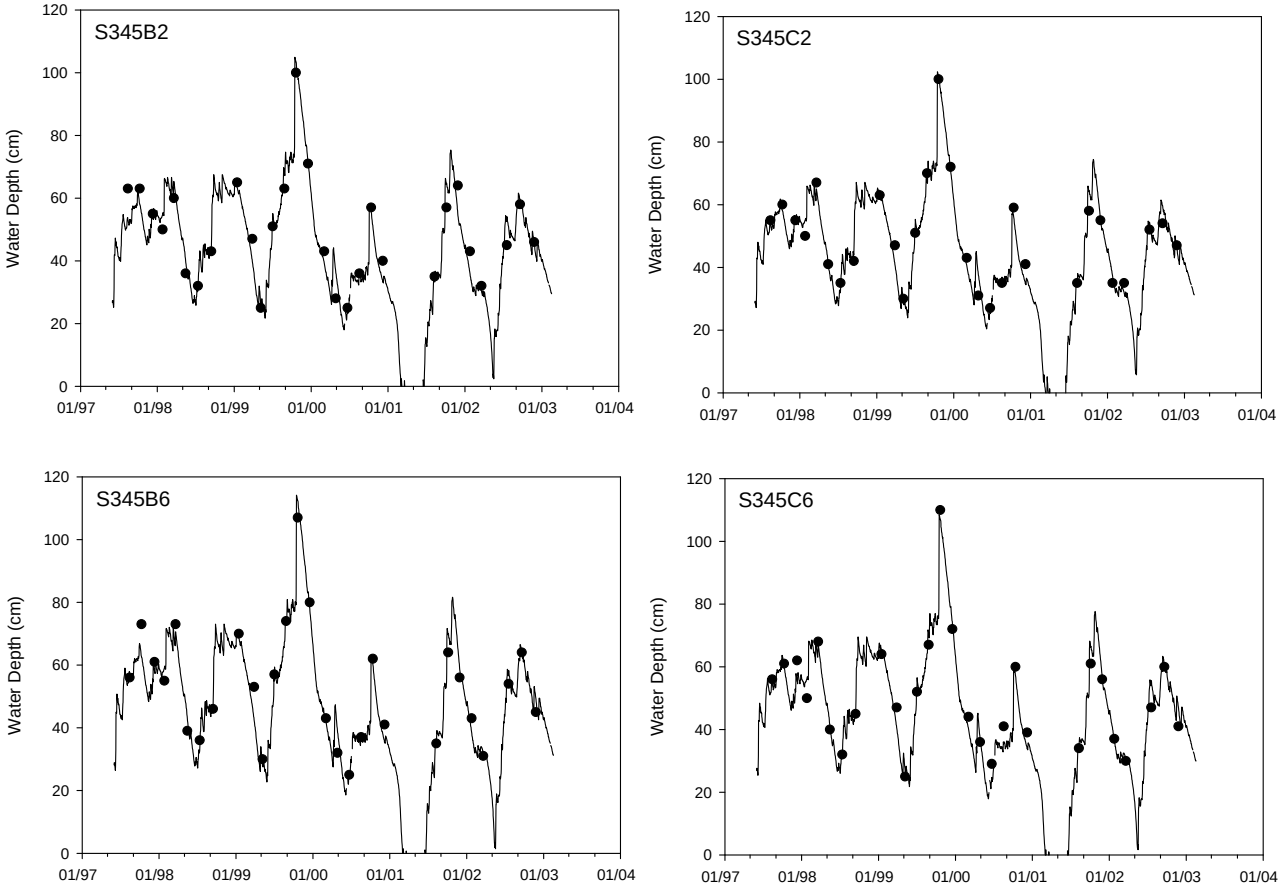

S345B2
S345C2
S345B6
S345C6
Water Depth (cm)
0
20
40
60
80
100
120
01/97
01/98
01/99
01/00
01/01
01/02
01/03
01/04

Figure 3

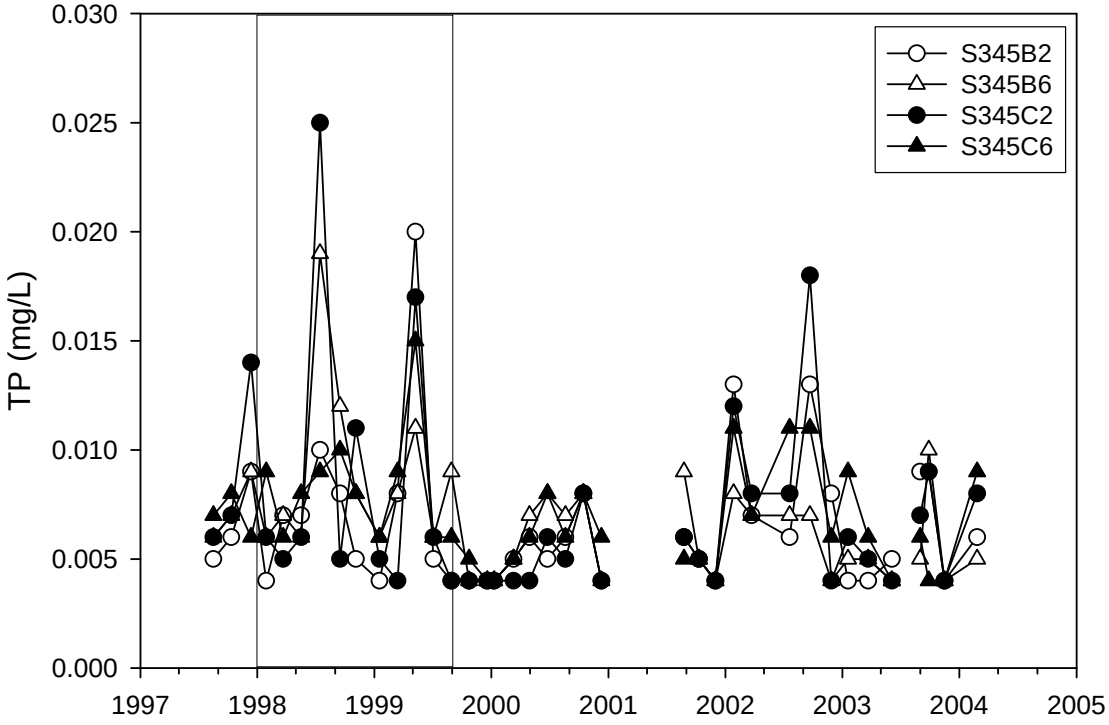

0.030
0.025
0.020
0.015
0.010
0.005
0.000
TP (mg/L)
1997
1998
1999
2000
2001
2002
2003
2004
2005
S345B2
S345B6
S345C2
S345C6

Figure 4

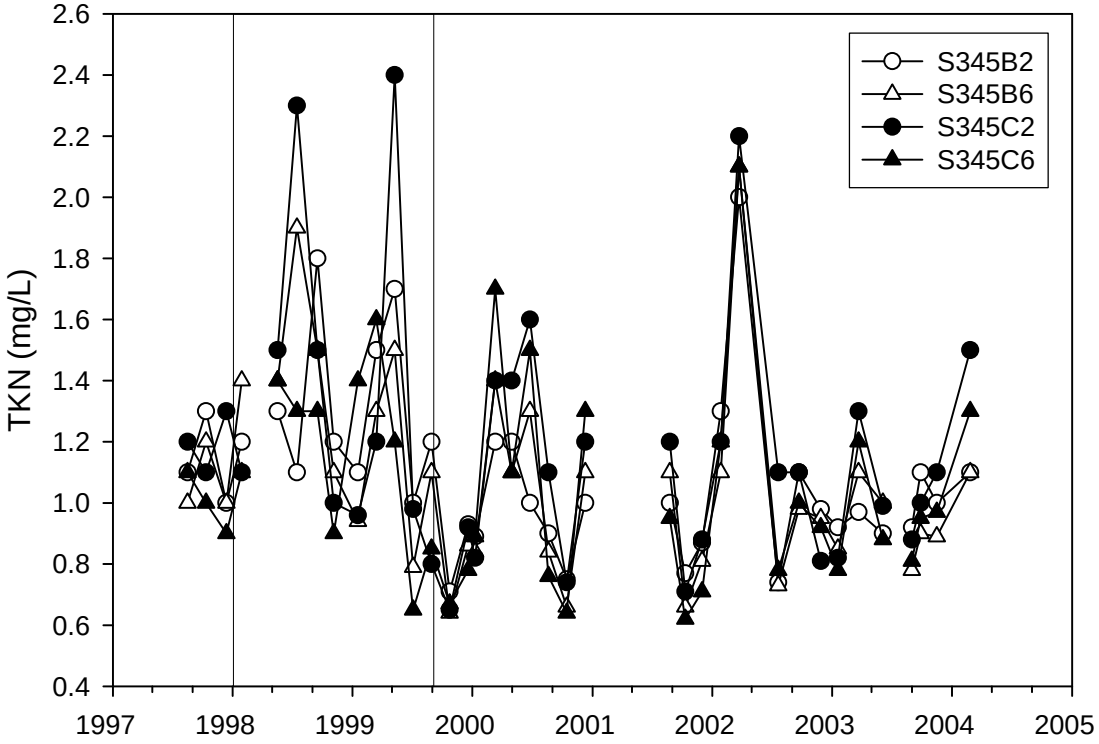

TKN (mg/L)
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
1997
1998
1999
2000
2001
2002
2003
2004
2005
S345B2
S345B6
S345C2
S345C6

Figure 5

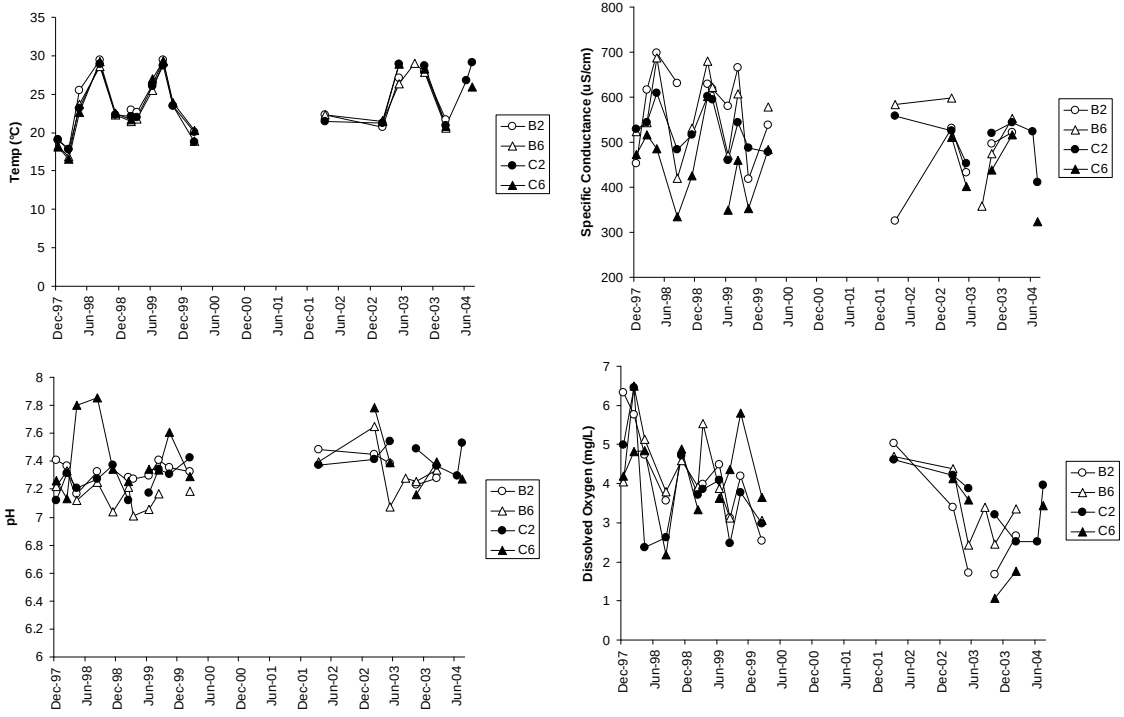

Temp (°C)
Specific Conductance (uS/cm)
pH
Dissolved Oxygen (mg/L)
B2
B6
C2
C6
Dec-97
Jun-98
Dec-98
Jun-99
Dec-99
Jun-00
Dec-00
Jun-01
Dec-01
Jun-02
Dec-02
Jun-03
Dec-03
Jun-04

Figure 6

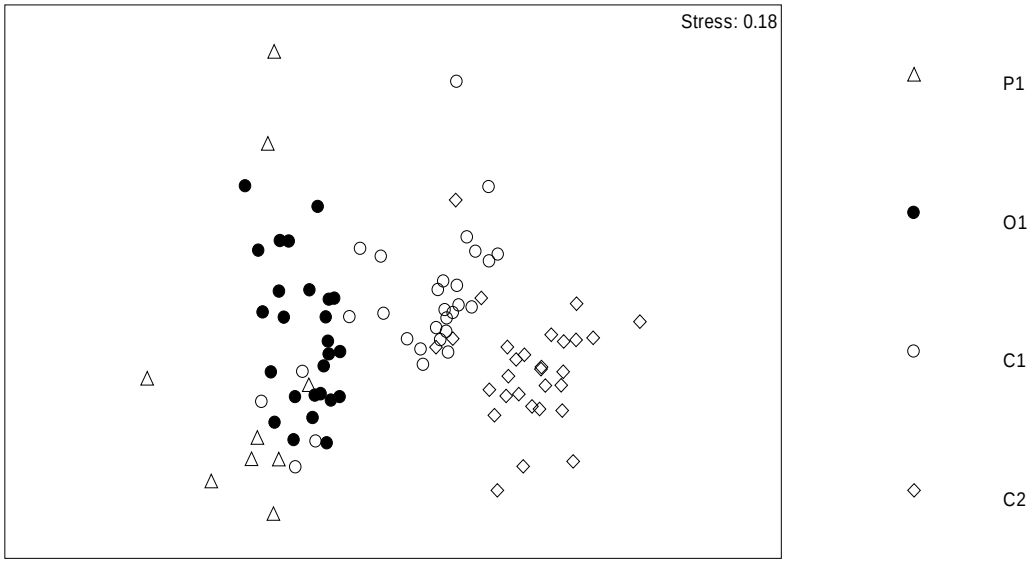


Figure 7

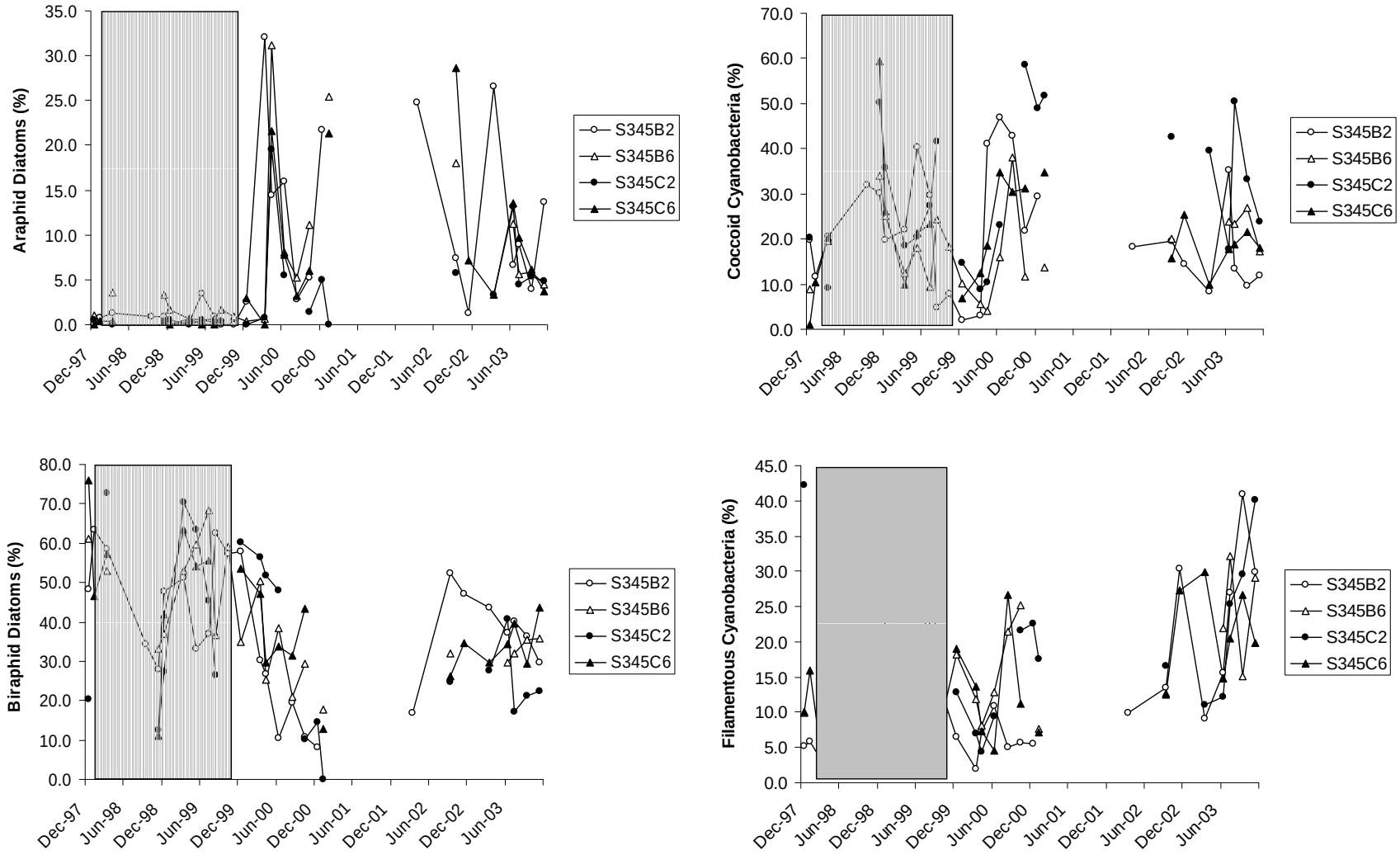

Araphid Diatoms (%)
Coccoid Cyanobacteria (%)
Biraphid Diatoms (%)
Filamentous Cyanobacteria (%)
S345B2
S345B6
S345C2
S345C6
Dec-97
Jun-98
Dec-98
Jun-99
Dec-99
Jun-00
Dec-00
Jun-01
Dec-01
Jun-02
Dec-02
Jun-03

Figure 8

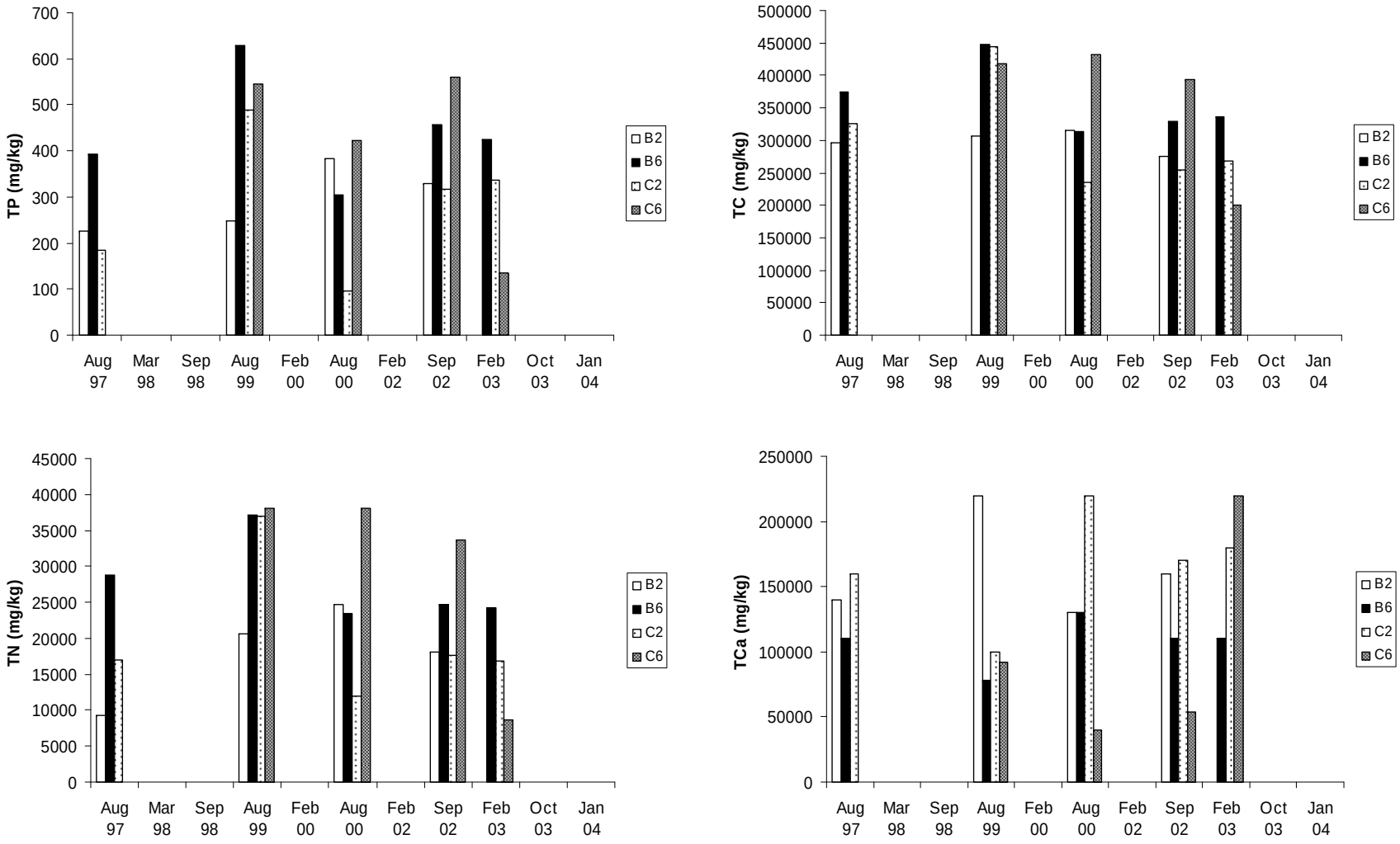

TP (mg/kg)
TC (mg/kg)
TN (mg/kg)
TCa (mg/kg)
B2
B6
C2
C6
Aug 97
Mar 98
Sep 98
Aug 99
Feb 00
Aug 00
Feb 02
Sep 02
Feb 03
Oct 03
Jan 04

Figure 9

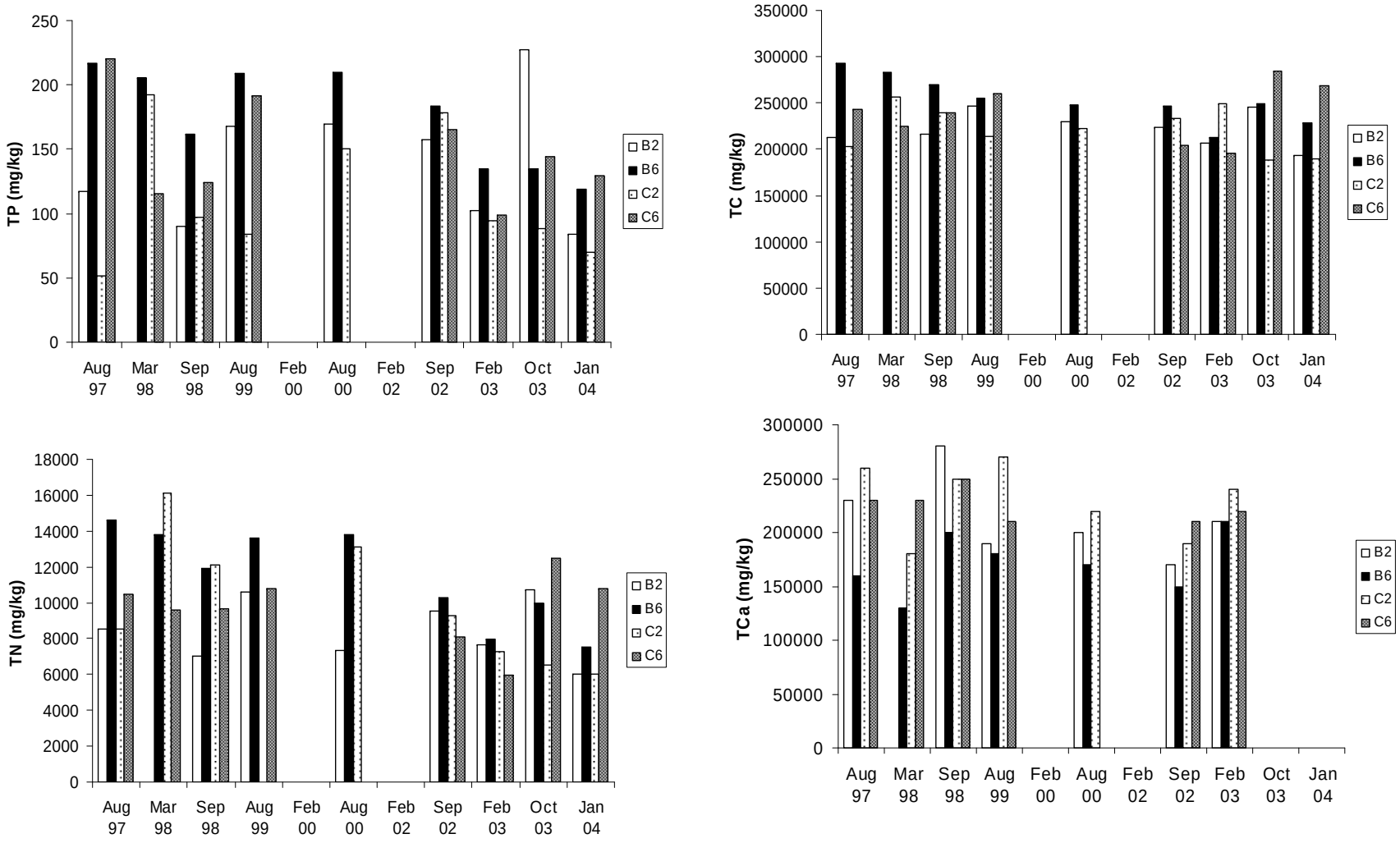
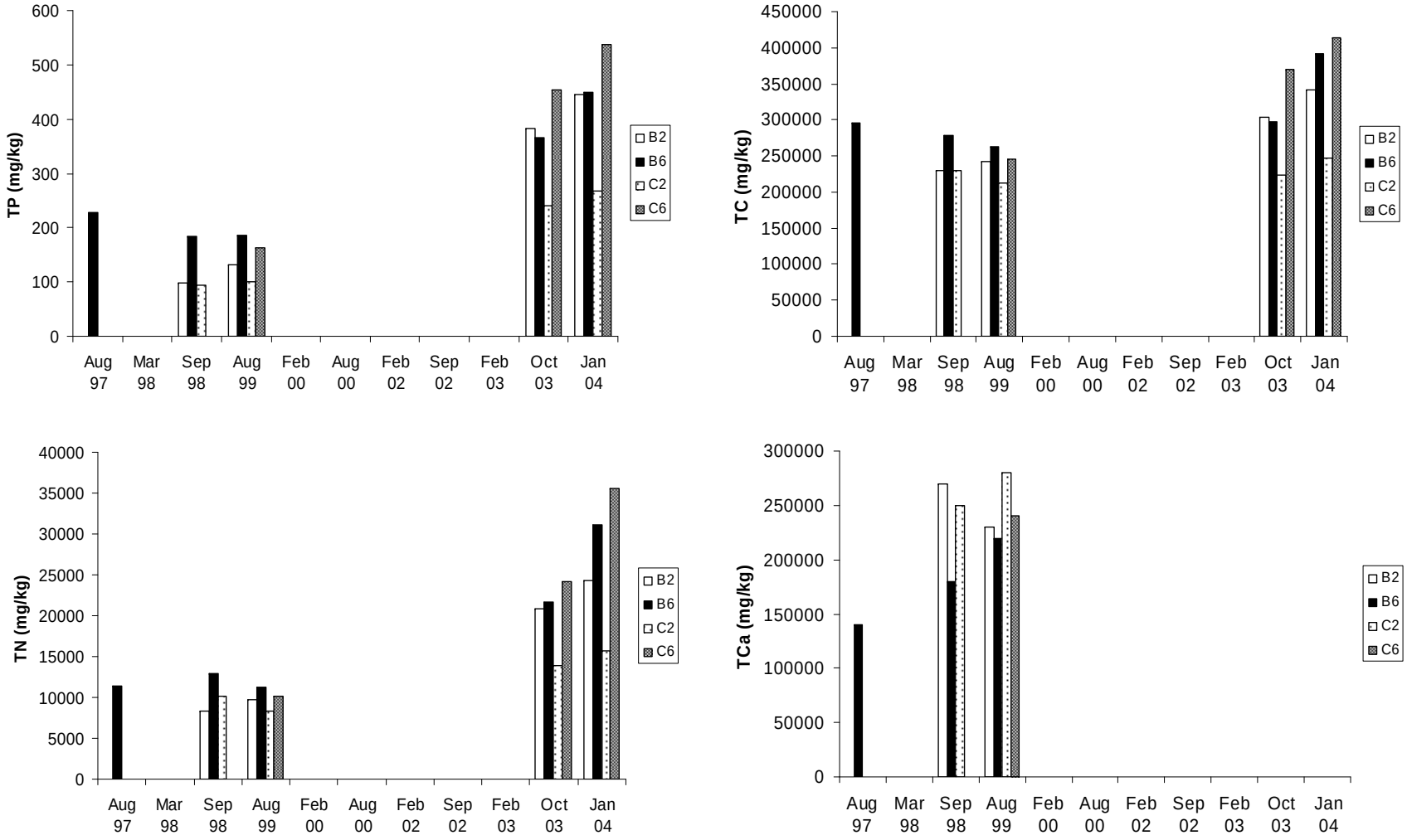

TP (mg/kg)
250
200
150
100
50
0
Aug 97
Mar 98
Sep 98
Aug 99
Feb 00
Aug 00
Feb 02
Sep 02
Feb 03
Oct 03
Jan 04
B2
B6
C2
C6
TC (mg/kg)
350000
300000
250000
200000
150000
100000
50000
0
TN (mg/kg)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
TCa (mg/kg)
300000
250000
200000
150000
100000
50000
0

Figure 10


TP (mg/kg)
600
500
400
300
200
100
0
Aug 97
Mar 98
Sep 98
Aug 99
Feb 00
Aug 00
Feb 02
Sep 02
Feb 03
Oct 03
Jan 04
B2
B6
C2
C6
TC (mg/kg)
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
TN (mg/kg)
40000
35000
30000
25000
20000
15000
10000
5000
0
TCa (mg/kg)
300000
250000
200000
150000
100000
50000
0

Appendix A: Species list and mean density for periphytometers deployed in WCA-3B for pre and post closure of the L-67A gap.

Species List	Pre-Opening (P1)	Opening (O1)	Closed (C1)	Closed (C2)
	cells/cm^2 n=9	cells/cm^2 n=30	cells/cm^2 n=29	cells/cm^2 n=25
Filamentous Cyanibacteria				
Anabaena sp.	328	696	3547	17
Anabaena subcylindrica	10	0	0	0
Borzia sp.	0	0	0	0
Borzia trilocularis	0	0	0	0
Calothrix sp.	0	0	0	0
Cylindrospermum sp.	0	0	0	1
Fortiea sp.	0	0	0	0
Fortiea bossei	3	0	0	1
Jaaginema sp.	0	0	0	2772
Leibleinia epiphytica	0	0	0	0
Limnothrix sp.	0	0	0	6
Lyngbya sp.	200	1810	2563	4
Lyngbya aerugineo-caerulea	0	0	0	1
Microchaete sp.	2	0	0	0
Oscillatoria sp.	657	1693	6652	8
Oscillatoria granulata	2	0	0	0
Oscillatoria minima	1	0	0	0
Planktolyngbya sp.	0	0	0	1655
Planktolyngbya subtilis	0	0	0	0
Planktothrix sp.	0	0	0	7
Porphyrosiphon martensianus	0	0	0	0
Pseudanabaena limnetica	1	0	0	640
Schizothrix calcicola	10	1	1	1
Scytonema sp.	5	6	1	11
Spirulina sp.	2	1	0	4
Spirulina subsalsa	0	0	1	3
Stigonema sp.	0	0	0	0
Coccoid Cyanobacteria				
Aphanocapsa sp.	0	1	6	2
Aphanocapsa incerta	4	0	0	0
Aphanothece sp.	1	2	0	12
Aphanothece clathrata	0	0	3	7
Aphanothece nidulans	0	0	1	1

Chamaesiphon sp.	0	2	0	0
Chroococcaceae	2	26	0	0
Chroococcus sp.	3	133	0	0
Chroococcus minimus	0	0	0	0
Chroococcus minor	0	0	0	0
Chroococcus minutus	3	130	69	41
Chroococcus pallidus	0	0	0	0
Chroococcus turgidus	4	0	2	3
Chroococcus varius	1	1	3	1
Cyanobium parvum	12	0	16254	11939
Cyanobium plancticum	0	0	277	2055
Cyanothece aeruginosa	0	0	1	0
Dactylococcopsis sp.	0	1	0	0
Gloeocapsa sp.	3	4	0	1
Gloeothece sp.	1	11	1	0
Johannesbaptistia pellucida	0	3	2	0
Merismopedia sp.	0	1	0	0
Merismopedia minima	0	0	0	0
Merismopedia punctata	1	0	0	0
Microcystis sp.	1	10	2	3
Rhabdoderma sp.	0	1	0	1
Rhabdoderma lineare	2	0	0	0
Synechococcus sp.	78	6236	0	1
Synechocystis sp.	0	0	0	26
Diatoms				
Achnanthes sp.	16	75	727	116
Achnanthidium exiguum	0	0	0	0
Achnanthidium minutissimum	5	62	372	145
Anomoeoneis sp.	69	32	68	0
Bacillariophyceae	1131	3372	3	3
Brachysira sp.	0	0	0	6
Brachysira serians	3	39	12	0
Brachysira serians acuta	4	0	0	0
Brachysira vitrea	823	582	905	1848
Cocconeis sp.	0	0	0	0
Cocconeis placentula	1	0	0	0
Cyclotella sp.	1	1	4	2
Cyclotella meneghiniana	0	0	0	0
Cymbella sp.	7	1	0	0
Cymbella angustata	0	0	0	0
Cymbella microcephala	11	7	28	74
Cymbellaceae	54	167	810	1870

Denticula sp.	0	0	1	1
Diploneis sp.	0	0	0	1
Diploneis oblongella	0	0	0	0
Diploneis ovalis	0	1	0	0
Encyonema sp.	0	0	0	6
Encyonema evergladianum	4	2055	4063	9140
Encyonema gracilis	293	2	0	0
Encyonema minutum	26	1	0	0
Encyonema minutum pseudogracil	0	17	1	0
Encyonema muelleri	0	1	0	0
Encyonema neomesianum	0	0	26	34
Encyonema silesiacum	0	4	0	9
Encyonopsis subminuta	0	0	1	0
Eunotia sp.	0	6	129	149
Eunotia glacialis	0	0	0	0
Fragilaria sp.	1	0	0	1
Fragilaria synegrotesca	2	66	303	376
Fragilariaceae	0	0	1753	6917
Gomphonema sp.	6	6	264	352
Gomphonema affine	0	2	1	0
Gomphonema gracile	10	24	353	9
Gomphonema hebridense	0	0	0	8
Gomphonema intricatum vibrio	3	6	1	0
Gomphonema parvulum	1	0	0	0
Gomphonema subclavatum	0	0	0	0
Gomphonema vibrio	0	0	58	61
Gomphonema vibrio intricatum	0	0	5	3
Mastogloia sp.	60	917	892	5057
Mastogloia smithii	100	524	688	2870
Mastogloia smithii lacustris	0	1	2	0
Navicula sp.	0	0	0	7
Navicula cryptocephala	0	0	0	1
Navicula cryptotenella	0	0	1	0
Navicula radiosa	0	1	3	7
Nitzschia sp.	0	2	2	10
Nitzschia amphibioides	0	0	0	1
Nitzschia frustulum	0	0	0	0
Nitzschia palea	12	4	8	1
Nitzschia serpentiraphe	2	19	20	34
Pennales	1	0	0	0
Pinnularia sp.	0	0	0	0
Rhopalodia gibba	0	0	0	0
Rossithidium linearis	1	0	0	0

Sellaphora pupula	0	2	0	0
Synedra sp.	0	0	1	0
Synedra delicatissima	1	2	4	0
Synedra ulna	4	0	0	0
Chlorophytes				
Ankistrodesmus sp.	1	1	0	4
Bulbochaete sp.	4	1	5	52
Chaetosphaeridium sp.	0	1	0	0
Chaetosphaeridium globosum	0	0	3	0
Characium sp.	0	0	0	0
Chlamydocapsa planctonica	0	0	1	0
Chlamydomonas sp.	10	6	30	0
Chlorella sp.	19	185	1697	414
Chlorococcaceae	0	1	0	0
Chlorococcum sp.	5	2	13	19
Chlorophyceae	0	2	0	0
Closterium sp.	1	0	1	1
Coelastrum sp.	0	0	0	0
Elakatothrix sp.	0	0	0	0
Gloeocystis sp.	0	4	0	0
Hormotilaceae	0	0	0	0
Kirchneriella sp.	0	0	0	0
Monoraphidium contortum	1	2	7	1
Mougeotia sp.	339	353	821	1342
Nannochloris sp.	0	0	0	2
Oedogonium sp.	19	18	16	25
Oocystis sp.	1	1	13	1
Pediastrum obtusum	0	0	0	0
Pediastrum tetras	0	0	0	0
Scenedesmus sp.	1	1	0	1
Scenedesmus arcuatus	0	0	0	0
Scenedesmus ellipticus	1	1	3	2
Scenedesmus incrassatulus	0	0	0	0
Selenastrum sp.	0	1	2	1
Spirogyra sp.	1	0	0	0
Tetraedron minimum	1	2	4	2
Tetraedron muticum	0	0	1	0
Zygnema sp.	0	0	0	0
Desmids				
Actinotaenium sp.	1	8	1	14
Cosmarium sp.	88	102	13	102

Cylindrocystis sp.	1	0	0	0
Desmidium sp.	0	0	0	1
Euastrum sp.	1	1	1	6
Genicularia sp.	0	0	0	0
Gonatozygon sp.	4	1	3	1
Hyalotheca sp.	0	0	0	0
Micrasterias sp.	0	0	0	0
Onychonema sp.	0	0	0	0
Pleurotaenium sp.	2	0	0	1
Staurastrum sp.	0	2	0	19
Staurodesmus sp.	0	0	0	0
Triploceras sp.	0	0	0	0
Other				
Derepyxis sp.	0	0	0	0
Derepyxis amphora	5	25	28	156
Dinobryon sp.	49	3	11	18
Dinobryon sertularia	0	0	13	0
Dinococcus bicornis	0	0	0	0
Kephyrion sp.	0	3	4	10
Lagynion sp.	10	0	0	0
Lagynion ampullaceum	0	0	0	2
Lagynion macrotrachelum	1	24	557	146
Lepocinclis sp.	0	0	0	0
Peridiniopsis sp.	0	9	8	16
Peridinium sp.	7	0	0	0
Phacus sp.	1	0	0	0
Stipitococcus sp.	0	0	0	0
Trachelomonas sp.	0	1	2	5

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SECTION 5

Water surface slope and phosphorus concentrations interact to determine the DPM operational window

Jed Redwine (EPJV) and Kelly Legault (USACE)

Summary

The DECOMP physical model (DPM) is designed to test hypotheses about how reintroducing flows across the L-67A and C canals affect the redistribution of sediments and suspended particles by non-linear particle transport processes. Periodic opening of eight 72" diameter culverts that are installed across the L-67A canal are intended to create a dynamic flow field in the area between the L-67A and C canals (hereafter referred to as the "pocket" area). It is expected during these pulse-flow events that the three historical sloughs present immediately downstream of the L-67A canal will experience flow velocities above a 3 cm/sec threshold that is required to suspend particles. If this occurs, it will allow the DPM to test additional hypotheses focused on the factors affecting the development of ridge and slough habitats. This document is intended to verify in which portions of the year the water stage conditions that are required to support the dynamic flow field are likely to exist, and to what degree the hydrologic constraints on operation of the DPM culverts intersect with constraints imposed by water quality. The final determination of when conditions are appropriate for the DPM culverts to be opened and pulse-experiments conducted is a consequence of the presence of appropriate water stages and the absence of relatively high concentrations of phosphorus in the marsh waters.

Introduction

The DPM science team has a high degree of confidence that the proposed design of eight 72" gated culverts across the L-67 canal and a 3000 ft gap in the L-67 canal will produce the type of dynamic flow field that is required to occur so that the specific hypotheses of the DPM can be tested in a statistically rigorous manner. This document is intended to explain the reasons why the team has this level of confidence to a broad audience of stakeholders and Project Delivery Team (PDT) members who do not have the specialized background in hydrology and ecology that is required of the DPM science team members.

Fortunately, the DPM is being planned in a portion of Water Conservation Area 3 which has been intensively monitored for over a decade. A large quantity of both historical observations and long term data sets exist that describe water quality, stages, and depths in this area. These data sets allow the science sub-team to develop specific, comprehensive insights into the past conditions around the site, and to develop a weight-of-evidence approach to describe the anticipated conditions during the 2010-2013 time period when the site will be intensively sampled and the experiment will be operated. While the future conditions of the site cannot be predicted with absolute certainty, the range of conditions that have occurred in the past can be described in a detailed manner. This description can then be used to identify the range of future conditions where it is

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certain that the DPM can be operated successfully and the proportion of the three year period where it is likely that these conditions will occur.

In addition to the long-term data sets that describe historical conditions surrounding the site, the science team has three very specific case studies available to it that support planning for the DPM. The first is a set of detailed observations of hydrologic conditions that document a 180-day test where a pair of 1000 ft gaps were opened at the L-67 A and C canals. This "gap" test allowed Dr.'s Kelly Legault (USACE), Scot Hagerthey (SFWMD), and Vic Engel (ENP)[1] to conduct an analysis of the local water depths, water surface slopes, and water flow velocities that are predicted from a set of nearby long-term monitoring gauges, and to compare these to depths and flow velocities observed directly by Vic Engel (ENP) at the site. A statistically significant (R^2 = 0.75 and 0.78) high level of agreement between the observed and predicted water velocities contributes to the DPM science team's confidence in the proposed design. This is one important component of the weight-of-evidence approach utilized by the DPM science team.

A second important set of information about the non-linear dynamics of hydrologic conditions in Everglades marshes was developed by USGS scientists including Dr.'s Judson Harvey, Laurel Larson, and Greg Noe. The results of their flow manipulation experiments are available in several peer reviewed articles (Harvey et al. 2009 and others), and these experiments led directly to the development of a conceptual model of Everglades landscape development dynamics that is linked directly to a numerical model describing peat accumulation (Larsen et al 2007). The combination of direct measurements combined with scientifically sound and peer reviewed numerical models are a strong basis for devising a large-sized project for restoring flow into a partially degraded ridge-slough landscape. There are in fact, key positive and negative feedback loops that are the principal cause of determining whether a healthy/sustainable landscape or degraded/deteriorating landscape is the result of alternative forms of decompartmentalization. The primary inference that can be drawn from the combination of research and modeling conducted so far by the USGS team is that sediment transport is the key process which, if understood clearly, will allow CERP managers and stakeholders to influence the recovery of ridges and sloughs. This capacity of engineering designs to influence the rate and trajectory of landscape recovery can only be understood in the context of how the background nutrient conditions at specific locations in the landscape interact with the realized flow fields that are created by the engineering solution. The combination of field scale experiments, conceptual models, and explicit numerical models provided by the USGS team of scientists is the second component of the DPM science team's weight of evidence approach.

The third set of information was collected and published by the South Florida Water Management District's Everglades Division. This research describes the consequences of a wide range of soil phosphorus conditions to plant and microbial communities in the Everglades Landscape (Hagerthey et al. 2008). This information can be applied in combination with the conceptual and numerical models described above to predict specific ecological consequences to alternative decompartmentalization designs. Since the DPM will be installed and operated at only one location, and since no obvious local

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gradient in soil nutrient conditions is known to exist, broader conclusions about the interaction of sediment transport and background nutrient conditions will need to be made through modeling based inference. In addition, the information present in Hagerthey et al. 2008 should be useful for attributing causes to any changes in the landscape that occur subsequent to the operation of the DPM.

One of the key constraints to the DPM is that the waters passing through the culverts should be near an ecologically determined goal of 10 ppb (or 0.010 mg/L). This goal was developed in part by research conducted by Noe et al. (2001, 2002). The TP measures made at five nearby water quality monitoring stations are presented as boxplots in Figure 1. The boxplot summarizes all of the values in a sample with the dark center line indicating the median value of the dataset, the top and bottom of the box indicating the threshold of the upper and lower quartiles of the dataset, and the whiskers extend to the range of the values in the dataset up to one and a half times the value of the interquartile range (i.e. the span of the box). Additional points that are more than one and a half times the range of the box are plotted as individual points. If the underlying dataset were normally distributed, the box and whiskers would appear symmetric. Figure 1 demonstrates that measured levels of TP in surface waters are not normally distributed in either canals or marshes and that canal waters contain generally higher concentrations of TP. The more exhaustive analysis of the TP data that is present in the TP constraints document demonstrates a seasonal cycle of TP concentrations in canal and marsh waters as well as more details about the long term TP datasets (see TP_summary_2-18-2009.doc)[2].

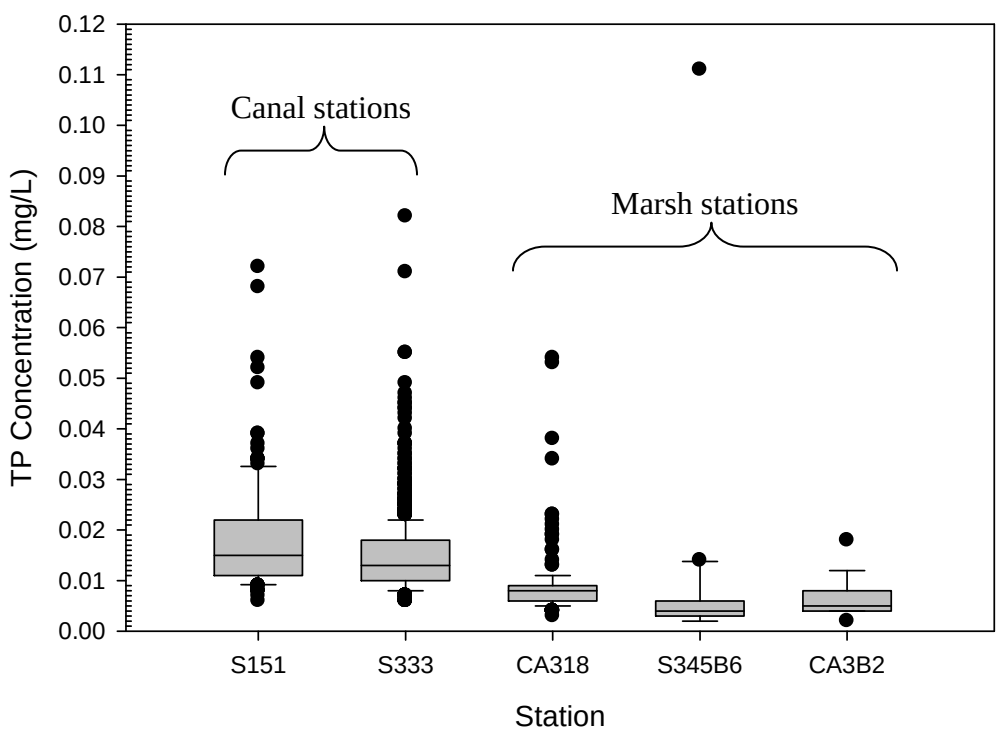


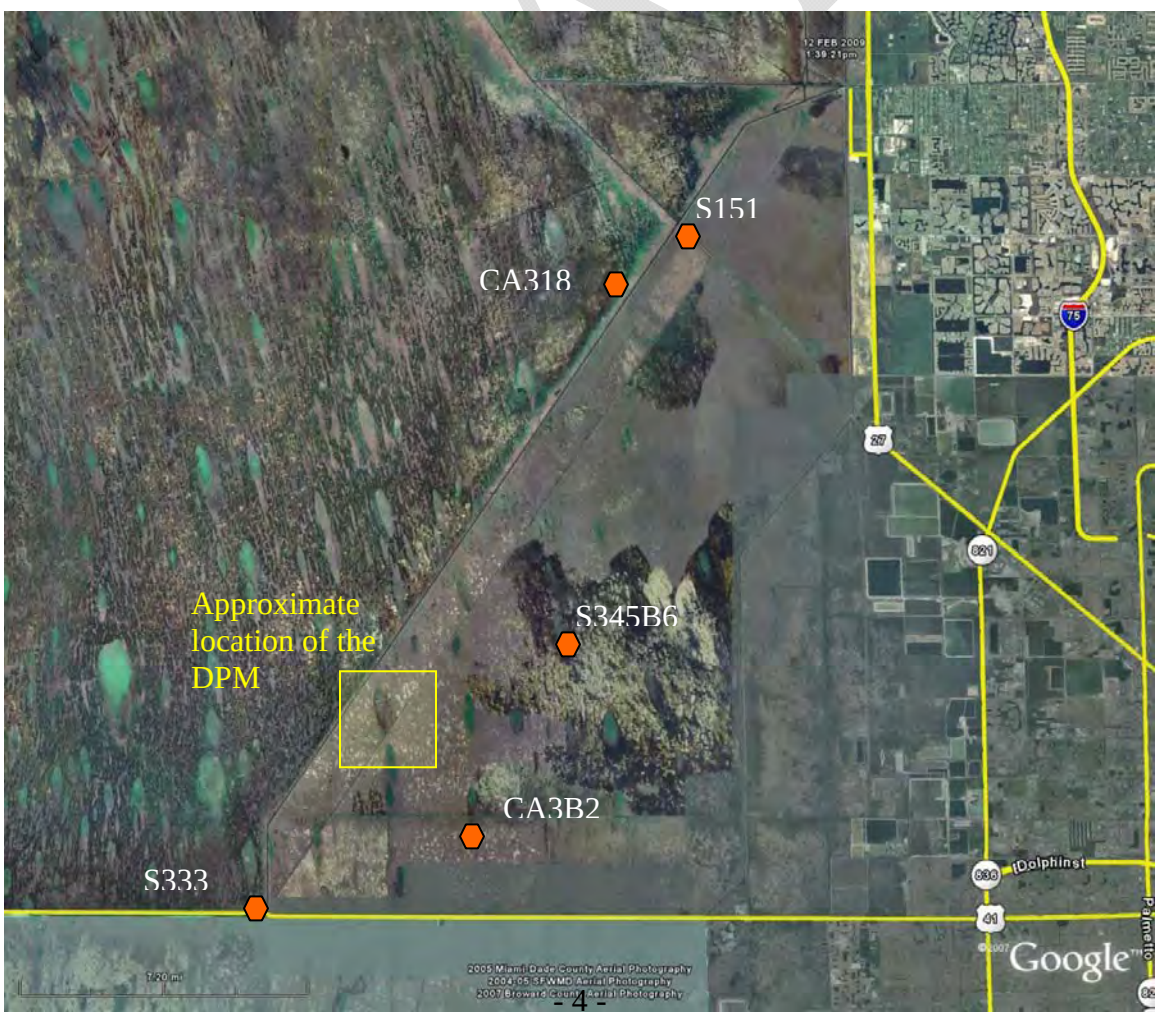
Figure 1 compares data from five water quality monitoring stations using a box and whisker plot of TP concentration data from 2000-2007.

The consequence of these water quality data to the planners of the DPM is that since the DPM will only be operated in a series of short-duration (14 days at most) periods, it is critical that these periods only occur when the team expects water quality to be dependably at or near the 10 ppb goal. This report conducts further analysis of the TP data presented in the prior TP constraints report, and attempts to determine the intersection of conditions where stages to support critical flow velocities are likely to occur in the DPM and the water that is flowing is expected to be close to 10 ppb.

Analysis:

The intersections of appropriate stage and water quality conditions that are required for the operation of the DPM were determined by the following two step process. Step one is to relate stage conditions to predicted velocities over a long period of record. Step two is to compare the periods where predicted velocities appear appropriate for operating the DPM to water quality conditions in the area over the same period of record. The following paragraphs describe the details associated with each step. In order to orient the reader to the general area of interest, Figure 2 depicts the L-67 A and C canals, the locations of all of the relevant stage and water quality monitoring sites, and the texture of the landscape in the area where the experiment is going to be conducted.

Figure 2. Locations of gauges used to monitor water surface stages and total phosphorus concentrations in marsh waters.



Step 1: Predicting velocities from long duration stage observations.
Relating water surface slopes directly to observed velocities was the primary subject of Legault et al. (2008) "Predicting water velocity from stage conditions during the L-67 gap test" report. The exhaustive analysis presented in this report concludes that there is strong agreement between water velocities predicted by Kadlec's equation for velocity in open marshes and those observed directly by USGS and ENP scientists.

$$U = K_f h^{\beta} S^{\lambda}$$

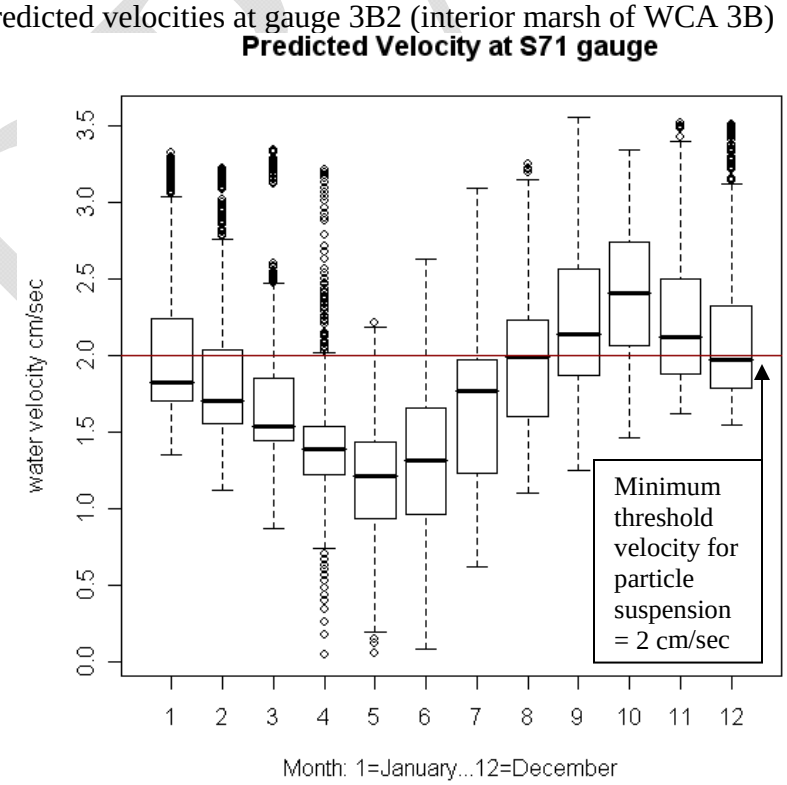
where: U= velocity
h= depth
S= hydraulic gradient

K_f, β and λ are parameters determined from non linear regression. The resulting equation used to predict velocity was:

$$U = 63.53 h^{0.744} S^{0.775} \qquad \textit{(equation 1)}$$

Since the water stage monitoring is conducted continuously, and direct observations of velocity in the marsh are rarely conducted, the statistically significant relationship between the predicted and observed water velocities is a key component of the analysis presented in this document. The agreement between water velocities calculated by Kadlec's equation (1) that utilizes water surface slopes and observed water velocities allows us to extend the period of record for predicting appropriate hydraulic conditions for the operation of the DPM to a period from 1992-2007. Figure 3 shows the distribution of predicted water velocities at gauge 3B2 (immediately downstream of the L-67 A/C gaps in WCA 3B). These monthly distributions were calculated using daily stage estimates from the S-69 W, S-69 E, and 3B2 stage monitoring sites.

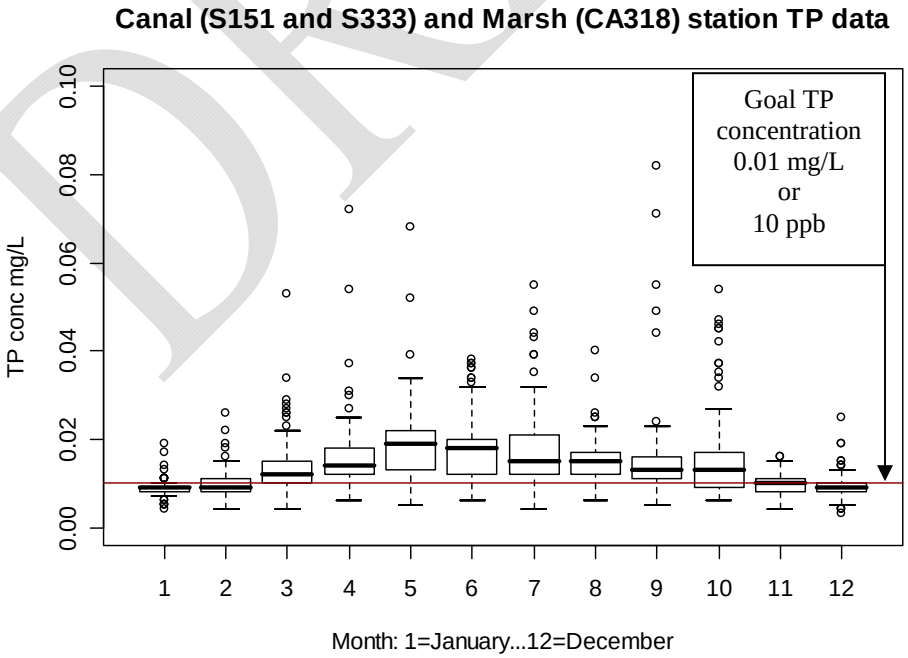
Figure 3. Predicted velocities at gauge 3B2 (interior marsh of WCA 3B)



Information from each gauge for each day between 1/1/1992 and 12/31/2007 is used to predict velocity for each day (via equation 1), and every predicted velocity calculated during this fourteen year period is displayed in Figure 3. The science subteam expects realized velocities in the L-67 A/C pocket to exceed those predicted in Figure 3, since the experimental flow field will be at least 3 kilometers closer to the L-67A levy that is the proximal cause of the stage gradient, and the water surface slope is expected to be steepest near the L-67 A levy (Legault et al. 2008, Figures 4-6). **The data presented in Figure 3 indicate that suitable stage conditions for operating the DPM are likely to exist beginning in August through January, with September through December being the most likely period that suitable stages will occur.** Calculating the precise velocities expected in the experimental field would require the development of high resolution topography coupled with dynamic hydrological modeling, and at this time the science team is comfortable that the existing analyses are sufficient for supporting the expectation that 2-3 cm/sec threshold velocities are likely to occur in the L-67 A/C pocket.

Step 2: The intersection between appropriate stage and water quality conditions. Figure 4 shows the average monthly TP values derived from the three monitoring locations where TP samples have been consistently collected from 1/1/2000 through 1/1/2009. **From this graphic it appears that the period of November through January is likely to have the most consistently low TP concentrations appropriate for opening the gated culverts**.

Figure 4. Monthly distribution of TP concentrations at both canal (S151 and S333) and marsh (CA318) water quality monitoring stations.



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Conclusion/Summary

Water surface slopes across the L-67A levy between August and January are likely to support the formation of a dynamic hydraulic flow field that contains a sufficient number of locations in the L-67 A/C pocket where water velocities will be at least 3 cm/sec. Suitable stages are very likely to occur between September to December. Both canal and marsh TP concentrations are very likely to average 10 ppb from November through January. **The weight-of-evidence approach used to identify suitable conditions for the operation of the DPM suggests that both suitable stages and water quality conditions are almost certain to occur in November, December and January, and may occur in September and October**. During September and October, care should be taken to inspect the site for indications that one of the rare high TP concentration events is occurring. This inspection could be based on a characterization of the species composition of the microbial community immediately prior to opening of the gated culverts.

Literature cited:

Publications:

Hagerthey, S.E., S. Newman, K. Rutchey, E. P. Smith, and J. Godin. 2008. Multiple regime shifts in a subtropical peatland: community-specific thresholds to eutrophication. Ecological Monographs, 78(4): 547–565.

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Reports:

[1]Legault, K. 2009. Predicting water velocity from stage conditions during the L-67 gap test. Documentum Northdocbase: Cabinets/Project Teams/Decomp/Decomp Physical Model (DPM)/Environmental Assessment/DPM Constraints

[2] Huebner, S. and J. Redwine. 2009. Summary of TP data for DPM. Documentum Northdocbase: Cabinets/Project Teams/Decomp/Decomp Physical Model (DPM)/Environmental Assessment/DPM Constraints

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ANNEX 3

CURRICULUM VITAE

CONTRIBUTING AUTHORS AND PRINCIPLE INVESTIGATORS

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VITAE

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Education:

Ph.D. 1983. Louisiana State University, Baton Rouge. Dissertation title: 'Water Budget, Benthological Characterization, and Simulation of Aquatic Material Flows in a Louisiana Freshwater Swamp.

M.S. 1976. Louisiana State University, Baton Rouge. Thesis title: 'Primary Production in the Mississippi Delta Bight Near a Shallow Bay Estuarine System.'

B.A. 1973. Rutgers College, New Brunswick, NJ.

Scientific and Technical Expertise:

Wetland restoration, adaptive management, landscape ecology, ecosystem modeling, wetland and coastal ecology, biogeochemical processes, natural resource management, marine biology, systems analysis, dynamic simulation, computer applications in environmental science, computer programming, experimental field ecology (primary production, water chemistry, hydrology, sedimentation, subsidence and accretion), physiological ecology (adenylate energy charge, scope for growth), benthic ecology, and impacts of global climate change.

Management and Policy Expertise:

Adaptive management, wetland and coastal restoration, cost/benefit analysis, plan evaluation modeling, performance measures, facilitation, conference planning, US Army Corps of Engineers project management (i.e., functional area planning, project implementation), performance appraisals, budget management for multifunctional and multidisciplinary programs, organizational planning, and strategic planning.

Positions Held:

2007-Present:	South Florida Water Management District, Director, Everglades Division
2000-2007:	South Florida Water Management District, Chief Environmental Scientist
1993-2000:	South Florida Water Management District, Sr. Supervising Scientist
1996-Present	Adjunct Professor, Department of Biology, Florida International University, Miami
2002-Present	Adjunct Professor, Department of Environmental Science, Florida A&M University, Tallahasee
1994-2001	Adjunct Professor, Rosenstiel School of Marine & Atmospheric Sci., Univ. of Miami
1987-1993:	Assistant Professor of Research, Belle W. Baruch Institute for Marine Biology and Coastal Research, University of South Carolina.
1991-1992:	Adjunct Professor, Grice Marine Lab, College of Charleston.
1985-1987:	Assistant Professor of Research, Coastal Ecology Institute, Center for Wetland Resources, Louisiana State University.
1983-1985:	Postdoctoral Research and Teaching Associate, Coastal Ecology and Fisheries Institute, Center for Wetland Resources, Louisiana State University.
1976-1979:	Research Associate, Center for Wetland Resources, Louisiana State University.

Short List of Publications:

1. Wetzel, P., A. van der Valk, S. Newman, C. Coronado, T. Troxler, D. Childers, B. Orem and F. Sklar. 2008. Heterogeneity of phosphorus distribution in a patterned landscape, the Florida Everglades. Plant Ecology. 200(1):83-90.
2. van der Valk, A.G., P. Wetzel, E. Cline and F.H. Sklar. 2008. Restoring Tree Islands in the Everglades: Experimental Studies of Tree Seedling Survival and Growth. Restoration Ecology. 16(2):281-289.

3. Rutchey, K., T. Schall and F. Sklar. 2008. Development of vegetation maps for assessing Everglades restoration progress. Wetlands. 28(3):806-816.
4. Wetzel, P.R., A.G. van der Valk, S. Newman, D.E. Gawlik, T. Troxler Gann, C.A. Coronado, D.L. Childers, and F.H. Sklar. 2005. Maintaining tree islands in the Florida Everglades: nutrient redistribution is the key. Frontiers in Ecology and the Environment 7:370–376.
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15. Sklar, F.H. and J. A. Browder. 1998. Coastal environmental impacts brought about by alterations to freshwater flow in the Gulf of Mexico. J. Environ. Mgt. 22(4):547-562.
16. Wu, Y., F.H. Sklar and K. Rutchey. 1997. Analysis and simulations of fragmentation patterns in the Everglades. Ecol. Application. 7(1):268-276.
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20. Costanza, R., F.H. Sklar and M. White. 1990. Modeling coastal landscape dynamics. Bioscience. 40(2):91-107.
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Curriculum Vitae

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Education

Ph.D. 1996. Michigan Technological University, Houghton, Michigan. Thesis: The Ecological Significance of Groundwater-Lake Interactions: Epibenthic Algal Communities. Advisor- Dr. W. Charles Kerfoot.

B.S. 1989. East Carolina University, Greenville, North Carolina. Research Project: Hydrologic Features of a Groundwater Slope Wetland at Otter Creek Natural Area, Pitt County, North Carolina. Advisor- Dr. Mark Brinson.

Professional Experience

2007-Present:	Lead Environmental Scientist, South Florida Water Management District
2002-2007:	Senior Environmental Scientist, South Florida Water Management District
2008-Present:	Courtesy Assistant Professor, Soil and Water Science Department, University of Florida
2002-2002:	Assistant Research Scientist, Center for Freshwater Studies, University of Alabama
2001-2002:	Visiting Assistant Research Professor, Center for Marine Science, University of North Carolina at Wilmington
1998-2001:	Post Doctoral Research Fellow, Gatty Marine Laboratory, University of St. Andrews, Scotland
1996-1998:	Post Doctoral Research Fellow and Co-Principle Investigator, Michigan Technological University

Publications: In Print

Hagerthey, Scot E., Susan Newman, Ken Rutchey, Eric P. Smith, and Jason Godin. 2008. Multiple Regime Shifts in a Subtropical Wetland: Establishing Community Specific Thresholds to Eutrophication. Ecological Monographs 78(4) 547-565.

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Hagerthey, Scot E. Brent Bellinger, Kristin Wheeler, Miroslav Gantar, Evelyn Gaiser. *In Review.* Everglades Periphyton: A Biogeochemical Perspective. Critical Reviews in Environmental Science and Technology.
Gaiser, Evelyn, Paul V. McCormick, and Scot E. Hagerthey. *In Review.* Landscape Patterns of Periphyton in the Florida Everglades. Critical Reviews in Environmental Science and Technology.
Newman, Sue and Scot E. Hagerthey. *In Review.* Water Conservation Area 1- A Case Study of Hydrology, Nutrient, and Mineral Influences on Biogeochemical Processes. Critical Reviews in Environmental Science and Technology.
Larsen, Laurel, Nicholas Aumen, Christopher Bernhardt, Vic Engel, Thomas Givnish, Scot Hagerthey, Judson Harvey, Lynn Leonard, Paul McCormick, Christopher McVoy, Gregory Noe, Martha Nungesser, Kenneth Rutchey, Fred Sklar, Tiffany Troxler, John Volin, Debra Willard. *In Review.* Recent and Historic Drivers of Landscape Change in the Everglades Ridge, Slough, and Tree Island Mosaic. Critical Reviews in Environmental Science and Technology.
Bellinger, Brent J. and Scot E. Hagerthey. *In Review.* Presence and Diversity of Cyanotoxins from Periphyton of the Florida Everglades, USA. Journal of Phycology.
Bellinger, Brent J., Michael R. Gretz, David S. Domozych, Sarah N. Kiemle, and Scot E. Hagerthey. *In Review*. Contrasting EPS Composition for Periphyton Assemblages in the Florida Everglades. Journal of Phycology.

Synergistic Activities

- Co-PI on project entitled "*Cattail Habitat Improvement Project- CHIP: Options for Accelerating Recovery of Phosphorus Impacted Areas of the Florida Everglades*" with Dr. Sue Newman and Dr Mark Cook (SFWMD)
- Graduate Advisor, Florida Atlantic University and Florida International University

Collaborators

Jon Cole (Cary Institute for Ecosystem Studies), Mike Gretz (Michigan Technological University), William J. Louda (Florida Atlantic University), David S. Domozych (Skidmore College), Evelyn Gaiser (Florida International University), Joel Trexler (Florida International University), Kevin Black (PARTRAC , LTD), Ramesh Reddy (University of Florida), Patrick Inglett (University of Florida)

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Professional Preparation

1987 – 1991 New College of South Florida, Environ. Studies, B.A.
1993 – 1995 Univ. of Florida, Gainesville, FL., Systems Ecology, M.Sc.
1997 – 2002 Columbia Univ., New York NY, Earth and Environ. Sci., Ph.D.
2002 – 2003 Duke Univ., Durham NC., Post-doctoral research associate in Biology

Appointments

2007 - present **Member** Exec. Steering Committee, Fla. Coastal Everglades LTER
2005 - present **Co-chairman,** Greater Everglades CERP Assessment Team
2004 – present **Collaborating Scientist**, Florida Coastal Everglades LTER
2003 – present **Hydrologist GS-13,** Everglades National Park, Homestead, FL.

Publications

He G, **Engel VC**, Leonard L, Croft A, Childers D, Laas M, Deng Y, and Solo-Gabriele H 2009. Factors controlling surface water flow in a low gradient subtropical wetland. *Accepted*: Wetlands

Barr JG, Fuentes JD, **Engel VC**, and Zieman JC. 2008. Physiological responses of red mangroves to the climate in the Florida Everglades. In Press: *J. of Geophysical Research-Biogeosciences*

Variano EA, Ho DT. **Engel VC**, Schmeider PJ, and Reid MC. 2009. Flow and mixing dynamics in patterned wetland: kilometer-scale tracer releases in the Everglades. In Press: *Water Resources Res.*

Ho DT, **Engel VC**, Variano EA, Schmeider PJ, and Condon ME 2008. Tracer studies of sheetflow in the Everglades. In Press*: Geophysical Res. Letters*

Warrach K, Stieglitz M, Shaman J, **Engel VC**, Griffin KL, 2006. Twentieth century climate in the New York Hudson highlands and the potential impacts on eco-hydrological processes. Climatic Change 75: 455-493.

Engel VC, Jobbagy E, and Jackson RB. 2005. The hydrologic consequences of *Eucalypt* afforestation in the Argentine Pampas. Water Resources Res. 14(10)

Engel VC, Griffin K, Murthy R, Climas K, Patterson L, and Potosnak M. 2004. Growth CO_2 modifies the transpiration response of *P. deltoides* to drought and vapor pressure deficit. Tree Phys. 24, 1137-1145

Engel VC, Stieglitz M, Griffin K, and Williams M. 2002. Canopy hydraulic conductance and catchment water balance: observations and modeling. Ecol. Modeling 154 (3): 263-288

Shaman, J., Stieglitz, M., **Engel, VC**, Koster, R., and Stark, C. 2001. Representation of

subsurface stormflow and a more responsive water table in a TOPMODEL-based hydrology model. Water Resources Res. *38* (8)

Engel VC, and Odum HT. 1999. Simulation of community metabolism and atmospheric carbon dioxide and oxygen concentrations in Biosphere 2. Ecol. Eng. (13) 107-134.

Synergistic Activities

- Co-PI on project entitled "*Vegetation Dynamics in Relation to Hydrology and Flow in the Everglades*" with Dr. Marc Stieglitz (Ga Tech)
- Co-PI on a project entitled "*Mangrove forest functioning in response to hurricane disturbance*" with Jose Fuentes (Univ. of Virginia) funded in FY09-10 by DOE National Institute of Climate Change Research
- Co-PI and ENP Agreements Representative for a project entitled "*Determination of large-scale flow patterns and air-water gas exchange in ridge and slough habitat using a conservative tracer*, with David Ho (University of Hawaii) and Evan Variano (Berkeley).
- Co-PI and ENP Agreements Representative for a project entitled "*Tree Islands in the ridge and slough landscape: current status, historical changes, and hydrologic impacts on population dynamics and moisture relations*", with Michael Ross and Steve Oberbauer (FIU), and Leonel de la Silva Sternberg (University of Miami).

Collaborators:

Jordan Barr (Everglades National Park), Daniel L. Childers (Arizona State University), Paolo D'Odorico (University of Virginia), Charles Downer (US Army Corps of Engineers), Sharon Ewe (Ecology and Engineering Inc), Jose D. Fuentes (University of Virginia), David Ho (University of Hawaii), Steven Oberbauer (Florida International University), Michael Ross (Florida International University), Colin Saunders (South Florida Water Management District), Leonel de la Silva Sternberg (University of Miami), Marc Stieglitz (Georgia Tech University), Michael Sukop (Florida International University), Evan Variano (Berkeley University), Fernando Miralles-Wilhelm (Florida International University)

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RESEARCH INTERESTS

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EDUCATION

Ph.D. 1990, Environmental Sciences (Hydrology), University of Virginia.
M.S. 1986, Environmental Sciences (Hydrology), University of Virginia.
B.A. 1979, Environmental Sciences (Biology), New College.

PROFESSIONAL EXPERIENCE

2003 – 2008: Research Advisor to Chief Scientist, Research Hydrologist, and Project Chief, USGS National Research Program, Reston, VA.
1998-present: Research Hydrologist and Project Chief, 'Hydro-ecology of Flowing Waters, USGS National Research Program, Reston, VA.
1995-1998: Research Hydrologist, USGS National Research Program, Reston, VA.
1992- 1995: Research Hydrologist, USGS National Research Program, Menlo Park, CA.
1990-1992: National Research Council Postdoctoral Fellow, U.S. Geological Survey, Menlo Park, CA.
1983-1990: Teaching and Research Assistantships, University of Virginia.
1982-1983: Staff Scientist, Natural Resource Department, Collier County, FL.
1979-1982: Assistant Staff Scientist, Mote Marine Laboratory, FL

HONORS

2002 Superior Service Award, U.S. Geological Survey
2008, 2007, 2000, 1995 STAR Award, U.S. Geological Survey
1995 (summer) Parker Fellow, Hokkaido River Disaster Prevention Center, Sapporo, Japan.

PROFESSIONAL SOCIETIES

American Geophysical Union, American Society of Limnology and Oceanography, Geological Society of America

RECENT PROFESSIONAL SERVICE

Society of Wetland Scientists, Associate Editor, *Wetlands*, January 2005 - 2008.
American Geophysical Union, Associate Editor, *Water Resources Research*, January 2001 - 2003. Water Quality Committee, January 1998 -2002.
National Academy of Science, Water Science and Technology Board, Committee on Riparian Zones, October 1999 – March 2002.
National Academy of Science, Water Science and Technology Board, Committee on Hydrologic Science, Invited Presentation at the workshop 'Towards Integration of Hydrological and Ecological Sciences'. October 26–27, 2000.
National Center for Environmental Analysis and Synthesis (NSF sponsored center at UCSB, Santa Barbara), Working Group on Merging Aquatic and Terrestrial Perspectives of Biogeochemistry, July 1999 – October 2000.
Reviewer: *Water Resources Research, Limnology and Oceanography, Hydrological Processes, Ground Water, Journal of Hydrology, Journal of Contaminant Hydrology, Applied Geochemistry, Applied Hydrogeology*

SYNERGISTIC ACTIVITIES
Rappeteur for ASLO working group on "Emerging Research Questions for Limnology", December, 2002. Convener of technical sessions on surface-water and groundwater interactions (Dec. 2004; Dec. 2001; May 1998; Dec. 1994; Oct. 2006). Instructor at USGS training courses on measuring and modeling contaminant fate and transport at terrestrial-aquatic interfaces. Co-author of "Ground Water and Surface Water: A Single Resource", fourth printing (40,000) as a USGS circular.

FIVE SIGNIFICANT PUBLICATIONS
O'Connor, B.L., and Harvey, J.W., 2008. Scaling hyporheic exchange and its influence on biogeochemical reactions in aquatic ecosystems. *Water Resources Research*, 44, W12423.
Larsen, L.G., Harvey, J.W., and Crimaldi, J.P., 2007. A delicate balance: ecohydrological feedbacks governing landscape morphology in a lotic peatland, *Ecological Monographs*, 77(4): 591-614.
Wörman, A., Packman, A.I., Marklund, L., Harvey, J.W., and Stone, S.H., 2007, Fractal topography and subsurface flows from fluvial bedforms to the continental shield, *Geophysical Research Letters*, 34, L07402, doi:10.1029/2007GL029426.
Harvey, J.W., M.H. Conklin, and R.S. Koelsch, 2003, Predicting changes in hydrologic retention in an evolving semi-arid alluvial stream. *Advances in Water Resources* 26: 939-950.
Harvey, J.W., and B.J. Wagner, 2000, Quantifying hydrologic interactions between streams and their subsurface hyporheic zones, pp 3-43 in Jones, J.A. and P.J. Mulholland, (eds), Streams and Ground Waters, Academic Press, San Diego.

FIVE OTHER PUBLICATIONS
Harvey, J.W., Newlin, J.T., and Krupa, S.L., 2006. Modeling decadal timescale interactions between surface water and ground water in the central Everglades, Florida, USA. *Journal of Hydrology*, 320:400-420.
Scott, D., Harvey, J.W., Alexander, R.A., and Schwarz, G.E., 2006. Dominance of organic nitrogen from headwater streams to large rivers across the conterminous US. *Global Biogeochemical Cycles, GB1003*, doi:10.1029/2006GB002730.
Bohlke, J.K., J.W. Harvey, M.A. and Voytek, 2004, Reach-scale isotope tracer experiment to quantify denitrification and related processes in a nitrate-rich stream, mid-continent United States. *Limnology and Oceanography* 49(3):821-838.
Saiers, J.E., J.W. Harvey, and S.E. Mylon, 2003, Surface-water transport of suspended matter through wetland vegetation of the Florida Everglades. *Geophysical Research Letters* 30(19), 1987, doi:10.1029/2003GL018132.
McClain, M.E., Boyer, E.W., Dent, C.L., Gergel, S.E., Grimm, N.B., Groffman, P.M., Hart, S.C., Harvey, J.W., Johnston, C.A., Mayorga, E., McDowell, W.H., Pinay, G., 2003, Biogeochemical hot spots and hot moments at the interface of terrestrial and aquatic ecosystems, *Ecosystems* 6(4):301-312. doi: 10.1007/s10021-003-0161-9.

COLLABORATORS IN PAST FIVE YEARS: Alexander, R.A., Bohlke, J.K., Boyer, E.W., Cardenas, M.B., David, M.B., Hondzo, M., Krest, J.M., Krupa, S.L., Larsen, L.G., Mulholland, P.J., Mylon, S.E., Newlin,, J.T., Noe, G.B., O'Connor, B.L., Packman, A.I., J.E., Schwarz, G.E., Smith, L.K., Smith, R.L., Seitzinger, S.P., Tobias, C.R., Voytek, M.A., Wollheim, W.M., Worman, A.

ADVISEES: Postdoctoral: Ben O'Connor (USGS) 2006 – , Durelle Scott (USGS) 2003 – 2005, James Krest (USGS) 2000 – 2003, Jungyill Choi (USGS)1998 - 2001; PhD: Jesus Gomez (New Mexico Institute of Mining and Technology), Laurel Larsen (University of Colorado), Craig Tobias (Virginia Institute Marine Science), Jungyill Choi (University of Arizona); M.S.: Scott Hulseapple (University of Arizona), Roger Koelsch (University of Arizona), Elizabeth Robbins (University of Arizona). B.S.: Jonah Jackson (University of Virgina)

GRADUATE ADVISERS: George Hornberger, William Odum, William Nuttle, Peter Germann
POSTDOCTORAL ADVISER: Kenneth Bencala

Laurel Griggs Larsen

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PROFESSIONAL PREPARATION

B.S. 2003, Systems Science and Mathematics, Environmental Studies, Washington University in St. Louis.

M.A. 2003, Earth and Planetary Sciences (Hydrology), Washington University in St Louis.

Ph.D 2008, Civil, Environmental, and Architectural Engineering, University of Colorado, Boulder

APPOINTMENTS

2008-present: Research Hydrologist, U.S. Geological Survey
2003-2008: Research Assistant, University of Colorado
2001-2003: Fossett Fellow (student research appointment): Washington University in St. Louis
2000-2000: Research Assistant, University of Central Florida.
1999-1999: HHMI Prefreshman Summer Biology Scholar, Washington University in St. Louis.

SELECTED PUBLICATIONS

Larsen, L.G., J.W. Harvey, and J.P. Crimaldi, 2007, A delicate balance: feedback mechanisms affecting landscape patterns and function in a low-gradient, pulsed flow peatland. *Ecological Monographs*

Harvey, J.W., R. W. Schaffranek, G. B. Noe, L. G. Larsen, D. Nowacki, and B. L. O'Connor, in press, Hydro-ecological factors governing surface-water flow on a low-gradient floodplain, *Water Resources Research*, doi:10.1029/2008WR007129.

Larsen, L. G., J. W. Harvey, and J. P. Crimaldi, 2009, Morphologic and transport properties of natural organic floc, *Water Resources Research* 45, W01410, doi:10.1029/2008WR006990.

Larsen, L. G., J. W. Harvey, G. B. Noe, and J. P. Crimaldi, 2009, Predicting organic floc transport dynamics in shallow aquatic ecosystems: Insights from the field, the laboratory, and numerical modeling, *Water Resources Research* 45, W01411, doi:10.1029/2008WR007221.

Larsen, L.G., 2008, Hydroecological feedback processes governing self-organization of the Everglades ridge and slough landscape, Ph.D dissertation, University of Colorado, Boulder, CO.

OTHER PUBLICATIONS

Larsen, L.G. and J.P. Crimaldi, 2006, The impact of photobleaching on planar laser-induced fluorescence (PLIF). *Experiments in Fluids* 41, 803-812.

Griggs, L, 2003, Development and testing of a coupled heat and moisture transfer model to assess subsurface moisture gradients, M.A. thesis, Washington University, St. Louis, Missouri.

SYNERGISTIC ACTIVITIES

- Member of Science Subteam, Decompartmentalization Physical Model, Comprehensive Everglades Restoration Plan, 2007-present
- Author, One Night in the Everglades, a children's book that will be integrated into the curriculum of south Florida elementary schools
- Chair, Hydrologic Sciences Student Symposium, University of Colorado, May 2006
- Member, sediment and landscape dynamics technical committee, AGU, 2006-2008
- Science fair advisor and mentor, Forest Hill Community High School, West Palm Beach, FL, 2006-2008

COLLABORATORS

Judson Harvey, USGS
John Karl Bohlke, USGS
Mary Voytek, USGS
Matthew Kirwan, USGS
John Crimaldi, University of Colorado
Gregory Noe, USGS
Raymond Schaffranek, USGS
Benjamin O'Connor, USGS
Amy Burgin, Wright State University

GRADUATE ADVISORS

John Crimaldi, University of Colorado
Judson Harvey, USGS, Reston, VA
George Aiken, USGS, Boulder, CO
Diane McKnight, University of Colorado
John Pitlick, University of Colorado
Joseph Ryan, University of Colorado
Raymond Arvidson, Washington University
Roger Phillips, Washington University
Robert Criss, Washington University

THESIS ADVISOR AND POSTRGRADUATE-SCHOLAR SPONSOR

Not applicable.

Kelly Rankin Legault, Ph.D.

US Army Corps of Engineers
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RESEARCH INTERESTS

Bottom Shear Stress; Nearshore Sediment Transport; Boundary Layer Dynamics; Surf Zone Processes; Nearshore Mixing; Estuarine Circulation; Fate and Transport of Contaminated Sediments; Coastal Structures; Wave Transformation in the coastal zone; Times Series Analysis; Flow / Organism Interaction

EDUCATION

Institution	*Degree, Major, Year*
Stevens Institute of Technology	Ph.D., Ocean Engineering, 1997

Stanley Fellow, Department of Civil, Environmental and Ocean Engineering, Stevens Institute of Technology; $70,000; 1995-1997

Stevens Institute of Technology	M.E.., Ocean Engineering, 1994

Stanley Fellow, Department of Civil, Environmental and Ocean Engineering, Stevens Institute of Technology; $50,000; 1992-1994

Rutgers University	B.S., Env. Sci./Marine Ecol.,1992 (summa cum laude)

George H. Cook Scholar: $40,000; 1988-1992

W.H.O.I. Summer Fellow, Woods Hole Oceanographic Institution**,** Redfield Laboratory of Marine Biological Sciences. 1991

PROFESSIONAL EXPERIENCE

Years	*Position, Institution*
3/2009 – present	Senior Coastal Engineer, USACE
3/2008 - 3/2009	Senior Hydraulic Engineer, USACE
3/2005 – 3/2008	Coastal Scientist, Ocean and Coastal Consultants
6/2003 – 2/2005	Adjunct Senior Research Scientist, Bigelow Laboratory for Ocean Science
5/1997 – 5/2003	Research Professor, Stevens Institute of Technology
6/1992 - 5/1995	Research Assistant, Stevens Institute of Technology

PAPERS / PROJECTS ***(née Rankin)***

Guest Editor – Journal of Coastal Engineering. Special Issue 33: Function and Design of Coastal Groins

Rankin, K.L., M.S. Bruno, T.O. Herrington, and P.B. Burke. (2004). "Observations of Nearshore Hydrodynamics and Sediment Transport in the Vicinity of a Notched Groin." J. Coastal Res. SI 33. pp. 237-254.

Rankin, K.L., T.O. Herrington, M.S. Bruno, and A.M. Pence. (2004). "Analysis of Notched Groins and Sediment Transport." J. Coastal Res. SI 33. pp. 255-268.

Bruno, M.S., K.L. Rankin and T.O. Herrington. (2001). "Re-engineering existing coastal structures: design guidelines and impacts." Coastlines, Structures and Breakwaters 2001, London, England, ASCE.

Rankin, K.L. and R.I. Hires. (2000). “Laboratory Measurement of Bottom Shear Stress on a Movable Bed", J. Geophys. Res., 105, C7, pp. 17011-17019.

Herrington, T.O., M S. Bruno, and K. L. Rankin. (2000). “The New Jersey Coastal Monitoring Network: A Real-Time Coastal Observation System." J. of Mar. Env. Eng., 6, 1, Gordon and Breach.

Rankin, K.L., Mullineaux, L.S. and W.R. Geyer. (1994). “Transport of juvenile gem clams (Gemma gemma) in a headland wake.” Estuaries, 17 (3), pp. 655-667.

CLUBS AND SOCIETIES

Sigma Xi; SNAME; American Geophysical Union; American Shore and Beach
The Explorers Club

SELECTED PRESENTATIONS/POSTERS

Herrington, T.O., Legault, K.R. (2008) “Nearshore Circulation and Sediment Transport in the Vicinity of Notch Groins.” *Nicholas C. Kraus Honorary Symposium.* March 9-10, 2009. Florida Institute of Technology. Melbourne, FL.

Legault, K.R, T.H. Hillier, J.F. Marrone (2007) “Application of US Army Corps of Engineers Coastal Engineering Manual Wave Runup Methodologies to FEMA Coastal Flood Hazard Mapping Projects” *ASCE Coastal Protection Manual Workshop,* October 11-12, Woods Hole, MA.

Legault, K.R, M.S. Bruno, D. Gaffney, K. Schmid (2006) “Very Low Profile Groins at Stump Pass State Park, Florida.” *American Shore and Beach Association, Annual Conference,* October 9-11, 2006, Long Branch, NJ.

Pence, A., M.S. Bruno, A.F. Blumberg, N. Dimou, and K.L. Rankin. (2005). “Elucidation of the Major Processes of Circulation and Dispersion in the Newark Bay Complex”. Third International Conference on Remediation of Contaminated Sediments, New Orleans, January 24-27, 2005.

Rankin, K.L. (2005) “Wave Transformation and Nearshore Currents in the Vicinity of a Coral Reef” *Florida Shore and Beach Association; Technical Conference,* February 2 – 4, 2005, Destin FL.

Lemieux, E.J, Rankin, K.L., Brown, R. and W. Hyland. (2004) “Relevant Factors in Engineering and Design of Test Facilities for Testing Ballast Water Treatment Devices.” *Second International Ballast Water Management Conference,* May, Singapore.

Lapointe, B.E., Barile, P.J., Rankin, K.L. and C.S. Yentsch. (2003). “Physiology and ecology of macroalgal blooms (green tides) on coral reefs off northern Palm Beach County, Florida (USA).” Second Symposium on Harmful Marine Algae in the U.S., December 8 – 13, 2003, Woods Hole, MA.

Rankin, K.L., R. Chant, M.S. Bruno and S. Glenn. (2002) “Meteorological Forcing of the Kills in New York Harbor.” *AGU Fall Meeting, Abstract published in EOS Transactions,* AGU December, San Francisco.

Susan Newman
Everglades Division, South Florida Water Management District, 3301 Gun Club Road, West Palm Beach, FL 33406. Tel: 561-682-6608, Fax: 561-682-5608, snewman@sfwmd.gov

Research Interests
Wetland biogeohemistry, nutrient dynamics within the plant-sediment-water interface, plant competition among wetland plant species, hydrologic needs of wetland plants, wetland ecology and restoration.

Education
B.Sc. Honors 1984. University of Manchester Institute of Science and Technology, Joint Honors Degree in Management and Chemical Sciences.
M.S. 1987, University of Florida, Major in Agronomy (aquatic plants), minor in Soil Science, Advisor W.T. Haller.
Ph.D. 1991, University of Florida, Major in Soil Science (wetland biogeochemistry), minor in Environmental Engineering Sciences (water chemistry). Advisor K.R. Reddy

Appointments

Years	*Position, Institution*
2008-Present	Senior Scientific Section Lead, South Florida Water Management District
2000-2008	Senior Supervising Environmental Scientist, South Florida Water Management District
1992-2000	Senior Environmental Scientist, South Florida Water Management District
1991-1992	Staff Environmental Scientist, South Florida Water Management District
1997-present	Courtesy Assistant Professor, Soil and Water Science Department, University of Florida

Synergistic Activities
1. Editorial Board, *Journal of Environmental Quality (2009-2011)*
2. Project collaborator, USDA-NRI examining phosphorus sequestration in wetlands.
3. Advisor and committee member for graduate students at UF

Five Relevant Publications (of 52)
Hagerthey, S.E., **S. Newman**, K. Rutchey, E.P. Smith, and J. Godin. 2008. Multiple regime shifts in a subtropical peatland: establishing community specific thresholds to eutrophication. Ecol. Mono. 78(4): 547-565.
Penton, C.R. and **S. Newman**. 2008. Enzyme resource allocation influences on landscape heterogeneity in the Florida Everglades. J. Env. Qual. 37:972-976.
Bruland, G.L., T.Z. Osborne, K.R. Reddy, S. Grunwald, **S. Newman** and W.F. DeBusk. 2007. Recent changes in soil total phosphorus in the Everglades: Water Conservation Area 3. Environ. Monitor. Assess. 129:379-395.
Newman, S., P.V. McCormick, and J.G. Backus. 2003. Phosphatase activity as an early warning indicator of wetland eutrophication: problems and prospects. J. Appl. Phycol. 15:45-59.
Newman, S., H. Kumpf, J.A. Laing, and W.C. Kennedy. 2001. Decomposition Responses to Phosphorus Enrichment in an Everglades (USA) Slough. Biogeochemistry. 54:229-250.

Collaborators in past 5 years: Leo Condron, (Lincoln Univ, NZ), Mark Cook (SFWMD), Bill Cooper (FSU), Carlos Coronado (SFWMD), Scot Hagerthey (SFWMD), Ben Marchant (Rothamsted Research, UK), Paul McCormick (SFWMD), ShiLi Miao (SFWMD), Bill Orem (USGS), Andy Ogram (UF), Todd Osborne (UF), K.R. Reddy (UF), John Robbins (NOAA), Ken Rutchey (SFWMD), Fred Sklar (SFWMD), Eric Smith (V. Tech), Ben Turner (Smithsonian, Panama), Paul Wetzel (Smith College), Alan Wright (UF)

Gregory B. Noe
U.S. Geological Survey
430 National Center, Reston, VA 20192
Ph: 703-648-5826, Fax: 703-648-5484, gnoe@usgs.gov

Research Interests

- Wetland ecosystem ecology, focusing on the interactive influences of hydrology, geomorphology, climate, and biology on nitrogen and phosphorus biogeochemistry in fluvial and wetland ecosystems, as well as plant community ecology and restoration ecology.

Education

Institution	*Degree, Major, Year*
Virginia Polytechnic Institute & State University	B.S. In Honors, Biology, 1994
University of California, Davis and San Diego State University Joint Doctoral Program	Ph.D., Ecology, 1999
Florida International University	Postdoc, 1999-2002

Appointments

Years	*Position, Institution*
2002-Present	Research Ecologist, U.S. Geological Survey, National Research Program
1999-2002	Postdoctoral Scientist, Florida International University
1994-1999	Research and Teaching Assistant, San Diego State University

Synergistic Activities

- Editorial Board, *Wetlands Ecology and Management* (2005 – present) and *Wetlands* (2009)
- Affiliated Faculty and graduate student thesis committees, Department of Environmental Science and Policy, George Mason University, 2005 – present
- Chair of the South Atlantic chapter, Society of Wetland Scientists, 2005 – 2007
- Project collaborator, Florida Coastal Everglades LTER site, 2000 – present
- Manuscript reviewer for over 20 journals, panel reviewer for NSF Ecosystems proposals and EPA STAR fellowships, and proposal reviewer for NSF Ecosystems and Oceanography.

Relevant Publications

Noe, G.B., D.L. Childers, and R.D. Jones. 2001. Phosphorus biogeochemistry and the impacts of phosphorus enrichment: Why is the Everglades so unique? *Ecosystems* 4: 603-624.

Noe, G.B., D.L. Childers, A.L. Edwards, E. Gaiser, K. Jayachandaran, D. Lee, J. Meeder, J. Richards, L.J. Scinto, J. Trexler, and R.D. Jones. 2002. Short-term changes in phosphorus storage in an oligotrophic Everglades wetland ecosystem receiving experimental nutrient enrichment. *Biogeochemistry* 59:239-267.

Noe, G.B., L.J. Scinto, J. Taylor, D.L. Childers, and R.D. Jones. 2003. Phosphorus cycling and partitioning in oligotrophic Everglades wetland ecosystems: A radioisotope tracing study. *Freshwater Biology* 48: 1993-2008.

Childers, D.L., R.F. Doren, R.D. Jones, G.B. **Noe**, M. Rugge, and L. Scinto. 2003. Decadal change in vegetation and soil phosphorus patterns across the Everglades landscape. *Journal of Environmental Quality* 32: 344-362.

Noe, G.B., and C. Hupp. 2005. Carbon, nitrogen, and phosphorus accumulation in floodplains

of Atlantic Coastal Plain rivers, USA. *Ecological Applications* 15: 1178-1190.
Gaiser E.E., J.C. Trexler, J.H. Richards, D.L. Childers, D. Lee, A.L. Edwards, L.J. Scinto, K. Jayachandran, G.B. **Noe**, R.D. Jones. 2005. Cascading ecological effects of low-level phosphorus enrichment in the Florida Everglades. *Journal of Environmental Quality* 34: 717-723.
Davis, S.E. III, D.L. Childers, and G.B. **Noe**. 2006. The contribution of leaching to the rapid release of nutrients and carbon in the early decay of oligotrophic wetland vegetation. *Hydrobiologia* 569: 87-97.
Noe, G.B., and D.L. Childers. 2007. Phosphorus budgets in Everglades wetland ecosystems: The effects of hydrology and nutrient enrichment. *Wetlands Ecology and Management* 15: 189-205.
Noe, G.B., J. Harvey, and J. Saiers. 2007. Characterization of suspended particles in Everglades wetlands. *Limnology & Oceanography* 52: 1166-1178.
Noe, G.B., and C.R. Hupp. 2007. Seasonal variation in nutrient retention during inundation of a short-hydroperiod floodplain. *River Research and Applications* 23: 1088-1101.
Moser, K., C. Ahn, and G. **Noe**. 2007. Characterization of microtopography and its influence on vegetation patterns in created wetlands. *Wetlands* 27: 1081-1097.
Huang, Y.H., Saiers, J.E., Harvey, J.W., G.B. **Noe**, and S. Mylon. 2008. Advection, dispersion, and filtration of fine particles within emergent vegetation of the Florida Everglades. *Water Resources Research* 44, W04408.
Hupp, C.R., A. Pierce, and G. **Noe**. 2009. Floodplain geomorphic processes and ecological impacts of human alteration along coastal plain rivers, USA. *Wetlands* 29:413-429.
Larsen, L.G., J.W. Harvey, J.P. Crimaldi, and G.B. **Noe**. 2009. Predicting organic floc transport dynamics in shallow aquatic ecosystems: insights from the field, laboratory, and numerical modeling. *Water Resources Research* 45, W01411, doi:10.1029/2008WR007221.
Harvey, J.W., R.W. Schaffranek, G.B. **Noe,** L.G. Larsen, D. Nowacki, and B.L. O'Connor. 2009. Hydroecological factors governing surface-water flow on a low gradient floodplain. *Water Resources Research* 45, W03421, doi:10.1029/2008WR007129.
Moser, K., C. Ahn, and G. **Noe**. 2009. The influence of microtopography on soil nutrients in created mitigation wetlands. *Restoration Ecology*.
Noe, G.B., and C.R. Hupp. In press. Retention of riverine sediment and nutrient loads by coastal plain floodplains. *Ecosystems*.
Noe, G.B., J. Harvey, R. Schaffranek, and L. Larsen. In review. Controls of suspended sediment concentration, nutrient content, and transport in a subtropical wetland. *Wetlands*.

Collaborators, Advisees, and Advisors

Collaborators in past 5 years: Changwoo Ahn (GMU), JK Bohlke (USGS), Dan Childers (ASU) Steve Davis (TAMU), Allen Gellis (USGS), Jud Harvey (USGS), Cliff Hupp (USGS), Dan Kroes (USGS), Laurel Larsen (USGS), Aaron Pierce (NSU), Nancy Rybicki (USGS), Victor Rivera-Monroy (LSU), Jim Saiers (Yale), Colin Saunders (SFMWD), Len Scinto (FIU), Durelle Scott (Univ Nebraska).

Served as a graduate advisor for: Matt Baber, Susan Dailey, David Iwaniec, Kurt Moser, Frank Parker, Gustavo Rubio, and Kristin Wolf.

Advisors: Joy Zedler (U. Wisc), Ph.D. advisor; Dan Childers (ASU), postdoctoral advisor.

Jed R. Redwine Ph.D

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RESEARCH INTERESTS

Regional Ecosystem Restoration Programs; Wetland health and sustainability; Stormwater treatment systems; Community ecology, phenology, and ecophysiology of south Florida vegetation; South Florida pine rockland fire ecology; Vegetation mapping

EDUCATION

Institution	*Degree, Major, Year*
Florida International University	Ph.D. Biological Sciences, 2007
EPA doctoral fellow: $93,000 for 2003-2006	
Louisiana State University	B.S., Botany, 1996
Board of Regents Certificate of Excellence	

PROFESSIONAL EXPERIENCE

Years	*Position, Institution*
1/1/2009 – present	Scientist I, PBS&J
7/2007 – 12/2008	Scientist II, PBS&J
9/1/2006 – 7/21/2007	Research Scientist, Florida International University/SFWMD
8/2003 – 8/2006	Doctoral Fellow, EPA-STAR (Science to Achieve Results)
8/99 – 8/2003	Teaching Assistant, Florida International University
12/98 – 8/99	Technician, National Audubon Society
1/97 - 6/97	Associated Investigator – Louisiana State University
5/94 - 8/1996	Research Assistant, Louisiana State University

PAPERS / PROJECTS:

Redwine, J.R. 2007. Mechanisms of phosphorus removal, factors affecting the health of emergent marshes, and the sustainability of the Stormwater Treatment Areas. Report to STA division of the South Florida Water Management District.

Jed R Redwine, "Leaf morphology scales multi-annual trends in nutrient cycling and leaf, flower, and fruiting phenology among species in the sub-tropical hardwood forests of the northern Florida Keys" (January 1, 2007). *ETD Collection for Florida International University.* Paper AAI3279233.
http://digitalcommons.fiu.edu/dissertations/AAI3279233

Redwine, J.R., R. Sawicki, J.J. Lorenz, and W. Hoffman. 2007. Ripe fruit availability in the fragmented hardwood forests of the northern Florida Keys. Natural Areas Journal 27(1): 8-15.

CLUBS AND SOCIETIES

Association for Tropical Biology and Conservation; Ecological Society of America
Natural Areas Association; Plant Biologists of South Florida

SELECTED PRESENTATIONS/POSTERS

Redwine, Jed R. Performance Measures are Essential for Planning, Operation and Validation of Landscape Restoration. National Conference on Ecosystem Restoration, July 2009. Presentation

Vearil, J., A. Mclean, L. Cannon, **J. Redwine**, and A. LoSchiavo. System-wide Planning and Evaluation: Simulating the Hydrologic Effects of the first ten proposed Restoration Projects on the Everglades Ecosystem and Regional Infrastructure. National Conference on Ecosystem Restoration, July 2009. Poster

Nehler, D., A. LoGalbo, G. Reynolds, D. Donalson, A. Mclean, A. Gottlieb, and **J. Redwine**. Interpreting the ecological effects of the first ten Everglades Restoration Projects using simulation modeling and Performance Measures. National Conference on Ecosystem Restoration, July 2009. Poster

Vearil, J., E. Kurzbach, A. Mclean, S. Traxler, A. Gottlieb, R. Elliot, T. St. Clair, **J. Redwine**, and A. Loschaivo. Comprehensive Everglades Restoration Program Adaptive Management Opportunities: What regional simulations suggest about the risks and rewards of the first ten proposed restoration projects. National Conference on Ecosystem Restoration, July 2009. Poster

J. R. Redwine, D. Tomasko, and T. St. Clair. Calculating carbon storage performance of three St. Johns River water management district wetland restoration projects. Greater Everglades Ecosystem Restoration. July 2008. Presentation

Reynolds, G., A. R. McLean, V. Engel, S. Komlos**,** A. Gottlieb, P. Goodman, F. James, T. Pinion, and **J. Redwine**. Methods for Evaluating Landscape-Scale Sheet Flow Properties in Greater Everglades Wetlands. Greater Everglades Ecosystem Restoration. July 2008. Poster

Quan Dong, **J. Redwine**, M. Ross, J. Sah, A. Gottlieb, and D. Donalson. Predicting the Impact of CERP on Wet Prairie Vegetation Communities located on Marl Soils. Greater Everglades Ecosystem Restoration. July 2008. Poster

S. Komlos[1], P. Goodman[2], A. Gottlieb[2], **J. Redwine[3]**, and J. Newman. Predicting CERP influences on Extreme High and Low Water Levels in Greater Everglades Wetlands. Greater Everglades Ecosystem Restoration. July 2008. Poster

Redwine, J.R. and M. Ross. Are species composition and diversity related to forest age in the sub-tropical forests of the Northern Florida Keys? Association of Tropical Biology and Conservation annual meeting. August 2005. Presentation

Redwine, Jed R., William J. Platt and Harold H. Slater. The effects of fire season and fire intensity on mortality of juveniles for Florida slash pine (***Pinus*** ***elliottii*** var. *densa*) in the Long Pine Key region of Everglades National Park. Bulletin of the Ecological Society of America, Vol. 77, No. 3, July 1996, pg. 368.

Colin J. Saunders, Ph.D.

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Email: CSaunder@sfwmd.gov

EDUCATION

Ph.D. in Biology (Ecosystem Modeling), 2003. Duke University, Durham, NC
B.S. in Ecology, Evolution, and Systematics, 1994. Humboldt State University, Arcata, CA

RECENT PROFESSIONAL EXPERIENCE

Senior Environmental Scientist, Everglades Division, South Florida Water Management District, West Palm Beach, FL, 2007-present
Visiting Faculty and Post-Doctoral Research Associate, Southeast Environmental Research Center, Florida International University, Miami, FL, 2003-2007
Research and Teaching Assistant, Biology, Duke University, Durham, NC, 1995-2003

SELECTED SCIENTIFIC PUBLICATIONS, REPORTS AND MANUSCRIPTS IN PREP

Blum, M.J., J.S. McLachlan, **C.J. Saunders**, Rebecca Hamilton, and J.D. Herrick. Genetic variation within *Schoenoplectus americanus* (Cyperaceae) across multiple spatial scales. *Molecular Ecology* [in press]

Saunders C.J., R. Jaffe, M. Gao, W. Anderson, J.A. Lynch, D.L. Childers. 2008. Decadal to millennial dynamics of ridge-and-slough wetlands in Shark Slough, Everglades National Park: Integrating paleoecological data and simulation modeling. Final Report submitted to National Park Service, Everglades National Park. (GA) 5280-00-007.

Blum, M.J., M.J. Bagley, J.S. McLachlan, **C.J. Saunders**, J.D. Herrick. 2006. The influence of genetic adaptation on global change forecasting with special reference to global change scenarios for marsh plan communities. United States Environmental Protection Agency. USEPA / 600 / R

Saunders C.J., J.P. Megonigal, and J.F. Reynolds. 2006. Comparison of belowground biomass in C_3- and C_4-dominated mixed communities in a Chesapeake Bay brackish marsh. Plant and Soil. 280 (1-2): 305-322.

Saunders C.J., Min Gao, Jason Lynch, Rudolf Jaffe, and Daniel L. Childers. 2006. Using soil profiles of seeds and molecular markers as proxies for sawgrass and wet prairie slough vegetation in Shark Slough, Everglades National Park. Hydrobiologia. 569: 475-492.

Iwaniec D.M., D.L. Childers, D. Rondeau, C.J. Madden, and **C.J. Saunders**. 2006. Effects of hydrologic and water quality drivers on periphyton dynamics in the Southern Everglades. Hydrobiologia. 569: 223-235.

Blum M.J., J. McLachlan, **C.J. Saunders**, and J. Herrick. 2005. Characterization of microsatellite loci in *Schoenoplectus americanus* (Cyperaceae). Molecular Ecology Notes 5: 661-663.

Saunders C. J., M.J. Blum, J. McLachlan, C. Craft, and J. Herrick. Genetic variation in salinity tolerance within a coastal marsh sedge population resurrected from a seed bank spanning 110 years (1885 to 1995). [in prep; target: *American Journal of Botany*]

Saunders C.J., D.L. Childers, J. Trexler, E. Gaiser. Phosphorus dynamics in Shark River Slough, Everglades National Park: a budget and dynamic 'ribbon-modeling' approach for

freshwater marsh ecosystems. [in prep; target: *Ecological Modeling*]

Saunders C.J., S. Ewe, E. Gaiser, D.L. Childers, and C. Taylor. The production and fate of windthrow mats generated by Hurricane Wilma, 2006 in freshwater marshes of Shark River Slough, Everglades National Park [in prep; target: *Ecosystems*]

SELECTED PRESENTATIONS

Saunders C.J., David Rudnick, Fred Sklar, Carlos Coronado-Molina *et al*. "Everglades accretion: Sorting out the regional importance of hydrologic, nutrient, and sea-level drivers." 2008 American Society of Limnology and Oceanography (ASLO), Orlando, 2008

David T. Rudnick, **C.J. Saunders**, F.H. Sklar, C. Coronado, and R.B. Halley. "Everglades – Florida Bay responses to hydrologic restoration and sea level rise: considerations of wetland soil and mud bank dynamics." 2008 ASLO, Orlando, 2008

Saunders, C.J., D.L. Childers, J.A. Lynch, M. Gao and R. Jaffé. GLADES' ANATOMY: The degradation of the ridge-and-slough landscape in Shark Slough, Everglades National Park. 92nd Annual Meeting of the Ecological Society of America, San Jose, CA, August 2007.

Debra A. Willard, Christopher Bernhardt, and **Colin Saunders**. Vegetation and Hydrologic History of Everglades' Marl Prairies: Paleoecological Evidence from Big Cypress National Preserve. Greater Everglades Ecosystem Restoration Conference (GEER), July, 2008.

Peter A. Stone, Patrick J. Gleason, Maria-Theresia Graf, Margo J. Schwadron, Michael S. Ross, **Colin J. Saunders**, et al. Climatic Changes in Rainfall Regime Suggested by Holocene Freshwater Wetland Sediments in South Florida. GEER. Naples, FL. July, 2008.

Colin J. Saunders. Accretion modeling in Everglades wetlands. Presented at the Tree Island Conceptual Ecological Model workshop. Florida Atlantic University. December, 2007.

Lynch, J.A., **Saunders, C.J**., Bohner, C.E., and Peterson, C.N. Reconstruction of the fire history of the Florida Everglades. 92th Annual Meeting of the Ecological Society of America, San Jose, CA, August 2007

Saunders, C.J. and D.L. Childers. Linked at the ridge. Phosphorus exchanges between *Cladium* and wet prairie communities make for a fitter, happier model of Shark River Slough. Long-term Ecological Research All Scientists Meeting, September, 2006.

Saunders, C.J., D.L. Childers, J.A. Lynch, R. Jaffé, and M. Gao. Modeling the dynamics of *Cladium jamaicense* biomass over the last century in Everglades National Park. 18th Biennial Conference of the Estuarine Research Federation, Norfolk, VA, October 2005.

Saunders, C.J. and D.L. Childers. Modeling Phosphorus Dynamics in Shark River Slough, Everglades National Park. 9th International Symposium on Biogeochemistry of Wetlands, Baton Rouge, LA March 2005.

Blum, M.J., J.S. McLachlan, **C.J. Saunders**. Adaptive responses of upland coastal marsh plant communities to climate change. 88th Annual Meeting of the Ecological Society of America, Savannah, GA, August 2003.

PROFESSIONAL AFFILIATIONS

Ecological Society of America, Estuarine Research Federation, Society of Wetland Science, Phi Kappa Phi

MANUSCRIPT REVIEWS

2005 - 2007. Oecologia, Wetlands, Hydrobiologia, National Science Foundation grant proposals.

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EDUCATION

1982-1986 Florida State University, Ph.D. in Biology
1979-1982 Florida State University, M. Sc. in Biology;
1975-1979 University of South Carolina, B. Sc. in Marine Science

PROFESSIONAL EXPERIENCE

2005-2007 **Interim Director, Marine Sciences**
2003-pres **Florida International University, Professor**
2000-2003 **Director, Biology Graduate Program**
1991-2003 **Florida International University, Assistant & Associate Professor**
1989-1991 **University of Mississippi, Assistant Professor**
1986-1989 **Eckerd College, Assistant Professor**

SELECTED PUBLICATIONS (67 peer-reviewed papers; 9 book chapters; 1 edited book; 2 edited journal issues)

2008 Liston, S. E., S. Newman, and **J. C. Trexler**. 2008. Macroinvertebrate community response to eutrophication in an oligotrophic wetland: An in situ mesocosm experiment. Wetlands 28:686-694

2008 Chick, J. H., P. Geddes, and **J. C. Trexler**. 2008. Periphyton mat structure mediates trophic interactions in a subtropical wetland. Wetlands 28:378–389

2007 Dorn, N., and **J. C. Trexler**. 2007. Crayfish assemblage shifts in a large drought-prone wetland: the roles of hydrology and competition. Freshwater Biology 52, 2399–2411

2006 Williams, A. J., and **J. C. Trexler**. 2006. A preliminary analysis of the correlation of food-web characteristics with hydrology and nutrient gradients in the southern Everglades. Hydrobiologia 569: 493-504

2005 DeAngelis, D. L., **J. C. Trexler**, and W. F. Loftus. Life history trade-offs and community dynamics of small fishes in a seasonally pulsed wetland. Canadian Journal of Fisheries and Aquatic Sci. 62:781-790

2005 **Trexler, J. C**., W. F. Loftus, and S. Perry. Frequency of disturbance limits Everglades fishes demonstrated with a twenty-five year intervention study. Oecologia 145:140-152

2005 Gaiser, E. E., **J. C. Trexler**, J. H. Richards, D. L. Childers, D. Lee, A. L. Edwards, L. J. Scinto, K. Jayachandran, G. B. Noe, R. D. Jones. Exposure to above-ambient phosphorus causes ecosystem state change in the Everglades. Journal of Environmental Quality 34: 717-723

2005 Ruetz, C. R., III, **J. C. Trexler**, F. Jordan, W. F. Loftus, and S. A. Perry. Population dynamics of wetland fishes: Spatiotemporal patterns shaped by hydrological disturbance? Journal of Animal Ecology 74:322-332

2003 Busch, D. E. and **J. C. Trexler** (Editors) Monitoring Ecosystems: Interdisciplinary Approaches for Evaluating Ecoregional Initiatives. Island Press, Washington. 447pp

SNYNERGISTIC ACTIVITES

- Served on numerous technical panels for Everglades restoration and provided expert testimony to the Florida Environmental Regulatory Commission on setting nutrient standards
- Member editorial boards: Oecologia 2002-present; Hydrobiologia 2006-2008; Hydrobiologia Advisory Board 2008-present; Wetlands Ecology and Management (2009-pres)
- Treasurer and past-Treasurer for the American Society of Naturalists (1999-2005)
- Co-PI, LTER Florida Coastal Everglades grant (2000-2006)

GRADUATE AND POST DOCTORAL SUPERVISORS

J. Travis, FSU: Ph.D. supervisor; D. Simberloff, UTenn: MS supervisor; Esa Ranta, UHelsinki: Post-doc supervisor

POST DOCs and Ph.D.s SUPERVISED

Post-docs (current position): Joseph Parkos, FIU; Brooke Sargeant, Univ Washington; Tish Robertson, Virginia Department of Environment; Alexander Hernandez, Univ of Rhode Island; Nathan Dorn, FAU; Doug Creer, Concord Univ; Jennifer Rehage, FIU; Carl Ruetz, Annis Water Resources Ctr; Tom McElroy, Kennesaw State Univ; John Chick, Illinois Natural History Survey; Joe Pechmann, Western Carolina Univ; Karen Kandl, Western Carolina Univ; Andrew Turner, Clarion Univ

Ph.D. Students(current positions): Shawn Liston, National Audubon Society; William Loftus, USGS (retired); Tom Turner, University of New Mexico; Michael Schirripa, NMFS

MS Students: 15 completed degrees

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