Mixed-Use at the Landscape Scale: Integrating Agriculture and Water Management as a Case Study for Interdisciplinary Planning

By

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Abstract

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Mixed-use planning is now a standard practice in city design and development. It is believed to support diverse and mutually reinforcing elements within a neighborhood. Agricultural landscapes present an analogous opportunity for mixed-use planning in order to capitalize on the synergies between food production, economic development, water management, biodiversity, energy production, and cultural preservation.

This thesis develops a model specifically for integrating agriculture and water management in the United States context. The model is derived from an in-depth case study of a payment for ecosystem services program being tested in central Florida and a review of background literature from a variety of disciplines.

The case study is the Florida Ranchlands for Environmental Services Project, currently in its pilot phase, which aims to design a program in which ranchers are paid to retain water on their pastures and reduce phosphorous levels in the Everglades.

The thesis begins with a discussion of the challenges and prior attempts to integrate agriculture and water management as well as a summary of the case study's context. Next, it presents the model for integrated management, supported by findings from the case study and contextualized within current literature on payment for ecosystem services. It also investigates the financial feasibility and regional benefits of a scaled-up program. A future research agenda is then suggested, followed by a summary of key findings and implications for planning practice.

Thesis Supervisor:	Dr. Michael Flaxman, Associate Professor of Urban Technologies and Information Systems, Department of Urban Studies and Planning, MIT
Thesis Reader:	Dr. Sarah Lynch, Director of FRESP, World Wildlife Fund

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Glossary of Acronyms and Abbreviations

ASR	Aquifer Storage and Recovery—the reinjection of water back into an aquifer for later recovery and use. Water may be treated going in or out of the aquifer depending on its initial quality and intended use
CRP	Conservation Reserve Program—a voluntary US Department of Agriculture program, administered by the Farm Service Agency, that provides cost share assistance and rental payments to farmers for adopting environmentally sound management practices on their land
FDACS	Florida Department of Agriculture and Consumer Services—the Florida state agency that ensures the safety of food and consumer products throughout Florida, protects consumers from unfair business practices, and helps Florida's farmers produce and promote their products
FRESP	Florida Ranchlands Environmental Services Project—a pilot project initiated by the World Wildlife Fund with the goal of designing a program in which Florida state agencies purchase water retention and nutrient load reduction services from ranchers on a contract basis. At the time of publication, this project is in its pilot phase
NRCS	Natural Resources Conservation Service—part of the US Department of Agriculture, the NRCS provides technical assistance to farmers and landowners. Its mission is to improve, protect, and conserve natural resources on private lands through a cooperative partnership with local and state agencies. While its primary focus has been agricultural lands, it has made many technical contributions to soil surveying, classification and water quality improvement
PES	Payment for Ecosystem Services—a model of environmental conservation in which private landowners are provided an incentive, often financial, to manage their land in a way that creates ecological benefits
PWRM	Potential Water Retention Model—the model used by the Florida Ranchlands Environmental Services Project to predict average annual water retention on ranchland.
RASTA	Reservoir Assisted Storm Water Treatment Area—a combination of a reservoir and a storm water treatment area. A reservoir is built upstream to regulate the quantity and timing of water that flows into the storm water treatment area

SFWMD	South Florida Water Management District—a regional governmental agency supervised by the Florida Department of Environmental Protection. The district covers a 16 county area that stretches from the Florida Keys to Orlando. It is responsible for water quality, flood control, water supply, and environmental restoration
STA	Stormwater Treatment Area—a wetland, pond, or other water storage facility that is constructed to remove nutrients, suspended sediment, and other pollutants from upstream water before it is released into natural areas
USACE	United States Army Corps of Engineers—a federal agency that provides public engineering services. Along with the South Florida Water Management District, they are the primary entity responsible for water management in the Greater Everglades Ecosystem.
WMA	Water Management Alternative—the name used in the Florida Ranchlands Environmental Services Project to describe a combination of infrastructure and ranching management practices that provide ecosystem services.
WWF	World Wildlife Fund—an international non-governmental organization dedicated to conservation, environmental restoration, and research. They were the agency that designed, initiated, and currently manages the Florida Ranchlands Environmental Services Project.

Chapter 1
Introduction

1.1 Research Objective

Agriculture is the most widespread managed ecosystem on the planet (Swinton et al. 2006). As the nexus between nature and civilization and the convergence point of many fundamental socio-economic, cultural, and environmental forces, it is inherently mixed-use. Depending on how it is managed, it can either be a major environmental stressor or a driver of ecosystem restoration, as it was, for example, in the Malpai Border project (Piorr 2003; Primdahl 1999; Steiner 2000; Curtin 2002). The challenge, therefore, is to find an agricultural model that simultaneously optimizes economic, environmental, and social objectives.

One mechanism for achieving such synergy is payment for ecosystem services (PES). This involves a buyer, typically a government agency, offering financial incentives to private landowners to manage their land to provide specific ecological benefits. The most prominent PES program in North America is the Conservation Reserve Program (CRP). Managed by the United States Department of Agriculture, this program has been in existence since the 1950s. It has a $2 billion budget and purchases ecological services from a portfolio of properties the cumulative size of New York State (USDA 2010). Several Latin American countries also have prominent PES programs (Wunder, Engel, and Pagiola 2008), with the Costa Rican national program being one of the largest and most widely recognized programs in the world (Sánchez-Azofeifa et al. 2007).

These efforts have achieved some success, but there are still many significant barriers for PES (Kleijn and Sutherland 2003; Sánchez-Azofeifa et al. 2007; Wunder, Engel, and Pagiola 2008). These barriers include high institutional transaction costs, difficulty achieving regulatory compliance, a lack of dedicated buyers, and difficulty in measuring and documenting services (Bohlen et al. 2009; Engel, Pagiola, and Wunder 2008; Lynch 2010a; Wunder, Engel, and Pagiola 2008).

The Florida Ranchlands for Environmental Services Project (FRESP) has taken an innovative approach to PES that has enabled it to address many of these barriers. At the same time, optimism must be tempered by the fact that the program has yet to be tested in a fully scaled-up form. Therefore, the research objective of this thesis is two-fold:

1. To distill the ingredient's of FRESP's success into a proposed model for integrated agriculture and water management

2. To investigate whether FRESP would be feasible at a large-scale

Before discussing the case, however, it is important to establish some context.

1.2 The Everglades Context

The importance of the Everglades has been recognized internationally by its designation as an International Biosphere Reserve, a World Heritage Site, and a Ramsar Convention Wetland of International Importance (Davis and Ogden 1994).

Over the last 100 years, the Everglades' hydro-regime has been completely transformed. The United States Army Corps of Engineers (USACE) has constructed miles of canals, drainage ditches, levees, water control structures, and pumping stations across the region. Places that were marshes historically have been drained for agriculture and urban development (Steinman and Rosen 2000).

These changes have resulted in the loss of more than half of the Everglades' original spatial extent, a severe reduction in biodiversity, and an array of hydrological problems (Chimney and Goforth 2001; Dahm et al. 2006; Davis and Ogden 1994; Everglades Foundation 2007; Grunwald 2006; Havens et al. 1995; SFWMD 2010; USACE 1999). Even without taking into account the ethical implications of this, the decline of the Everglades has created social and economic problems related to water quality, water supply, flood control, and tourism (*ibid.*). Climate change impacts such as sea level rise, saltwater intrusion, and storm surge are expected to amplify these problems (Stanton and Ackerman 2007).

FRESP focuses its efforts on the Northern Everglades, a formally recognized sub-region within the Greater Everglades Ecosystem (Section 373.4595, Florida Statutes 2007). This region includes the Okeechobee, Caloosahatchee, and St. Lucie watersheds (see figure 1).

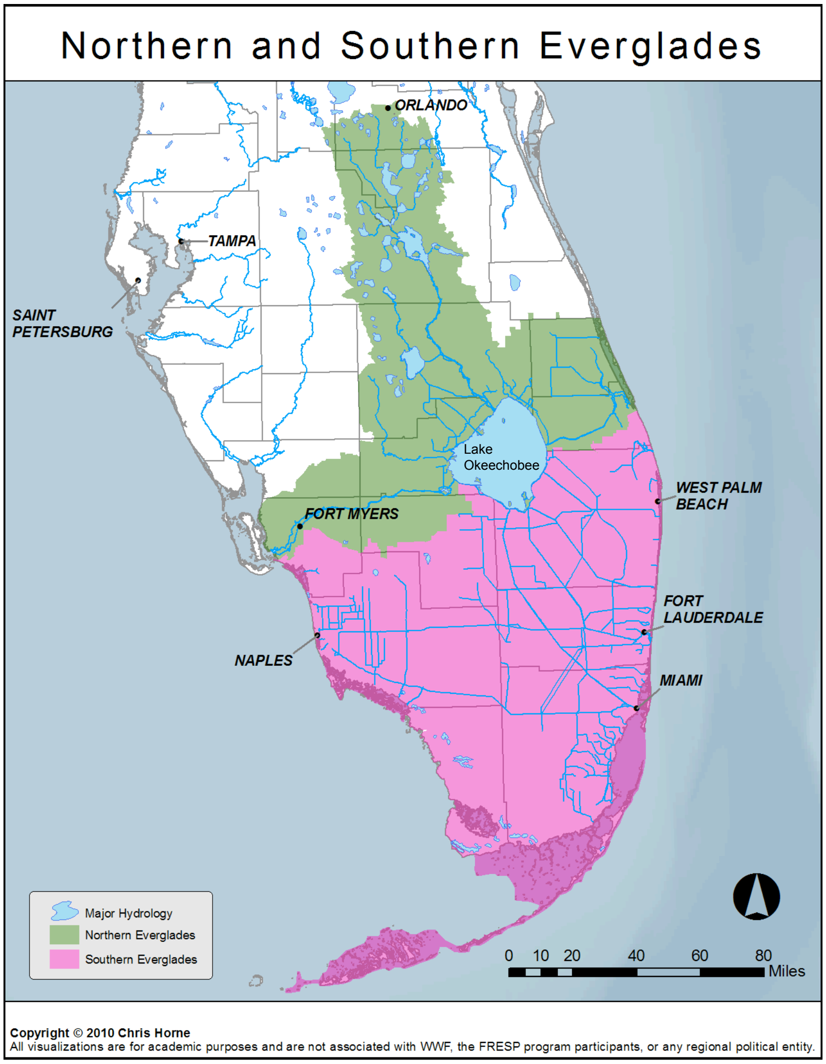

Figure 1: Greater Everglades Ecosystem

The focal point of the Northern Everglades is Lake Okeechobee, which has a horizontal extent of 730 square miles and an average depth of 9 ft. It is the hydrological "heart" of the Everglades ecosystem. As a result of the changes described above, the water flowing into the lake is heavily polluted and mistimed (Lynch et al. 2005; SFWMD 2008; Steinman and Rosen 2000).

Historically, most of the region was a perennial marsh due to its vast, dynamic storage capacity and the slow rate of water flow over its surface (USACE 1999). Under these conditions, the lake formed a continuous gradient with the surrounding landscape, allowing water to fill up and spill out as necessary (*ibid.*).

Currently, the lake is enclosed in a levee, and its water level is tightly controlled. During the wet season, excess water is pumped to the estuaries, disrupting their salinity regimes and overloading them with pollutants. During the dry season, the water that the Everglades has historically depended on is now diverted to developed areas to serve the needs of south Florida's residents (Lynch et al. 2005; SFWMD 2008; Steinman and Rosen 2000).

To date, there have been numerous attempts to solve this and other hydrological problems facing the Everglades (Grunwald 2006). The largest of these—the Comprehensive Everglades Restoration Plan, authorized by Congress as part of the Water Resources Development Act of 2000—has been the most ambitious and expensive environmental restoration project in history, with a budget now exceeding $10 billion (Grunwald 2006; USGAO 2007). The plan is intended to restore, protect, and preserve the water resources of south and central Florida.

To address the specific problem of water retention and storage, the conventional approach has been for the state or federal government to purchase land and build large-scale regional water management infrastructure. This infrastructure comes in a variety of forms, including:

- Stormwater Treatment Areas (STAs): wetlands, ponds, or other water storage facilities that are constructed to remove nutrients, suspended sediment, and other pollutants from upstream water before it is released into natural areas. While STAs do provide some water retention, their primary purpose is nutrient load reduction, thus giving them a low acre-ft capacity relative to horizontal footprint (see figure 2).

- Surface reservoirs: large, above ground impoundments with the primary purpose of storing water. They provide comparatively small ecological benefits compared with STAs and rehydrated wetlands, yet they maximize storage because of their depth.

- Reservoir Assisted Stormwater Treatment Areas (RASTAs): a combination of a reservoir and a storm water treatment area. A reservoir is built upstream to regulate the quantity and timing of water that flows downstream into a storm water treatment area.

Figure 2: An STA in the Northern Everglades surrounded by sugarcane fields (USGS 2008)

- Aquifer Storage and Recovery (ASR): reinjection of water back into an aquifer for later recovery and use. While pilot testing of ASR over the last ten years has shown promising results, there are still concerns and disagreements about its risks and large-scale feasibility (Nguyen and Mueller 1996; Scholz and Stiftel 2005; SFWMD and USACE 2008).

These projects have had some success addressing storage needs, particularly the STAs (SFWMD 2010). However, progress has been slower and more costly than expected (Everglades Foundation 2007; SFWMD 2008; South Florida Restoration Task Force 2007; USGAO 2007). The experiences with restoration over the last several decades have revealed several limitations inherent to these conventional approaches. First, large infrastructure projects like these are slow to implement, sometimes taking 10 years or more before they become operational (Lynch 2010d; MacVicar 2010b). Second, massive cost overruns have been common and contribute to implementation delays (USGAO 2007). Third, these projects tend to be highly politicized and legally contentious (Gunderson and Light 2006). Fourth, the start-up costs associated with modeling, designing, permitting, constructing, and financing large regional water infrastructure presents a significant budgeting hurdle (Lynch 2010e).

1.3 FRESP Overview

The problems associated with conventional water management have created a demand for alternatives. One such alternative is FRESP. This project was initiated in 2005 by World Wildlife Fund (WWF), ranchers, researchers and state and federal agency partners with the goal of designing a program in which the state of Florida (through one or more of its agencies) could buy through a fixed term contract water management services from ranchers.

In the Northern Everglades, where ranching is the dominant land use, agriculture presents a tremendous opportunity for achieving environmental objectives. In addition to being a vital part of Florida's economy, ranchland serves as corridors for wildlife movement, critical areas for water recharge, and habitat for several endangered species, including the wood stork, indigo snake, crested caracara, Florida grasshopper sparrow, and Florida panther (Bohlen et al. 2009).

Currently, if FY 2011 funding is secured, FRESP will transition from a pilot phase with 8 participating ranches to a PES program[1]. If funded, the current PES design would have the state agencies issue a solicitation for water management services, interested ranchers would propose water management alternatives (WMAs) on their land, and if the buyer is interested in the service, the two parties will negotiate a fixed-term contract. Participation is voluntary, and the rancher may revert to pre-project conditions after his contract expires.

The WMAs are a combination of modified land management and low-tech water control infrastructure. The specific technologies include riser boards, impoundments, berms, and pumps. As an example, figure 3 depicts a riser board system:

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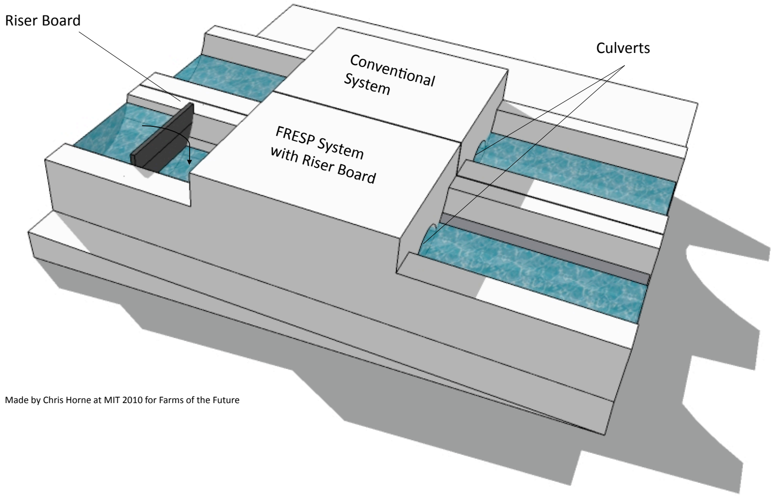
[1] 7 out of 8 of the ranches were providing water retention service—the 8th was providing phosphorous reduction. Because this thesis focuses specifically on water retention, I only use data from the first 7.

The image depicts two culverts side-by-side. The culvert in the background does not have any modifications. The culvert in the foreground has a riser board on one side. At this location, water is blocked and fills up in front of the board. If the water level goes up higher than the board, it will spill over into the next stage of the system.



Made by Chris Horne at MIT 2010 for Farms of the Future

Figure 3: Riser board diagram

Below are two photographs of the riser board system being implemented on one of the pilot ranches:

Figure 4: Riser board photograph (taken by author)

Figure 5: Three water stages (taken by author)

Figure 4 shows a culvert and a riser board retaining water. Figure 5 shows 3 different stages of the stepped riser board system, one in the foreground, one in the middle ground, and a third in the background. These step-downs follow the natural drainage patterns of the landscape.

Figure 6 shows a WMA on one of the pilot ranches:

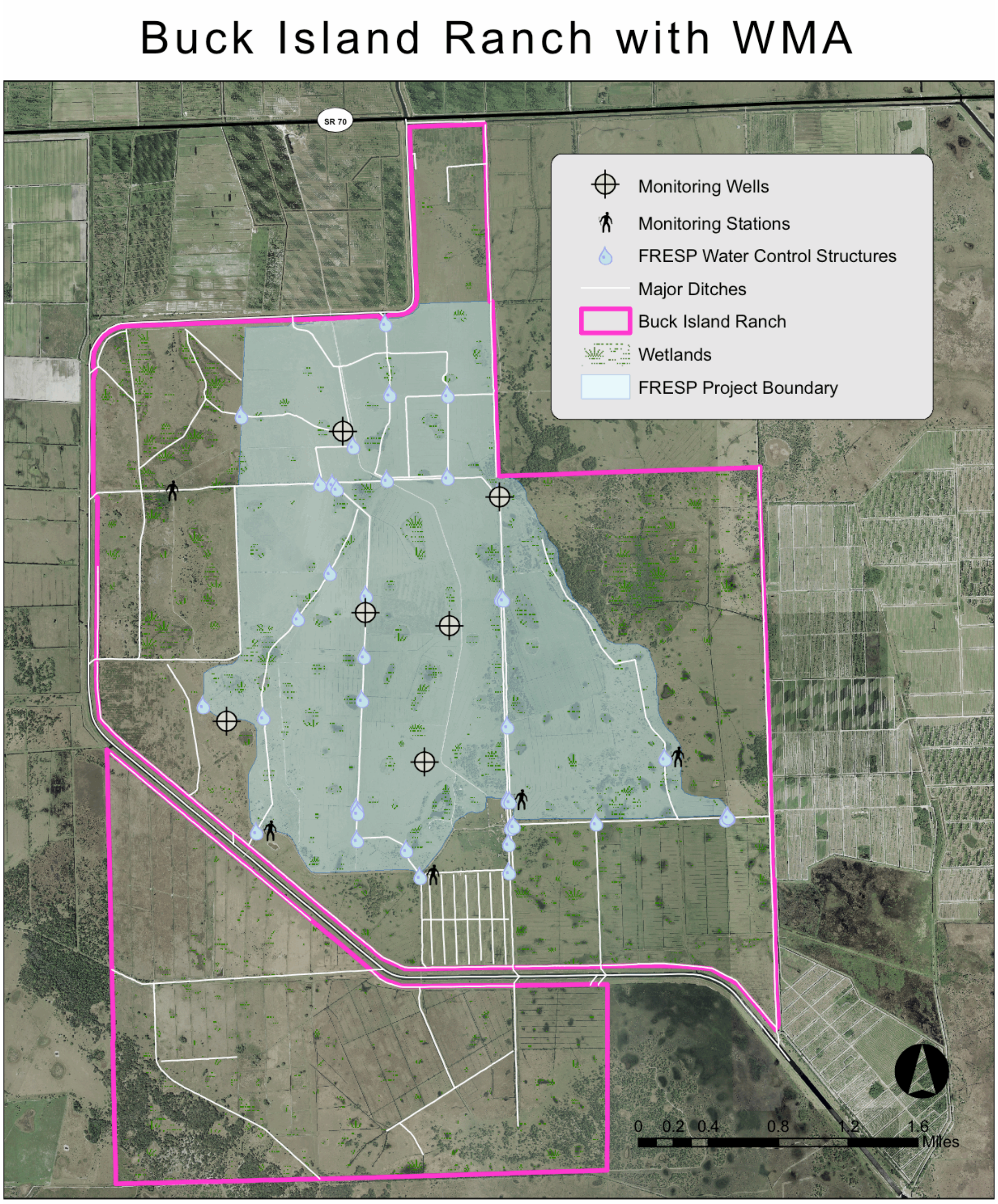

Buck Island Ranch with WMA

Figure 6: Areal view of example pilot ranch

The purple outline is the boundary of the ranch property; the blue polygon is the extent of the WMA. Notice that the WMA occupies only a portion of the total of the ranch—generally FRESP ranchers will only contract a portion of their land to provide increased water retention while managing the rest for normal commercial operation.

Table 1 shows the 7 water retention pilot ranches, their sizes, and the portion of the land that was put into a WMA:

Ranch	Total Size (acres)	WMA Size (acres)	% of Ranch Under WMA
1	783	367	47%
2	3,230	364	11%
3	10,494	3,748	36%
4	5,074	1,624	32%
5	9,094	659	7%
6	3,062	2,197	72%
7	3,353	322	10%
AVG	5,013	1,326	31%

Table 1: Pilot ranches with WMA sizes, from (WWF 2010)

In the pilot project, the percentage of each ranch that was managed under a WMA was limited by the budget and focus on learning about potential impacts, so these numbers would not necessarily be the same in a scaled-up program   Nevertheless, they provide a first-level approximation of potential project scale. Table 2 compares the size and performance of the pilot WMAs with 4 different reservoirs:

Project		Project Size (acres)	Storage/Retention Capacity (acre-ft)	Storage/Retention per acre (acre-ft/acre)
Reservoirs	Taylor Creek	4,000	32,000	8.00
	Kissimmee	10,000	161,000	16.10
	I-17	5,000	80,000	15.91
	C-44	3,000	40,000	13.33
WMAs	1	367	164	0.45
	2	364	227	0.62
	3	3,748	2,411	0.64
	4	1,624	850	0.52
	5	659	303	0.46
	6	2,197	939	0.43
	7	322	138	0.43

Table 2: WMA and reservoir performance comparison

Section 3.3 specifically investigates with the scalability of FRESP, that is to say, the percentage of the total needed water storage/retention that the WMAs could feasibly provide, but in general, FRESP has always been advocated as a complement to regional water management, not a replacement (Bohlen et al. 2009; Lynch 2010c).

Also, it is important to point out that reservoirs and WMAs provide different services. Reservoirs provide water *storage*: the water is held inter-annually and can be drawn as needed. WMAs provide water *retention*: the water is held temporarily and then released through evapotranspiration, groundwater recharge, overflow, or intentional drainage.

Chapter 2
On-Ranch Water Retention PES Model

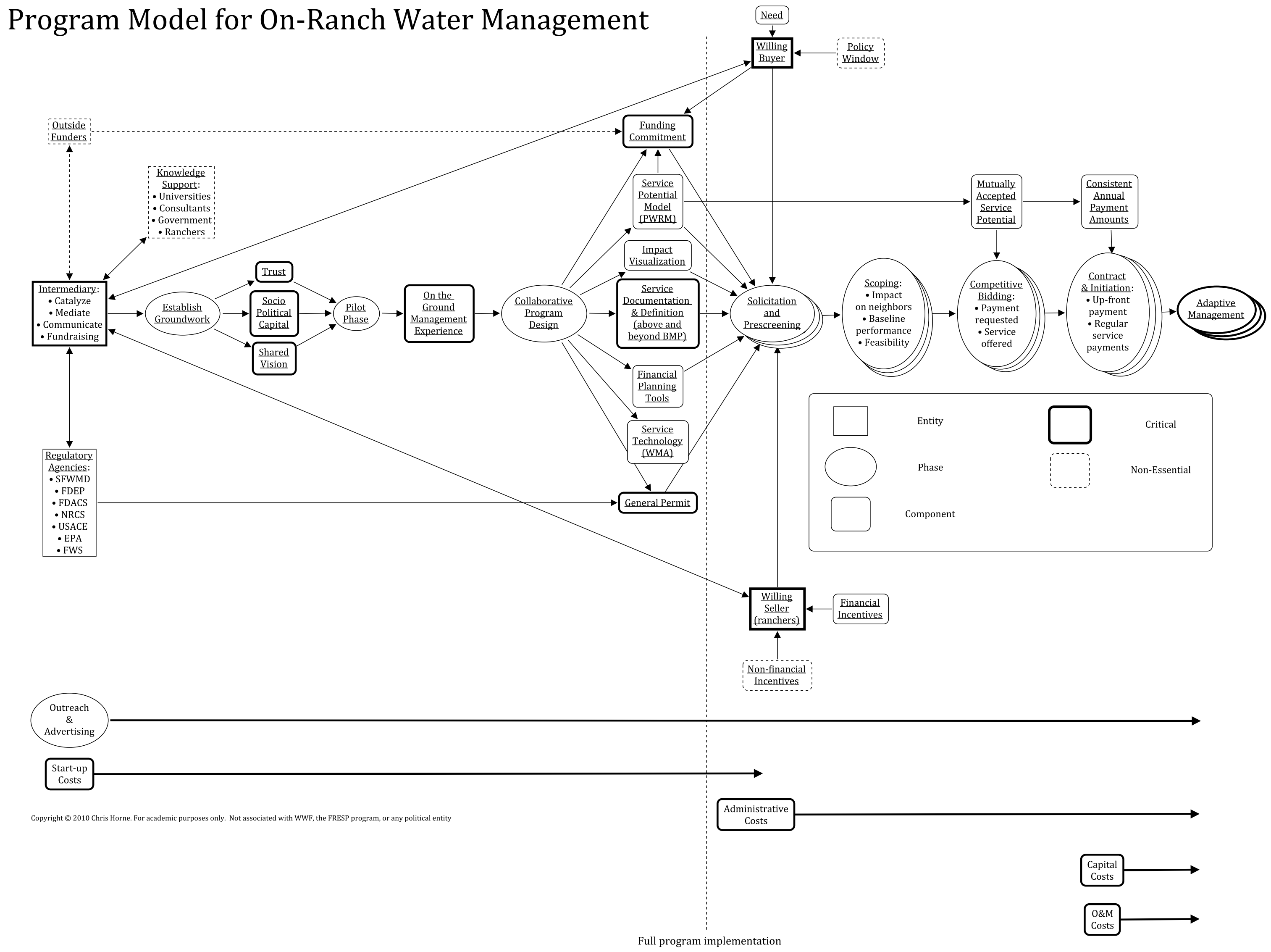


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Figure 7: On-ranch water management PES model

2.1 The Model

Figure 7 shows the proposed model for an on-ranch water management PES. It illustrates the entire process from development to implementation. To be clear, the steps of the model were planned, designed, and tested by the FRESP team, not the author. The author's contribution has been to study the FRESP case, contextualize it within current PES literature, and propose a generalized process model from the lessons learned.

Within the diagram, the movement from left to the right represents a forward movement through time. Square boxes represent individuals, government agencies, or organizational entities; ovals represent phases; rounded boxes represent model components, including inputs, outputs, and necessary conditions; the bulleted items are examples from FRESP; the large, dashed vertical line in the center represents the beginning of program implementation; any object with a thick outline is critical; and any object with a dashed outline is non-essential.

In a PES program, the most fundamental components are the buyer and the seller, and in order for those parties to exist, they must have a genuine incentive to participate (Antle and Capalbo 2002; Bohlen 2010; Bohlen et al. 2009; Ferraro and Kiss 2002; Lollis 2010; Lynch 2010a; Pagiola et al. 2004). The prominence of these two entities is the reason they are positioned in the middle of the diagram above (or below) all of the other elements, as if they were bracketing the entire process

The buyer and the seller each have two components driving their participation: for the buyer those components are the need for a service and a policy window, and for the seller, they are financial incentives and non-financial incentives. The policy window represents timing and circumstances that mobilize policy makers to prioritize certain objectives. If an event demonstrates a need for a potential service, it will motivate the buyer to enter the market. For almost all potential sellers, their involvement must be demonstrably profitable or they will not participate.

Another crucial entity in the model is the intermediary, which appears on the far left of the diagram. Both the FRESP experience and PES literature heavily emphasize the necessity of this role (McDonald 2006; Wunder, Engel, and Pagiola 2008). The intermediary initiates the process, finds a buyer and seller, assists with project design and development, and mediates conflict. They put forth the time and energy to advance the project, because neither the buyers nor sellers have the time to do so on their own. This person must be comfortable communicating with participants from a wide variety of fields and sectors. They are involved in every phase and activity from the beginning until the project is ready for implementation. Even during implementation, the intermediary is a valuable source of knowledge and useful as a neutral third party to mediate conflicts.

Additional entities include outside funders, regulatory agencies, and other providers of support, including consultants, academics, farmers, etc. These entities, plus the buyer, seller, and intermediary, represent the constellation of direct stakeholders involved in the program. It is necessary that they all be involved from the beginning of the process.

The first phase of the process is to establish trust, socio-political capital, and a shared vision for the program (Bohlen 2010; Lynch 2010a; McDonald 2006). The intermediary is the direct facilitator of this phase by applying her knowledge of diplomacy, dialogue, and process management. This phase marks the creation of a cohesive unit, i.e., a project team capable of collaboration.

One type of socio-political capital is what Olsson calls “shadow organizations” (Olsson et al. 2006). These are groups that exist outside the bounds of normal regulatory, political, and professional frameworks whose sole purpose is to develop collaborative capacity. Like many of the initial activities in the model, formation of these groups will likely originate from the intermediary. Also, when working to establish these and other collaborative mechanisms, the intermediary must be sensitive to the values and cultural norms of the other stakeholders—it would be easy to alienate a potential collaborator at the beginning of the project, and if this were to happen, it may undermine the entire process.

Once the foundation is set, the project must go through a pilot phase. A fundamental methodological assumption within the model is that the combination of experiential learning and adaptive management is more effective than theoretical planning. This means that it is better to select a handful of test sites, implement a prototype, and monitor the results than it would be to wait until the team is convinced that it has accounted for every possible factor, because surprises inevitably occur that cannot be foreseen (Bohlen et al. 2009; Bohlen 2010; McDonald 2006; Lynch 2010a; Lynch 2010b; Lynch 2010d; Lynch 2010e). The value of this approach is also echoed in the literature (Asquith, Vargas, and Wunder 2008).

The purpose of the pilot phase is to gain on-the-ground management experience. This provides each of the participants with concrete knowledge that will help them adapt to a PES and to gauge whether or not a scaled-up program would be desirable. It also extends the development of social capital by acclimating the participants to collaborative work.

Once the pilot is underway, it is possible to start designing the program itself. As with the earlier phases, inclusion and transparency are critical.

One of the fundamental objectives of the design phase is to secure a dependable, committed funding stream to pay for service—failure to so is a common weakness in PES programs (Lynch 2010a; Pagiola et al. 2007). This responsibility rests mostly on the buyers, but not entirely. Since the service provider is effectively both a water manager *and* a farmer, it is possible to link a PES program to existing agriculture subsidies, such as the Environmental Quality Incentives Program (EQIP)[2].

A commitment to funding is important because ranchers in the United States typically operate with small profit margins and are not in a position to sacrifice a guaranteed source of income, i.e., the use of their fields for grazing, so that they can participate in a program

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[2] EQIP a voluntary program run by the Natural Resources Conservation Service (NRCS) that provides financial and technical assistance to farmers that implement structural and management practices that benefit the environment.

that *might* generate income (Bohlen et al. 2009; Lynch 2010b). This is also why payments cannot be linked to factors beyond the rancher's control. For example, even if it rains so little that no actual retention services are provided, the rancher must still receive the same level of payment (Bohlen et al. 2009)

One of the most important aspects of this process is developing service documentation methods and protocols. This has been the Achilles heel of many PES programs (Pagiola et al. 2004). The reason documentation is so important is that it, "assures 'buyers' that they are getting what they paid for, and 'sellers' that they are getting a fair price for what they produce" (Bohlen et al. 2009). There are trade-offs, however, in pursuing documentation accuracy: the marginal value gained to the buyer must be weighed against the marginal cost of collecting, analyzing, and managing that data (*ibid.*). One of the virtues of water management is that it is relatively easy to measure compared with other ecological services, such as enhancing biodiversity.

A second reason that documentation is so important is that it enables the buyer to distinguish between ecological services that are required and those that "go above and beyond" expected management practice (Lynch et al. 2005; Lynch 2010b). In other words, a rancher must first achieve the baseline best management practices in order to claim that he or she is providing a service that warrants payment. The difficulty of establishing this baseline should not be underestimated—doing so is frequently limited by money, time, or data availability (Bohlen et al. 2009). This is known as the "additionality" problem in PES programs, i.e., ensuring that the service is "in addition to" whatever would have been done anyway (Wunder, Engel, and Pagiola 2008).

An ideal way to meet documentation criteria is by using a service potential model. This calculates the amount of service that a particular ranch would provide during a hypothetical average year. This is in contrast to an approach in which actual service is measured empirically at regular time intervals.

There are several reasons why a service potential model is preferable to empirical measurements. The first is that fluctuations in annual precipitation cause actual WMA retention to vary significantly from year to year. Therefore, in a program based on empirical performance, payment levels would also fluctuate. Not only do the ranchers require a reliable income stream—as discussed above—but also the buyer will likely need to budget their expenses over several years. A constant annual payment is much easier to budget than one that fluctuates significantly from year to year.

Another benefit of using a model is that the aggregate level of service over the life of the contract can be determined up front. This provides a common starting point from which the buyer and seller can negotiate. Otherwise, the seller may think his land will provide more service than the buyer does, and there would be no way to prove the claims of either party a-priori.

Yet another benefit of the modeling approach is that it minimizes administration costs. In a program based on measured performance, site visits require expensive hydrological monitoring. On the other hand, in a model-based program, the only empirical information required is whether the farmer is providing service in accordance with the contract. This could be verified with an automated system or a spot check of a water gauge and recent precipitation data. Both of these are much less expensive the first option.

Though it may seem like a concession to model service as opposed to measuring it empirically, it is actually an improvement over many other PES monitoring approaches. In nearly every PES program to date, the service being provided is monitored by means of a proxy. One common proxy is a land use or land cover that is presumed to correlate with a desired ecological activity (Wunder, Engel, and Pagiola 2008). The Conservation Reserve Program uses this approach, for example. With water management, the link between modeled dynamics and observed dynamics are well studied and more concrete than land use proxies. That is to say, just knowing the land use of an area still leaves much unknown, whereas precipitation, slope, and soil interact in more discrete, discernable ways (RUSLE 2010)

Another crucial component of project design is regulatory compliance. Not only must the participants be protected from legal risk, but also the process of monitoring compliance must administratively feasible. In the United States, the major regulations that come into play when dealing with on-ranch water management involve the National Environmental Policy Act, the Endangered Species Act, and section 404 of the Clean Water Act, i.e., the wetland regulations. In this model, a general permit is created through collaboration among all of the relevant regulatory agencies. Once the program is in effect, a single entity can be tasked with the responsibility of holding the permit and ensuring compliance.

The design of the WMAs also needs to be determined at this point. This involves using the experience from the pilot phase and knowledge of the project region to design appropriate infrastructure for the desired service. For example, the team may decide to implement wetlands for nutrient load reduction and riser boards for water retention.

The final component of project design involves a suite of tools that will support the rancher's planning and bidding process. For example, most ranchers want to know how the WMAs will change the extent, depth, and duration of the water in their fields (Bohlen 2010; Lynch 2010c). A visualization tool using Geographic Information Systems could serve this purpose. Another tool would assist the ranchers in calculating the financial impacts of the project. It would establish a baseline economic performance level for the ranch, incorporate the project costs, and then assist the rancher in making a competitive bid.

Once the program design is completed and funding has been committed, implementation begins. The first step is to announce a solicitation for bids. . Managing the solicitation process can be done by a public sector entity at the state or local level, a for-profit company, or a non-governmental organization.

The responses to the solicitation undergo a preliminary screening process. Those proposals that pass this step would then enter a scoping phase. Aspects of scoping would include consistency with the requirements of the general permit, technical feasibility, impact on neighboring properties, an exploration of partnership opportunities with neighboring landowners, and a baseline performance assessment. This phase includes the use of the service potential model.

Once the project has been scoped, the rancher creates a formal bid. The amount of payment requested will vary depending on individual considerations. These considerations include the amount of new construction required for the WMA and the extent of the impact on normal ranch operations (Lynch 2010d).

Once formal bids have been submitted, the buyer selects the ones that will achieve its goals most effectively. Upon selection, the contract is prepared.

After the contract is signed, the rancher receives an upfront payment to subsidize capital expenses and thereafter receives a regular, annual service payment for the term of the contract. During the operation of the WMA, certification of compliance and enforcement must be performed. Most likely, the contract will include a safety clause whereby the rancher reserves the right to suspend provision of service in case of an emergency, such as a severe flood, for example.

As with the pilot and design phases, adaptive management is important during implementation. This would entail performing model refinements, reevaluating the monitoring process, and conducting management practice audits (Bohlen et al. 2009).

One last model component is outreach and advertising, which appears at the bottom of the diagram and continues for the duration of the process. Sustained energy and media savvy are necessary to raise awareness of the program.

In terms of timing, it takes about 4-5 years for the pre-implementation steps, and once the program is in place, new WMAs can be up and running within 1-2 years (Lynch 2010f). This means that the process is frontloaded in terms of investment and effort, but once a program is established, it is easy to initiate new service. The entire process, when compared with the implementation of large-scale water infrastructure, is relatively fast.

2.2 Examples from FRESP

As I mentioned before, most of the model components derive from the FRESP case study. This section discussed what they look like in action.

If funded, the buyer in FRESP will be the SFMWD, since it is the local agency responsible for water supply, flood control, water quality, and the restoration of the Everglades. Its incentive derives from its political mandate. Furthermore, the Lake Okeechobee and Estuary Recovery initiative specifically calls for partnerships between the public and private sectors to achieve restoration goals (SFWMD et al. 2005).

Not only is water retention and nutrient load reduction a mandated government responsibility, specific events and precedents prior to the pilot phase had created a policy window for on-ranch water management. The severe hurricane season of 2005 served as a dramatic reminder of the need for additional water capacity and enhanced the profile of the FRESP mission (Lynch 2010e; McDonald 2006; MacVicar 2010a).

Another event that contributed to FRESP's policy window was the 2004 drawdown of Lake Tohopekaliga, during which approximately 49,000 acre-ft of water was relocated to public, private, and tribal land, including farms, where it evaporated or drained into the soil. This event demonstrated the technical feasibility of distributed water management on private land (MacVicar 2010a).

The sellers, of course, are the ranchers. In FRESP, they indicated both financial and non-financial incentives for participation. Profit was one incentive, but there was also a desire to provide a public service, create a network within which to share knowledge with one another, and show the public that they are concerned about environmental issues and wish to be good stewards of the land (Lynch 2010d; McDonald 2006).

The intermediary is WWF. An internal study conducted in 2006 found that most participants believed that the project would not have been possible without their involvement (McDonald 2006). One participant described WWF as the initiator and prodder. Most cited their primary contribution as being a neutral 3rd party to mediate between sides that have not always worked together amicably (*ibid.*).

An example of a shadow organization within the case study was the Everglades Friendly Beef Steering Committee, which was formed by representatives of the Florida cattle industry and the WWF (Lynch et al. 2005). It was one of the first steps in the process, occurring even before the formal initiation of the FRESP. This group facilitated the identification of shared goals and helped to re-frame the environmentalist-agriculturalist relationship as one of cooperation and mutual gain (Lynch 2010a).

In the process of forming the Everglades Friendly Beef Steering Committee, WWF gained significant goodwill by reaching out to both large and small ranches and using a landowner's reputation for stewardship as the primary criteria of inclusion, rather than ranch size (McDonald 2006). One participant thought that such an approach resulted in an important diversity of viewpoints and experience (*ibid.*).

Several public and private entities were involved in FRESP beginning in the early stages. These included the Florida Department of Environmental Protection, the University of Florida, the Florida Department of Agriculture and Consumer Services, the Natural Resources Conservation Service, Florida Cattlemen's Association, Environmental Defense, and the Macarthur Eco-Agriculture Research Center. Not only was this level of collaboration valuable for implementation and stakeholder buy-in (Lynch 2010a), but it also pooled knowledge of various kinds, including technical, management, political, and fundraising expertise (McDonald 2006).

The SFWMD supported FRESP in order to better understand the potential synergies between on-ranch water management and regional water management (ibid.). In addition they were willing to test the concept, for which they offered funding to conduct an assessment on the options, costs, and benefits of on-ranch water management alternatives.

Much of the public relations effort behind FRESP was voluntarily: ranchers promoted FRESP to other ranchers and to other ranchers (*ibid.*). Additional outreach was coordinated through NRCS and FDACS local staff. This suggests that if the process is sufficiently inclusive and engaging, participants will become excited and advertise the project without being prompted.

Like almost every other PES program, FRESP struggled with documentation issues. Initially they thought they would measure physically in real-time acre-ft of water retention on the ranches, but later abandoned that notion. Instead, the team created two different service potential models: the Potential Water Retention Model (PWRM) and the Potential P Load Reduction Model. The PWRM predicts a WMA's net incremental acre-ft retention during an average year to provide a baseline for contract negotiations and program budgeting. This approach will significantly reduce administrative costs if a program is expanded in the Northern Everglades.

In fact, one of the primary reasons that the project was able to attract the interest of the SFWMD in the first place was that it offered a potential water management alternative that might be cost-effective when compared to large conventional systems that have enormous up-front costs and can take over 10 years to become operational.

Although the buyers and sellers were not particularly concerned about the details of the service potential models, it was still important that the model was non-proprietary and the broad-level assumptions were made clear to everyone involved. The simplicity of the model lent itself to understanding and transparency. Likely as a result of these considerations and the good will that had already been built in the early stages of the process, current FRESP participants have accepted model output (Lynch 2010a).

As an example of outside funding, one of the pilot ranches received $343,000 from the NRCS EQUP program to assist with WMA construction costs.

Accounting for the Endangered Species Act was the biggest regulatory challenge in developing the general permit (Bohlen 2010). During the pilot, individual permits were sought for each of the participants—an approach that was decided to be too onerous in a full-scale program with many contracts (Lynch 2010c). A general permit is now being created that streamlines regulatory compliance. The USFWS and USACE have agreed to entrust NRCS with enforcing and enabling compliance. NRCS and USFWS have developed a Consultation Matrix that will guide the design, construction, and operation of the WMA to avoid impacts on endangered species.

Chapter 3
FRESP Cost and Scalability Analysis

3.1 From a Pilot to a Scaled-up Program

The results of the pilot thus far indicate that FRESP has been a success—WMAs are operational, measurable services have been provided, and the buyers and sellers are positive about the experience (Bohlen 2010; McDonald 2006). Collaborators from the SFWMD expressed enthusiasm about a scaled-up program, and as a concrete indication of interest, the district's proposed budget for the upcoming year allocates $5M to fund the first year transition from a pilot to a scaled-up program (Lynch 2010c).

The feedback from the ranchers has also been positive. Two of the eight ranchers have placed portions of their land under permanent conservation easement through the Wetland Reserve Program. All of the remaining ranchers have expressed strong interest in continuing with a scaled-up PES program (Bohlen 2010; Lynch 2010b; Lollis 2010). In general, attitudes toward FRESP are positive among both the participating ranchers as well as the ranching community more broadly (*ibid.*).

However, in order for FRESP to be a viable model for a scaled-up PES program, the case must be made that, first, it is financially competitive with conventional water management, and, second, that it is sufficiently scalable to make a significant difference. In this chapter, I will investigate both of these issues.

3.2 Cost Comparison Between WMAs and Reservoirs

The following analysis investigates the financial feasibility of the WMAs by comparing the cost of on-ranch water retention with the cost of reservoir storage[3]. The unit of comparison

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[3] Because the thesis focuses on water storage and retention, I compared the average cost of retention WMAs with similarly purposed regional management options, i.e., those that are meant primarily for storage or retention. In this case, that option is reservoir storage. I did not include ASR in the cost analysis because of

is the cost per acre-ft of water management. This is obtained by dividing the total lifetime cost of the project by its total lifetime acre-ft service. From a purely financial perspective, this is the number that would have the largest impact on the buyer's decision. These quantities can be expressed as follows:

Reservoir Cost:

$$\frac{Cost}{Acre-ft} = \frac{\frac{b(C+S)[(r(1+r)^{b}]}{[(1+r)^{b}-1]} + \sum_{t=0}^{N}\frac{F+LMV}{(1+i)^{t}} + \sum_{t=0}^{n}\frac{O}{(1+i)^{t}}}{nA}$$

Equation 1

WMA Cost:

$$\frac{Cost}{Acre-ft} = \frac{\frac{b(C+S)[(r(1+r)^{b}]}{[(1+r)^{b}-1]} + \sum_{t=0}^{N}\frac{F}{(1+i)^{t}} + \sum_{t=0}^{n}\frac{O+P}{(1+i)^{t}}}{nA}$$

Equation 2

N = the total duration of the project
C = non-administrative capital costs
S = administrative start-up costs
r = monthly bond interest rate
b = bond duration
n= the number of years that the project provides service (will be less than N)
F = programmatic (annual) administrative costs
L = footprint of average reservoir per acre-ft of storage
M = average Florida millage rate
V = average taxable land value of L
i = discount rate of future payments

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the disagreement concerning its large-scale feasibility. RASTAs and STAs were also not included because they serve a hybrid purpose. See chapter 1.3 for more information about ASR, STAs, or RASTAs.

O = cost of operations and maintenance
A = annual acre-ft retention capacity
P = annual payment for ecosystem services

The reservoir model has four general components. The first is the upfront cost with financing. This is represented by the following expression:

$$\frac{b(C+S)[(r(1+r)^{b}]}{[(1+r)^{b}-1]}$$

Equation 3

"C" represents capital costs such as land acquisition, design, construction, and materials. Although the state has purchased significant amounts of land over the last decade, those acquisitions have been predominately for STAs, so the cost of buying land must be included in the analysis (MacVicar 2010b). "S" represents all the upfront administrative costs. The sum of "C" and "S" equals the total upfront cost.

The other terms account for the cost of financing this initial investment. It assumes that the reservoir will be funded by capital investment bonds and therefore incorporates a bond interest rate "r" and a maturation period "b".

The second model component accounts for costs incurred annually over the period of the project. This is represented by the following expression:

$$\sum_{t=0}^{N}\frac{F+LMV}{(1+i)^{t}}$$

Equation 4

The annual costs are added over the period "N", which represents the total duration of the project. If the project takes 10 years to build and lasts for 60 years, the duration of the project is 70 years. "F" represents the annual administration costs of managing the reservoir, and LMV represents the opportunity cost of the property taxes lost once the government purchases the land. Annual property tax is calculated by multiplying the property's taxable value "V" by the millage rate "M", and the resulting quantity is multiplied over the size of the property "L". The denominator adjusts these annual costs according to the buyer's discount rate of future payments.

The third model component accounts for those costs incurred annually over the period during which the reservoir is operational. This is represented by the following expression:

$$\sum_{t=0}^{n} \frac{O}{(1+i)^t}$$

Equation 5

"O" represents the cost of operations and maintenance. It is discounted at the rate "i", just like the previous expression. Unlike the previous expression, this cost is calculated over the period "n" because it is only incurred while the project is actually operating.

The fourth and final component of the model, its denominator, provides a unit of service against which to compare the cost. Multiplying the number of years of operation "n" by the annual storage capacity "A" yields the total amount of storage provided over the life of the reservoir. The first three model components, i.e., the numerator, represent the total lifetime project cost, and the fourth model component, i.e., the denominator, represents the total lifetime project performance.

The model for WMAs is the same except for three differences: first, the opportunity cost of lost property tax does not appear since the land in a WMA stays in private ownership. Second, land acquisition is not included in "C". Third, there is the additional cost of paying the ranchers for their service over the period of "n", represented by "P".

Identifying values for these variables is the first step in solving the equations. Several of these were straight-forward: I used the same average millage rate "M" as Florida Homestead Services (Florida Homestead Services Ltd. Co. 2010), which is 24 mills (0.024).

For average taxable land value “V” I used $11,000 based on a review of current real estate listings for agricultural land in the Northern Everglades (FDOR 2010; Zillow 2010). The analysis also assumes that “i”, or the discount rate for future payments, equals 5%. I calibrated this against the historical long-term US Treasury Bond rate. For monthly bond interest rate “r”, I used 0.375% (4.5% per year) compounded monthly based on a sample of recent capital improvement bond issues for the state of Florida (MunicipalBonds.com 2010).

The time variables “N” and “n” are important because reservoirs and WMAs have radically different time frames. Reservoirs provide water storage for a period of approximately 60 years (Lynch 2010e; MacVicar 2010b), whereas the life span of a WMA is more likely to be determined by the length of the contract as opposed to the limits of the infrastructure. Contract length can be anywhere from 5 to 20 years. A contract of less than 5 years does not justify the capital investment, while 20 years is the outer limit of the infrastructure’s physical durability (Lynch 2010d; Lynch 2010e). Currently, the SFWMD is planning for 10-year PES contracts. Although the District has not provided a rationale for this number (Lynch 2010e), it is the best indicator of actual contract length, and, consequently, the value I use in the model for the FRESP “n”.

Implementation times, and therefore “N” values, are also significantly different for the two alternatives. FRESP WMAs typically take about 1-2 years to get up and running, while reservoirs and other major water management infrastructure can take 10 years or more (Lynch 2010c; MacVicar 2010a). Based on this, I use 11.5 as “N” for WMAs and 70 as “N” for the reservoirs.

Assuming these values for the time variables, it is more feasible to make a supposition about bond maturation periods “b”. Since I am assuming a 10-year contract length for the WMAs, I will also assume 10-year bonds to finance them. My assumed maturation period for reservoir bonds is 30 years based on the same data that I used to determine “r” (MunicipalBonds.com 2010).

For the annual administrative costs "F" for the WMAs, I am using a 5% over-head cost modeled after the recent iterations of the CRP (OECD Publishing 2007).

Any other known quantities in my analysis were derived from financial data of existing or planned infrastructure. In particular, I used 3 reservoirs and the 7 FRESP pilot ranches as my data sources. Throughout the analysis, anytime that multiple data points are used to derive single values, an average (AVG), standard deviation (STDEV), standard error (SE), and bounding values at a 95% confidence level are provided. This data is summarized in tables 3 and 4:

Reservoir	C Capital Cost	L Size (acres)	A Storage Capacity (acre-ft)	O O & M Costs
Taylor Creek	$350,165,000	4,000	32,000	$1,293,280
Kissimmee	$613,091,000	10,000	161,000	$3,233,200
I-17	$331,576,000	5,000	80,000	$1,616,600
AVG	$431,610,667	6,333	91,000	$2,047,693
High	$609,772,120	9,971	164,780	$3,223,804
Low	$253,449,214	2,696	17,220	$871,583
STDEV	157,441,168	3,215	65,200	1,039,328
SE	90,898,701	1,856	37,643	600,057

Table 3: Basic reservoir variables

Ranch	C Capital Cost	O O & M Costs	A Retention Capacity (acre-ft)
1	$115,000	$26,000	164
2	$62,000	$5,000	227
3	$293,000	$43,000	2,411
4	$676,000	$32,000	850
5	$65,000	$5,000	303
6	$61,000	$20,000	939
7	$46,000	$5,000	138
AVG	$188,286	$19,429	719
High	$359,848	$30,670	1323
Low	$16,724	$8,187	115
STDEV	231,587	15,175	815
SE	87,532	5,736	308

Table 4: Basic WMA variables

Because the STAs and reservoirs operate on such different scales, the table 5 is intended to help the reader compare these technologies against common performance benchmarks:

Project	Reservoir/WMA Size (acres)	Acre-ft of Service	O&M cost per Acre-ft of Service	Capital Cost per Acre-ft of Service
Taylor Creek Reservoir	4,000	32,000	$106	$10,943
Kissimmee Reservoir	10,000	161,000	$22	$3,808
I-17 Reservoir	5,000	80,000	$23	$4,145
1	367	164	$159	$701
2	364	227	$22	$273
3	3,748	2,411	$18	$122
4	1,624	850	$38	$795
5	241	303	$17	$215
6	521	939	$21	$65
7	322	138	$36	$333

Table 5: Performance benchmarks WMAs versus Reservoirs

Table 5 shows that the O&M costs of the two types of systems are generally similar. Also, as one might expect, the WMAs, which pay for service through a continual payment stream rather than a large up-front investment, have a much lower capital cost per acre-ft than the reservoirs

The reservoir O&M numbers in table 5 were obtained indirectly because my primary data lacked this information. To calculate these values, I multiplied the reservoir size by a base coefficient that I derived from 2 other water control structures. This data is presented in the table 6:

Project	Size (acres)	Annual O&M Costs	O&M Cost Per Acre
C-44[4]	3,000	$992,794	$331
SFWMD STAs for FY 2010	43,226	$15,000,000	$347
AVG			$339
High			$355
Low			$323
STDEV			11
SE			8

Table 6: Reservoir O&M data

Even though I could only find 2 data points, and they are for different types of infrastructure (an STA versus a reservoir), the operation and maintenance of those systems is similar (USACE 1999), and indeed, the numbers are quite close.

The remaining values were unknown to the author at the time of writing. These include the annual administrative costs of a reservoir "F", startup administrative costs "S" for both reservoirs and WMAs, and the service payment "P" for the WMAs. Regarding "P", it is impossible to extrapolate its value from the pilot data, because pilot participants were paid

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[4] All historical numbers, such as the C-44 annual O&M costs, have been adjusted for inflation

for land rental, forgone production, and consultation on the design of the PES program, not on the basis of service provided. (Lynch 2010e). In a scaled-up program, the payment for service would be negotiated between buyer and seller on an individual basis[5].

Plugging in the known quantities and simplifying equations 1 and 2 yields the following:

Reservoir Cost:

$$\frac{Cost}{Acre-ft} = \frac{(1.52S + \sum_{t=0}^{N} F)}{5{,}460{,}000} + 128$$

Equation 6

WMA Cost:

$$\frac{Cost}{Acre-ft} = \frac{(1.24S + \sum_{t=0}^{N} \frac{F}{(1+i)^t} + \sum_{t=0}^{n} \frac{P}{(1+i)^t})}{7{,}189} + 56$$

Equation 7

Although we have a rate for “F” in the case of the WMA, its resulting cost is a function of “P”, which is unknown. However, since the administration of the WMA almost completely coincides with the duration of the payments, “F” can be incorporated into the “P” term as a coefficient of 1.05.

$$\frac{Cost}{Acre-ft} = \frac{(1.24S + \sum_{t=0}^{n} \frac{1.05P}{(1+i)^t})}{7{,}189} + 56$$

Equation 8

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[5] See chapter 2.1 for a full discussion of the FRESP PES process model.

Putting the two expressions together and simplifying them provides a direct comparison between the two quantities of interest:

$$\frac{\overset{WMA}{(1.24S_W + \sum_{t=0}^{n}\frac{1.05P}{(1+i)^t})}}{7{,}189} + 56 \overset{?}{<} \frac{\overset{\mathrm{Re}servoir}{(1.52S_R + \sum_{t=0}^{N}\frac{F_R}{(1+i)^t})}}{5{,}460{,}000} + 128$$

Equation 9

$$\frac{\overset{WMA}{(1.24S_W + \sum_{t=0}^{n}\frac{1.05P}{(1+i)^t})}}{7{,}189} \overset{?}{<} \frac{\overset{\mathrm{Re}servoir}{(1.52S_R + \sum_{t=0}^{N}\frac{F_R}{(1+i)^t})}}{5{,}460{,}000} + 72$$

Equation 10

$$759\overset{WMA}{(1.24S_W + \sum_{t=0}^{n}\frac{1.05P}{(1+i)^t})} \overset{?}{<} 393{,}120{,}000 + \overset{\mathrm{Re}servoir}{1.52S_R + \sum_{t=0}^{N}\frac{F_R}{(1+i)^t}}$$

Equation 11

$$\overset{WMA}{1.24S_W + \sum_{t=0}^{n}\frac{1.05P}{(1+i)^t}} \overset{?}{<} 517{,}945 + \overset{\mathrm{Re}servoir}{0.002S_R + \frac{\sum_{t=0}^{N}\frac{F_R}{(1+i)^t}}{759}}$$

Equation 12

We also know that the sum of the "P" payments must be less than 10.5P, since there is a discount rate on future payments, but I will use this number for the sake of simplicity, which yields:

$$\overset{WMA}{1.24S_W + 10.5P} \overset{?}{<} \overset{\text{Reservoir}}{517{,}945 + 0.002S_R + \frac{\sum_{t=0}^{N}\frac{F_R}{(1+i)^t}}{759}}$$

Equation 13

$$\overset{WMA}{0.12S_W + P} \overset{?}{<} \overset{\text{Reservoir}}{49{,}328 + 0.0002S_R + \frac{\sum_{t=0}^{N}\frac{F_R}{(1+i)^t}}{7{,}970}}$$

Equation 14

On the WMA side, the first term—1/10th of the administrative start-up cost—is likely to be negligible. The PWRM, visualization tools, and general permit streamline the administrative start-up process. The only aspects of start-up that would create administrative costs would be reviewing the application and negotiating payment. Even if someone were paid $100K per year and it took them a month to execute those tasks, it would cost $8,333, 1/10th of which would be $833. This is relatively small compared to the constant of $50,000 on the reservoir side, so it can be dropped for the purposes of approximate comparison.

On the reservoir side, the "F" term—1/7,910 multiplied by the lifetime, discounted programmatic administrative cost—is also likely to be negligible. Even if it costs $750 thousand per year to administer reservoir operations, with a discount rate of 5%, the total cost over the assumed 70-year project life would be $15 million. Dividing that by 7,970 yields $1,882. Compared to $50,000, for a planning-level estimate, this number can be dropped as well.

I am less comfortable making an assumption about the administrative start-up cost of a reservoir, even though its coefficient is small. It seems plausible that the permitting and design costs alone could be high enough to justify keeping the term. For example, if the administrative start-up cost were $50 million, the "S" term would still be $10 thousand, a significant amount in this comparison. For this reason, I have retained that term.

Now we are left with the following:

$$\overset{WMA}{P} \overset{?}{<} \overset{\text{Reservoir}}{49{,}328 + 0.0002S_R}$$

Equation 15

That is to say, if the payment were less than $49,328+0.0002$S_R$ per year, then the program would be cost-effective. Even though the expression for the reservoir cost could not be reduced to a constant, the result can still be used for a planning-level comparison to judge whether WMAs are within the realm of financial feasibility. For example, if the constant on the right side of the inequality were 1,000, it would indicate that WMAs would not be cost-effective. However, the constant in the analysis--$49,328—plus the unknown S_R term, indeed put the WMAs in the realm of financial feasibility.

There is another interesting result of this model: if the contract length of the WMA is assumed to be 20 years instead of 10, you get[6]:

$$0.07S_W + \overset{WMA}{P} \overset{?}{<} \overset{\text{Reservoir}}{65{,}684 + 0.002S_R + \frac{\sum_{t=0}^{N} \frac{F_R}{(1+i)^t}}{7{,}980}}$$

Equation 16

As with the 10-year calculation, the S_W and F_R can reasonably dropped, yielding:

$$\overset{WMA}{P} \overset{?}{<} \overset{\text{Reservoir}}{65{,}684 + 0.002S_R}$$

Equation 17

The constant on the right side of the inequality has increased by 33% compared to equation 15, meaning that by switching to a 20-year contract, the cost of FRESP is reduced by $16,356 annually, or, $327,120 over the life of the project. The reason for this

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[6] Bond financing is also assumed to increase to 20 years.

phenomenon is that the buyer is getting more return on the same capital investment, not to mention that over the additional 10 years, the added payments are discounted, but the retention service is not. That is to say, receiving $100 in 10 years is preferable to receiving $100 in 20 years, but 5 acre-ft of retention in 10 years has the same value as 5 acre-ft of retention in 20 years. One more note about this: remember that "P" equals annual payment, not total payment. This means that the left side has already incorporated the fact that the contract length doubled, i.e., this inequality is indeed comparing the same things as the inequality in equation 15.

Though this model focuses solely on direct, financial cost, the author recognizes that this is only one factor in justifying a PES program. It is important to be conscious of the positive externalities that often result from such programs[7].

- One of the benefits of the mixed-use ranching and water management PES model is the ability to receive support from pre-existing agricultural best management practices programs to subsidize other uses simultaneously. The sponsoring agency achieves its objectives by finding an ideal candidate for funding (i.e., each dollar spent not only goes toward ecological preservation but also water management), the cost of the program goes down for the buyer, and the rancher can negotiate that a percentage of that money be folded back into the payment stream. As I mentioned in section 2.2, one of the pilot ranches received $343,000 for WMA construction through the NRCS EQIP program. These linkages could potentially reduce some of the cost figures in the model.

- By providing ranchers with an additional revenue stream, a PES program would help offset the industry's diminishing profit margins and potential subsidy loss due to international free-trade pressure on the US (USDA-NASS 2007; Zinn 2005).

- From an environmental perspective, ranching is better than most other land uses aside from conservation. Consider the following statistics:

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[7] A discussion of some of the potential drawbacks can be found in section 4.1

Land Use	% of Okeechobee Basin	Phosphorous runoff (lbs/acre)
Row Crops	1%	170
Dairy	2%	48
Residential	2%	14
Golf Course	<1%	9
Ornamentals	1%	8
Citrus	5%	6
Field Crops	<1%	6
Improved Pasture	36%	3

Table 7: Phosphorous impacts of different land uses (WWF 2010)

Though ranching is often depicted as being at odds with the environment, it actually has the lowest phosphorous per acre run-off out of the land uses listed in table 7. Also, as I mentioned in the introduction, Florida ranches are known to provide ground water recharge, wildlife corridors, and endangered species habitat (Bohlen et al. 2009). To the extent that WMAs make it more likely that ranches will remain operational, they support a land use with several positive environmental externalities.

Also, in addition to the assumptions mentioned already, there are several other important caveats associated with the model:

- I was working with small data sets with high variance. Throughout the analysis, values were calculated based on averages with the assumption that the case studies were representative of those systems in general. By pushing the numbers out to the margins of a 95% confidence interval, either system (reservoirs or WMAs) could be made to look orders of magnitude more costly than the other.

- As I mentioned in section 1.4, the two systems provide somewhat different services: a reservoir permanently stores water that can be withdrawn at any time; a WMA temporarily retains water that eventually dissipates through evapotranspiration, groundwater recharge, overflow, and timed release.

- Another important difference between WMAs and regional water management projects is that the former is a fixed-term contract for estimated, average annual water retention on privately owned land, whereas the latter is an investment in long-term infrastructure that is owned and managed by the public sector. One is a rental and the other is a purchase.

- The increase in cost-effectiveness resulting from an extended contract does not take into account the disincentive that it might create for potential participants. That is to say, the SFWMD might pay less per WMA with 20-year contracts, but the number of ranchers willing to implement WMAs may lower by a factor large enough to offset the gains in affordability.

Notwithstanding its caveats, the results of this analysis indicate that it is at least plausible that WMAs could provide cost-effective water management service and support a payment level that would be sufficient to attract potential sellers.

3.3 FRESP Scalability

Scalability is another critical issue for a PES program. Even if there were no doubts about the cost-effectiveness of on-ranch water retention, unless it were demonstrated that the program could have an impact on a sufficiently large scale, the state would not be able to justify the transaction costs associated with implementing it; therefore, there would be no scaled-up program. Indeed, when asked about FRESP's barriers to implementation, an engineer and former employee at the SFWMD suggested that scalability, not cost-effectiveness, is the biggest issue, i.e., will the state be able to get enough out of it to make it worthwhile? (MacVicar 2010a)

The FRESP team is currently developing a detailed suitability analysis to investigate this issue. Variables such as soil, slope, land cover, commodity prices, real estate prices, land tenure, spatial relationship with regional water infrastructure, and contiguous land uses all likely affect site suitability. Attempting to perform a full analysis is beyond the scope of this thesis. It is possible, however, to present a range of plausible scenarios to get an approximate sense of a PES program's potential impact.

The first step in determining the upper limits of scalability is to calculate the total ranch acreage in the Northern Everglades, which, as of 2009, is 1,433,808 acres[8], depicted in figure 8. In terms of total need, various studies have suggested between 900,000 and 1.3 million acre-feet of additional storage capacity north of the lake. This is approximately the size of a lake with the same depth and half the horizontal extent of Lake Okeechobee (Everglades Foundation 2007). For calculation purposes, this thesis assumes the high-end estimate, i.e., 1.3 million acre-feet.

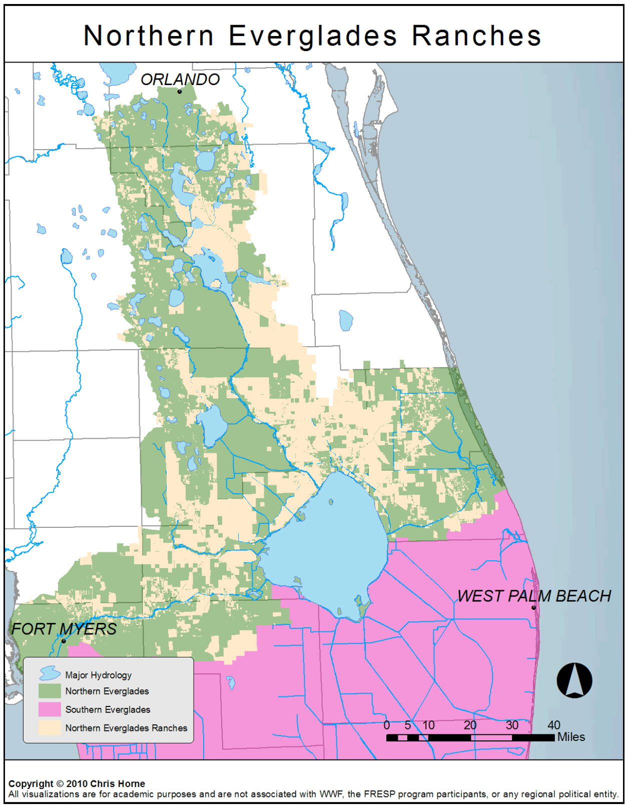

Figure 8: Ranchland in the Northern Everglades

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[8] This number is derived from analysis of the 2009 Florida Department of Revenue parcels data using Geographic Information Systems.

There are two variables that determine the impact of a scaled-up distributed water management PES program. The first is the amount of water retained for each additional acre of land managed under a WMA. Table 8 shows the performance level of the 7 water retention pilot projects:

Ranch	Total WMA Service Area (acres)	Retention per WMA acre (acre-ft/acre)
1	367	0.45
2	364	0.62
3	3,748	0.64
4	1,624	0.52
5	659	0.46
6	2,197	0.43
7	322	0.43
AVG		0.51

Table 8: WMA retention peformance

This shows that the pilot WMAs were operating near 0.5 acre-ft/acre. The FRESP team intentionally constrained the pilot ranches to provide more manageable conditions for experimentation, but they believe that a scaled-up program the average would be at least 0.75 (Lynch 2010f).

The second variable determining impact is the percentage of total ranch land that becomes managed under a WMA. Combining this variable with performance efficiency yields net impact, which can be stated in terms of the percent of regional water retention goals achieved.

Table 9 shows a full range of possible efficiencies and coverage:

Percent of ranchland switching to WMA	75%	43%	52%	61%	69%	78%	87%
	70%	40%	48%	57%	65%	73%	81%
	65%	38%	45%	53%	60%	68%	75%
	60%	35%	42%	48%	55%	62%	69%
	55%	32%	38%	44%	51%	57%	63%
	50%	29%	35%	40%	46%	52%	58%
	45%	26%	31%	36%	42%	47%	52%
	40%	23%	28%	32%	37%	42%	46%
	35%	20%	24%	28%	32%	36%	40%
	30%	17%	21%	24%	28%	31%	35%
	25%	14%	17%	20%	23%	26%	29%
	20%	12%	14%	16%	18%	21%	23%
	15%	9%	10%	12%	14%	16%	17%
	10%	6%	7%	8%	9%	10%	12%
	5%	3%	3%	4%	5%	5%	6%
		0.5	0.6	0.7	0.8	0.9	1
	Acre-ft of retention per surface acre						

Table 9: WMA Impact matrix

The columns are grouped by retention performance from 0.5 to 1. The rows are grouped according to the assumed WMA coverage as a percentage of total ranch acreage. The range is from 5% to 75%. The values in the middle represent the percentage of regional retention needs that would be met by that particular combination of extent and performance. So, for example, if a system operating at 0.7 acre-ft per acre covered 50% of the ranchland in the region, it would provide 40% of the total 1.3 million acre-ft required.

This same information is displayed below in figure 9 as a 3-dimensional graph:

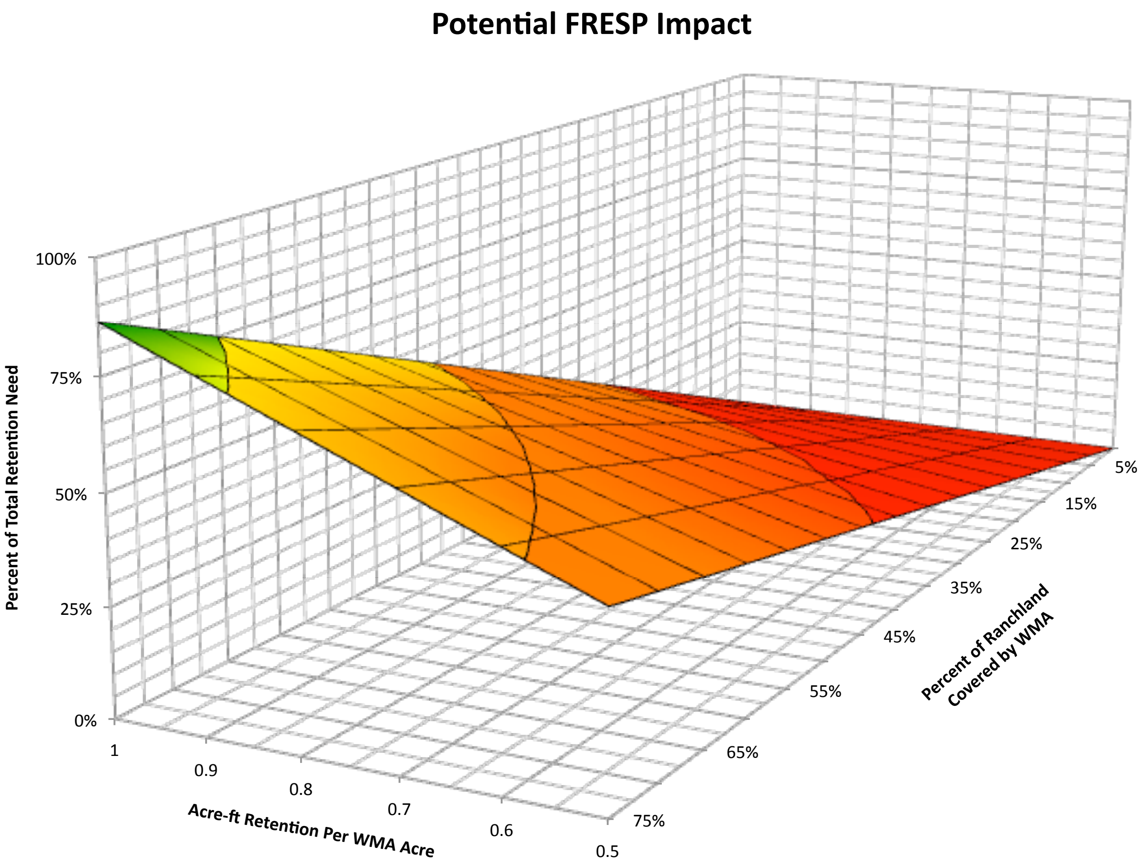

Figure 9: 3-D FRESP scalability matrix

The closer of the two horizontal axes is the retention efficiency, the other horizontal axis is WMA coverage as a percent of total ranch acreage, and the vertical axis is the percent of total need provided.

Rather than forecasting a single impact level, this analysis shows a range of plausible impacts. What counts as significant ultimately depends on the judgment of the buyer, but in my opinion, being able to provide, for example, 20% of the region's retention needs by converting a quarter of existing ranch lands to WMAs operating at 0.7 efficiency is a significant contribution. It is important to remember that FRESP has always been advocated as a complement, rather than a replacement, to regional water management (Bohlen et al. 2009; Lynch 2010c).

This chapter makes the case that a PES program for on-ranch water retention in the Northern Everglades is cost-effective, significantly scalable, and results in an array of positive externalities. The next chapter identifies some remaining issues and outlines a future research agenda to resolve them.

Chapter 4
Remaining Issues and Research Agenda

4.1 Remaining Issues

Although FRESP is a highly compelling pilot project that appears to be capable of making a contribution to the restoration of the Northern Everglades, there are still some unresolved issues. The first of these is the uncertainty of the relationship between real estate prices and willingness to participate in a PES program. While it is true that both conventional infrastructure and on-ranch retention would both become more expensive if real estate prices go up, the number of willing PES participants may shrink. That is to say, a landowner may be less willing to sign a 10-20 year contract to provide services if he thinks there is a limited window of time to cash out. Having said that, the disincentive to participate would be less severe in a PES than in an easement program, since the latter is permanent.

There are also questions about the PWRM model. Despite the benefits of its simplicity and the improvement over current methods for estimating water retention on ranches (Lynch 2010e), results from regression analysis testing the PWRM's predictive accuracy have been mixed. R^2 values ranged from 0.10 to 0.99 with an average value of 0.42. However, interpreting these results is difficult because the data was expressed in terms of annualized performance, which meant that none of the regressions had more than 3 data points (WWF 2009).

One logistical challenge is to determine who will fill which roles in a scaled up program (Lynch 2010c). After the pilot phase, WWF will be involved in the project only on a limited consulting basis—the management work will need to be done by another entity, or perhaps several entities. This choice will have important implications.

For example, SFWMD typically relates to farmers as a regulatory agency—they tell them what they cannot do through the permitting process. Suppose that in a PES program, SFWMD was the agency responsible to perform site checks for WMA compliance—this might make some ranchers uncomfortable. It would be like having the Internal Revenue Service come to your house to alphabetize your financial files—even if there is nothing to hide, people may prefer to minimize encounters of that nature. And if they were to see something on non-WMA land that they do not like, would they be in a position to assist the rancher in solving the problem?

The identity of the buyer is also important. Because environmental interests are fragmented across several government agencies, a single-buyer system may constrain the potential suite of desired ecosystem services. For example, if the SFWMD is the sole buyer, they may not have the interest or capacity to pursue carbon sequestration in addition to water retention.

To the extant that FRESP coordinates the *rental* of environmental services, questions have been raised about its lack of permanence. Some environmentalists prefer programs like conservation easements or fee simple purchase that protect land in perpetuity (TNC 2009). The concern with a non-permanent program is that its environmental gains may be wiped out when the land reverts to pre-project conditions, or worse, if it is later developed.

The permanence issue has also been one of the obstacles to large-scale institutional investment into the WMAs. That is to say, the SFWMD and the USACE have an obligation to provide certain hydrological services, and just like the ranchers needs guaranteed service payments, the public agencies need a guarantee on infrastructure capacity. The thought that an investment into water management services could disappear at the end of the contract is a cause for hesitation.

This concern is mitigated by the fact that FRESP is meant to be a complement to other infrastructure, not a replacement. Also, as discussed in chapter 3, the WMAs are relatively quick and easy to implement compared with reservoirs, for example.

4.2 Research Agenda

Some of these issues can be addressed by future research. Other topics, even if they are not problematic, are worth additional exploration. Several of these topics are listed below:

- A review the program after it has been scaled-up to see how implementation plays out. One component of that would be to conduct structured interviews of the program participants. Topics of interest would include the payment negotiation process, role assignment, renewal rates, etc.

- An investigation into the biotic impacts of a large-scale conversion from dry ranchland to wetlands. It would be valuable to understand this both at the ranch scale, i.e., the effects that the WMAs are having on species occurrence and movement patters on the ranch, as well as on the landscape scale, i.e., how would regional migration corridors and habitat matrices be affected? How would it overlap with the affects of climate change? Research on this topic at the ranch scale is already under way (Bohlen 2010)

- Some of the missing quantities in the cost analysis could likely be obtained with some additional investigation, including, for example, the administrative costs of operating a reservoir. Every additional piece of the equation clarifies the upper limits of service payments. Perhaps more importantly, additional data sets for both WMAs and reservoirs would substantially decrease the data variance and therefore provide a smaller band of possible values.

- Additional refinement of the PWRM is necessary, and the FRESP team knows that (Lynch 2010e). However, I would only advocate this up to a point. One of the appeals of the PWRM is its simplicity, and the gains of additional complexity need to be weighed against any losses in communicability. Also, modeling is expensive and time consuming, and after a certain point, the marginal gains in accuracy are not worth the money.

- A study of the factors that determine WMA suitability and their relative weights. This would provide two immediate benefits: a more refined estimate of scalability and guidelines for maximizing service efficiency.

- An investigation into the extent to which participation in interdisciplinary and multi-purpose planning projects changes institutional culture. In other words, is it enough to make a change in the SFWMD that some of its members participated in FRESP? Understanding the connection between collaborative process and institutional evolution would create new opportunities for mixed-use planning.

- A study of how contract length affects willingness to participate. The analysis on page _____ shows that increasing the contract length increases the cost-effectiveness of FRESP significantly. If the disincentive of a longer contract is weak enough that the buyer could still find the desired number of sellers, then the contract length should be extended to its outer limit.

Chapter 5
Conclusions

5.1 Reviewing Research Results

This thesis proposes a model for integrating agriculture and water management in the US based on a study of FRESP. Several key ideas emerged from that process, including:

- The need of a 3rd party facilitator regardless of the circumstances
- The understanding that an interdisciplinary, multi-sector alliance takes years of careful work to establish, yet is indispensible to the success of the program
- The value of using a simple model to calculate a constant annual performance metric. This significantly reduces administrative costs, facilitates the negotiation process, and is budget-friendly. Empirically measured distributed water management may not be feasible.
- The importance of developing a general permit, but only after gaining experience with a prototype.
- The understanding that in order for there to be a legitimate market for ecosystem services, there must be willing buyers and sellers with genuine, sustained incentives to participate.
- The power of adaptive management in designing a PES program. Many of the critical insights in FRESP resulted from actual experience with a prototype version of the eventual WMA. By extension, it indicates that a pilot phase is indispensible, even if the proposed services are only changes in management (no additional technology)

In addition to distilling the key components of the FRESP model, the thesis also attempted to determine whether FRESP is cost-effective and sufficiently scalable to justify continued investment. The analysis has convinced me that FRESP is at least comparable in cost to building a reservoir. Furthermore, by increasing the contract length, FRESP could become significantly more cost-effective. As a consequence of this last point, I urge the SFWMD to increase contract length from 10 to 20 years, provided that the pool of willing sellers would remain sufficiently large upon doing so.

The investigation into scalability was less conclusive, yet for a planning-level, first approximation of impact magnitude, I believe that table 9 and figure 9 strongly suggest that FRESP is capable of making an impact at least on the order 5-10% without major investment.

5.2 Model Portability

In any US context, each one of the key findings listed in section 5.1 would be relevant. Aside from process, the visualization and financial planning tools are probably the most portable elements of FRESP. The inputs to the tools—water stage, revenue, expenses, etc.—are standard data in the US and in most other countries. The outputs are also universal to the extent that they address intuitive needs that would confront any commercial ranch considering water retention.

The PWRM seems like the next most portable component. Though the author is unfamiliar with the detailed hydrological aspects of the model, the general architecture is logical and straightforward. It is unclear to what extent local geophysical variation affects the model, but if it does affect it significantly, only the basic model architecture could be transplanted, not the model as-is.

The general permit would not be portable without substantial revision (Lynch 2010f). There are some aspects of the process that would be universal: in the US, a general permit will likely involve the NRCS, the USFWS, and the USACE. It would also need to cover the same general set of regulations—the National Environmental Policy Act, the Endangered Species Act, and Clean Water Act. Beyond that, the details would be dependent on local agricultural practices and the threatened and endangered species present in the project region.

One important element that is not portable is the social capital. It would not be possible to point to FRESP as a precedent and then demand that the local equivalent of the SFWMD implement the same program. The collaboration and good will necessary to establish an integrated water management PES program cannot be achieved by coercion—it must be built patiently and in response to local political and social dynamics.

5.3 Implications for Policy and Planning

Aside from process, there are several strategic elements of FRESP policy makers and planners should be aware of in the future. The first is that it focuses on water management, which is unique among ecosystem services. It is well documented that the valuation of ecosystem services is immensely controversial and the cause of many failed PES programs (Robertson and Swinton 2005; Feather et al. 1999; Rasul 2009). Hydrological service, unlike biodiversity or carbon sequestration, escapes this problem because there is already concrete demand and regulatory responsibility for flood control and water management. These services are not ambiguously valued or economically external—the direct costs and benefits of various options can be compared quantitatively. To me, this suggests that water management PES programs are uniquely positioned to succeed and could be the leading edge of PES in the future.

A second strategic element of FRESP is that plugs into a largely pre-existing infrastructure and management framework. Even without WMAs, water management is a fundamental part of agricultural life in Florida (Lorenz 2010; Bohlen 2010; Lynch 2010a). Most of the region's farmers already use culverts, pumps, and ditches—adding WMA infrastructure and managing it does not require a radical adjustment. This is another instance of seeking synergies wherever they are possible.

FRESP also points toward tremendous institutional opportunities. The integration of agriculture and water management represents a push toward a new paradigm of governance that coordinates across agency boundaries to achieve common goals. For example, water managers, environmentalists, and agriculturalists all stand to gain by synchronizing their goals vis-à-vis a program like FRESP. A higher level of synergy could include a program design that merges water management, commercial ranching, the cultivation of silvopasture, and carbon sequestration (Pagiola et al. 2004).

Despite the appeal of interdisciplinary governance, it seems unlikely that merely "pointing" to it will get us there. Yet, the case study goes further in indicating how such a change might come about. It suggests that institutional transformation requires both individual leadership and collaboration. However, simply being included in a collaborative process is not sufficient to transform an institution—its protocols, policies, and rules must also be formally amended (Lynch 2010a).

There is yet another subtle force at work that has profound implications for policy and planning. A significant reason why agriculture and water are managed separately is because we often think of them separately. In other words, world-view limits interdisciplinary planning just as much as bureaucracy, politics, institutional dynamics, transaction costs, or choice of environmental service.

For example, being paid for ecosystem services is often equated with taking a portion of land out of production, i.e., being paid not to farm. But in fact, food, just like water, is an ecosystem service with explicit value. A more dynamic outlook might see management as the optimization of several goods embedded within the complex system we call "a ranch" (Robertson and Swinton 2005). Several scholars have made the case that a systems approach to agricultural planning provides the opportunity for significantly enhanced ecosystem services and farm income (Antle and Capalbo 2002; Robertson and Swinton 2005; Swinton et al. 2006).

Likewise, the conventional attitude of environmentally conscious policy makers toward agriculture has been to “mitigate” impacts—this is what best management practices are meant to accomplish. But what if we think of agriculture proactively as a provider of integrated ecological services? It is analogous to making the transition from pursuing ever more efficient houses to an architectural paradigm that treats houses as active generators of energy.

These conceptual shifts do not only apply to consumers, planners, and policy makers, but also to the ranching community. The profession may need to transform its own concept of itself in order to fully achieve the promises of integrated management. A transformed view might look like something closer to a landscape manager as opposed to a commodity producer. The fact that landscape stewardship is already valued in the ranching community suggests that this view is already partially embedded in the culture (Lynch 2010d).

To conclude, I want to make the case that the role of the intermediary is fundamentally the role of a planner. It requires knowledge of process and the means to integrate thematically diverse knowledge into a coherent intervention. It requires the intellectual fortitude to tolerate complexity and uncertainty. Finally, it requires the capacity to envision a preferred reality that may not yet exist.

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