South Florida Water Management District

FINAL REPORT

STORMWATER TREATMENT AREAS HISTORICAL VEGETATION INFORMATION ANALYSIS

Contract ST060577-W003
Task 3.3

April 2008
4993017

INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

MALCOLM PIRNIE

South Florida Water Management District
3301 Gun Club Road • West Palm Beach, FL 33406

Stormwater Treatment Areas Historical Vegetation Information Analysis

April 2008

Report Prepared By:

Malcolm Pirnie, Inc.

500 Australian Avenue South
Suite 638
West Palm Beach, FL 33401
(561) 820-4890

4993017

Contents

Appendices

1. Introduction

The Everglades is an internationally recognized ecosystem and represents the largest subtropical wetland in the United States. During recent decades, the biotic integrity of the Everglades ecosystem has been affected by alterations of the hydrologic and nutrient regimes resulting from agricultural and urban development. Reduction of total phosphorus (TP) from the Everglades Agriculture Area (EAA) runoff is a prerequisite to restoring and protecting the remaining Everglades natural resources. The use of Stormwater Treatment Areas (STAs), constructed treatment wetlands, to intercept TP from the agricultural runoff is a key component of the South Florida Water Management District's (District or SFWMD) Everglades restoration program. Six STAs with a total effective treatment area of approximately 45,000 acres have been constructed in recent years and further expansion is adding effective treatment areas of 12,400 acres in accordance with the Long-Term Plan for Achieving Water Quality Goals (Long-Term Plan, Burns & McDonnell 2003).

Key to the performance of STAs in reducing TP load is the establishment and sustainability of desired vegetation communities. The different STA treatment cells have been designated as either emergent or submerged aquatic vegetation (SAV) community, as described in the Long-Term Plan. Cattails (*Typha domingensis* and *Typha latifolia)* are the dominant species in the emergent areas of the wetlands. Submerged aquatic vegetation (SAV) in the STAs includes southern naiad, coontail, potamogeton, and hydrilla. Vegetation management in the STAs is an on-going task that involves close coordination with the scientists, site managers, operation control room, and vegetation management personnel. It involves not only maintaining the desired vegetation but also controlling the undesirable species.

This document was prepared as a compilation and review of historical vegetation information for each STA and vegetation management practices over the years. Sources of information include published and unpublished reports, vegetation maps, aerial images, as well as from interview of the District staff and contractors who are involved or work in the STAs.

1.1. Background

The STAs are the world's largest network of treatment wetlands designed to remove nutrients from non-point source runoff. The STAs were constructed as required by the Everglades Forever Act (EFA, F.S. 373.4592) to achieve long-term TP reduction goals for the Everglades. The STAs in combination with agricultural Best Management

Practices are the best available option for reducing inputs of high levels of TP from the EAA entering the Everglades Protection Area (EPA).

The design criteria for the STA system (Kadlec and Newman 1992) require sufficient wetland areas to treat runoff to an interim concentration of 50 µg P/L. Since implementation, the current pattern of vegetation in STA flow-ways is emergent dominated communities in upstream treatment cells that receive inflow water directly from drainage canals, followed by SAV in downstream treatment cells (Burns & McDonnell 2003). The emergent-dominated treatment cells (emergent cells) enhance water clarity by settling suspended solids, and have demonstrated a capacity to reduce water column TP to a lower limit of ~30 µg/L (Chimney and Newman 2006). The SAV-dominated cells (SAV cells) further reduce TP concentrations of the partially treated, less heavily loaded water to even lower nutrient levels (Dierberg et al. 2002, Pietro et al. 2006a). The current STA system consists of six treatment wetlands (Table 1-1, Figure 1-1) and has demonstrated the capacity to perform to this level through coupling of emergent and SAV cells for nearly a decade (Pietro et al. 2007).

Table 1-1. Chronology of STA operating dates.

STA Operational Dates

Water Years (May - April)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
STA-1E (Central and Western Flow-way)														
ENR Section of STA-1W														
STA-1W														
STA-2														
STA-3/4														
STA-5 (Cells 1A, 1B, 2A, 2B)														
STA-6 Section 1														

Note: "ENR Section of STA-1W" refers to the Everglades Nutrient Removal Project, which consisted of Cells 1 through 4; after Cell 5 was constructed, the project was named STA-1W (Pietro et al. 2007).

The importance of periphyton, an assemblage of algae, bacteria and other microorganisms, in the nutrient removal process in wetlands has been realized (Pietro et al. 2006a, McCormick et al. 2006). A Periphyton-Based Stormwater Treatment Area (PSTA) is generally defined as a constructed wetland with a sparse emergent community

that provides structure to support a dominant periphyton assemblage. Two PSTAs are currently operational in the STA-1E and STA-3/4.

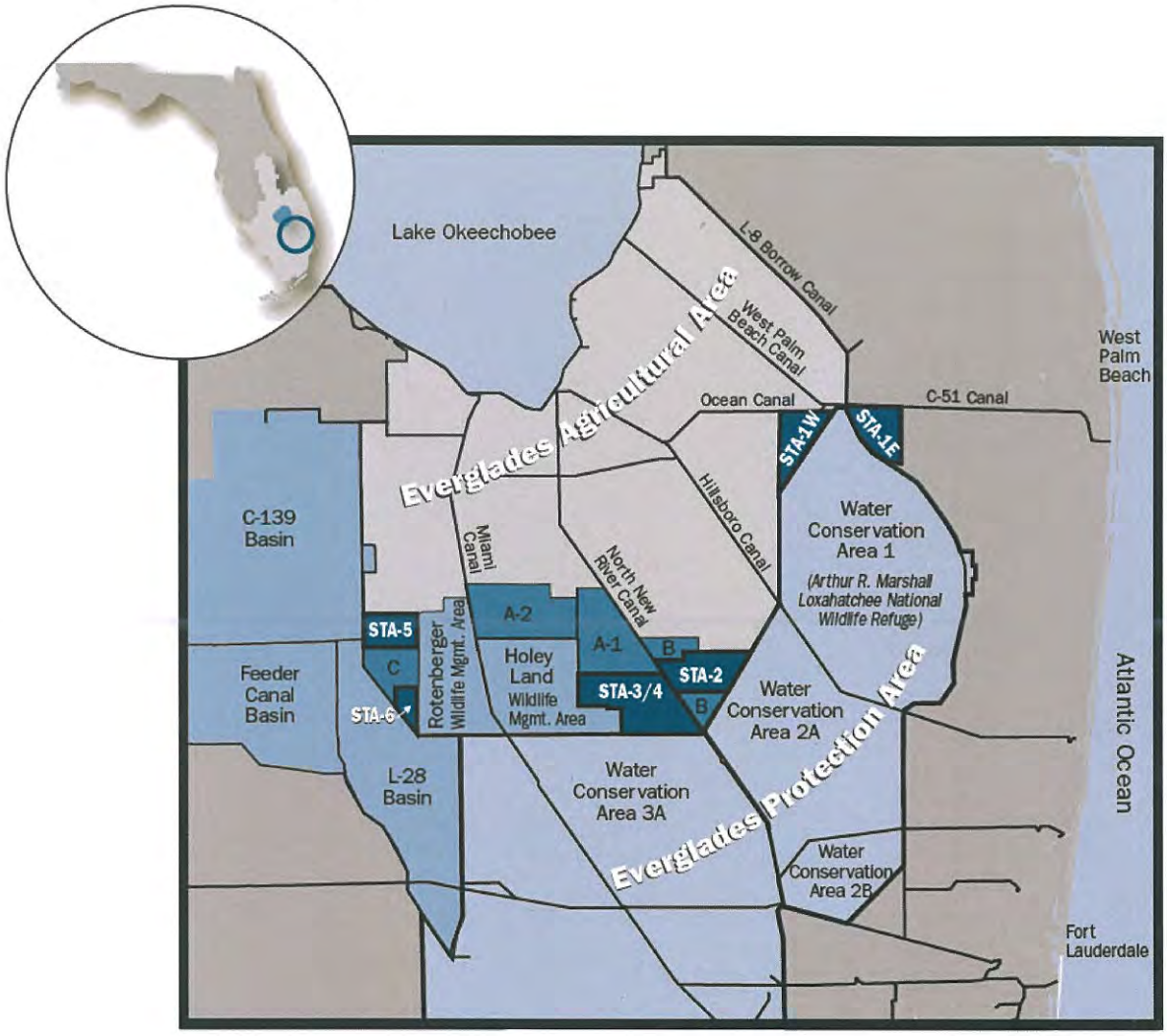


Figure 1-1. Location of the Everglades Stormwater Treatment Areas (STA-1E, STA-1W, STA-2, STA-3/4, STA-5, and STA-6) (Pietro et al. 2007).

1.2. Vegetation Classification for the STAs

In this report, a modified version of the STA Mapping Vegetation Classification System (Nick Miller Inc. 2003 and 2005) is used. This simplified classification is presented in Table 1-2 and includes barren, cattail, emergent, emergent with open water, floating aquatic vegetation, open water with or without SAV, open water with *Hydrilla* or

Potamogeton, shrub and upland. Most of the vegetation types listed in Table 1-2 are found within most but not in every STA. Barren, shrub, and upland are occasionally used to describe vegetation types.

Table 1-2. STA vegetation coverage classifications.

Vegetation types	Description
Barren	
Cattail	Areas dominated by *Typha latifolia* and/or *Typha domingensis*
Emergent	Contains mixture of grasses, sedges, and rushes.
Emergent with open water	A mixture of graminoid species and open water where plant signatures cannot be delineated separately.
Floating/Floating attached vegetation (FAV)	Areas covered by dense floating mats of water hyacinth and/or water lettuce; may contain some water fern or duckweed.
Open water with or without SAV	Open water without SAV or with SAV that is not distinguishable by signature. SAV includes macroalgae, coontail, southern naiad, *Potamogeton* spp.(pondweeds), and/or bladderwort.
Open water with *Hydrilla/Potamogeton*	*Hydrilla verticillata* and pondweeds.
Open water with periphyton	Periphyton is an assemblage of algae, bacteria, and other microorganisms.
Shrub	Mixed shrubs, including any combination of common buttonbush, willow, wax myrtle, primrose willow, and/or saltbush.
Upland	Areas vegetated with upland species.

2. Vegetation Management

For the purpose of this report, vegetation management activities are categorized into three distinct phases (pre-Routine Operational, Routine Operational, and Enhancement/ Recovery). The pre-Routine Operational phase includes STA design and construction. The Routine Operational phase includes start-up and normal operation and maintenance. The Enhancements/Recovery phase includes conversion of target vegetation, improvement of the site to encourage better plant growth, and creation of vegetation strips. Each phase has distinct vegetation management practices (Table 2-1). Vegetation management for the pre-Routine Operational phase is to establish an emergent macrophyte community within emergent cells and a SAV community within SAV cells. The strategies for the Routine Operational phase are to establish optimal water levels, maintain healthy vegetative communities, and control nuisance/invasive plants in the treatment cells.

Table 2-1. Vegetation management methods for the STAs.

	Management method
Start-up Phase	• Herbicide control of exotic woody plants and other undesirable species • Maintaining existing aquatic vegetation (either in strips perpendicular to flow, or in entirety) • Disking, mowing or use of roller chopper • Physical removal of woody species, including citrus trees • Dewatering • Flooding to promote wetland vegetation by volunteer recruitment • Earthwork activities to level out steeply sloped areas
Routine Operation Phase	• Water depth management to promote desirable vegetation, including periodic draw-down • Herbicide application for control of undesirable species • Physical removal (draglines, etc.) of floating mats • Chopping of floating mats, with and without removal • Periodic gate opening for flushing of SAV fragments to prevent build-up • Inoculation of SAV • Periodic burning
Enhancements/ Recovery phase	• Conversion of target vegetation • Creation of vegetation strips

Also there are different vegetation management strategies for each type of the treatment cells, because vegetation composition varies between the two type of treatment cells. For the perspective of vegetation management, STA vegetation is grouped into categories of "desirable" native plants and "un-desirable" nuisance/exotic plant species in this report. Generally, cattails and native wetland emergent species are considered desirable in emergent cells. In SAV cells, except for Hydrilla, all SAV species present in the STAs are considered desirable while floating aquatic vegetation are considered undesirable and are controlled.

2.1. Emergent Aquatic Vegetation

Emergent aquatic vegetation is a community of plant species that have roots anchored to the bottom of the marsh and leaves that grow up through the water and emerge above the water surface. The most common desirable emergent plants within the STA are listed in Table 2-2. Successful establishment of desirable emergent vegetation depends on various factors including the abundance of existing emergent vegetation or a viable seed bank, low relative abundance of undesirable vegetation, and the ability to control water levels. If appropriate environmental conditions exist after initial flooding, emergent aquatic vegetation is expected to expand rapidly into the flooded areas. The critical management strategy during the Routine Operational phase is to maintain an optimal/target water level for the desirable emergents and to promote natural recruitment.

Table 2-2. The most common desirable native emergent species within the STAs.

Common name	**Scientific name**
Arrowhead	*Sagittaria latifolia*
Beak rush	*Rynchospora* spp.
Bulrushes	*Scirpus* spp.(esp. *S. californicus)*
Cattail	*Typha latifolia* and/or *Typha domingensis*
Duck potato	*Sagittaria lancifolia*
Leather fern	*Acrostichum* spp.
Maidencane	*Panicum hemitomon*
Pickerelweed	*Pontederia cordata*
Wetland rice	*Oryza sativa*
Sawgrass	*Cladium jamaicens*e

2.2. Submerged Aquatic Vegetation

Submerged aquatic vegetation is a community of macrophytic plant species found in the water column that may not emerge above the water surface. These species may be un-rooted or rooted in the bottom substrate of the marsh. The most common desirable SAV expected within STA is listed in Table 2-3. Successful establishment of desirable SAV vegetation depends on various factors including abundance of SAV propagules, relative low abundance of undesirable vegetation, ability to control water levels, abundance of aboveground SAV "anchors", and water quality. If appropriate abiotic conditions exist after initial flooding, SAV is expected to expand rapidly within the SAV cell. SAV inoculation is often necessary when a desirable SAV community is absent in a SAV cell. A common method for SAV inoculation is mechanically to harvest using an aquatic harvester and transport SAV to a treatment cell.

Floating aquatic vegetation (FAV) is usually considered to be undesirable and are periodically controlled for the following reasons: 1) FAV expands and clogs the waterways, and 2) FAV "shades out" or impedes desirable SAV communities which are necessary for proper STA performance. To reduce movement of FAV in the SAV cell, in particular during the high water period, it is often necessary that emergent vegetation strips be established within the SAV cells. In the establishment phase of all SAV cells, herbicide activity must take into consideration the establishment of these emergent strips.

Table 2-3. The most common desirable SAV species within the STAs.

Common name	Scientific name	Rooting character*
Bladderwort	*Utricularia* spp.	All lack true roots. Long, slender, flexible stems generally detach from rooting base and float freely.
Coontail	*Ceratophyllum demersum*	Stems do not have roots at any time.
Muskgrass	*Chara* spp.	Root-like structures called holdfasts may attach to sediment.
Pondweeds	*Potamogeton* spp.	Stems are rooted to sediment.
Southern naiad	*Najas guadalupensis*	Stems arise from a fibrous rooted base.

* From Magee, D. W. (1981).

Hydrilla *(Hydrilla verticillata)* is not listed as a desirable species within the STAs in Table 2-4. Hydrilla is an extremely invasive aquatic plant that may form dense mats of vegetation, out-competing native SAV species, such as southern naiad and coontail. However, Hydrilla-dominated lakes and wetlands have the ability to remove TP and their TP removal efficiency is comparable to systems dominated by emergent and other SAV

(Gu 2006). *Hydrilla* within the STAs and constructed wetlands are considered to be able to improve nutrient removal performance. Whether Hydrilla is desirable or not depends on existing vegetation communities in a specific treatment cell.

2.3. Periphyton Community

The periphyton community is made up of many taxa of microalgae, bacteria and other microorganisms, serving as a food web base and building calcitic mud sediment and oxygenating the water column (Browder et al. 1994). A Periphyton-Based Stormwater Treatment Area, one type of treatment wetlands, has been studied by the SFWMD and is envisioned to be a post-STA technology that is operated at inflow TP concentrations of 50 µg P/L or less (Chimney et al. 2004, and Goforth et al. 2005). The primary nutrient removal mechanisms in a PSTA wetland are direct P uptake by the periphyton and algal-mediated co-precipitation of P with calcium carbonate. Presently the District has not conducted specific management activities for the periphyton community yet, as it grows throughout the STAs, most often in combination with SAV.

2.4. Nuisance and Exotic Plant Species

Common undesirable nuisance/exotic plants in the emergent and SAV cells include FAV, invasive exotics, and other nuisance plants (Table 2-4). Periodic control of nuisance and exotic vegetation are necessary for STA maintenance. In emergent cells, invasive exotic species, such as torpedo grass, are often undesirable. All FAV species such as water hyacinth, are considered undesirable in a SAV cell and are controlled to reduce shading of desirable SAV. Cattail may be encouraged in certain areas within SAV cells, as vegetation strips to buffer against wave action and compartmentalization of SAV beds.

Table 2-4. Common nuisance and exotic species within the STAs.

Common name	Scientific name	Vegetation type	Invasive exotic
Barnyard grass	*Echinochloa* spp.	Emergent	
Carolina willow	*Salix caroliniana*	Emergent	
Crested banana lily	*Nymphoides cristata*	Floated-leaf	√
Duckweed	*Lemna valdiviana*	Floating	
Flat Sedge	*Cyperus* spp.	Emergent	Some are exotics
Frog's-bit	*Limnobium spongia*	Floating	
Hydrilla	*Hydrilla verticillata*	Submersed	√
Mosquito fern	*Azolla caroliniana*	Floating	
Napier grass	*Pennisetum purpureum*	Emergent	√
Panic grasses	*Panicum* spp.	Emergent	
Para grass	*Brachiara mutica*	Emergent	√

Pigweed	*Amaranthus* spp.	Emergent	
Primrose willow	*Ludwigia peruviana*	Emergent	√
Smartweed	*Polygonum densiflorum*	Emergent	
Spatter–dock	*Nuphar lutea*	Floated-leaf	
Sprangle-top grass	*Leptochloa* spp.	Emergent	
Torpedo grass	*Panicum repens*	Emergent	√
Water fern	*Salvinia minima*	Floating	√
Water Hyacinth	*Eichhornia crassipes*	Floating	√
Water Lettuce	*Pista stratiotes*	Floating	√
Water Pennywort	*Hydrocotyle* spp.	Emergent	

3. Historical Vegetation Information

In the following section, an overview of each STA and its vegetation condition are presented, including the target and existing vegetation and vegetation management events. The details regarding the schematic and configuration of each of the STAs can be found in the 2008 South Florida Environmental Report (Pietro et al. 2008). The most recent vegetation maps for all the STAs are presented in Appendix 1.

3.1. STA-1 East

STA-1 East (STA-1E) is located northeast of the Arthur R. Marshall Loxahatchee National Wildlife Refuge and encompasses approximately 5,132 acres (Figure 1-1). Construction was completed in June 2004, initially flooded in summer 2004, and was operated in September 2004 (Goforth et al. 2005).

STA-1E is comprised of eight treatment cells (Figure 3-1). Since the start of its operation, cells 1, 3, 5, and 7 have been managed for emergent vegetation and cells 2, 4N, 4S, and 6 have been managed for SAV through vegetation management activities, including mowing, flooding, burning, application of herbicides, and transplanting. Target water levels are maintained 1.25 ft for emergent vegetation and 1.5 ft for SAV (Gary Goforth Inc. 2006). Torpedo grass and para grass were the dominant herbaceous species approximately 5 month after initial inundation. Based on vegetation maps developed in 2006, the coverage of vegetation was 8% cattail dominated marsh, 20% mixed emergents, 9% upland, and 57% open water with or without vegetation (Pickett 2006). A PSTA Demonstration Project was completed in a portion of cell 2 of the Eastern Flow-way (Cells 1 and 2) in February 2007. The PSTA Demonstration Project consists of three treatment cells (45.5 acres each). Historical vegetation information and management activities in each treatment cell are listed in Tables 3-1 through 3-9.

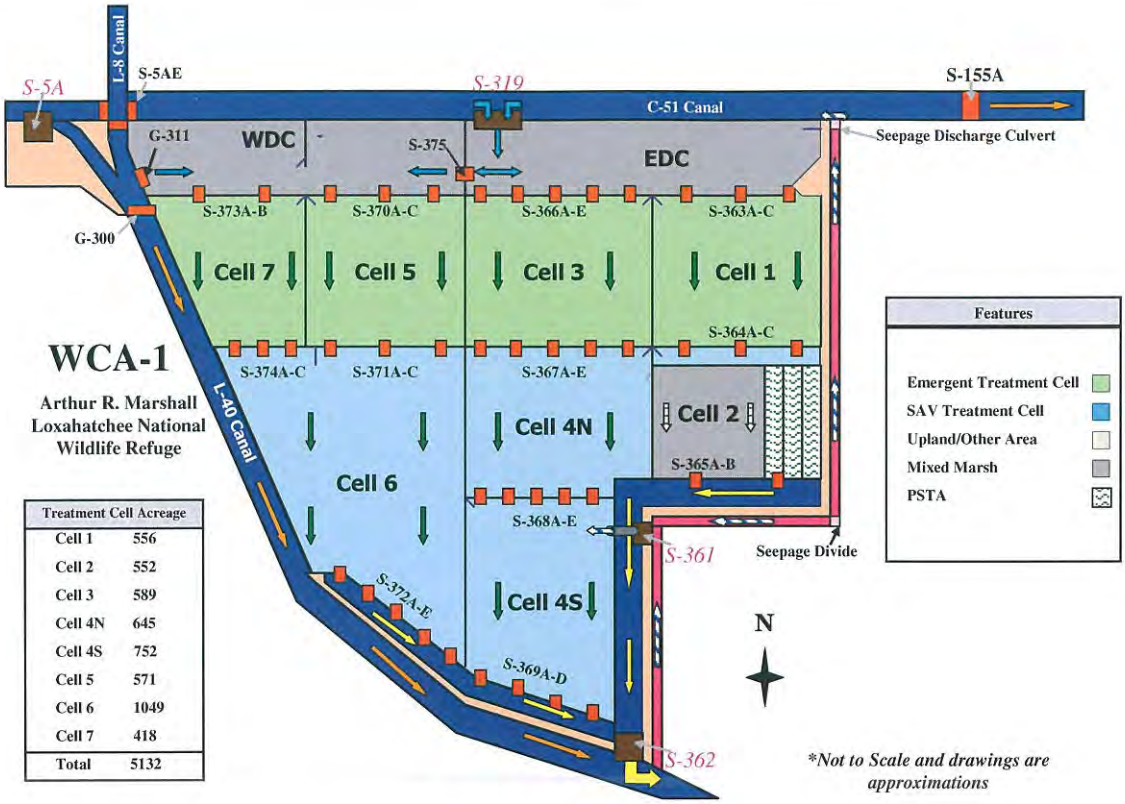


Figure 3-1. Schematic of STA-1E (not to scale). Inflow and outflow sites are designated with red/bold/italic font.

Table 3-1. Cell 1 in STA-1 East.

	Target vegetation	Existing vegetation	Vegetation management	Data source
Pre-STA		Sugarcane, vegetable or row crops, citrus grove farming, and small-scale nurseries.		Serbesoff-King 2004
WY 2004	Emergent	Terrestrial emergent	Application of herbicide for the eradication of Brazilian pepper, Australia pine, and *Melaleuca*.	Serbesoff-King 2004, Gary Goforth Inc. 2005
WY 2005	Emergent	Cattail dominated with mixed graminoids.	Off-line for construction of the PSTA Demonstration Project. Brazilian pepper and *Melaleuca* (600 acres) were aerially sprayed in November 2004.	Nick Miller, Inc. 2005, Pietro et al. 2006b
WY 2006	Emergent	Emergent/cattail with open water.	Off-line	Pickett 2006, Pietro et al. 2007
WY 2007	Emergent	85% emergent. Browned out cattail, with new growth on edges and some alligator flag (*Thalia dealbata*).	Off-line	Pietro et al. 2008, STA Overflight

WY 2008	Emergent	Emergent/cattail		Coghlan 2008

Table 3-2. Cell 2 in STA-1 East.

	Target vegetation	Existing vegetation	Vegetation management	Data source
Pre-STA		Upland terrestrial vegetation		Serbesoff-King 2004
WY 2004	SAV	Terrestrial emergents dominated. *Hydrilla* and primrose willow were noted in March 2004.	Off-line for PSTA demonstration project	Serbesoff-King 2004, Gary Goforth Inc. 2005
WY 2005	SAV	Large upland was dominant with a few pockets of primrose willow.	Off-line	Nick Miller, Inc. 2005, Pietro et al. 2006b
WY 2006	SAV	Upland terrestrial vegetation dominated.	Off-line	Pickett 2006, Pietro et al. 2007
WY 2007	SAV	Emergent grasses dominated and SAV occurred only near to northern levee.	Off-line and under construction	Coghlan 2008
WY 2008	SAV	SAV dominated near to northern levee and emergent grasses occurred in other section.	Off-line	Coghlan 2008

Table 3-3. The PSTA Demonstration Project within Cell 2 of STA-1 East.

	Target vegetation	Existing vegetation	Vegetation management	Data source
WY 2007	Periphyton			
WY 2008	Periphyton	SAV/Periphyton	Construction was completed in February 2007.	Pietro et al. 2008

Table 3-4. Cell 3 in STA-1 East.

	Target vegetation	Existing vegetation	Vegetation management	Data source
Pre-STA		A mixture of grasses, sedges, rushes, and shrubs		Serbesoff-King 2004
WY 2004	Emergent	Establishing wetland emergents	Kept FAV at maintenance control levels Water lettuce, water hyacinth, and primrose willow were sprayed in May 2004.	Serbesoff-King 2004, Gary Goforth Inc. 2005
WY 2005	Emergent	Mixed graminoids and open water dominated. Primrose willow was noted.	FAV was treated with herbicide.	Nick Miller, Inc. 2005, Pietro et al. 2006b

WY 2006	Emergent	Emergent/cattail with open water dominated. Para grass died back in December 2005. Torpedo grass was noted in 2006.	Massive amount of water lettuce was pushed up on top of the levee by Hurricane Wilma and was dead in November 2005. Primrose willow was treated.	Pickett 2006, Pietro et al. 2007
WY 2007	Emergent	85% emergent. Browned out cattail, with new growth on edges.		STA Overflight
WY 2008	Emergent	85% emergent.	50 acres of water lettuce and water hyacinth were observed primarily in the northern end of the treatment cell.	STA Overflight

Table 3-5. Cell 4N in STA-1 East.

	Target vegetation	**Existing vegetation**	**Vegetation management**	**Data source**
Pre-STA		Upland terrestrial vegetation.		Serbesoff-King 2004
WY 2004	SAV	Establishing SAV. Dominated by mosquito fern. A large area of *Hydrilla* and some band of mixed cattail/ graminoids were noted.	Treated/burned dominated terrestrial vegetation and exotics (Brazilian pepper and *Melaleuca*).	Serbesoff-King 2004, Goforth et al. 2005, Gary Goforth Inc. 2005
WY 2005	SAV	Mostly SAV species. Mosquito fern was prominent in February 2005.	Herbicide treatment of cattail and FAV. Para grass became the primary emergent species in the northern section and was treated in May 2005.	Nick Miller, Inc. 2005, Pietro et al. 2006b
WY 2006	SAV	Open water dominated in March 2006. Mostly *Chara* and naiad and one large patch of *Hydrilla* were noted in June 2005.	Created 4 vegetation strips and transplanted *Sagittaria* spp.	Pickett 2006 Pietro et al. 2007
WY 2007	SAV	*Hydrilla* and <5% emergent. Only two vegetation strips existed and were not well established.	Herbicide treatment of FAV.	Pietro et al. 2008, STA Overflight
WY 2008	SAV	*Hydrilla* dominated with Chara and naiad.		Coghlan 2008

Table 3-6. Cell 4S in STA-1 East.

	Target vegetation	**Existing vegetation**	**Vegetation management**	**Data source**
Pre-STA		Upland terrestrial vegetation.		Serbesoff-King 2004
WY 2004	SAV	Establishing SAV	Treated/burned/mowed terrestrial vegetation and invasive exotics (Brazilian pepper and *Melaleuca*).	Serbesoff-King 2004

WY 2005	SAV	Mostly open water with *Hydrilla* dominated. SAV found, possibly naiad and bladderwort in November 2004. Para grass became the primary emergent species in January 2005. Mosquito fern bloomed and became dominant with 30% cover in the spring 2005	Herbicide treatment of cattail and FAV. Crested banana lily was treated in December 2004.	Nick Miller, Inc. 2005, Pietro et al. 2006b
WY 2006	SAV	*Hydrilla* dominated in June 2005.	Created 4 vegetation strips.	Pickett 2006, Pietro et al. 2007
WY 2007	SAV	*Hydrilla* dominated with <5% emergent. Two vegetation strips existed and were not well established.	Herbicide treatment of FAV.	Pietro et al. 2008, STA Overflight
WY 2008	SAV	*Hydrilla*	Herbicide banana lily.	Coghlan 2008

Table 3-7. Cell 5 in STA-1 East.

	Target vegetation	**Existing vegetation**	**Vegetation management**	**Data source**
Pre-STA		Upland terrestrial vegetation.		Serbesoff-King 2004
WY 2004	Emergent	Establishing wetland emergents.		Goforth et al. 2005
WY 2005	Emergent	In the northeast half a graminoid/ emergent mix was dominant with less frequent *Hydrilla* and floating emergents bordering open water along the north. The southwestern half was mixed graminoids which was dominated by para grass and maidencane.	Herbicide treatment of FAV. Mosquito fern was prominent in February 2005.	Nick Miller, Inc. 2005, Pietro et al. 2006b
WY 2006	Emergent	Emergent/cattail dominant along open water. Para grass died back in December 2005.		Pickett 2006, Pietro et al. 2007
WY 2007	Emergent	75% emergent.	Primrose willow was treated.	Pietro et al. 2008, STA Overflight
WY 2008	Emergent	75% emergent.	75 acres of water lettuce and water hyacinth were observed primarily in the northern end of the cell.	STA Overflight.

Table 3-8. Cell 6 in STA-1 East.

	Target vegetation	**Existing vegetation**	**Vegetation management**	**Data source**
Pre-STA		Upland terrestrial vegetation.		Serbesoff-King 2004

WY 2004	SAV	Establishing SAV.	Treated/burned/mowed terrestrial vegetation and invasive exotics (Brazilian pepper and *Melaleuca*).	Serbesoff-King 2004, Goforth et al. 2005, Gary Goforth Inc. 2005
WY 2005	SAV	Mostly open water. Periphyton was noted in November 2004.	Herbicide treatment of cattail and FAV.	Nick Millller2005, Pietro et al. 2006b
WY 2006	SAV	Open water with *Hydrilla* and shrubs along the southwest boundary.	Created vegetation strips. Vegetation transplant experiment began. Herbicide treatment of FAV.	Pickett 2006, Pietro et al. 2007
WY 2007	SAV	Open water with *Hydrilla* and 10% emergent.	Herbicide treatment of FAV.	Pietro et al. 2008, STA Overflight
WY 2008	SAV	*Hydrilla*	Approximately 50 acres of water lettuce and water hyacinth were observed primarily in the northeast vegetation strip.	STA Overflight

Table 3-9. Cell 7 in STA-1 East.

	Target vegetation	**Existing vegetation**	**Vegetation management**	**Data source**
Pre-STA		Upland terrestrial vegetation.		Serbesoff-King 2004
WY 2004	Emergent	Establishing wetland emergents.		Gary Goforth Inc. 2005
WY 2005	Emergent	Dominated by open water with areas of *Hydrilla*, cattail, and mixed graminoids.	Herbicide treatment of FAV.	Nick Milller Inc 2005, Pietro et al. 2006b
WY 2006	Emergent	Primarily open water with some *Hydrilla*, cattail, and mixed graminoids in March 2006.		Pickett 2006, Pietro et al. 2007
WY 2007	Emergent	60% emergent.	Giant bulrush planted in May 2007.	Pietro et al. 2008, STA Overflight
WY 2008	Emergent	Primarily emergent.	Water lettuce was scattered primarily in the eastern half.	Coghlan 2008, STA Overflight

Cattails are dominant in emergent cells (Cells 3, 5, and 7) and *Hydrilla* is dominant in SAV cells (Cells 4N, 4S, and 6). Vegetation maintenance in emergent cells during the Normal Operation phase includes herbicide treatments of FAV on a routine schedule. In SAV cells, vegetation maintenance during the Normal Operation phase includes control of rapid cattail expansion, herbicide treatments of undesirable species, and creation of emergent strips. Because STA-1E is relatively new, the vegetation community has been in the establishment stage in the past two years. The coverage of emergent communities overall decreased 10% from 38% in February 2005 to 28% in December 2006 while the coverage of water with or without SAV communities increased 4% from 53% in 2005 to 57% in 2006 (Nick Milller Inc. 2005, Pickett 2006). Nuisance/exotic species within STA-

1E include torpedograss, para grass, primrose willow, crested banana lily, mosquito fern, water lettuce, and water hyacinth.

3.2. Everglades Nutrient Removal Project and STA-1 West

The Everglades Nutrient Removal Project (ENRP), the predecessor to STA-1W, which was located northwest of the Arthur R. Marshall Loxahatchee NWR (Figure 1-1), began operation in 1994. The ENRP consisted of four treatment cells, i.e., Cells 1, 2, 3, and 4. Details of the ENRP are provided in Chimney & Moustafa (1999) and Chimney and Goforth (2006). Historical vegetation information is presented in Table 3-10.

Table 3-10. Vegetation information for the ENRP Section of STA-1W (Chimney & Moustafa 1999).

	Target vegetation	Existing vegetation during August 1994 – July 1998	Vegetation management
Pre-STA		Primarily sugarcane, corn and rice	
Cell 1	Emergent	Vegetation was stable and consisted of 30-40% cattail, 15-20% other emergent, and 40-45% SAV.	Naturally revegetated
Cell 2	Emergent	Consisted of 50-80% cattail and 10-35% SAV. Cattail increased and peaked in 1995 and then decreased to a previous level in 1998.	Naturally revegetated
Cell 3	Mixed-marsh plant community	Consisted of 5-40% cattail, 40% other emergents, and 10-55% SAV. Cattail continued invading SAV areas and its cover increased from 2% to 4% while SAV areas decreased over the years.	Naturally recruited
Cell 4	Periphyton/SAV	Vegetation was stable and 95% was periphyton/SAV	Herbicide application to remove emergent and FAV

In May 1999, Cell 5 (5A and 5B) was constructed (Figure 3-2) and the project was renamed as STA-1W (Nungesser et al. 2001). STA-1W is approximately 6,670 acres in size and consists of eight treatment cells (Figure 3-2). Currently, Cells 1A, 2A, and 5A are managed as emergent cells while Cells 1B, 2B, 3, 4, and 5B are managed as SAV cells. The target water levels are maintained 1.25-1.55 ft for emergent and 1.25-1.75 ft for SAV (Gary Goforth Inc. 2005). The coverage of vegetation was 14% cattail dominated marsh, 20% mixed emergent, 14% upland, and shrubs, and 39% open water with or without vegetation in STA-1W (Pickett 2006). Historical vegetation information is presented by individual treatment cells below.

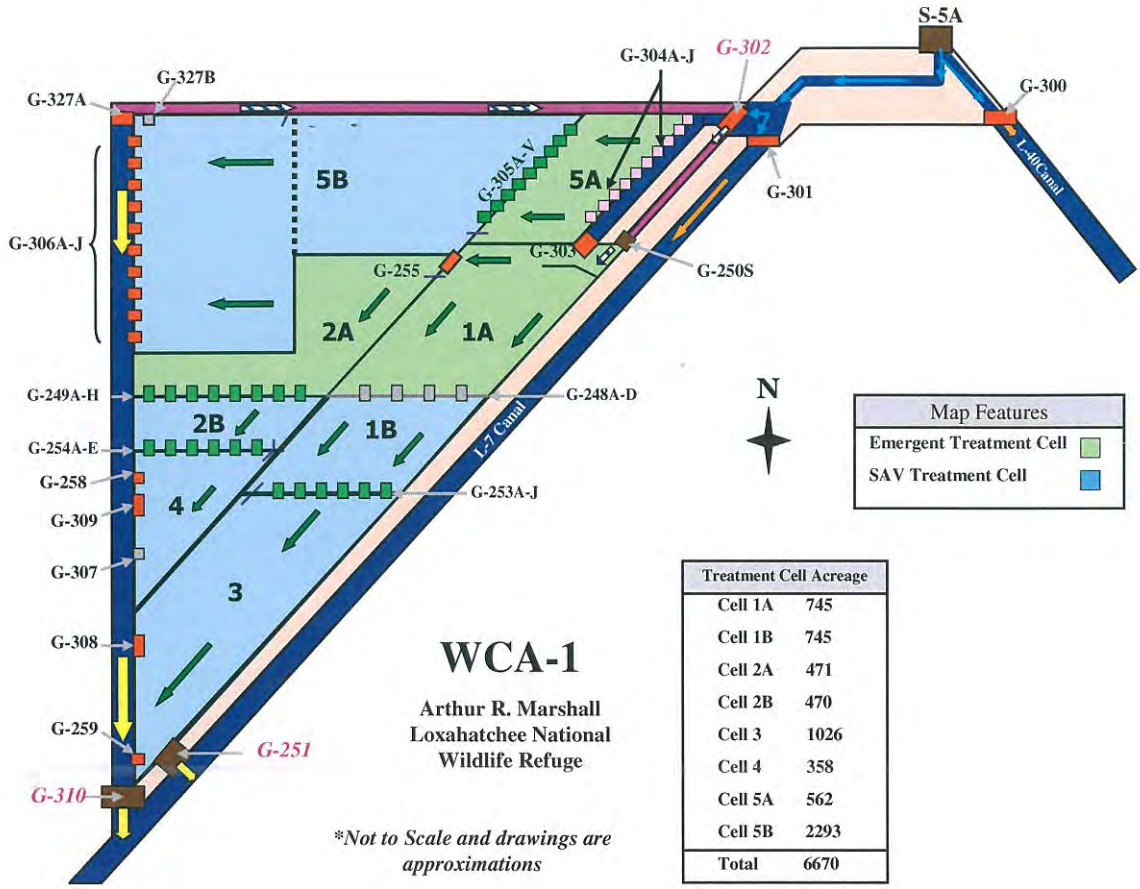


Figure 3-2. Schematic of STA-1W (not to scale). Inflow and outflow sites are designated with red/bold/italic font.

Table 3-11. Cell 1 (or Cell 1A) in STA-1 West.

	Target vegetation	Existing vegetation	Vegetation management	Data sources
WY 2001	Emergent	Cattail dominated but significant amounts of SAV and periphyton were also present. Leather fern and Carolina willow were noted.		Jorge et al. 2002
WY 2002	Emergent	Cattail dominated but significant amounts of SAV and periphyton were also present. Carolina willow and leather fern were noted.		Goforth et al. 2003
WY 2003	Emergent			
WY 2004	Emergent		Kept FAV at maintenance control levels.	Goforth et al. 2004, STA Log
WY 2005	Emergent	Contained water throughout, cattail and emergent marsh species in the south, cattail in the southeastern section, a combination of primrose willow, cattail, and mixed graminoids in the northeast, and emergent mixed with primrose willow in the northern and eastern sections.	FAV was treated and later removed in February 2005. Water hyacinth and pennywort were treated in June 2004.	Nick Milller Inc 2005, STA Log
WY 2006	Emergent	Open water was dominant with emergents, and shrubs along the eastern boundary.		Nick Milller Inc 2006
WY 2007	Emergent (Cell 1A)	30% emergent, primarily cattail and smartweed on the eastern side of this treatment cell. Moderate to high (>60%) SAV in the south.	Divided into Cells 1A (emergent) and 1B (SAV). FAV was removed from the STA.	Pietro et al. 2008, STA Overflight
WY 2008	Emergent (Cell 1A)	Open water with low SAV in the south and low cattail and smartweed on the eastern side.	Approximately 100 acres of water lettuce were observed in the northern portion.	STA Overflight

Table 3-12. Cell 1B in STA-1 West.

	Target vegetation	Existing vegetation	Vegetation management	Data sources
WY 2007	SAV	SAV and rice.	Rice was planted using a mechanical spreader, then rolled, and covered with a thin layer of peat soil. Water was brought back into the treatment cell in controlled amounts to allow rice to establish. This treatment cell was under construction	Pietro et al. 2008, STA Overflight
WY 2008	SAV	*Chara* and rice with low cattail.	Low coverage of smartweed	Coghlan 2008

Table 3-13. Cell 2 (or Cell 2A) in STA-1 West.

	Target vegetation	Existing vegetation	Vegetation management events	Data sources
WY 2001	Emergent	Cattail dominated with a large coverage of SAV and periphyton.		Jorge et al. 2002

WY 2002	Emergent	Dominated by cattail but also contained a large coverage of SAV and periphyton. Cattail clumps floated free from the treatment cell bottom and were blown around by winds.		Goforth et al. 2003
WY 2003	Emergent			
WY 2004	Emergent		Kept FAV at maintenance levels.	STA Log
WY 2005	Emergent	Water throughout and water with *Hydrilla* in the southern area in February 2005.	Many FAVs were sprayed and only large tussocks remained in December 2004. FAV in southern section was removed in May 2005.	Nick Miller, Inc. 2005
WY 2006	Emergent (Cell 2A)	Primarily cattail and small pocket of emergents, open water, and barren areas.	Primrose willow was sprayed in September 2005. FAV was removed. Divided into Cells 2A (emergent) and 2B (SAV).	Pickett 2006 Pietro et al. 2007
WY 2007	Emergent (Cell 2A)	95% emergent		STA Overflight
WY 2008	Emergent (Cell 2A)	95% emergent	Banana lily was observed along extreme southern perimeter of the treatment cell and water lettuce was along the northern perimeter.	STA Overflight

Table 3-14. Cell 2B in STA-1 West.

	Target vegetation	**Existing vegetation**	**Vegetation management**	**Data sources**
WY 2006	SAV	Dominated by open water and contained a lot of *Chara* with sparse *Hydrilla*.	Minimal water depths were maintained to encourage SAV re-growth. Rice was planted and the treatment cell was inoculated with SAV. Cattail expansion was controlled. One vegetation strip was established.	Pietro et al. 2007
WY 2007	SAV	5% emergent. SAV failed to establish, due to persistent high turbidity.	Rice was planted to stabilize the soil using a mechanical spreader, then rolled, and covered with a thin layer of peat soil. Water was brought back into the treatment cell in controlled amounts to allow rice to establish.	Pietro et al. 2008, STA Overflight
WY 2008	SAV	Rice with some *Chara* and grasses.	Banana lily was observed along extreme northern perimeter of the treatment cell.	STA Overflight

Table 3-15. Cell 3 in STA-1 West.

	Target vegetation	**Existing vegetation**	**Vegetation management**	**Data sources**

WY 2001	Emergent	Dominated by cattail but also contained a mosaic of other wetland plant species.		Jorge et al. 2002
WY 2002	Emergent	Cattail dominated but also contained a mosaic of native wetland plant species.		Goforth et al. 2003
WY 2003	Emergent	Cattail dominated but also contained a mosaic of native wetland plant species.		Goforth et al. 2004
WY 2004	Emergent		Kept FAV at maintenance control levels and controlled rapid emergent expansion.	Goforth et al. 2005
WY 2005	Emergent	Cattail dominated with water in the western section, and graminoid marsh species in the southeast.	Water lettuce was treated in July 2004.	Nick Miller, Inc. 2005, STA Log, Pietro et al. 2006b
WY 2006	Emergent	Dominated by cattail with a large band of shrubs along the eastern side and was interspersed with water and sawgrass.		Pickett 2006, Pietro et al. 2007
WY 2007	SAV	100% emergent. Will be converted from an emergent cell to a SAV cell.	Cattail stands were chopped and left on the ground; Approximately 150 acres were not chopped due to the wet ground conditions.	Pietro et al. 2008, STA Overflight.
WY 2008	SAV	Low coverage of cattail and some *Chara*	Water lettuce was scattered in northwestern corner.	STA Overflight.

Table 3-16. Cell 4 in STA-1 West.

	Target vegetation	**Existing vegetation**	**Vegetation management**	**Data sources**
WY 2001	SAV/ Periphyton			
WY 2002	SAV/ Periphyton		Emergent plant species were treated with herbicides.	Goforth et al. 2003
WY 2003	SAV/ Periphyton			
WY 2004	SAV/ Periphyton		Kept FAV at maintenance control levels and controlled expanding emergent vegetation such as torpedo grass.	STA Log
WY 2005	SAV /Periphyton	Dominated by water with *Hydrilla* in the southern portion and contained coontail, *Najas* spp, *Chara* spp.		Nick Miller, Inc. 2005, DeBusk 2007
WY 2006	SAV/ Periphyton	Water and barren areas. Cattail/emergent expanded. *Chara* spp. were noted.	Minimal water depths were maintained to encourage SAV re-growth. Rice was planted and the treatment cell was inoculated with SAV.	Debusk 2007, Pickett 2006, Pietro et al. 2007

WY 2007	SAV/ Periphyton	Water. 30% emergent, *Chara* spp. and *Hydrilla* were noted in the western side of the cell.	SAV failed to establish due to persistent high turbidity. Rice was planted to stabilize the soil, then rolled, and covered with a thin layer of peat soil. Water was brought back into the treatment cell in controlled amounts to allow rice to establish.	Debusk 2007, Pietro et al. 2008, STA Overflight
WY 2008	SAV/ Periphyton	Rice with moderate coverage of *Chara* spp. with *Najas* spp.		

Table 3-17. Cell 5A in STA-1 West.

	Target vegetation	**Existing vegetation**	**Vegetation management**	**Data sources**
WY 2001	Emergent	Dominated by cattail.		
WY 2002	Emergent	Dominated by cattail.		
WY 2003	Emergent	Dominated by cattail.		
WY 2004	Emergent	Mixture of emergents and SAV.	Kept FAV at a maintenance control level.	
WY 2005	Emergent	Primarily open water.	The SAV from the finger canals was placed in the water alongside the northern levee.	Nick Miller, Inc. 2005
WY 2006	Emergent	Shallow water and barren bottom with large areas of emergent and smaller pockets of shrubs along western and southern regions.	The emergent growth was poor so cattail planting was conducted but failed due to Hurricane Wilma.	Pickett 2006 Pietro et al. 2007
WY 2007	Emergent	45% emergent.	Pigweed and other terrestrial plants invaded during dry down. The pigweed was treated with herbicide and the resulting dead biomass was removed.	Pietro et al. 2008, STA Log, STA Overflight
WY 2008	Emergent	Emergent and water.	Approximately 125 acres of water lettuce and water hyacinth were observed in 4 large pockets.	STA Overflight

Table 3-18. Cell 5B in STA-1 West.

	Target vegetation	**Existing vegetation**	**Vegetation management**	**Data sources**
WY 2001	SAV	SAV and periphyton dominated.		
WY 2002	SAV	SAV and periphyton dominated.		
WY 2003	SAV	SAV and periphyton dominated.		

WY 2004	SAV		Water lettuce, *Phragmites*, pennywort, and frogs-bit were sprayed in March 2004. Treated cattail and torpedo grass in April 2004.	Goforth et al. 2005
WY 2005	SAV	Primarily open water throughout the treatment cell with some *Hydrilla* in the southern and northwestern sections.	Roughly 225 acres of FAV were treated in summer 2004. Mosquito fern bloomed in Cell 5B in the winter of 2004. *Lemna* and *Salvinia* became problems in November 2004. The SAV from the finger canals was placed in the water alongside the northern levee in February 2005.	Nick Miller, Inc. 2005, Pietro et al. 2006b
WY 2006	SAV	The southwestern quarter was dominated by cattail interspersed with shrubs, and barren area. The northwestern quarter was dominated by shallow water, barren bottom, and large area of emergents. The eastern half was dominated by barren bottom and water with a mix of emergent, shrubs, and barren bottom in the easternmost area.	Four vegetation strips were established that ran the entire length of the treatment cell from north to south.	Pickett 2006, Pietro et al. 2007
WY 2007	SAV	Rice and 5-10% emergent grasses. SAV experienced a decline due to persistent high turbidity. Sprangletop and barnyard grasses dominated in the southern portion during the dry down and died out when the treatment cell was rehydrated.	The treatment cell was dewatered and rice was planted in May 2006. Water was then gradually brought in to hydrate rice in early June 2006. Vegetation strips were established perpendicular to water flow in July/August 2006. The treatment cell was operated under flow and stage restrictions to allow for SAV re-growth.	STA Overflight, Peitro et al. 2008, STA Log
WY 2008	SAV	Rice and SAV, probably a mix of *Hydrilla,* Chara, and naiad.		Coghlan 2008

Cattail is dominant in emergent cells of STA-1W and a mixture of *Hydrilla,* Chara, and naiad is in SAV cells. The percent cover of emergent communities overall increased 14% from 20% in February 2005 to 34% in December 2006 while the coverage of SAV communities decreased 30% from 69% in 2005 to 39% in 2006 (Nick Miller, Inc. 2005 and 2006). Vegetation management focused on keeping FAV at maintenance control levels in both emergent and SAV cells. Along with the FAV treatments, emphasis was also placed on controlling expanding emergent vegetation, mainly torpedograss and cattail, which appeared in SAV cells. Nuisance/exotic plant species at STA-1W included water lettuce, water hyacinth, pennywort, primrose willow, torpedo grass, pigweed, giant reed, frogs-bit, mosquito fern, and crested banana lily.

3.3. STA-2

STA-2 is approximately 8,240 acres in size and is located west of the L-6 Borrow Canal (Figure 1-1). STA-2 consists of four treatment cells (Figure 3-3). The central and eastern treatment cells were flooded in 1999, and the western treatment cell was flooded in 2000. Cells 1, 2, and 3 were operational from 2004 - 2007. Cell 4 (a SAV cell) became flow-capable in December 2006, but the initial flooding of Cell 4 was delayed until June 2007.

Currently, target water depths are maintained 1.25 ft in all treatment cells. Coverage of vegetation is 43% cattail dominated marsh, 17% mixed emergents, and 37% open water with or without SAV in STA-2 (Pickett 2006). Recent enhancements to STA-2 included construction of interior levees and associated water control structures in the existing treatment cells as well as conversion of emergent vegetation to SAV in the new downstream treatment cells (Pietro et al. 2007). Historical vegetation management activities are listed by individual treatment cells below.

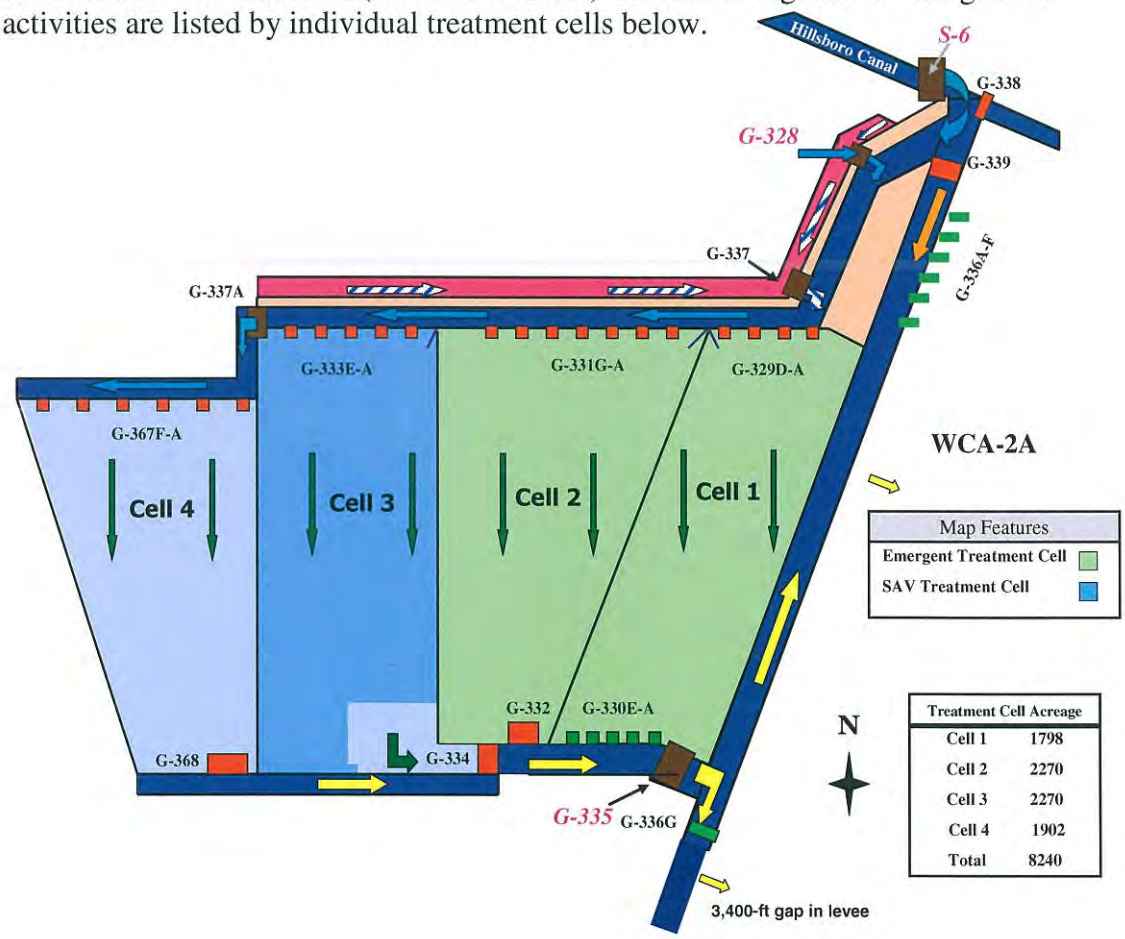


Figure 3-3. Schematic of STA-2 (not to scale). Inflow and outflow sites are designated with red/bold/italic font.

Table 3-19. Cell 1 in STA-2.

	Target vegetation	Existing vegetation	Vegetation management	Data sources
Pre-STA		Remnant Everglades that included emergents and some trees and shrubs; Dominated by sawgrass in 2001; Dominated by stable emergent vegetation, such as sawgrass with some cattail in 2002.	Herbicides were aerially applied to control Old World climbing fern, Brazilian pepper, and other nuisance vegetation.	Gary Goforth Inc. 2005
WY 2003	Emergent	The northern portion of the treatment cell largely consisted of open water covered with water lettuce and monocultures of cattail. Cattail transitioned into sawgrass in the southern portion of the treatment cell. Also unique to the southern portion was the presence of a large number of dead oak trees.		Nick Miller, Inc. 2003
WY 2004	Emergent		Kept FAV at maintenance control levels.	Goforth et al. 2005
WY 2005	Emergent	Dominated by cattail transitioning to a mix of cattail, graminoids, and emergents to the south, with pockets of sawgrass throughout the treatment cell. Along the northern edge was a large strip of a cattail/emergent mix bordering open water along with Water lettuce and spot hyacinth.		Nick Miller, Inc. 2005
WY 2006	Emergent	The northern half was dominated by cattail with pockets of emergent, sawgrass, and water. The center was composed primarily of sawgrass with some areas of cattail. The southern half transitioned from sawgrass back to cattail dominance with only isolated pockets of sawgrass.		Pickett 2006
WY 2007	Emergent	85% cattail, 5% sawgrass, and some open water.		STA Overflight
WY 2008	Emergent	85% cattail with spotted sawgrass.	Approximately 125 acres of water lettuce was observed in the northern portion of this treatment cell.	STA Overflight

Table 3-20. Cell 2 in STA-2.

	Target vegetation	Existing vegetation	Vegetation management	Data sources
Pre-STA		Remnant Everglades that included emergents and ~500 acres of sod farm; Dominated by sawgrass in 2001; Dominated by sawgrass with some cattail in 2002	Herbicides were aerially applied to control Old World climbing fern, Brazilian pepper, and other nuisance vegetation.	Gary Goforth Inc. 2005
WY 2003	Emergent/ SAV	A mixture of sawgrass and cattail with occasional patches of duck potato and pickerelweed.		Nick Miller Inc. 2003
WY 2004	Emergent/ SAV		Treated torpedo grass, cattail, and FAV.	Goforth et al. 2005

WY 2005	Emergent/ SAV	The northwestern corner was predominately open water and southern naiad, with two large areas of *Hydrilla* and some pockets of cattail. The central-eastern portion of the treatment cell was a large monoculture of sawgrass. The remainder of the treatment cell was almost entirely cattail.	Treated torpedo grass and cattail and FAV.	Nick Miller, Inc. 2005, Pietro et al. 2006b
WY 2006	Emergent/ SAV	Primarily consisted of vast areas of cattail with the exceptions of large areas of sawgrass in the southeast and open water in the northwest region.		Pickett 2006
WY 2007	Emergent/ SAV	60% cattail, 10% sawgrass, and a large area of open water in the northwest corner.		STA Overflight
WY 2008	Emergent/ SAV	80% cattail, 10% sawgrass, and a large area of open water in the northwest corner.	Approximately 30 acres of water lettuce and water hyacinth were observed just inside the eastern portion of the open water area.	STA Overflight

Table 3-21. Cell 3 in STA-2.

	Target vegetation	**Existing vegetation**	**Vegetation management**	**Data sources**
Pre-STA		Sod farm and sugarcane except for ~500 acres of Remnant Everglades. Dominated by SAV in 2001.	Herbicides were aerially applied to control Old World climbing fern, Brazilian pepper, and other nuisance vegetation. Water level was maintained to promote the growth of SAV that was still in a grow-in phase in 2002.	Gary Goforth Inc. 2005
WY 2003	SAV	The northern portion of the treatment cell was dominated by *Hydrilla* which became primarily pondweed in the south. *Chara* was present and periphyton covered a variety of vegetation.		Nick Miller, Inc. 2003
WY 2004	SAV		Treated torpedo grass, cattail, and FAV.	
WY 2005	SAV	Southern naiad with open water and some large areas of pondweed were dominant in the treatment cell. 500 acres of emergent cattail marsh existed in the southeastern section.	Treated torpedo grass, cattail, and FAV.	Nick Miller, Inc. 2005, Pietro et al. 2006b

WY 2006	SAV	Dominated by large of cattail and sawgrass stands with open water.	Flow into Cell 3 was restricted to allow plant establishment and SAV recovery. SAV test inoculation completed and small quantities of SAV were transplanted from the south area of the treatment cell to the north area in April 2006. Treated 167 acres of Hydrilla.	Pickett 2006, Pietro et al. 2007
WY 2007	SAV	Open water with *Hydrilla* dominated, 25% cattail, and 5% sawgrass. The SAV community recovered since the die-off, due to Hurricane Wilma.	Treated torpedo grass in the south end in October 2006.	Pietro et al. 2008, STA Overflight
WY 2008	SAV	*Hydrilla* dominated in the north, mixed-marsh of cattail and sawgrass in the center, and naiad dominated in the south.		STA Overflight

Table 3-22. Cell 4 in STA-2.

	Target vegetation	**Existing vegetation**	**Vegetation management**	**Data sources**
Pre-STA			Construction of an additional 2,015-acre treatment cell (new Cell 4) on Compartment B began January 2006.	Pietro et al. 2007
WY 2007	SAV		Three 200-foot wide vegetation strips, perpendicular to flow, were established.	Pietro et al. 2008
WY 2007	SAV	Naiad dominated in the north and mixed pondweed and *Chara* in central and southern portion.		Larson 2008

Cattail mixed with sawgrass is the dominant community in emergent cells at STA-2. In SAV cells, SAV communities have been established well. Vegetation maintenance in emergent cells (Cells 1 and 2) during the Normal Operation phase includes herbicide treatments of FAV on a routine schedule. In SAV cells (Cells 3 and 4), vegetation maintenance during the Normal Operation phase includes control of rapid cattail expansion and herbicide treatments of undesirable species. Emergent and SAV vegetation communities were stable from 2003 to 2006 (Nick Miller, Inc. 2003 and 2005, Pickett 2006). Undesirable nuisance/exotic species within STA-2 include torpedograss, *Hydrilla*, water lettuce, and water hyacinth.

3.4. STA-3/4

STA-3/4, the largest of the STAs, has approximately 16,543 acres of effective treatment area. STA-3/4 is located between U.S. Highway 27 and the Holey Land Wildlife Management Area (Figure 1-1). Cells 1A/1B and 2A/2B began start-up in October 2003

and Cell 3 began start-up in November 2003. STA-3/4 achieved full flow-through operation in September 2004. A schematic of STA-3/4 is presented in Figure 3-4.

Currently STA-3/4 consists of six treatment cells. Cells 1A, 2A, and 3A have been managed as emergent vegetation and Cells 1B, 2B, and 3B were converted to SAV in WY 2005 (Pietro et al., 2007). Target water depths are maintained 1.25 ft for emergent communities and 1.5 ft for SAV communities. Coverage of vegetation was 40% cattail dominated marsh, 6% mixed emergents, 31% open water with or without SAV, 9% shrubs, and 13% treated areas (NWI 2006). In 2007, Long-Term Plan Enhancements included the control of emergent vegetation in Cells 1B, 2B, and 3B to encourage establishment of SAV. Historical vegetation management activities are listed by individual treatment cells below.

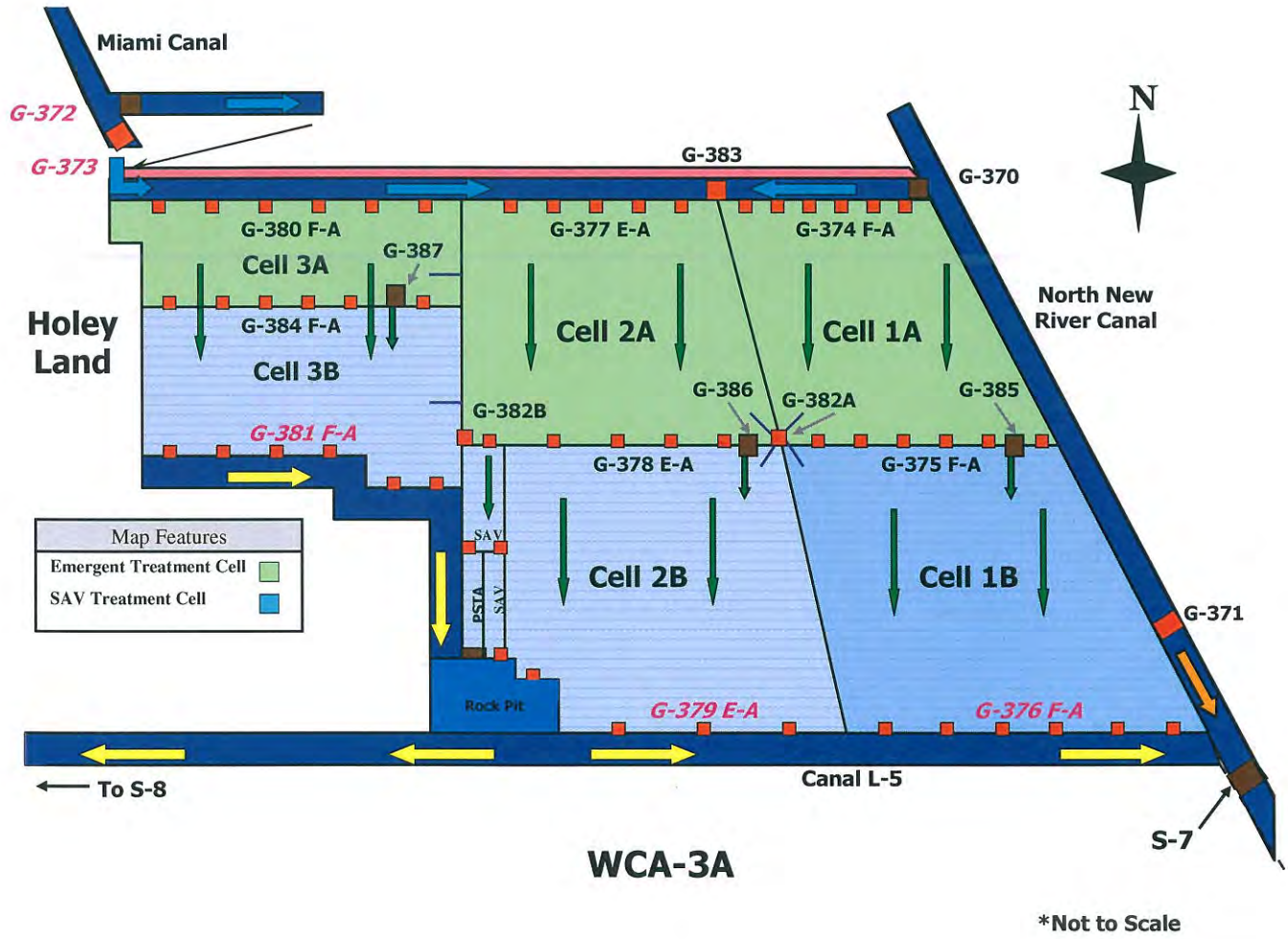


Figure 3-4. Schematic of STA-3/4 (not to scale). Inflow and outflow sites are designated with red/bold/italic font.

Table 3-23. Cell 1A in STA-3/4.

	Target vegetation	Existing vegetation	Vegetation management	Data sources
Pre-STA	Emergent	Sugarcane field. The STA was initially designed for emergent vegetation in all the treatment cells. During construction, it was vegetated and managed as the Terrytown Wildlife Management Area.	The hardwood non-target species, consisting primarily of Brazilian pepper and Melaleuca, were treated.	Gary Goforth Inc. 2005
WY 2004	Emergent	Mixed emergents, primarily torpedograss and cattail. Torpedograss expanded.		Toth et al. 2004, Gary Goforth Inc. 2005
WY 2005	Emergent	Dominated by open water with large areas of cattail mixed with FAV in the north. Several patches of cattail were located throughout the central and southwestern sections and cattail mixed with willow in the northern areas.	Herbicide treatment of FAV in August 2004.	Nick Miller, Inc. 2005, STA Log
WY 2006	Emergent	Primarily open water. Large areas of cattail mixed with FAV in the northeast and northwest. Several patches of cattail were located throughout the central and southwestern region and cattail mixed with willow in the northern areas.	Water lettuce was treated in August 2005.	Pickett 2006, STA Log
WY 2007	Emergent	65% emergent and open water. Cattail definitely stressed.	More than 1,000 acres of FAV in Cells 1A and 1B were treated in December 2006.	STA Log, STA Overflight
WY 2008	Emergent	65% emergent and open water.	Approximately 300 acres of FAV in open water areas in November 2007.	STA Overflight

Table 3-24. Cell 1B in STA-3/4.

	Target vegetation	Existing vegetation	Vegetation management	Data sources
Pre-STA	Emergent	Agricultural land (sugarcane)		Gary Goforth Inc. 2005
WY 2004	Emergent	Mixed emergents, primarily torpedograss and cattail with sugarcane.		Toth et al. 2004
WY 2005	SAV	The most frequently occurring species was willow in the northeast, southeast, and central portions of the treatment cell. Large areas of cattail occurred in the southeast and central regions.		Nick Miller, Inc. 2005
WY 2006	SAV	The most frequently occurring species was willow in the northeast, southeast, and central portions of the treatment cell. Large areas of cattail occurred in the southeast and central regions.	The bottom 20 % of Cell 1B (650 acres of emergent and shrub) was sprayed in November 2005.	Pickett 2006, STA Log
WY 2007	SAV	50% emergent (cattail), 15% open water, and treated willow.	FAV was treated in December 2006.	STA Log, STA Overflight.

WY 2008	SAV	50% cattail and sawgrass, 15% open water with *Chara* and naiad, and dead willow.	Approximately 10 acres of FAV were observed in November 2007.	STA Overflight.

Table 3-25. Cell 2A in STA-3/4.

	Target vegetation	Existing vegetation	Vegetation management	Data sources
Pre-STA	Emergent	Agricultural land (sugarcane)	Treated the hardwood non-target species, consisting primarily of Brazilian pepper and *Melaleuca*.	Gary Goforth Inc. 2005
WY 2004	Emergent	Mixed emergents, primarily torpedograss and cattail. Torpedograss expanded.		Toth et al. 2004
WY 2005	Emergent	Fully vegetated and dominated by large areas of cattail with an area of open water in the center of the treatment cell, and a large area of willow in the central-western portion.	FAV was treated in August 2004.	Nick Miller, Inc. 2005
WY 2006	Emergent	Dominated by large areas of cattail. There was an area of open water in the center of the treatment cell, and a large area of willow in the central-western portion.		Pickett 2006, STA Log
WY 2007	Emergent	80% emergent, primarily cattail, and spotty open water areas.		STA Log, STA Overflight.
WY 2008	Emergent	Primarily cattail and spotty open water areas with willow in the center.	Approximately 150 acres of FAV were observed in the northern section of the treatment cell	STA Overflight, Larson 2008.

Table 3-26. Cell 2B in STA-3/4.

	Target vegetation	Existing vegetation	Vegetation management	Data sources
Pre-STA	Emergent	Agricultural land (sod farm, tree nursery, and sugarcane)	Aerial herbicide applications on sugarcane.	Gary Goforth Inc. 2005
WY 2004	SAV	Mixed emergents, primarily torpedograss and cattail with sugarcane	Off-line to convert the emergent to SAV through herbicide and fire.	Toth et al. 2004
WY 2005	SAV	Dominated by open water.	A massive conversion from emergent vegetation to SAV occurred. Over 60,000 pounds of SAV were successfully transplanted from STA-2.	Nick Miller, Inc. 2005, Pietro et al. 2006b
WY 2006	SAV	Dominated by open water.	The establishment of SAV was accomplished during start-up by herbicide treatment, flooding, and aerial inoculations of SAV. Water lettuce was treated in August 2005.	Pickett 2006, STA Log, Pietro et al. 2007

WY 2007	SAV	Dense beds of southern naiad, Illinois pondweed and *Chara* spp. covered most of the treatment cell. 20% emergent.		Pietro et al. 2008, STA Overflight.
WY 2008	SAV	Southern naiad, Illinois pondweed and *Chara* spp. covered most of the treatment cell.	Approximately 10 acres of water lettuce were observed within the vicinity of the old tree farm in the northwest corner of this treatment cell in November 2007.	Larson 2008, STA Overflight.

Table 3-27. Cell 3 (or Cell 3A) in STA-3/4.

	Target vegetation	Existing vegetation	Vegetation management	Data sources
Pre-STA	Emergent	Agricultural land (sugarcane)		Gary Goforth 2005
WY 2004	Emergent	Mixed emergents (primarily torpedograss and cattail) with sugarcane.		Toth et al. 2004
WY 2005	Emergent	Contained several large monocultures of cattail stands, sections of willow in the southwest, water in the north, combinations of cattail with willow in the south and southwest, and cattail with mixed graminoids in the west.		Nick Miller, Inc. 2005
WY 2006	Emergent (3A)	Large monospecific cattail stands.	Construction of about 3.3 miles of interior levee was completed and then Cell 3 was subdivided into Cells 3A and 3B.	Pickett 2006 Pietro et al. 2007
WY 2007	Emergent (3A)	90-95% emergent, primarily large monospecific cattail stands.		Pietro et al. 2008, STA Overflight.
WY 2008	Emergent (3A)	Primarily large monospecific cattail stands.	Approximately 75 acres of water lettuce were observed in the northern portion of this treatment cell just downstream of the inflow structures.	Larson 2008, STA Overflight.

Table 3-28. Cell 3B in STA-3/4.

	Target vegetation	Existing vegetation	Vegetation management	Data sources
Pre-STA		Cattail mixed with willow (southern part of previous Cell 3)	Treated cattail and willow.	Pietro et al. 2007
WY 2006	SAV	Cattail mixed with willow	Sections of willow and combinations of cattail with willow were sprayed (1,400 acres of areas was treated). Vegetation strips (north/south orientation) were established.	Pietro et al. 2007

WY 2007	SAV	Establishing SAV and 25% emergent.	Aerial applications were conducted to re-configure and maintain vegetation strips. This treatment cell contained 11 north/south vegetations strips and 3 east/west vegetation strips.	Pietro et al. 2008, STA Overflight.
WY 2008	SAV	Mixed SAV (naiad) and emergent.	SAV communities looked very healthy and the vegetation strips were very well defined in November 2007.	Larson 2008, STA Overflight.

Cattail is dominant in emergent cells and SAV communities are established in SAV cells. Vegetation maintenance in emergent cells (Cells 1A, 2A, and 3A) during the Normal Operation phase includes control of torpedograss as well as willow and herbicide treatments of FAV on a routine schedule. In SAV cells (Cells 1B, 2B and 3B), vegetation maintenance during the Normal Operation phase includes development of SAV communities, inoculation of SAV from STA-2, control of torpedograss, cattail and willow expansion, and creation of vegetation strips from 2004 to 2007. The coverage of both emergent and SAV communities was stable generally from 2005 to 2006 (Nick Miller Inc 2005 and 2006). Nuisance/exotic species within STA-3/4 include willow, torpedograss, and water lettuce.

A PSTA Implementation Project, a 400-acre portion of Cell 2B in STA-3/4, consists of an upstream 200-acre treatment cell (upper SAV) and two adjacent downstream 100-acre treatment cells (lower SAV and PSTA) (Pietro et al. 2007, Figure 3-5). All treatment cells have been managed to promote a SAV community and its associated periphyton through repeated herbicide applications to suppress emergents. The vegetation throughout the project has been surveyed since September 2005. The coverage of SAV community at all sites was categorized as "low" (up to ⅓ coverage), "medium" (⅓ to ⅔ coverage), or "high" (greater than ⅔ coverage). The results of surveys in August 2006 - June 2007 are presented in Figure 3-5. Among 11 SAV taxa observed over the four sampling dates, the most abundant species was *Chara* sp. All other SAV taxa, including *Hydrilla*, had markedly lower coverage. The apparent decrease in SAV between November 2006 and February 2007, and the subsequent increase in June 2007, probably indicated a seasonal cycle in SAV biomass with the lowest coverage occurring in winter and the highest in late summer/early fall. See Pietro et al. (2008) for details.

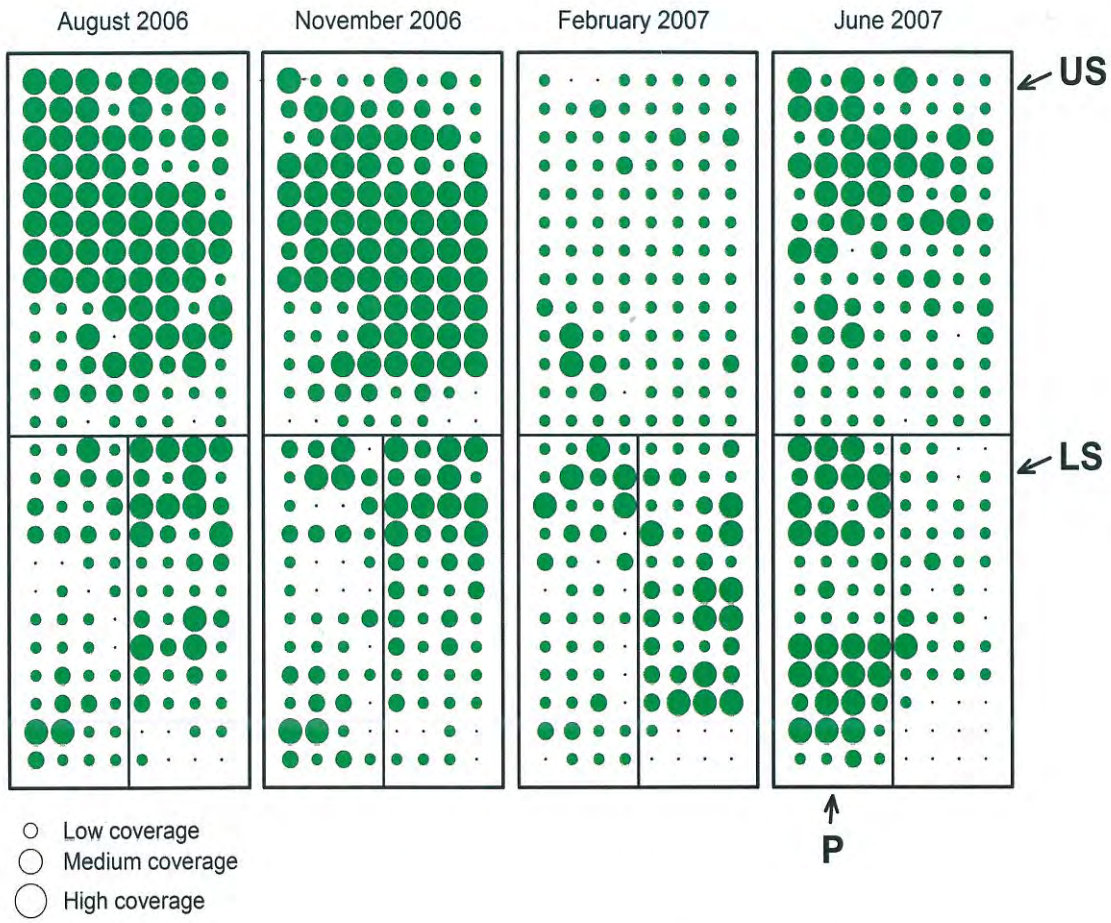


Figure 3-5. Composite distribution maps of SAV in the upper SAV cell (US), lower SAV cell (LS) and PSTA cell (P) of the STA-3/4 PSTA Implementation Project. Each closed circle represents SAV coverage at that site.

3.5. STA-5

STA-5 is approximately 6,095 acres in size and is located east of the L-2 Canal and west of the Rotenberger Wildlife Management Area (Figure 1-1, Gary Goforth Inc. 2007). STA-5 initially included two flow ways that consisted of four treatment Cells (1A, 1B, 2A, and 2B) and was flooded in December 1998. STA-5 was originally designed with the assumption that all treatment cells would be emergent vegetation (Gary Goforth Inc. 2005). The 3rd Flow-way of STA-5 became flow-capable and includes two additional treatment cells (Cells 3A, 3B) that were added to STA-5 in December 2006. The schematic of STA-5 is presented in Figure 3-6.

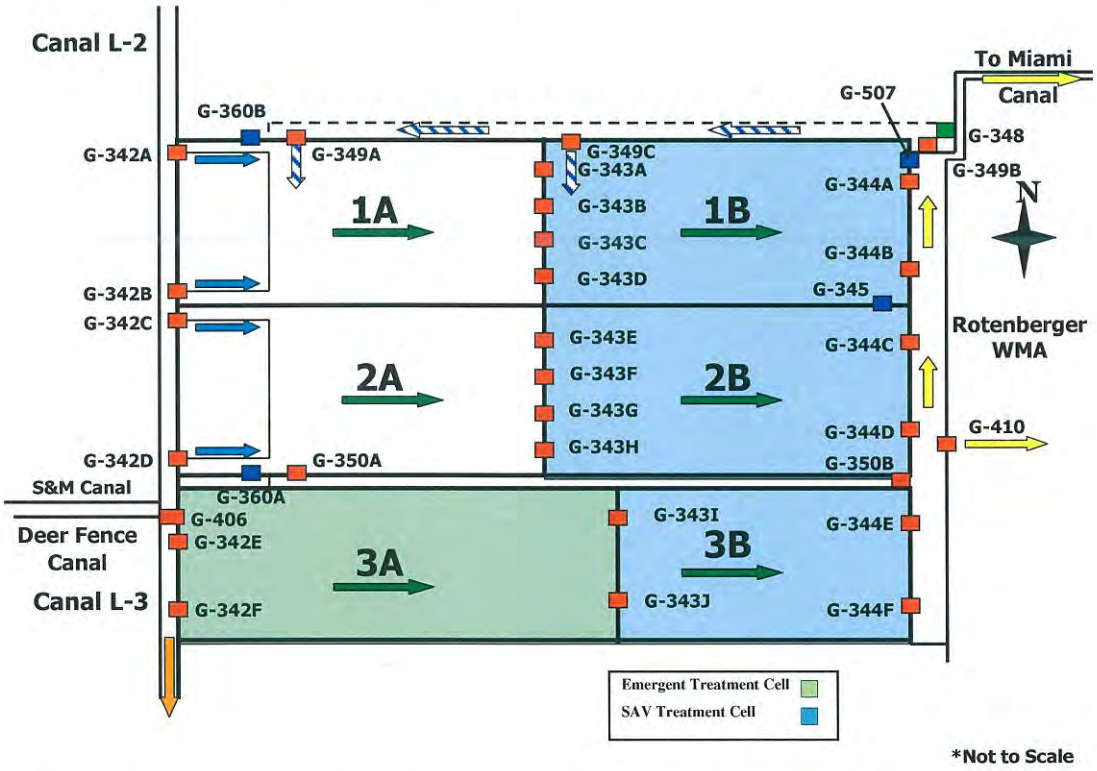


Figure 3-6. Schematic of STA-5 (not to scale). Inflow and outflow sites are designated with red/bold/italic font.

Currently target water depths are maintained at 1.25 ft for emergent and 2.00 ft for the SAV (Gary Goforth Inc. 2007). The percent cover of vegetation was 44% emergent containing cattail and 47% open water with or without SAV in STA-5 (Pickett 2006).

Historical vegetation management activities are listed below by individual treatment cells.

Table 3-29. Cell 1A in STA-5.

	Target vegetation	Existing vegetation	Vegetation management	Data sources
Pre-STA		Sugarcane		Gary Goforth Inc. 2005
WY 2000	Emergent		Treated undesirable vegetation	
WY 2001	Emergent	Dominated by cattail but also contained significant amounts of primrose willow and several *Panicum* grasses. The western quarter supported upland plant species such as wax myrtle and elderberry.		
WY 2002	Emergent	Dominated by cattail but also contained significant amounts of primrose willow and several *Panicum* grasses. The western quarter supported wax myrtle and elderberry.		
WY 2003	Emergent	Consisted primarily of cattail, primrose willow, and willow with scattered patches of smartweed and para grass. The eastern section of the treatment cell also contained large areas of periphyton while the western contained upland species.		Nick Miller, Inc. 2003
WY 2004	Emergent	*Lemna* was very thick in the southeastern portion and had some expansion. Open water areas previously co-dominated by *Hydrilla*, coontail, southern naiad, and *Chara* were dominated by *Hydrilla*.	Water lettuce and pennywort formed on southeast side and were treated.	Goforth et al. 2005
WY 2005	Emergent	Cattail and water with *Hydrilla* dominated in the northwestern half and open water with periphyton and *Hydrilla* in the southeast half. The large *Lemna* bloom showed signs of decline in August 2004.	FAV was treated.	Nick Miller, Inc. 2005
WY 2006	Emergent	Covered with a couple of expanses of water with *Hydrilla* and emergent, cattail in the central region, and emergents in the western side.		Pickett 2006
WY 2007	Emergent	70% emergent and open water (*Hydrilla*)	Abundant amount of primrose was noted.	STA Overflight
WY 2008	Emergent	Dominated emergent with *Hydrilla*.	Nearly 20% of this treatment cell was covered by willow in the western portions of the treatment cell in November 2007 where higher ground elevations cause relatively dry soil conditions.	STA Overflight

Table 3-30. Cell 1B in STA-5.

	Target vegetation	Existing vegetation	Vegetation management	Data sources
Pre-STA		Sugarcane		Gary Goforth Inc. 2005
WY 2000	SAV/ periphyton		High water was maintained to introduce SAV and encourage the establishment of SAV.	
WY 2001	SAV/ periphyton		Emergent plants were eliminated using appropriate herbicides.	
WY 2002	SAV/ periphyton		Emergent plants were eliminated using appropriate herbicides.	Goforth et al. 2003
WY 2003	SAV/ periphyton	Open water dominated with a large cover of *Hydrilla*. Periphyton prominently occurred on living and dead vegetation along the western boundary while the eastern portion had less periphyton.		Nick Miller, Inc. 2003
WY 2004	SAV/ periphyton	*Lemna* was very thick throughout and expanded.	Ground spraying of water lettuce	Goforth et al. 2005
WY 2005	SAV/ periphyton	Open water dominated with significant cover of *Hydrilla* interspersed with *Lemna* and small pockets of water. There was a narrow area of open water along the western boundary. The large *Lemna* bloom showed decline in August 2004.	FAV was treated.	Nick Miller, Inc. 2005, Pietro et al. 2006b
WY 2006	SAV/ periphyton	Northern half was dominated by water with *Hydrilla* and the southern half was dominated by open water interspersed with water vegetated with *Hydrilla*.	Emergent vegetation strips were created to protect the SAV against high wind and hydraulic loading events. Flat sedge and pigweed rapidly invaded and established, because of the dry out, and were treated.	Pickett 2006, Pietro et al. 2007
WY 2007	SAV/ periphyton	*Hydrilla*, 10% emergent, and 5% dead alligator flag.		STA Overflight
WY 2008	SAV/ periphyton	*Hydrilla* and approximately 10 acres of scattered cattail.		STA Overflight

Table 3-31. Cell 2A in STA-5.

	Target vegetation	Existing vegetation	Vegetation management	Data sources
Pre-STA		Sugarcane		Gary Goforth Inc. 2005
WY 2000	Emergent			

WY 2001	Emergent	Dominated by cattail and primrose willow but also contained a lot of smartweed and mixed grasses.		
WY 2002	Emergent	Dominated by cattail and primrose willow but also contained a lot of smartweed and mixed grasses.		Goforth et al. 2003
WY 2003	Emergent	Consisted primarily of cattail, primrose willow, and willow with scattered patches of smartweed, para grass, and large areas of periphyton. The extreme western of the treatment cell included upland plant species.		Nick Miller, Inc. 2003
WY 2004	Emergent	Water lettuce formed on southeast side.	Water lettuce was treated in 2004.	Goforth et al. 2005
WY 2005	Emergent	Contained cattail throughout with primrose willow primarily in the western section (the dryer area).	Shrubs in westernmost areas were treated. 300 acres of primrose willow were treated.	Nick Miller, Inc. 2005 Pietro et al. 2006b
WY 2006	Emergent	Cattail dominance, interspersed with pockets of emergents, shrubs, FAV, and water.	A moderate amount of primrose willow was treated and then burned within the treatment cell.	Pickett 2006, Pietro et al. 2007
WY 2007	Emergent	100% emergent. Abundant amount of primrose was noted.	Off-line in May – June 2006.	Pietro et al. 2008, STA Overflight
WY 2008	Emergent	100% emergent.	Very low water levels and exposed ground were observed throughout this treatment cell.	STA Overflight

Table 3-32. Cell 2B in STA-5.

	Target vegetation	**Existing vegetation**	**Vegetation management**	**Data sources**
Pre-STA		Sugarcane		Gary Goforth Inc. 2005
WY 2000	Emergent			
WY 2001	Emergent	Dominated by cattail with isolated areas occasionally occupied by water lettuce.		Jorge et al. 2002
WY 2002	Emergent	Cattail-dominated, with isolated areas occasionally occupied by water lettuce.		Goforth et al. 2003
WY 2003	Emergent	Consisted primarily of cattail, primrose willow, and willow with scattered patches of smartweed and paragrass. The center of the treatment cell contained large areas of open water with *Hydrilla*.		Nick Miller, Inc. 2003
WY 2004	Emergent	Open water areas previously co-dominated by *Hydrilla*, coontail, southern naiad, and *Chara*, were dominated by *Hydrilla*.	Ground spraying of water lettuce	Goforth et al. 2005

WY 2005	Emergent	Cattail was mixed with open water in the central and eastern portion. A large area of cattail occurred in the western area. Primrose willow tended to dominate the dryer areas.		Nick Miller, Inc. 2005
WY 2006	SAV	Cattail dominated the eastern and western thirds with small pockets of emergent, shrubs and floating emergent. Large areas of water and barren bottom dominated the central third.	Converted to a SAV cell. Emergent vegetation strips were established.	Pickett 2006, Pietro et al. 2007
WY 2007	SAV	Establishing SAV and 10% emergent. Alligator flag was throughout the treatment cell.	Vegetation conversion was completed and vegetation strips were incorporated in the treatment cell.	Pietro et al. 2008, STA Overflight
WY 2008	SAV	Mixed SAV species with 10% emergent.	Approximately 100 acres of water lettuce were observed primarily in the northwest corner of this treatment cell.	STA Overflight

Table 3-33. Cell 3A in STA-5.

	Target vegetation	**Existing vegetation**	**Vegetation management**	**Data sources**
Pre-STA		Compartment C		Pietro et al. 2007
WY 2006	Emergent	Establishing emergent	Emergent vegetation was treated in August 2005.	Pietro et al. 2007
WY 2007	Emergent	Mixed emergent		Larson 2008
WY 2008	Emergent	Mixed emergent		Larson 2008

Table 3-34. Cell 3B in STA-5.

	Target vegetation	**Existing vegetation**	**Vegetation management**	**Data sources**
Pre-STA		Compartment C		Pietro et al. 2007
WY 2006	SAV	Establishing SAV	Emergent vegetation was treated in August 2005.	Pietro et al. 2007
WY 2007	SAV	Mixed emergent		Larson 2008
WY 2008	SAV	Mixed emergent		Larson 2008

Cattail with primrose willow and open water is dominant in emergent cells. *Hydrilla* with open water is dominant in SAV cells. Vegetation maintenance in emergent cells during the Normal Operation phase included herbicide treatments of FAV on a routine schedule. In SAV cells, vegetation maintenance during the Normal Operation phase includes development of SAV communities, control of emergent expansion and *Hydrilla*, and herbicide treatments of water lettuce. The emergent and SAV communities overall have

been stable and shrubs were removed in 2003-2006 (Nick Miller, Inc. 2003 and 2005, Pickett 2006). Nuisance/exotic species within STA-5 include primrose willow, flat sedge, pigweed, smartweed, *Lemna* spp., and water lettuce.

3.6. STA-6

STA-6 is located east of the L-3 Borrow Canal and west of the Rotenberger Wildlife Management Area and consists of Sections 1 and 2, totaling approximately 2,170 acres (Figure 3-7, Pietro et al. 2008). Section 1 contains approximately 870 acres of effective treatment area, arranged in two emergent treatment cells. Cells 3 and 5 consists of approximately 245 and 625 acres of effective treatment area, respectively. The construction of Section 2 was completed and became flow-capable in December 2007, adding about 1,300 acres of additional treatment area to STA-6. This expansion will allow for the capture and treatment of runoff from the C-139 Annex located just west of the L-3 borrow canal. STA-6 exhibits the most vegetative diversity. Due to relatively high elevation, the longer period of hydration has increased the overall diversity of hydrophytic vegetation in STA 6 compared to the other STAs. Details on the schematic of STA-6 can be found in Operation Plan (Gary Goforth Inc. 2007).

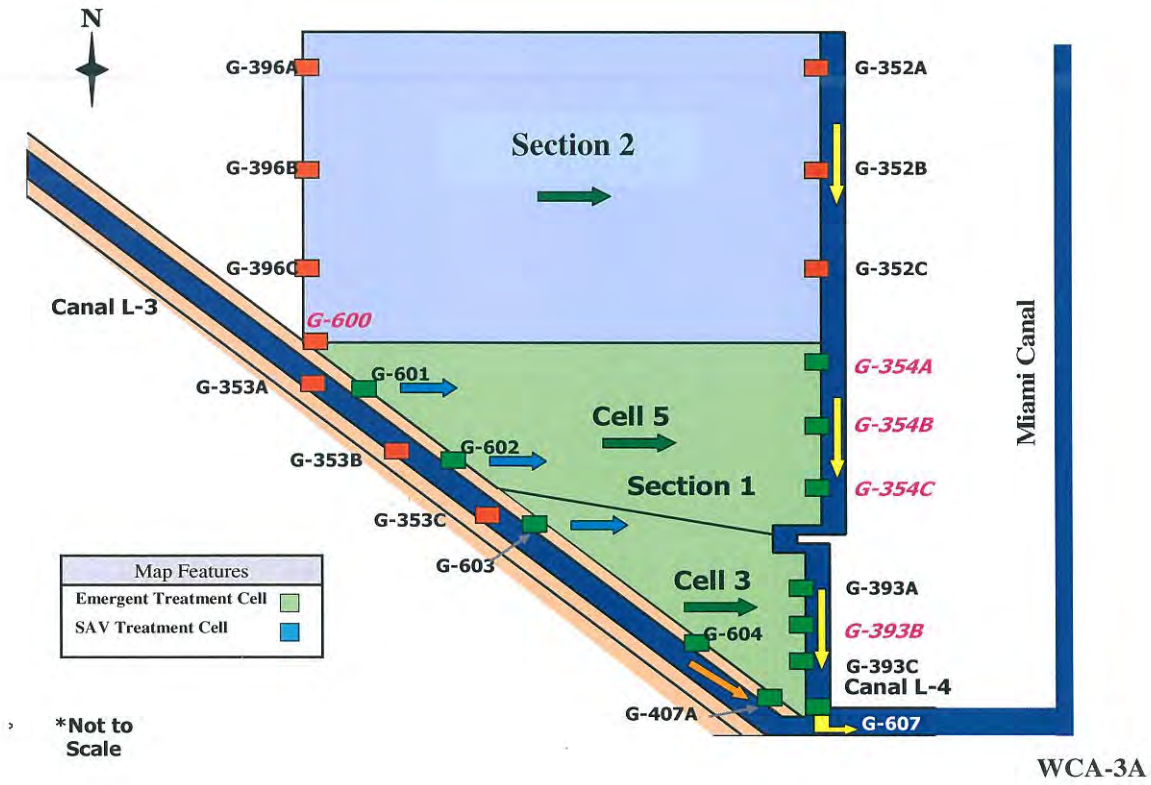


Figure 3-7. Schematic of STA-6 (not to scale). Inflow and outflow sites are designated with red/bold/italic font.

Currently, target water depths are maintained at 0.93-1.16 ft for emergent cells 3 and 5 and at 1.60 ft for Section 2, a SAV cell (Gary Goforth Inc. 2007). The coverage of vegetation was 25% cattail, 43% emergents including sawgrass, 19% shrubs, and 13% open water with or without SAV (Pickett 2006), not including Section 2. Historical vegetation information and management activities are listed by individual treatment cells below.

Table 3-35. Cell 3 in Section 1 of STA-6.

	Target vegetation	Existing vegetation	Vegetation management	Data sources
Pre-STA		STA-6 Section 1 was formerly a fully vegetated stormwater detention area.		Gary Goforth Inc. 2005
WY 2001	Emergent	Dominated by sawgrass		
WY 2002	Emergent			
WY 2003	Emergent	The primary vegetation consisted of cattail, sawgrass, and willow, with areas of *Panicum* and *Paspalum* grasses. Periphyton was prevalent in the open water and adjacent areas of *Panicum* grasses.		Nick Miller, Inc. 2003, Goforth et al. 2004
WY 2004	Emergent			
WY 2005	Emergent	Dominated by sawgrass mixed with willow in the central and southwestern portion, mixed graminoids and non-graminoid emergents in the south, cattail in the northeast, sawgrass mixed with willow in the northeast and northwest, and several sections of sawgrass throughout the treatment cell.	Willow cover increased and treated.	Nick Miller, Inc. 2005, Pietro et al. 2006b
WY 2006	Emergent	Largely swaths of shrubs with large areas of emergents, cattail, and sawgrass.		Pickett 2006
WY 2007	Emergent	100% emergent, including cattail, sawgrass, shrubs, etc.	Herbicide application to control willow.	Pietro et al. 2008, STA Overflight
WY 2008	Emergent	Mixed emergent including cattail, sawgrass, shrubs, etc.	Some willow trees were presently scattered throughout the treatment cell in November.	STA Overflight

Table 3-36. Cell 5 in Section 1 of STA-6.

	Target vegetation	Existing vegetation	Vegetation management	Data sources
Pre-STA		STA-6 Section 1 was formerly a fully vegetated storm water detention area.		Gary Goforth Inc. 2005
WY 2001	Emergent	A mixture of cattail, primrose willow, and *Panicum* grasses, most notably para grass.		
WY 2002	Emergent			

WY 2003	Emergent	The primary vegetation consisted of cattail, sawgrass, and willow mixed with cattail or sawgrass, and areas of *Panicum* and *Paspalum* grasses. Periphyton was prevalent in the open water features and adjacent areas of *Panicum* grasses. Vegetation in the northwest section included napier grass, para grass, and southern wild rice.		Nick Miller, Inc. 2003, Goforth et al. 2004
WY 2004	Emergent	Extensive areas of browning paragrass occurred within the eastern half.		
WY 2005	Emergent	Dominated by cattail and water with periphyton in the eastern section, and by mixed graminoids with cattail and a monoculture of mixed graminoids in the western area. Paragrass in the eastern portion regrew after a significant browning out the previous fall. Para grass and torpedo grass were both very thick. Vegetation (para grass, willow, and torpedograss) browned out in the areas with sparse emergent vegetation and deeper water. Bladderworts dominant in the eastern part, appeared to be somewhat senescent.	Cattail expanded in the treatment cell and 140 acres of cattail were treated.	Nick Miller, Inc. 2005, Pietro et al. 2006b
WY 2006	Emergent	Dominated by emergents with large areas of shrubs and cattail throughout except along the eastern side of the treatment cell.	Treated emergent vegetation in SAV communities locating in the northern treatment cell in December 2005.	Pickett 2006, STA Log
WY 2007	Mixed emergent/SAV	70% emergent, mainly cattail, with SAV and open water.	Herbicide application to control willow.	Pietro et al. 2008, STA Overflight
WY 2008	Mixed emergent/SAV	Mainly cattail and open water with *Hydrilla*.		Larson 2008

Table 3-37. Section 2 in STA-6.

	Target vegetation	Existing vegetation	Vegetation management	Data sources
Pre-STA		Part of Compartment C		
WY 2008	SAV	N/A	N/A	

Cattail and many other emergent plants occur in the emergent cell. Vegetation maintenance in emergent cells during normal operations included control of emergent expansion, and control of willow. In section 1, the emergent cover generally decreased 27% while SAV communities increased 25% from 2003 to 2006 (Nick Milller2003, Pickett 2006), due to vegetation management. Nuisance/exotic species within STA-6 include Brazilian pepper, para grass, napier grass, torpedograss, and willow.

4. Herbicide Application

A summary of the herbicide applications to the STAs during WY2001-2007 is presented in Table 4-1. Current herbicides in use are diquat, 2, 4-D, glyphosate, imazapyr, triclopyr, and endothall. Diquat, a contact-type herbicide, is used to control floating vegetation, which consists of water hyacinth and water lettuce. 2, 4-D is used only for water hyacinth. Systematic herbicides such as glyphosate, imazapyr, and triclopyr-based products are used to control emergent vegetation, which consists of numerous species such as cattail, torpedograss, para grass, and many others. *Hydrilla* is controlled using endothall-based herbicide. The majority of herbicide treatments are aerially applied.

Table 4-1. Summary of the amount of herbicide applied to the STAs during Water Years 2001-2007.

STA	Water Year	Herbicide Containing Glyphosate (gallons)	Herbicide Containing Imazapyr (gallons)	Herbicide Containing Triclopyr (gallons)	Herbicide Containing 2, 4-D (gallons)	Herbicide Containing Diquat (gallons)	Endothall
STA-1W	2001	633	28.5				
	2002	633	28.5				
	2003	707			730	1,050	
	2004	114				133	
	2005	151	40.3			15	
	2006	1,332	351			81	
	2007	1,432	130	31		695	
STA-1E	2004						
	2005	1797	479			15	
	2006	689	291			88.5	
	2007	640	14	605	2,340	155	
STA-2	2001	750		1,000			
	2002	80	40				
	2003	235					
	2004	163				96	393 gal; 2571 lb granular
	2005	6.5	1.75			67	285
	2006	108	14.3			87	3950 lb granular
	2007	1,907	522			92	
STA-3/4	2004	1,412					
	2005	2,576	687			279	

	2006	931	161			593
	2007	1,874	237	8.3		108
STA-5	2001	365				
	2002	231		56	491	50
	2003	291	6	10	965	1635
	2004	168				287.5
	2005	711	190			160
	2006	3,192	828			96
	2007	4,693	800	697		859
STA-6	2001			14.3		
	2002	43.2	4.3	26.5		
	2003	10	3	10		
	2004					
	2005	15.9	4.3			1.25
	2006	147	33			
	2007	1,518	384	124		0.5

The amount of herbicides applied to the STAs greatly increased over the years (Figure 4-1). The amount of glyphosate applied to the STAs increased a factor of seven times from 2001 to 2007.

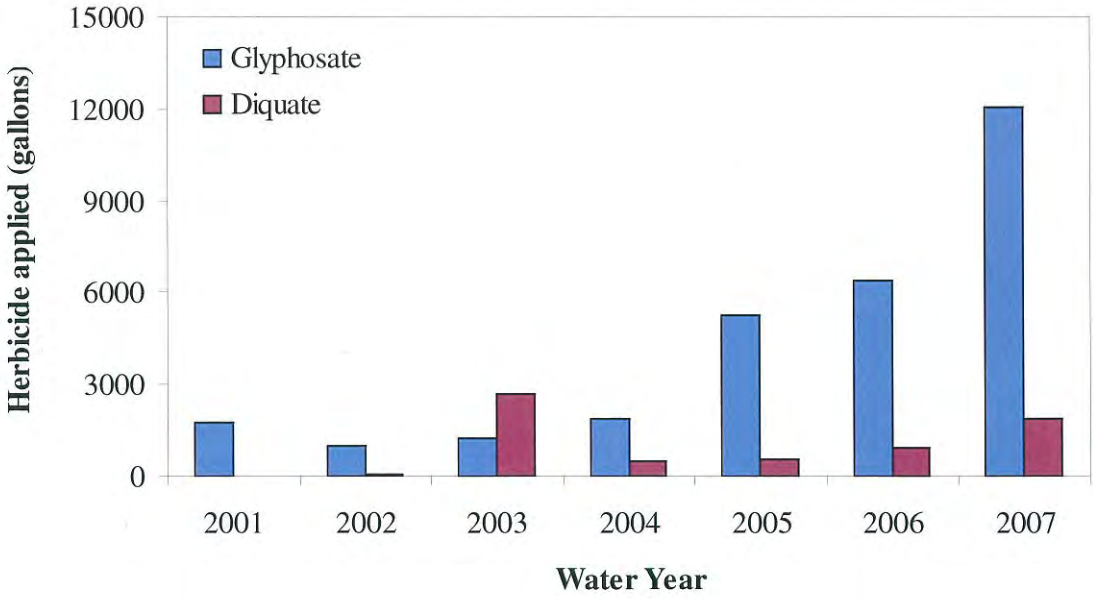


Figure 4-1. The amount of glyphosate and diquat applied to the STAs from Water Year 2001 to 2007

5. Hurricane and Drought Impacts

5.1. Hurricane Impacts

During WY 2005, the STAs experienced months of high rainfall, hydraulic overloading, and high TP inflows, due to Hurricanes Frances and Jeanne in September 2004 (Pietro et al. 2006b). The hurricanes caused physical damage to the wetlands, erroded levees, and damaged SAV, especially in STA-1E, STA-1W, and STA-2.

During WY 2006, Hurricane Wilma adversely affected the vegetation, especially the SAV communities, creating poor water clarity and high turbidity (Pietro et al. 2007). For example, STA-1W Cell 5B and STA-2 Cell 3 experienced severe turbidity problems.

Specific impacts of each hurricane season are presented in Table 5-1. Hurricane impacts prompted efforts to fortify the marsh to increase plant survivability in some treatment cells of the STAs. Emergent vegetation strips were established to help prevent SAV displacement across the wetland and reduce the impact of wind action. The extended deepwater and high TP loading caused by hurricanes also adversely affect the ability of the SAV and emergent communities to remove P.

Table 5-1. Impacts of 2004 and 2005 hurricanes on the STA vegetation communities.

STA	Hurricanes Frances/Jeanne (September 2004)	Hurricane Wilma (October 2005)
STA-1E		Wilma caused minor damage to the SAV and emergent plants, particularly in Cell 4N.
STA-1W	Extensive damage in Cell 5B with most of the SAV uprooted and pushed up onto the levee.	STA-1W was directly impacted by Hurricane Wilma. Hurricane caused moderate damage to SAV in Cell 5, and minor damage to emergent vegetation.
STA-2	Frances piled a large amount of SAV (mostly *Hydrilla*) onto the northern levee banks of Cells 2 and 3 along with some of the cattail.	The SAV in Cell 3 suffered severe damage, especially in the northern section of the treatment cell. Moderate damage was done to the emergent vegetation.
STA-3/4	No damage was observed in the wetland.	Wilma caused moderate damage to SAV in Cell 2B, and moderate damage to the emergent vegetation.
STA-5	No damage was observed in the wetland.	Wilma caused minor damage to the SAV and moderate damage to the emergent vegetation.
STA-6	No damage was observed to the wetland.	Wilma caused minor damage to SAV and emergent vegetation, and no damage to levees.

5.2. Drought Impacts

Extended drought periods adversely impact SAV and emergent communities within the STAs. During the dry season of WY2007, the District STA Management Division worked closely with the Operations and Maintenance Department to monitor water levels and to prioritize water needs within the STAs. Targeted stage levels during drought, i.e. minimal water depths set at 6 inches for SAV communities and 6 inches below the ground surface for emergent communities were maintained whenever possible. The District scientists also initiated monitoring of soil moisture in selected emergent cells and monitoring post-drought recovery of cattails. In WY2008, a Drought Contingency Plan has been developed and implemented (Chimney et al. 2008). The scientists at STA Management Division have also initiated drought-related studies: 1) to determine the specific impacts of drought on emergent vegetation and 2) to assess recovery potential of drought impacted plants. The proposed study is intended to help STA Management Division develop sound vegetation management strategies. In addition, the extended drought periods may accelerate the invasion of nuisance and exotic species within the STAs.

6. Summary and Recommendations

A critical component of optimizing STA performance is the sustainability of desirable vegetation community. The District has monitored vegetation in the STAs routinely and in an adaptive manner to understand performance and continually to develop and implement vegetation management strategies. Monitoring and surveys are accomplished by aerial imagery (entire STAs), ground surveys (selected cells, adaptive surveys), and vegetation management flights. Based on aerial imagery, annual vegetation maps were developed in 2003-2006. Results of ground surveys included identification of dominant species and vegetation coverage. Much descriptive information on vegetation management and on control of nuisance/exotic plants has also been accumulated in the past decade.

Overall, both emergent and SAV communities in STA-1E, STA-2, STA-3/4, and STA-5 were relatively stable while the vegetation communities in STA-1W and STA-6 from 2003 to 2006 were dynamic. Based on 2006 vegetation maps, the coverage ratio of the cattail/emergent community to open water with or without SAV communities was 2:1, 1:1, 2:1, 1.5:1, 1:1, and 5:1 in STA-1E, STA-1W, STA-2, STA-3/4, STA-5, and STA-6, respectively.

The maintenance of vegetation communities generally involves the establishment and expansion of desired species as well as control of nuisance and exotic species. Vegetation control is commonly accomplished through herbicide application. Due to the large amount of herbicides applied to within STAs, the District should investigate if the large amount of herbicide has any adverse effects on trophic interactions within these treatment wetlands and subsequently impact their performance and sustainability.

Although there have been much success in establishing and maintaining emergent and SAV communities, there are constant challenges to sustain the vegetation and minimize the need for costly recovery of cells. Despite the comprehensive management experience has been obtained over the last fifteen years, additional scientific and practical questions remain effectively to manage the STAs, optimize, and sustain their performance. Hence, there is a continued need for conducting science-based investigations of various vegetation management strategies.

STA-1W and STA-5 had the lowest coverage of emergent community, compared with other STAs based on STA Vegetation Survey Reports (Nick Miller Inc. 2003 and 2005, Pickett 2006). These two STAs also had the lowest P load reduction percentage (49% and 55%) in WY2006 (Pietro et al. 2007). A correlation between vegetation cover ratio and P removal was examined, based on available data from the District's SFER (Goforth et al 2005, Pietro et al. 2006 and 2007) and STA vegetation data (Nick Miller Inc. 2003 and

2005, Pickett 2006) (Figures 6-1 and 6-2). These two figures suggest a positive relationship between the emergent/ SAV and water cover ratio and P reduction rate (R^2 = 0.588, P<0.01) and a negative relationship between the emergent/ SAV and water cover ratio and outflow TP concentration (R^2 = 0.570, P<0.01). The relationship between the ratio of vegetation cover and P removal efficiency within the STAs provides valuable information for STA vegetation management. Further studies are needed for a more in-depth understanding of the linkage between vegetation dynamics and P removal performance.

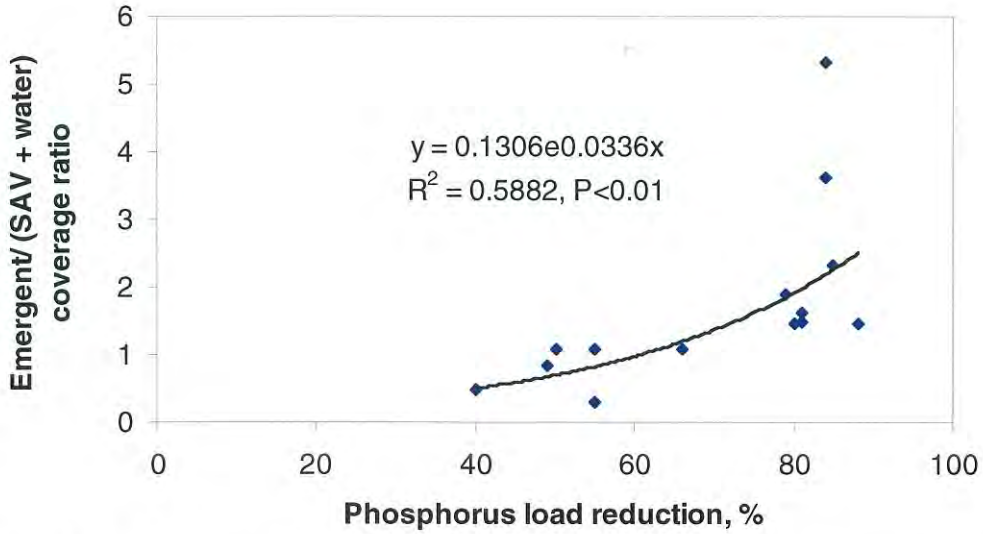


Figure 6-1 A correlation between the ratio of emergent to open water with or without SAV and P load reduction in the STAs.

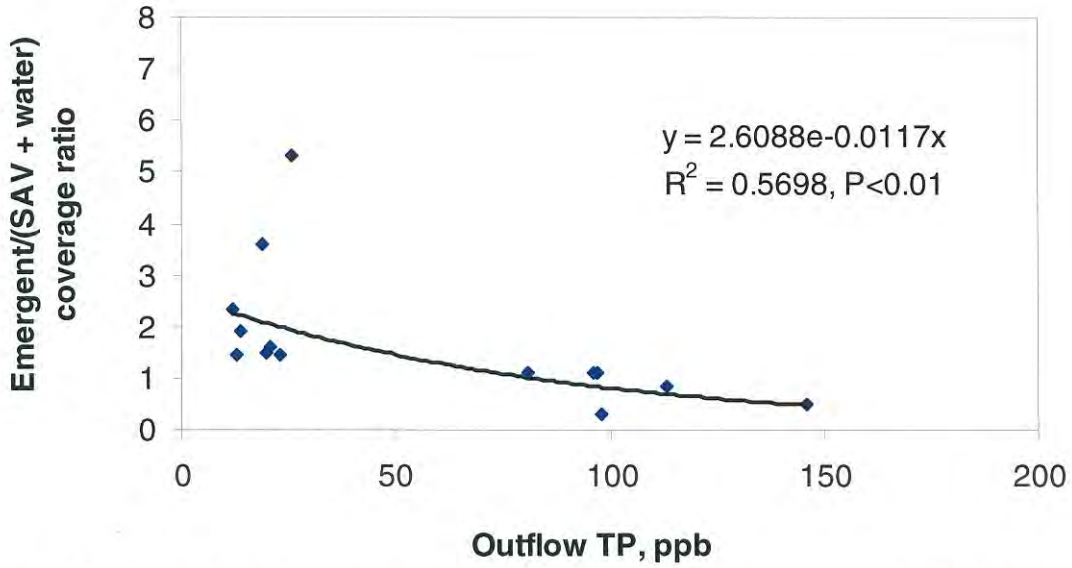


Figure 6-2 A correlation between the cover ratio of emergent community to open water with or without SAV and outflow TP concentration in the STAs.

7. References

Browder, J. A., P. J. Gleason, and D. R. Swift. 1994. Periphyton in the Everglades: spatial variation, environmental correlates, and ecological implications. *In*: Davis, S. M. and Ogden, J. C. (eds.), Everglades: The Ecosystem and its Restoration. P. 379-418. St. Lucie Press, Delray Beach, FL.

Burns & McDonnell. 2003. Long-term plan for achieving water quality goals in Everglades protection area tributary basins. Prepared for South Florida Water Management District, West Palm Beach, FL.

Chimney, M. J. and G. Goforth. 2006. History and description of the Everglades nutrient removal project, a subtropical constructed wetland in south Florida (USA). Ecological Engineering 27: 268-278.

Chimney, M. J. and J. Newman. 2006. Everglades Nutrient Removal Project Test Cell Research: Optimizing Stormwater Treatment Area Performance – The Importance of Hydrologic Conditions in Maximizing Nutrient Retention by the STAs. Technical Publication ERA #438. South Florida Water Management District, West Palm Beach, FL.

Chimney, M. J. and M. Z. Moustafa. 1999. Chapter 6: Effectiveness and Optimization of Stormwater Treatment Areas for Phosphorus Removal. *In*: *1999 Everglades Interim Report*, South Florida Water Management District, West Palm Beach, FL.

Chimney, M. J., M. K. Nungesser, C. Combs, B. Gu, E. Fogarty-Kellis, J. M. Newman, W. Wagner, and L. Wenkert. 2004. Chapter 4B: STA Optimization and Advanced Treatment Technologies. *In*: *2004 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.

Coghlan, C. 2008. STA-1W and STA-1E. Personal Communication.

Davis, S. M. 1982. Patterns of radiophosphorus accumulation in the Everglades after its introduction into surface water. Technical Publication #82-2:28. South Florida Water Management District, West Palm Beach, FL.

Davis, S. M. 1994. Phosphorus inputs and vegetation sensitivity in the Everglades. *In*: Davis, S. M. and Ogden, J. C. (eds.), Everglades: The Ecosystem and its Restoration. P 357-378. St. Lucie Press, Delray Beach, FL.

DeBusk, T. 2007. STA-1W SAV communities. Personal Communication.

Dierberg, F. E., T. A. DeBusk, S. D. Jackson, M. J. Chimney, and K. Pietro. 2002. Submerged aquatic vegetation-based treatment wetlands for removing phosphorus from agricultural runoff: response to hydraulic and nutrient loading. Water Research 35: 1409-1422.

Gary Goforth, Inc. 2007. Operation Plan Integrated Stormwater Treatment Areas 5 & 6. Prepared for South Florida Water Management District, West Palm Beach, FL.

Gary Goforth, Inc. 2006. Interim Operation Plan Stormwater Treatment Area 1 East. Prepared for South Florida Water Management District, West Palm Beach, FL.

Gary Goforth, Inc. 2005. Summary of STA vegetation management practices. Prepared for South Florida Water Management District, West Palm Beach, FL.

Goforth, G., T. Bechtel, G. Germain, N. Iricanin, L. Fink, D. Rumbold, N. Larson, R. Meeker, and R. Bearzotti. 2003. Chapter 4A: STA Performance and Compliance. *In*: *2003 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.

Goforth, G., K. Pietro, G. Germain, N. Iricanin, L. Fink, D. Rumbold, and R. Bearzotti. 2004. Chapter 4A: STA Performance and Compliance.. *In*: *2004 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.

Goforth, G., K. Pietro, M. J. Chimney, J. Newman, T. Bechtel, G. Germain, and N. Iricanin. 2005. Chapter 4: STA Performance, Compliance, and Optimization. *In*: *2005 South Florida Environmental Report*, South Florida Water Management District, West Palm Beach, FL.

Gu, B. 2006. Environmental conditions and phosphorus removal in Florida lakes and wetlands inhabited by *Hydrilla verticillata* (Royle): implications for invasive species management. Biological Invasions 8: 1569-1578.

Jorge., J., J. M. Newman, M. J. Chimney, Goforth, G., T. Bechtel, G. Germain, M K Nungesser, D. Rumbold, J. Lopez, L. Fink, B. Gu, R. Bearzotti, D. Campbell, C Combs, K. Pietro, N. Iricanin, N. Larson, and R. Meeker. 2002. Chapter 4A: STA Performance and Compliance. *In*: *2002 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.

Kadlec, R.H. 2006. Free surface wetlands for phosphorus removal: The position of the Everglades Nutrient Removal Project. Ecological Engineering 27: 361-379.

Kadlec, R.H. and S Newman. 1992. Everglades Protection Stormwater Treatment Area Design Support, Phosphorous Removal in Wetland Treatment Areas Principles and Data. DOR 106, South Florida Water Management District, West Palm Beach, FL.

Larson, N. 2008. STA-2. Personal Communication.

Loveless, C. M. 1959. A study of the vegetation of the Florida Everglades. Ecology 40: 1-9.

Magee, D. W. 1981. Freshwater Wetlands: a Guide to Common Indicator Plants of Northeast. The University of Massachusetts Press, Amherst, MA. P.246.

McCormick, P V., R. B. E. Shuford III, and M. J. Chimney. 2006. Periphyton as a potential phosphorus sink in the Everglades nutrient removal project. Ecological Engineering 27: 279-289.

Nick Miller, Inc. 2003. Vegetation Map Report (Stormwater Treatment Areas 2, 5 & 6). Prepared for South Florida Water Management District, West Palm Beach, FL.

Nick Miller, Inc. 2005. Vegetation Map Report (Stormwater Treatment Areas 1E, 1W, 2, 3/4, 5 & 6). Prepared for South Florida Water Management District, West Palm Beach, FL.

Nungesser, M. K., J. M., Newman, C. Combs, T. Lynch, M. J., Chimney, and R. Meeker. 2001. Chapter 6: Optimization Research for the Stormwater Treatment Areas. *In*: *2001 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.

Pickett Surveying & Photogrammetry (Pickett). 2006 Vegetation Map Report (Stormwater Treatment Areas 1E, 1W, 2, 3/4, 5 & 6). Prepared for South Florida Water Management District, West Palm Beach, FL.

Pietro, K. C., M. J. Chimney, and A. D. Steinman. 2006a. Phosphorus removal by the *Ceratophyllum*/periphyton complex in a south Florida (USA) freshwater marsh. Ecological Engineering 27: 290-300.

Pietro K., R. Bearzotti, M. J. Chimney, G. Germain, N. Iricanin, T. Piccone, and K. Samfilippo. 2006b. Chapter 4: STA Performance, Compliance and Optimization. *In*: *2006 South Florida Environmental Report*, South Florida Water Management District, West Palm Beach, FL.

Pietro K., R. Bearzotti, G. Germain, and N. Iricanin. 2008. Chapter 5: STA Performance, Compliance and Optimization. In: *2008 South Florida Environmental Report*, South Florida Water Management District, West Palm Beach, FL.

Pietro K., R. Bearzotti, and M. J. Chimney, G. Germain, N. Iricanin and T. Piccone. 2007. Chapter 5: STA Performance, Compliance and Optimization. In: *2007 South Florida Environmental Report*, South Florida Water Management District, West Palm Beach, FL.

Reddy K. R., R. D. DeLaune, W. F. DeBusk, and M. S. Koch. 1993. Long term nutrient accumulation in the Everglades. Soil Society of America Journal 57: 1147-1155.

Richardson, C.J., and P.E. Marshall. 1986. Processes controlling movement, storage, and export of phosophorus in a fen peatland. Ecological Monographs 56: 279-302.

Richardson, C. J., S. Qian, C. B. Kraft, and R. G. Qualls. 1997. Predictive models for phosphorus retention in wetlands. Wetlands Ecology and Management 4: 159-175.

Serbesoff-King, K. 2004. Stormwater Treatment Area 1E Vegetation Management Plan. Prepared for South Florida Water Management District, West Palm Beach, FL.

STA Log , Observation of the STAs from 2000-2006 as Reported by C. Combs, J. Galloway, and N. Larson. South Florida Water Management District, West Palm Beach, FL.

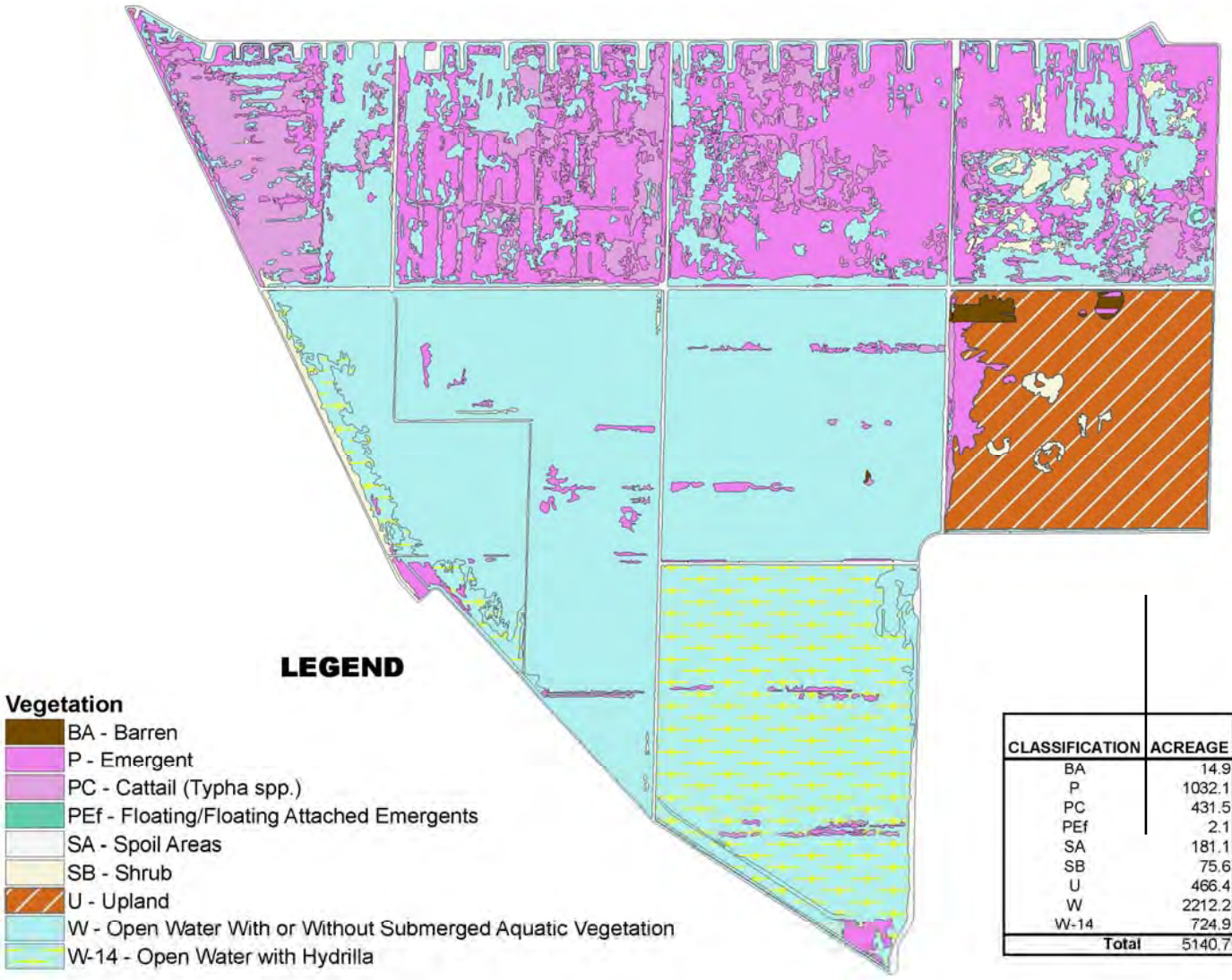
STA Overflight of 12/21/2007. Aerial Vegetation Survey by South Florida Water Management District, West Palm Beach, FL.

Toth, L., D. Thayer, K. Serbesoff, L. Rodgers, T. Piccone, G Goforth, and N. Larson. 2004. STA-3/4 Vegetation Management Demonstration project. Prepared for DEP Agreement No. G0040 Subtask 2.1 Vegetation Management Plan. South Florida Water Management District, West Palm Beach, FL.

Appendix A

STA-1E 2006 Vegetation Map

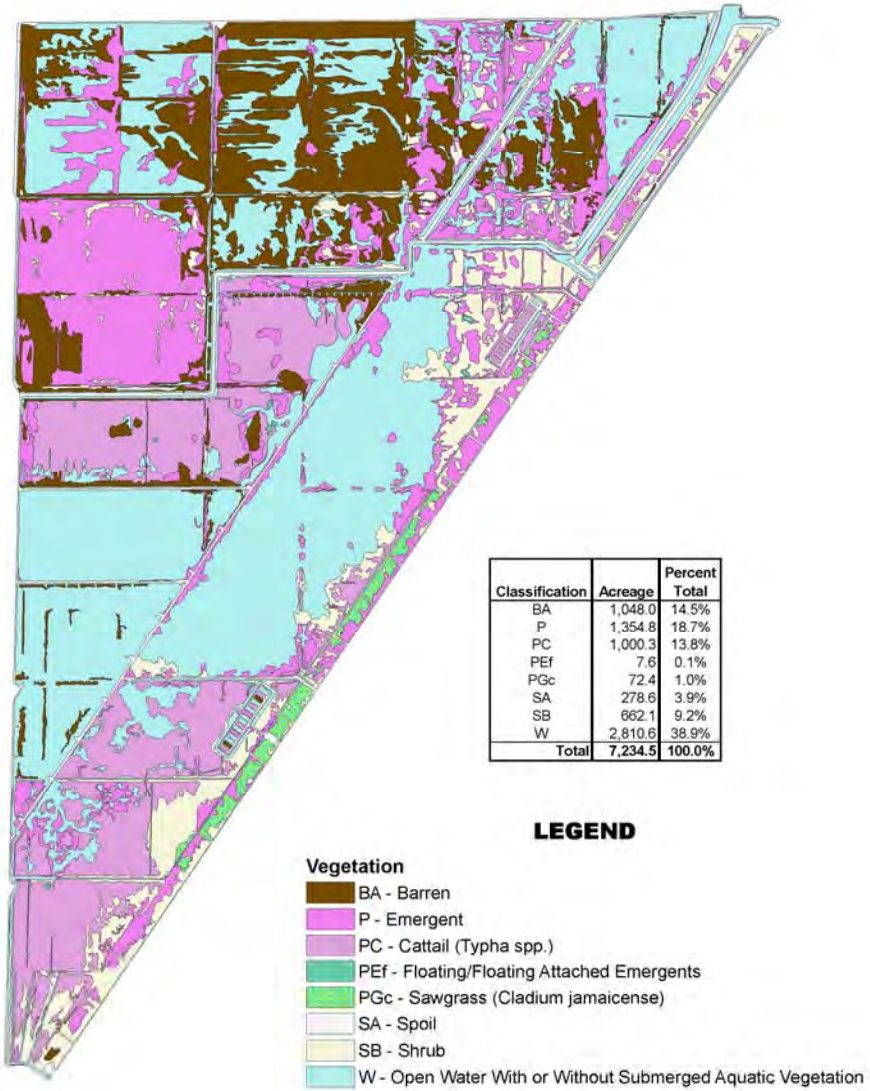
Aerial imagery flown March 25, 2006



CLASSIFICATION	ACREAGE	PERCENT TOTAL
BA	14.9	0.3%
P	1032.1	20.1%
PC	431.5	8.4%
PEf	2.1	0.0%
SA	181.1	3.5%
SB	75.6	1.5%
U	466.4	9.1%
W	2212.2	43.0%
W-14	724.9	14.1%
Total	5140.7	100.0%

STA-1W 2006 Vegetation Map

Aerial imagery flown March 25, 2006



Classification	Acreage	Percent Total
BA	1,048.0	14.5%
P	1,354.8	18.7%
PC	1,000.3	13.8%
PEf	7.6	0.1%
PGc	72.4	1.0%
SA	278.6	3.9%
SB	662.1	9.2%
W	2,810.6	38.9%
Total	7,234.5	100.0%

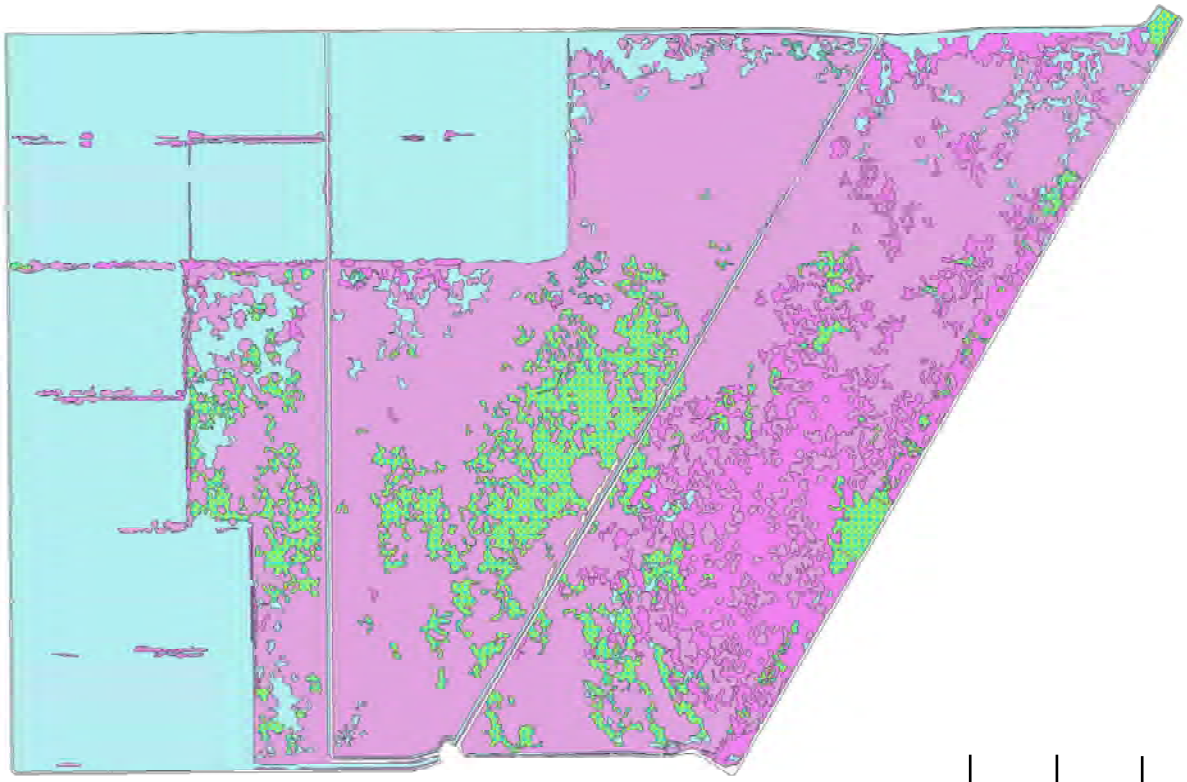
LEGEND

Vegetation

- BA - Barren
- P - Emergent
- PC - Cattail (Typha spp.)
- PEf - Floating/Floating Attached Emergents
- PGc - Sawgrass (Cladium jamaicense)
- SA - Spoil
- SB - Shrub
- W - Open Water With or Without Submerged Aquatic Vegetation

STA-2 2006 Vegetation Map

Aerial imagery flown March 25, 2006



LEGEND

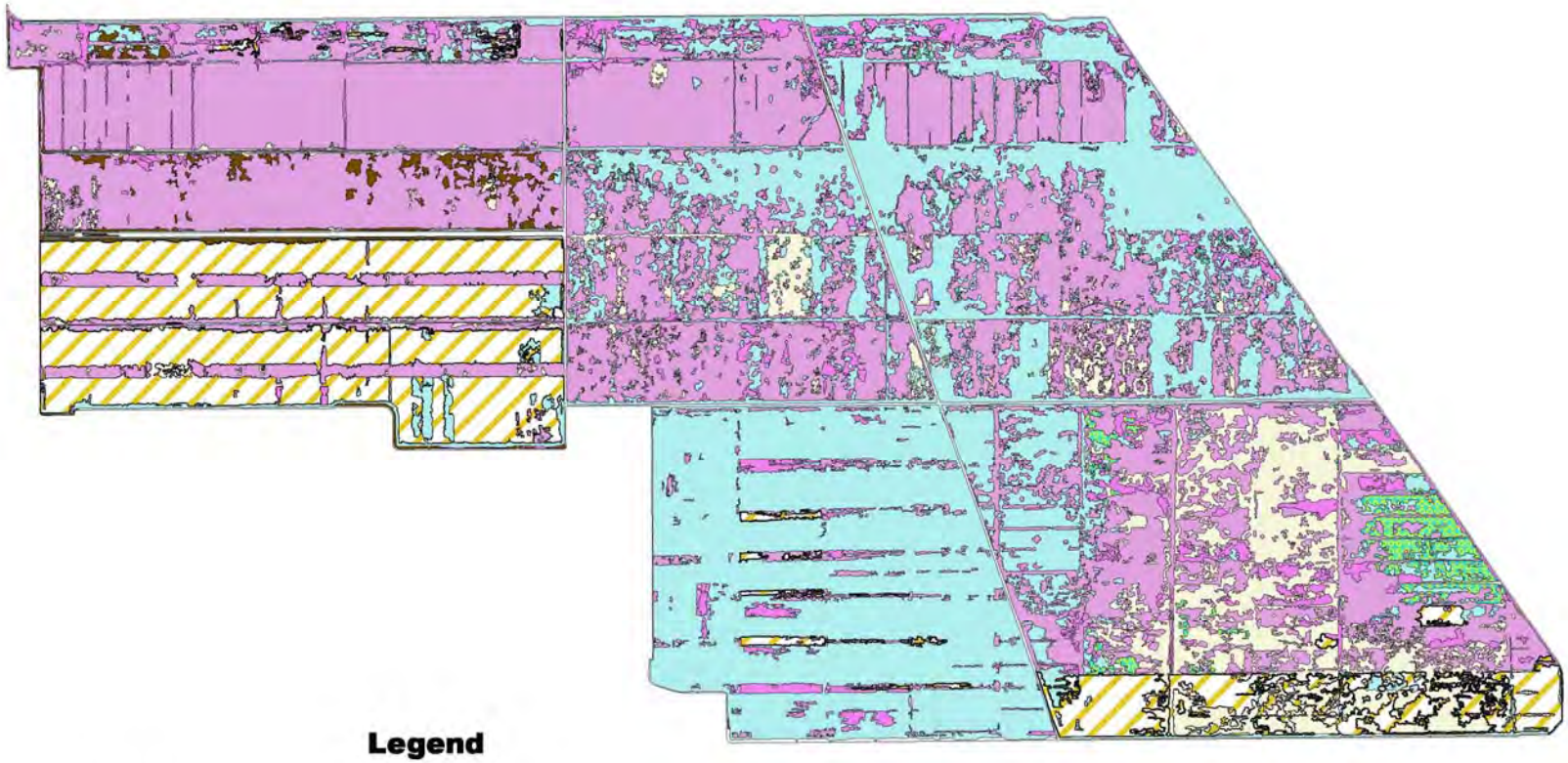
Vegetation

- P - Emergent
- PC - Cattail (Typha spp.)
- PEf - Floating/Floating Attached Emergents
- PGc - Sawgrass (Cladium jamaicense)
- SA - Spoil
- SB - Shrub
- W - Open Water With or Without Submerged Aquatic Vegetation

Classification	Acreage	Percent Total
P	633.76	9.30%
PC	2,953.26	43.34%
PEf	8.82	0.13%
PGc	539.55	7.92%
SA	119.90	1.76%
SB	5.78	0.08%
W	2,553.24	37.47%
Total	**6,814.32**	**100.00%**

STA-3/4 2006 Vegetation Map

Aerial imagery flown March 25, 2006



Legend

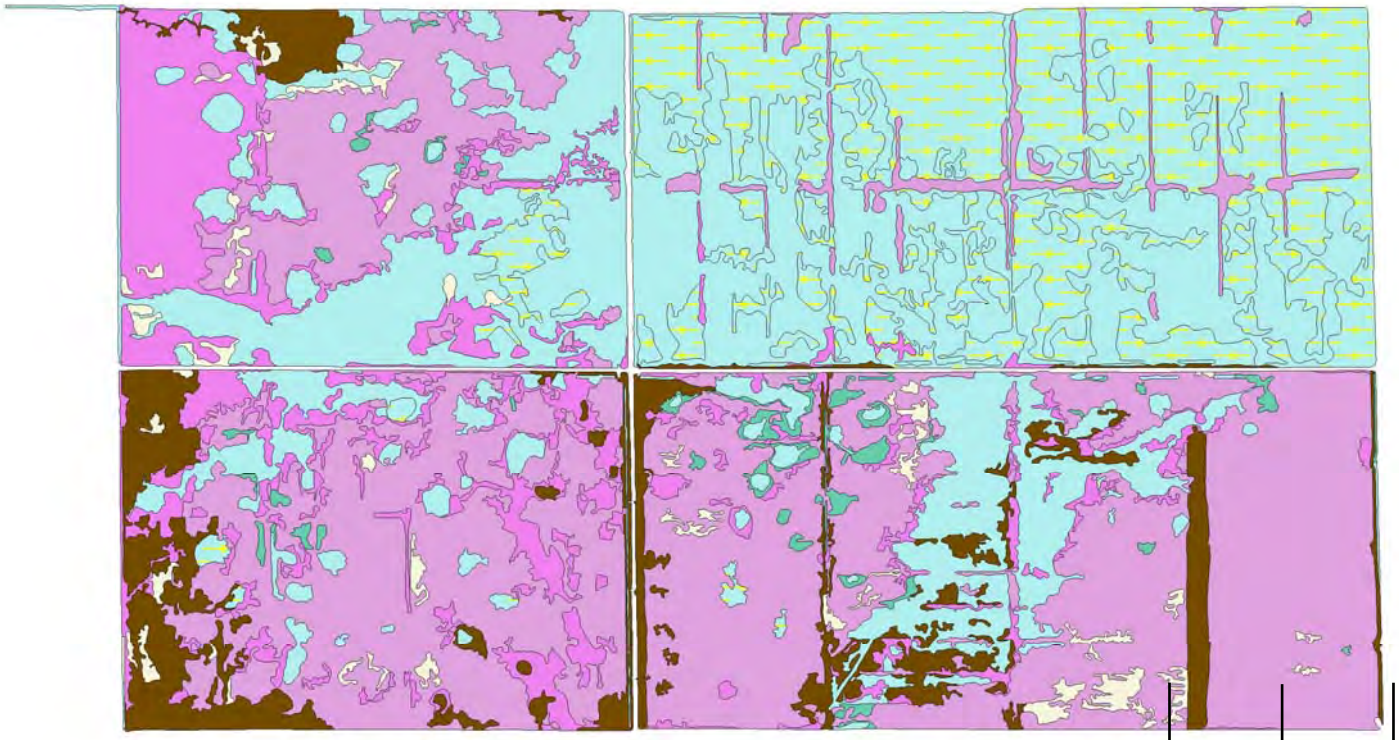
Vegetation

- BA - Barren
- P - Emergent
- PC - Cattail (Typha spp.)
- PEf - Floating/Floating Attached Emergents
- PGc - Sawgrass (Cladium jamaicense)
- SA - Spoil
- SB - Shrub
- TA - Treated Area
- W - Open Water With or Without Submerged Aquatic Vegetation

CLASSIFICATION	ACREAGE	PERCENT TOTAL
BA	162.0	1.0%
P	685.0	4.3%
PC	6,371.4	39.6%
PEf	49.9	0.3%
PGc	175.6	1.1%
SA	267.9	1.7%
SB	1,378.5	8.6%
TA	2,034.8	12.7%
W	4,947.4	30.8%
TOTAL	**16,072.5**	**100.0%**

STA-5 2006 Vegetation Map

Aerial imagery flown March 25, 2006



LEGEND

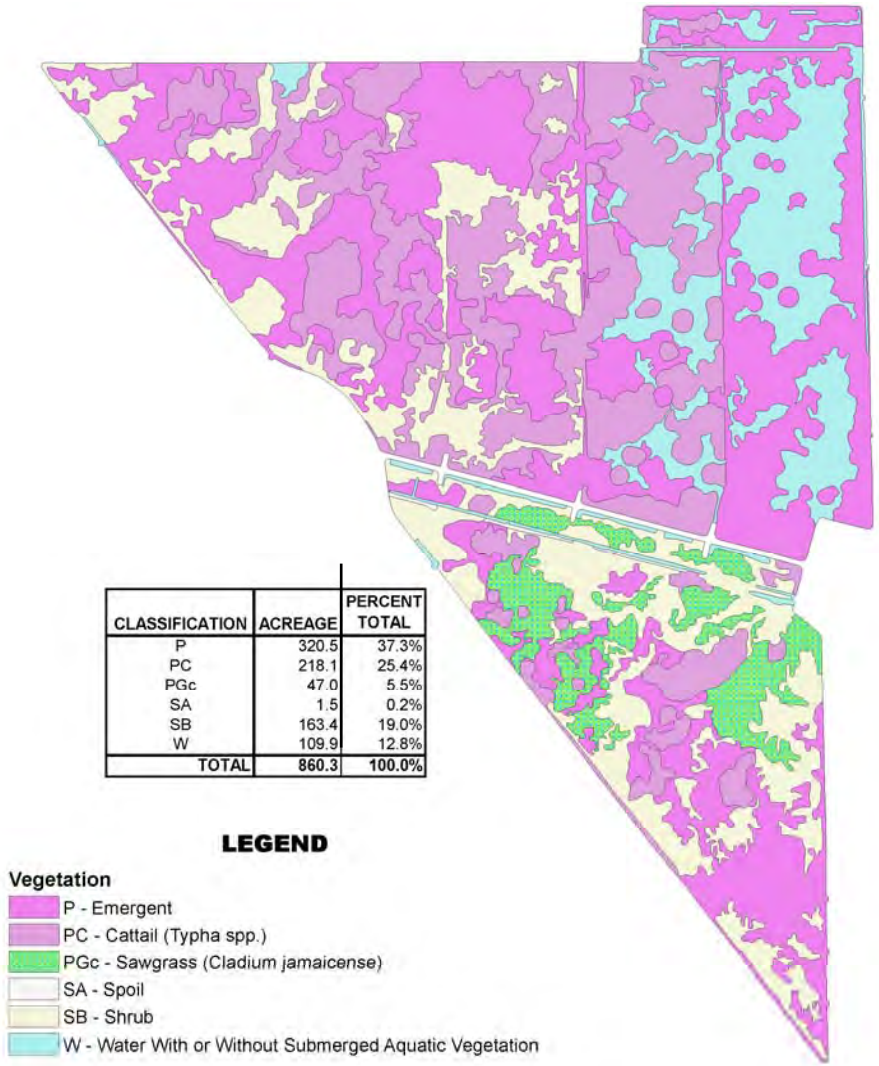
Vegetation

- BA - Barren
- P - Emergent
- PC - Cattail (Typha spp.)
- PEf - Floating/Floating Attached Emergents
- SB - Shrub
- W - Open Water With or Without Submerged Aquatic Vegetation
- W-14 - Open Water with Hydrilla (Hydrilla verticillata)

CLASSIFICATION	ACREAGE	PERCENT TOTAL
BA	292.4	7.1%
P	423.4	10.3%
PC	1,493.4	36.2%
PEf	46.0	1.1%
SB	72.9	1.8%
W	1,081.5	26.2%
W-14	717.2	17.4%
TOTAL	**4,126.7**	**100.0%**

STA-6 2006 Vegetation Map

Aerial imagery flown March 25, 2006

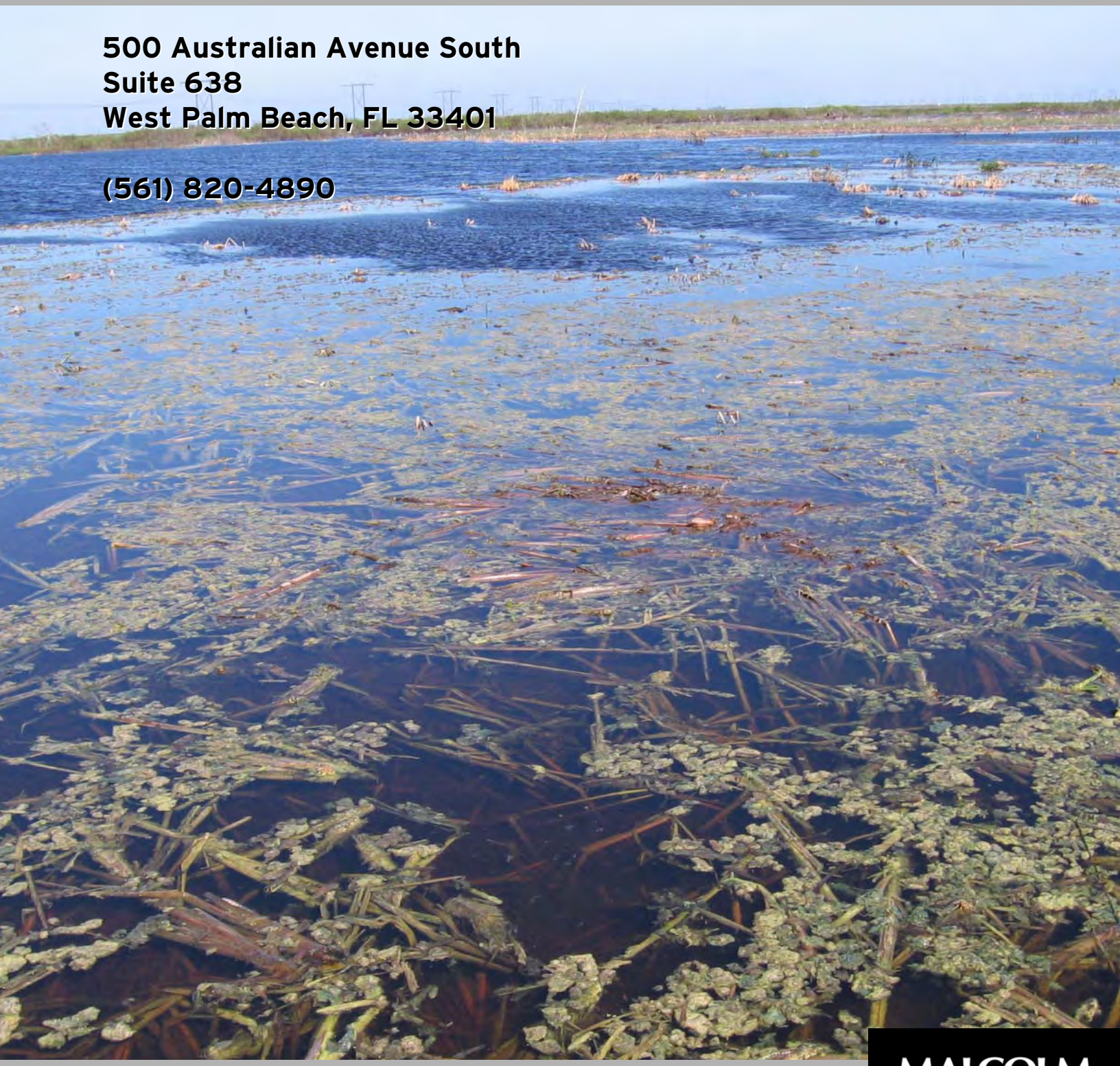


CLASSIFICATION	ACREAGE	PERCENT TOTAL
P	320.5	37.3%
PC	218.1	25.4%
PGc	47.0	5.5%
SA	1.5	0.2%
SB	163.4	19.0%
W	109.9	12.8%
TOTAL	860.3	100.0%

LEGEND

Vegetation

- P - Emergent
- PC - Cattail (Typha spp.)
- PGc - Sawgrass (Cladium jamaicense)
- SA - Spoil
- SB - Shrub
- W - Water With or Without Submerged Aquatic Vegetation



500 Australian Avenue South
Suite 638
West Palm Beach, FL 33401

(561) 820-4890

April 2008
4993017

INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

MALCOLM PIRNIE