

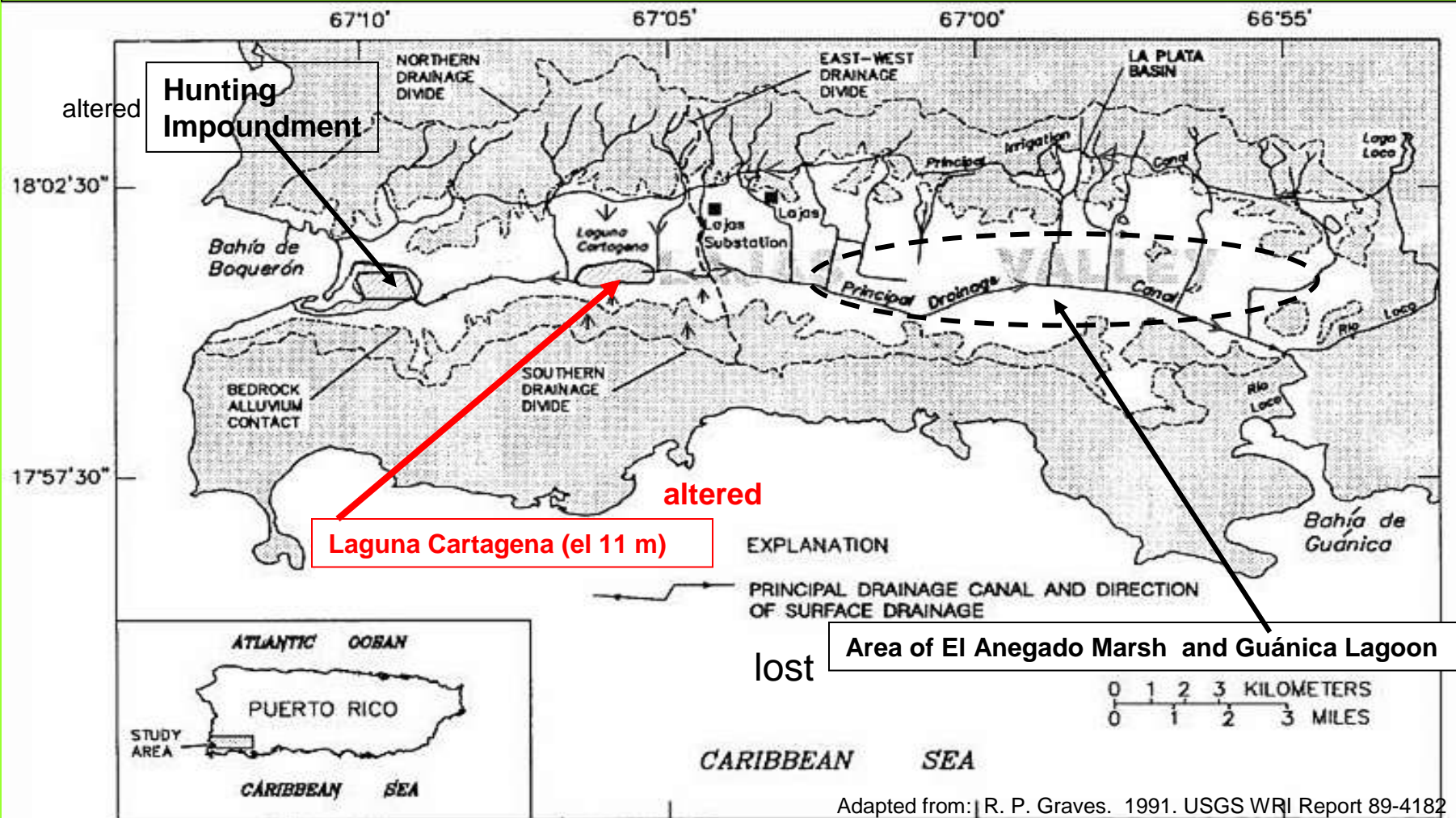
***Too Much of a Good Thing:  
Eutrophication and it's ecological and possible public health  
consequences via interactions with environmental Fe and S?***

***Hemispheric Conference on Medical Geology  
17 November, 2005  
Universidad del Turabo***

***Fred C. Schaffner, Ph.D.***

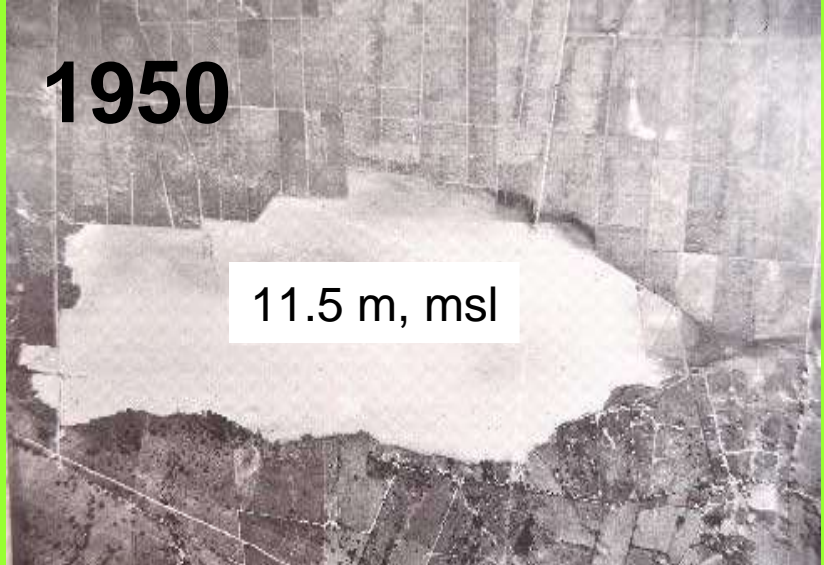
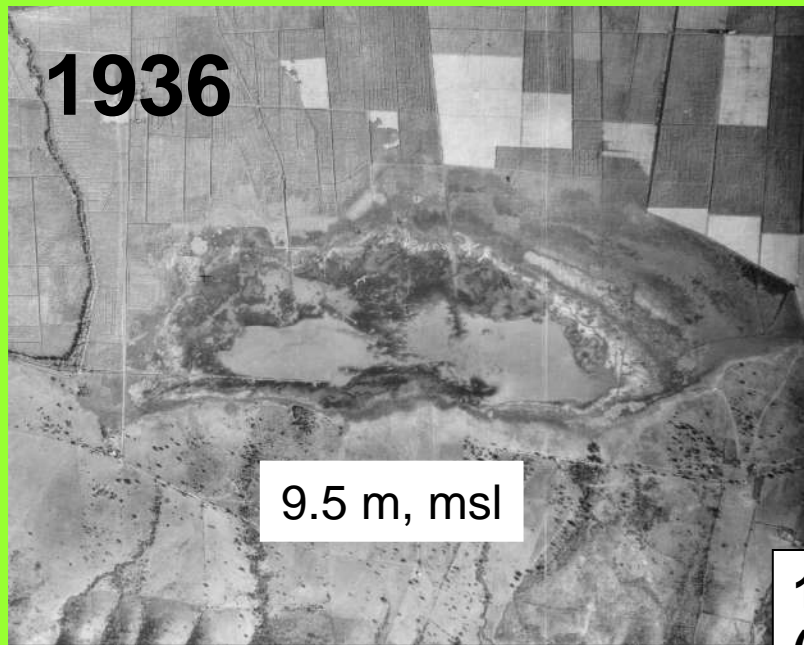


Laguna Cartagena was first used as a source of irrigation water for sugar cane in 1923, *then...* In the late 1950's a new regional irrigation system connected its drainage (effluent) discharge canals through the lagoon to the sea. (Culprits: Fed. Ag., PR Ag. & PR Elec. Power Authority)

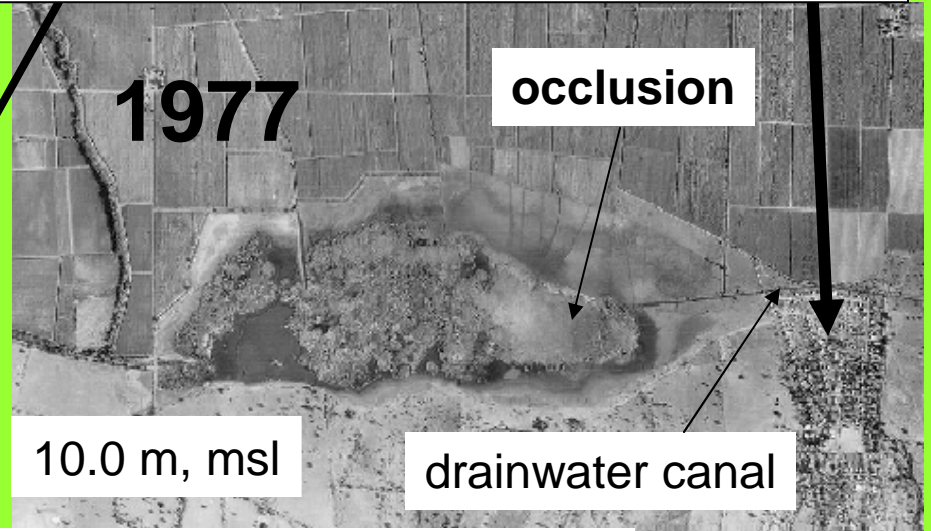
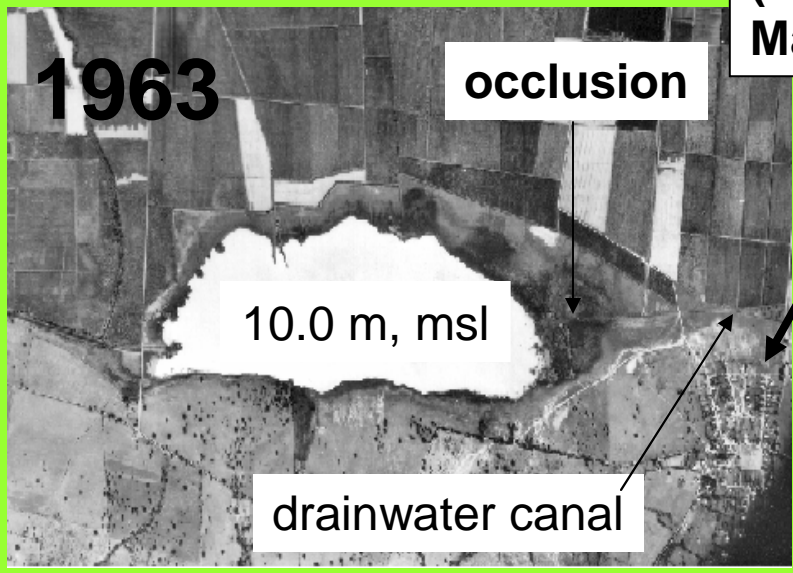


Adapted from: R. P. Graves. 1991. USGS WRI Report 89-4182

Nominal lagoon surface at 11 m above mean sea level.



**1960-1975: PR Rural Housing Authority (with Fed HHS Funds) establishes town of Magüayo along drainage canal.**



Water level set at 11m in 1950's, but in 1960 vandals lower it to 10 m



# Canal Principal de Desagüe, El Anegado, Valle de Lajas Earthen, above the surrounding terrain

canal



2005.10.15





# Boqueron Bay

"Refugio de Aves", DRNA

Drainage canal from lagoon



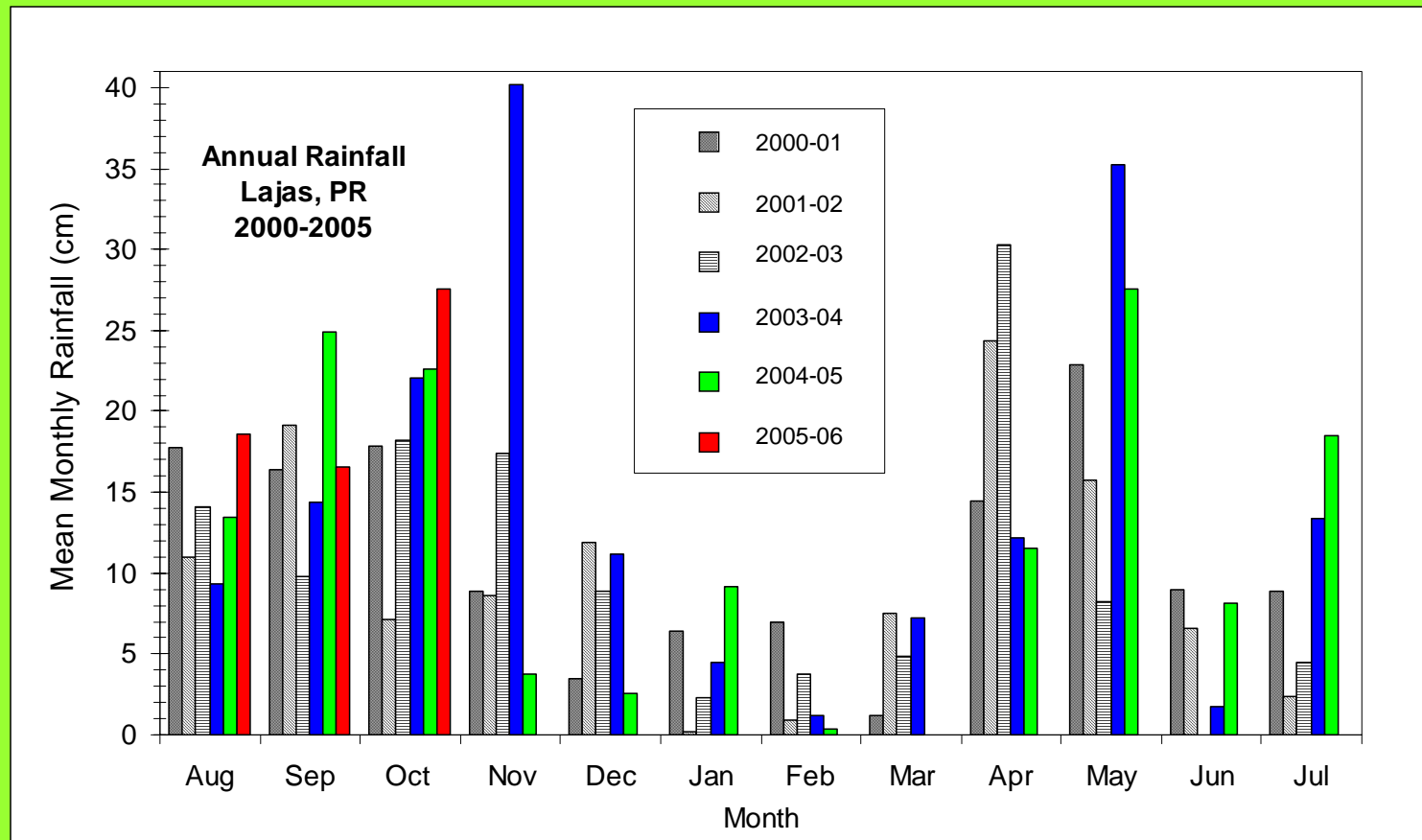
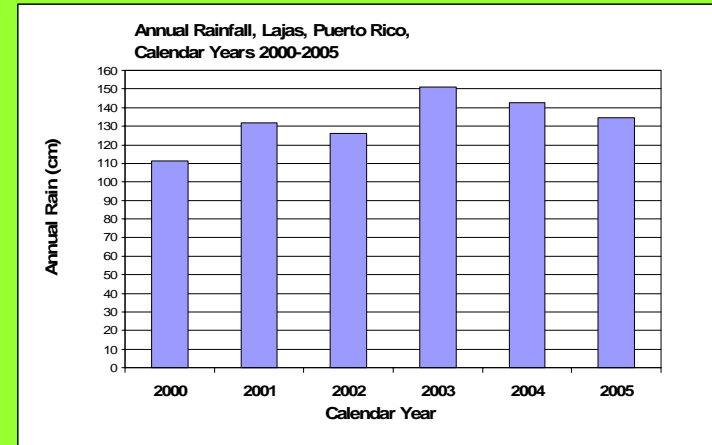
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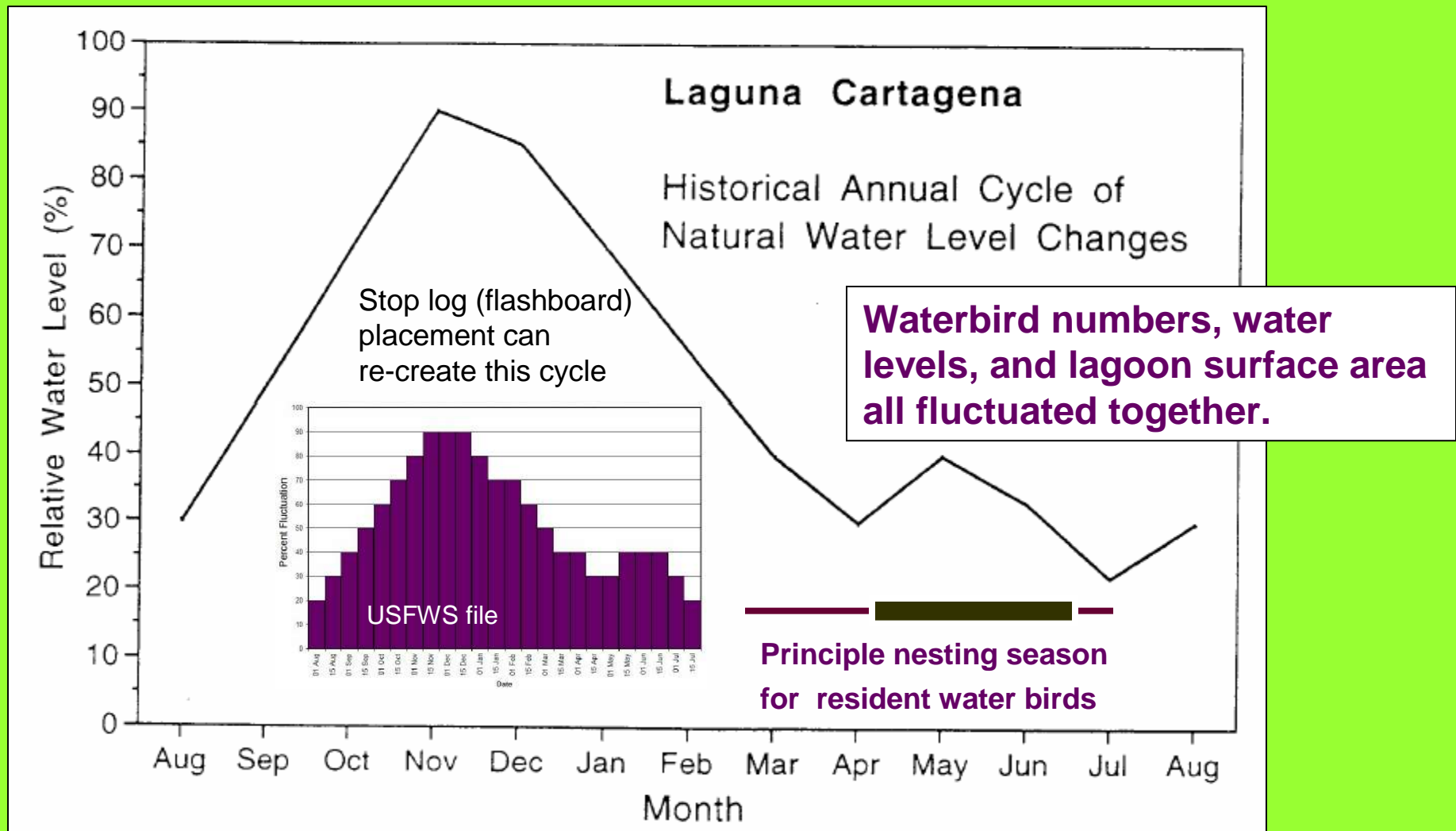
**Laguna Cartagena is a shallow (2m) rainfall-charged 160-ha freshwater lagoon located in semi-arid southwestern Puerto Rico (130 cm annual rainfall)**

**2 rainy Seasons per Year**



Laguna Cartagena historically exhibited marked twice-yearly water level fluctuations, without complete dry-downs, through the 1920's and was a haven for thousands of aquatic birds: Waders, Waterfowl, Shorebirds, including seasonal migrants and nesting species (Danforth 1926).

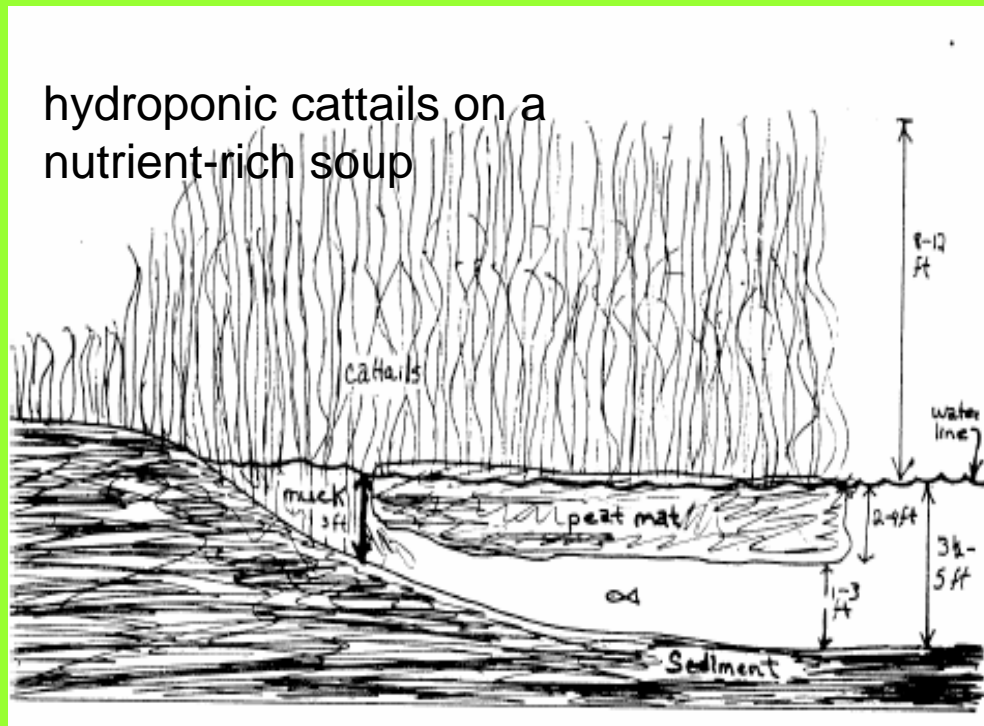
Area = 150 ha; 160 total species of terrestrial and aquatic birds.



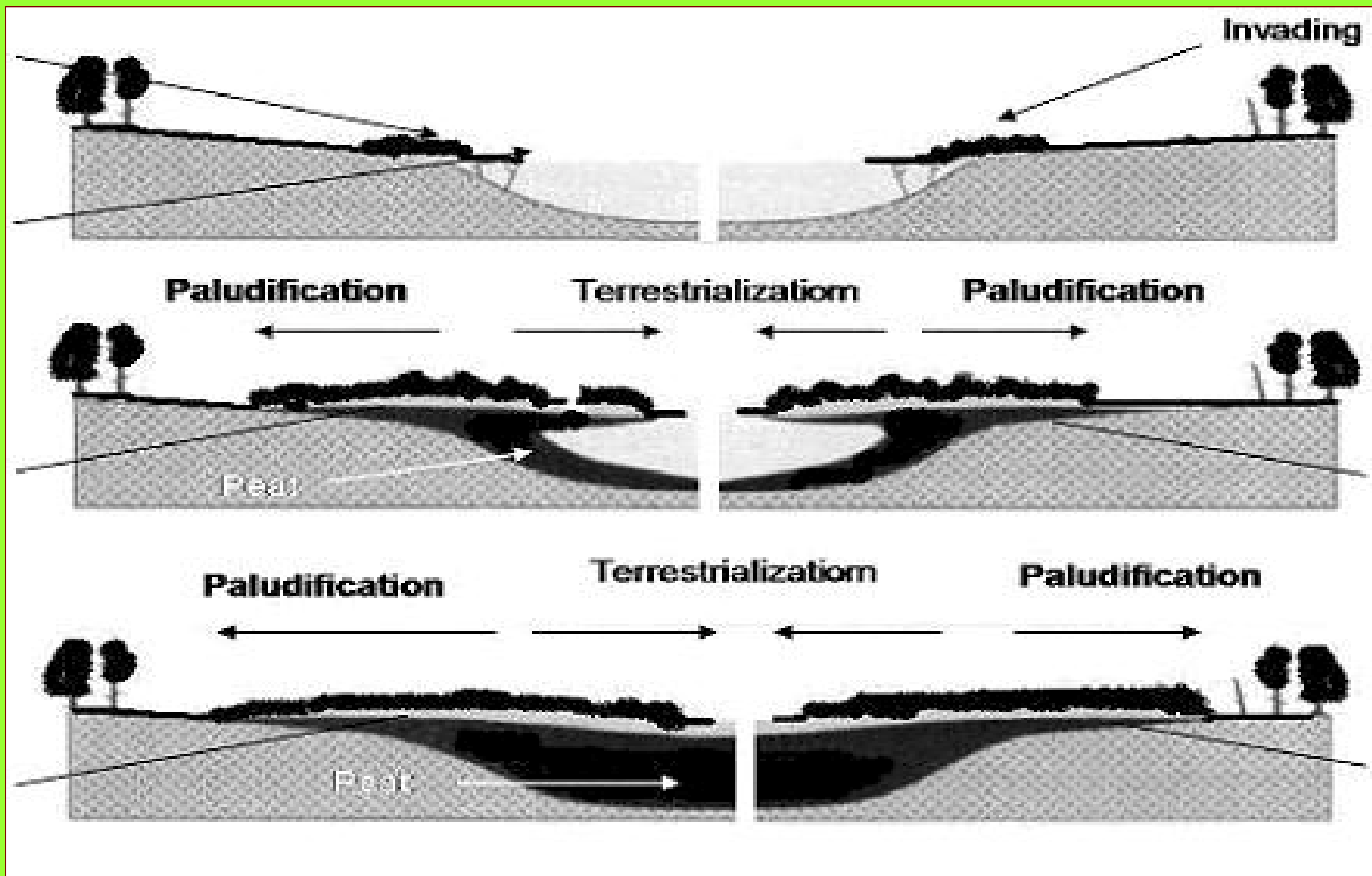


## These blunders produced:

- (1) disrupted hydroperiods and hydrologic regime,
- (2) very excessive nutrient inputs (100's to 1,000's ppb Ortho-P),  
(Currently, nutrient concentrations coming out of the lagoon usually exceed those entering the lagoon),
- (3) the development of a meter-thick floating peat mat and floating islands covered with cattails (*Typha domingensis*) that eliminated nearly all quality habitat for aquatic birds,
- (4) Flooding in the town.



# Peat formation and terrestrialization





# 1989 – Acquisition by the US Fish and Wildlife Service, “Laguna Cartagena National Wildlife Refuge”

## Two Congressional Mandates:

- (1) Acquisition
- (2) Restoration

Hills: cherts and serpentine  
Valley: alluvium  
Lagoon bottom: clay

## Estimated Costs (1987):

Acquisition - \$500,000 (realized)  
Restoration and Maintenance -  
\$500,000 (estimated). *Funds were  
allocated in 1989, 1991, 1993 but used  
elsewhere.*

Sugar cane and  
subsidized fertilizer  
through 1998

See:

[http://www.fws.gov/birdhabitat/NAWCA/projects/  
USprojects/smallgrants060904/PRLajasValley.pdf](http://www.fws.gov/birdhabitat/NAWCA/projects/USprojects/smallgrants060904/PRLajasValley.pdf)



USFWS file photo

**While nutrient concentrations (e.g. phosphorus) have declined in recent years, and may continue to decline, they remain high enough to promote accelerated plant growth, thus requiring repeated, periodic maintenance.**

**Field Orthophosphate P concentrations  
One month before hurricane Georges  
1998-08-23**

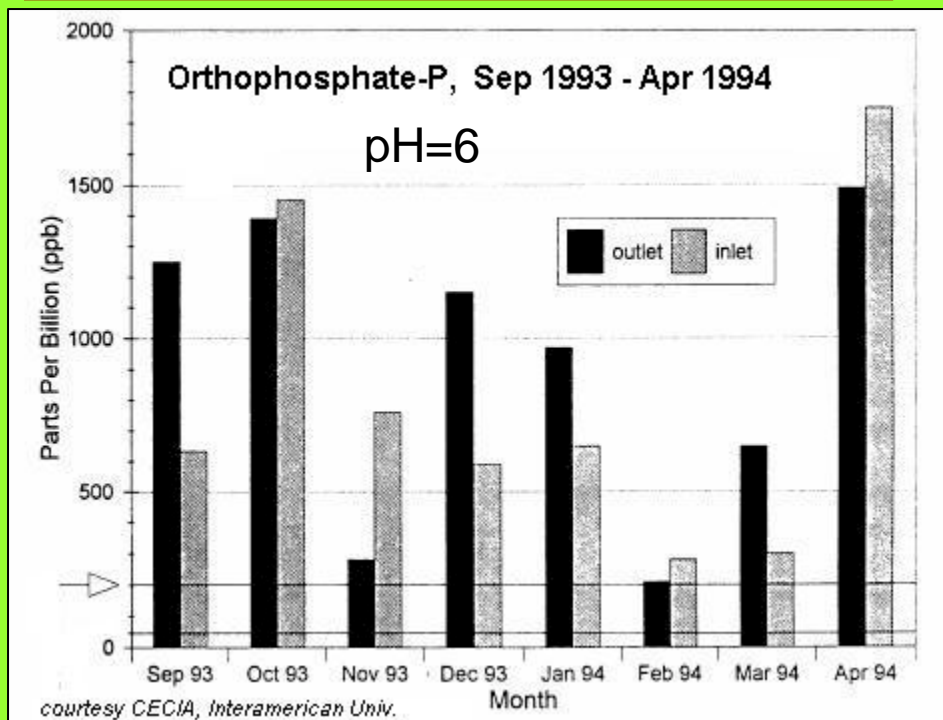
**Lagoon Center: 500 ppb**

**Lagoon Outlet: 267 ppb**

**One month after hurricane Georges  
1998-10-25**

**Lagoon Center: 933 ppb**

**Lagoon Outlet: 1,000 ppb                      pH=6**



**Ortho-P = 5% to 20% of Total-P**

**2005 Field Orthophosphate P concentrations (ppb), pH =7.5-8**

Date	Center	Outlet
17 Jan	27	40
20 Feb	40	80
21 May	107	67
30 May	107	67
25 Sep	60	120
16 Oct	47	113
13 Nov	67	100

	Total	Ortho	
Oligitrophic =	3-10	< 0.05-.15	ppb
Mesotrophic =	18-27	< 0.9-1.35	ppb
Eutrophic =	30-50	< 1.5-2.50	ppb
Dystrophic	>50	>2.5	ppb



## **Interagency Committee for Laguna Cartagena Formed in 1991**

**Goals: Restore, to the extent possible, aquatic bird habitat to pre-disturbance conditions, and alleviate flooding in the town.**

### **Recommendations (proposed since 1991):**

- (1) Mechanical removal of peat mat and floating islands**
- (2) Restoration of hydroperiod and hydrologic regime  
(removal of unneeded ditches and levees built for sugar cane cultivation)**
- (3) Control of vegetative overgrowth, using livestock, and through a coordinated combination of burning and water level management.**

**Note: FWS has no control over the principle irrigation and drainwater canal inputs or rainfall...**

**One way or another...**



***Pulling floating  
peat islands***





## Peat is a Highly Marketable Commodity in Puerto Rico!

A community co-op from Magüayo proposes to eliminate the occlusion, alleviate flooding, and begin restoration of the lagoon by harvesting the peat mat and floating islands. Thus far FWS has been in opposition.

Your advice and recommendations are welcomed!







727.520.8181  
www.aerophoto.com

Lake Panasoffkee

Negative # 50912 012  
Date 9.12.05

*Courtesy Mike Holtkamp, PE, Southwest Florida Water Management District*

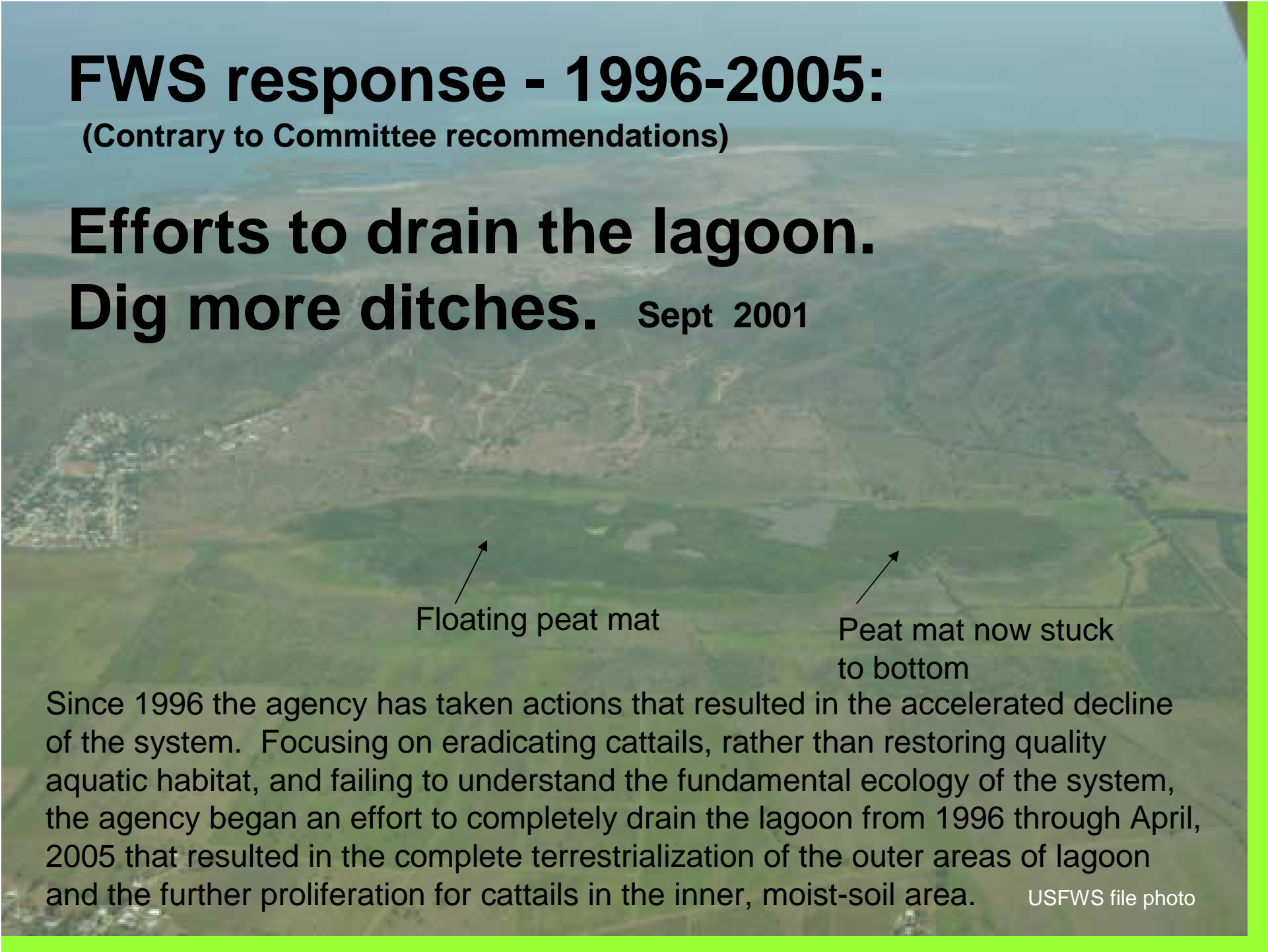


# FWS response - 1996-2005:

(Contrary to Committee recommendations)

## Efforts to drain the lagoon.

## Dig more ditches. Sept 2001



Floating peat mat

Peat mat now stuck  
to bottom

Since 1996 the agency has taken actions that resulted in the accelerated decline of the system. Focusing on eradicating cattails, rather than restoring quality aquatic habitat, and failing to understand the fundamental ecology of the system, the agency began an effort to completely drain the lagoon from 1996 through April, 2005 that resulted in the complete terrestrialization of the outer areas of lagoon and the further proliferation for cattails in the inner, moist-soil area.

USFWS file photo

**Inside the peat mat during the dry season – evaporative salts –  
Lots of phosphorus.**





Habitat continues to decline, and most short-term gains are lost.

Flooding in Magüayo continues – caused by the occlusion (residence time) and has little relation to lagoon water level, *per se*.

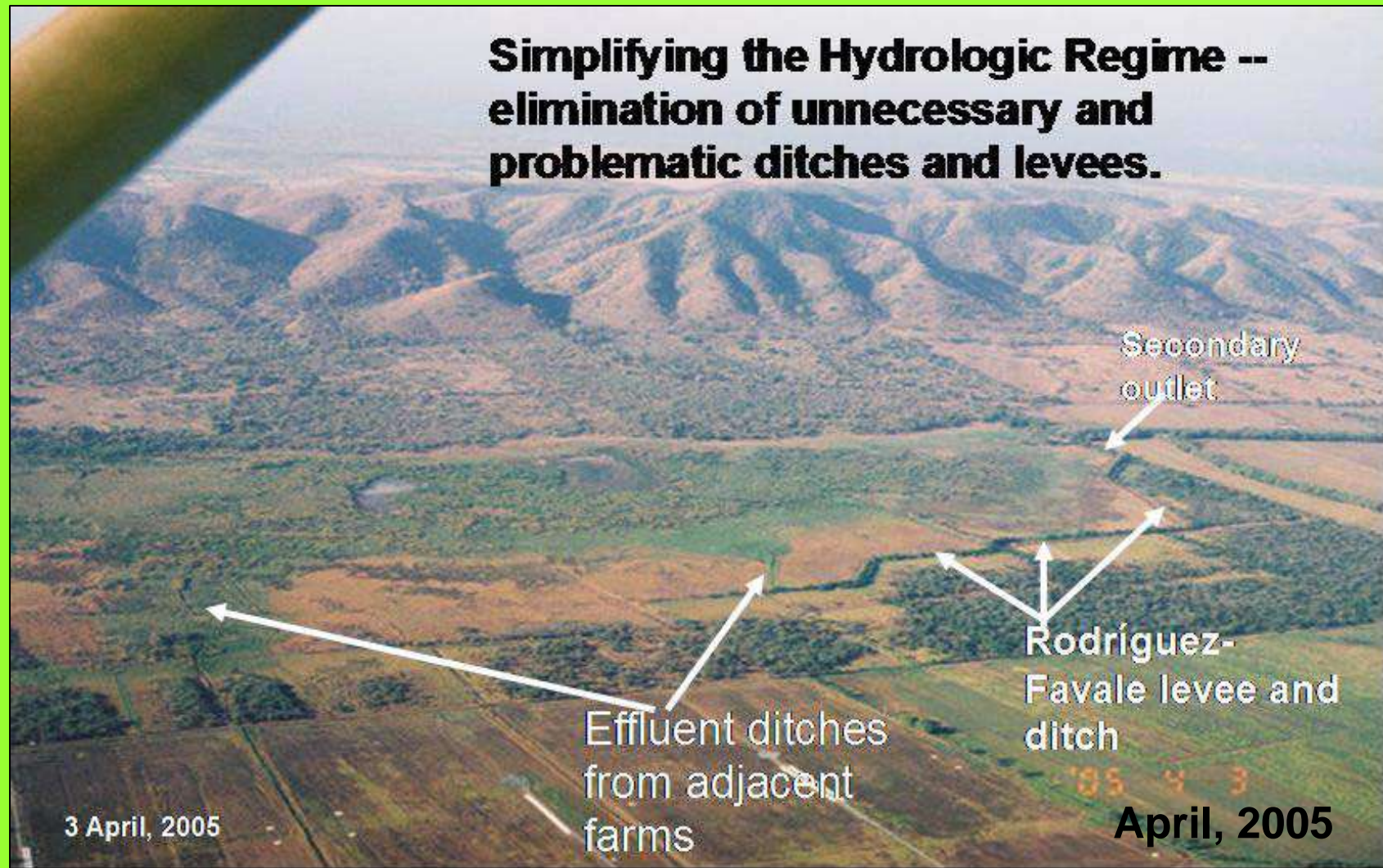
**Feb., 2004**



**Feb., 2005**



# Work with the land, not against it! (Our proposal)

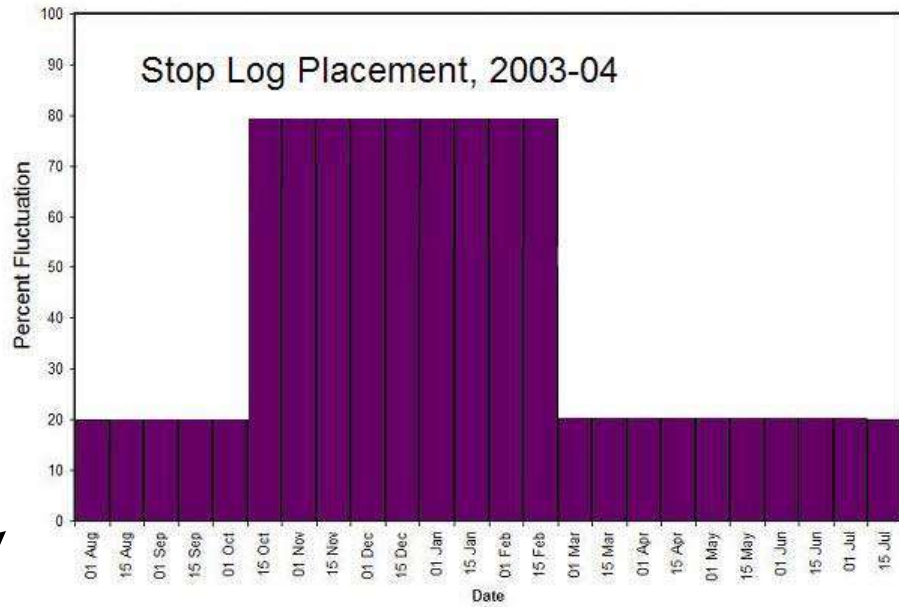
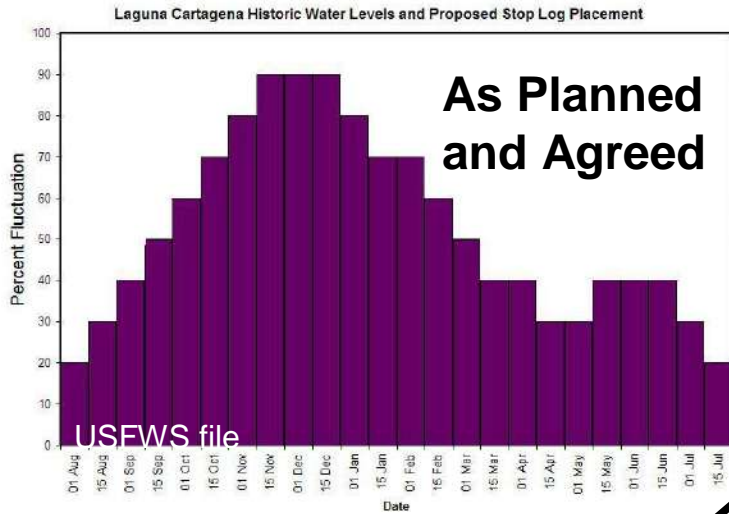




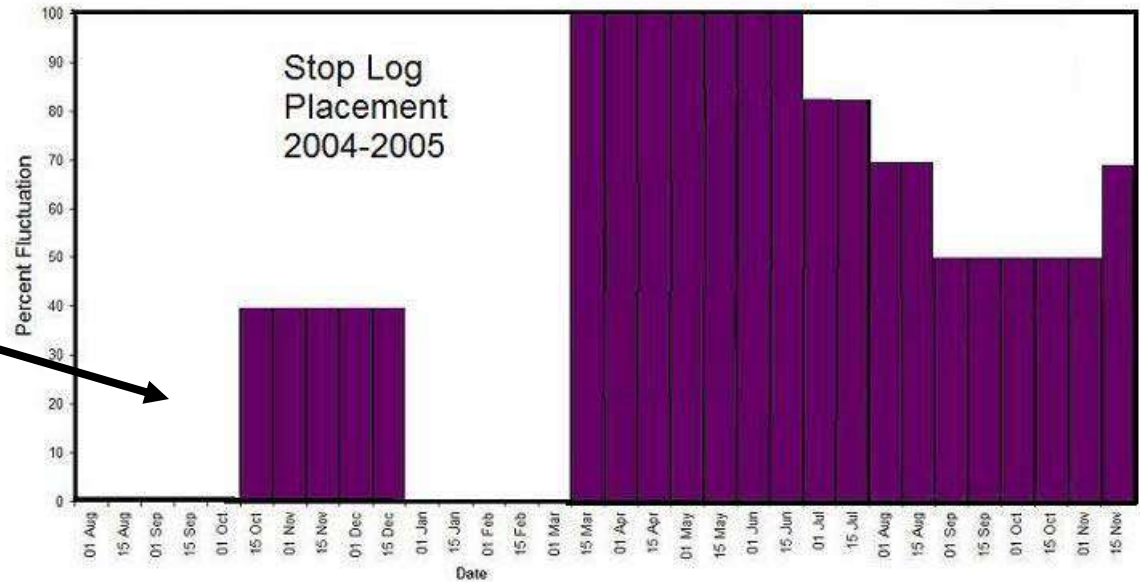
*F. C. Schaffner, 2005-04-17*



# Stop Log (flashboard) Placement



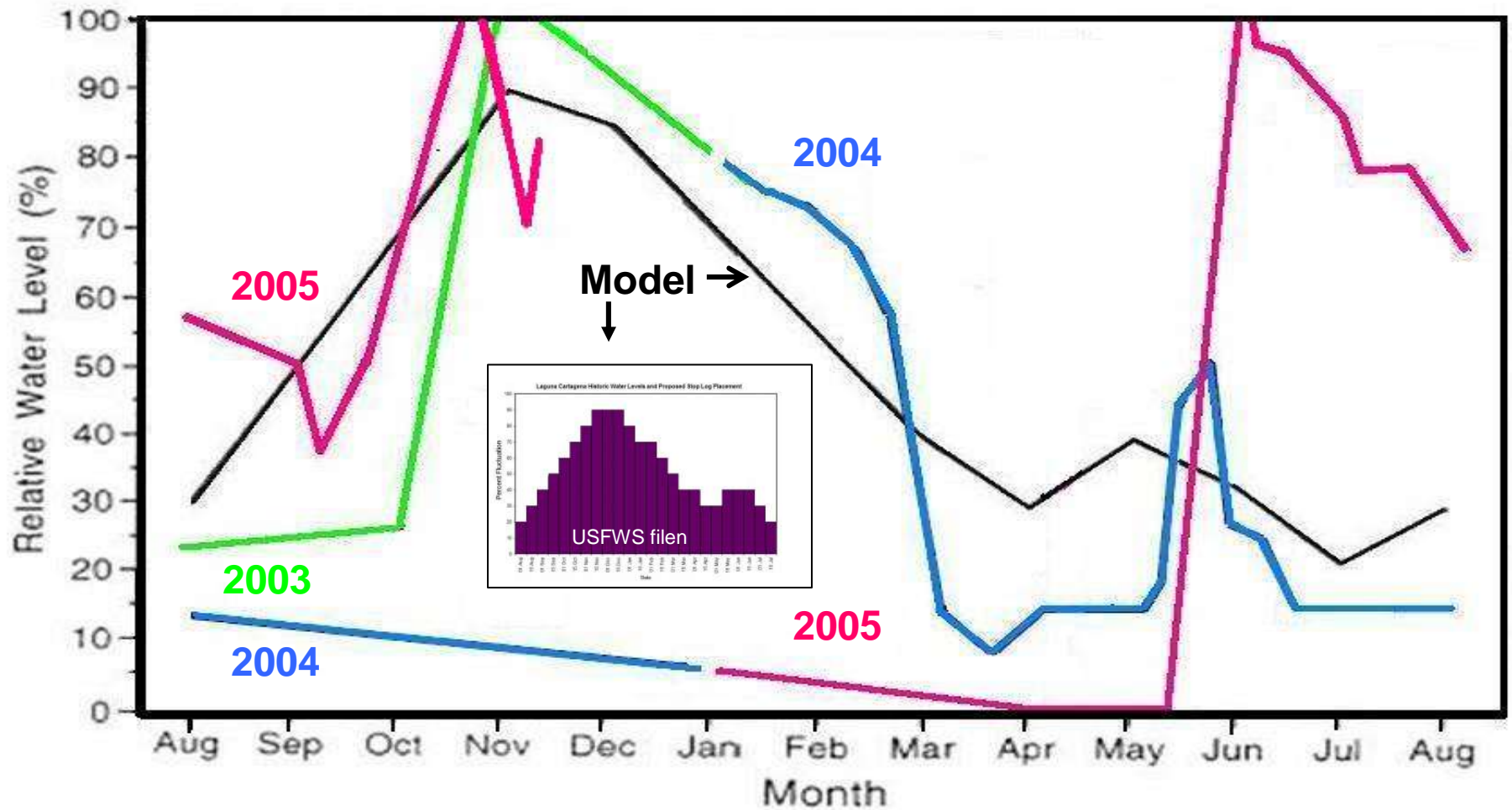
Implemented by  
FWS





# FWS Hydroperiod manipulation

Observed Water Level Changes August 2003 – November 2005





*F. C. Schaffner, 2005-05-15*

“Shock” re-filling of the lagoon by a single 3.5 in rainstorm (second of the season) – flooding the terrestrialized portions of the lagoon and drowning the terrestrial vegetation.



*F. C. Schaffner, 2005-05-21*





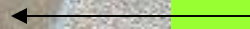
**30 May, 2005**

**Choking Stench of H<sub>2</sub>S at Lagoon Outlet Structure**



**30 May, 2005**

**Choking Stench of H<sub>2</sub>S  
at Lagoon Outlet  
Structure**

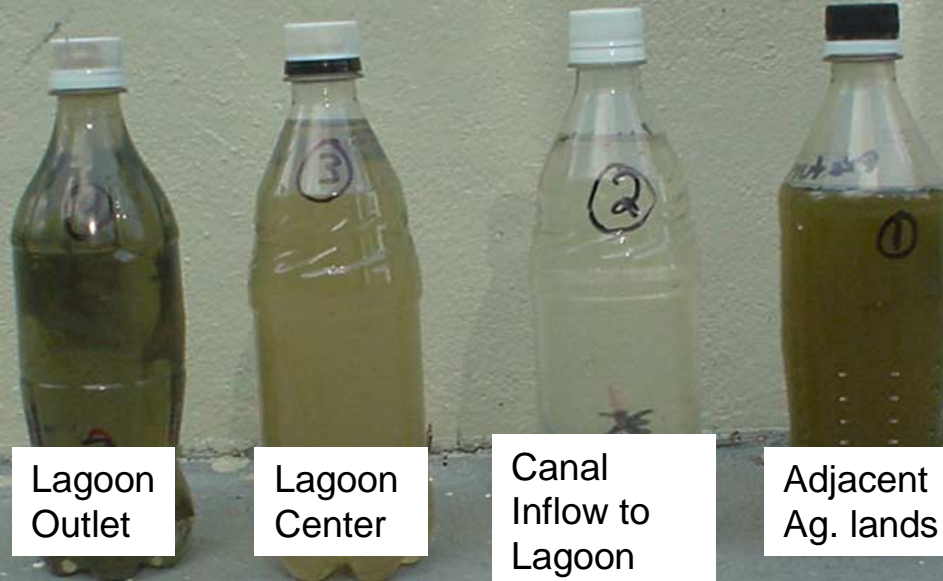


Filamentous yellow  
streamers in moving water





Water Samples, 30 May, 2005



Lagoon  
Outlet

Lagoon  
Center

Canal  
Inflow to  
Lagoon

Adjacent  
Ag. lands



Black Water:

Sulfides?

Mammalian  
Toxicity?

# Dead Horses

30 May, 2005







*F. C. Schaffner, 2005*

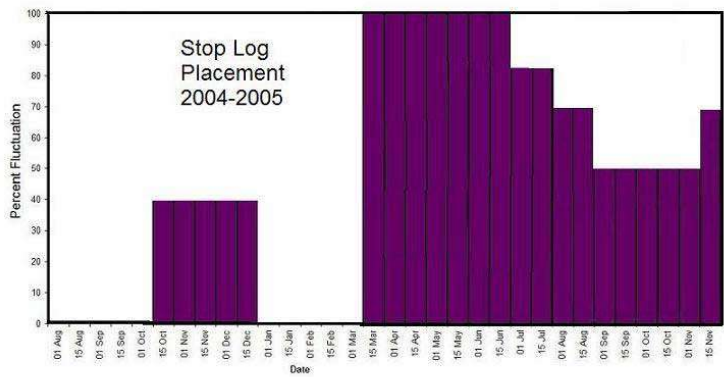
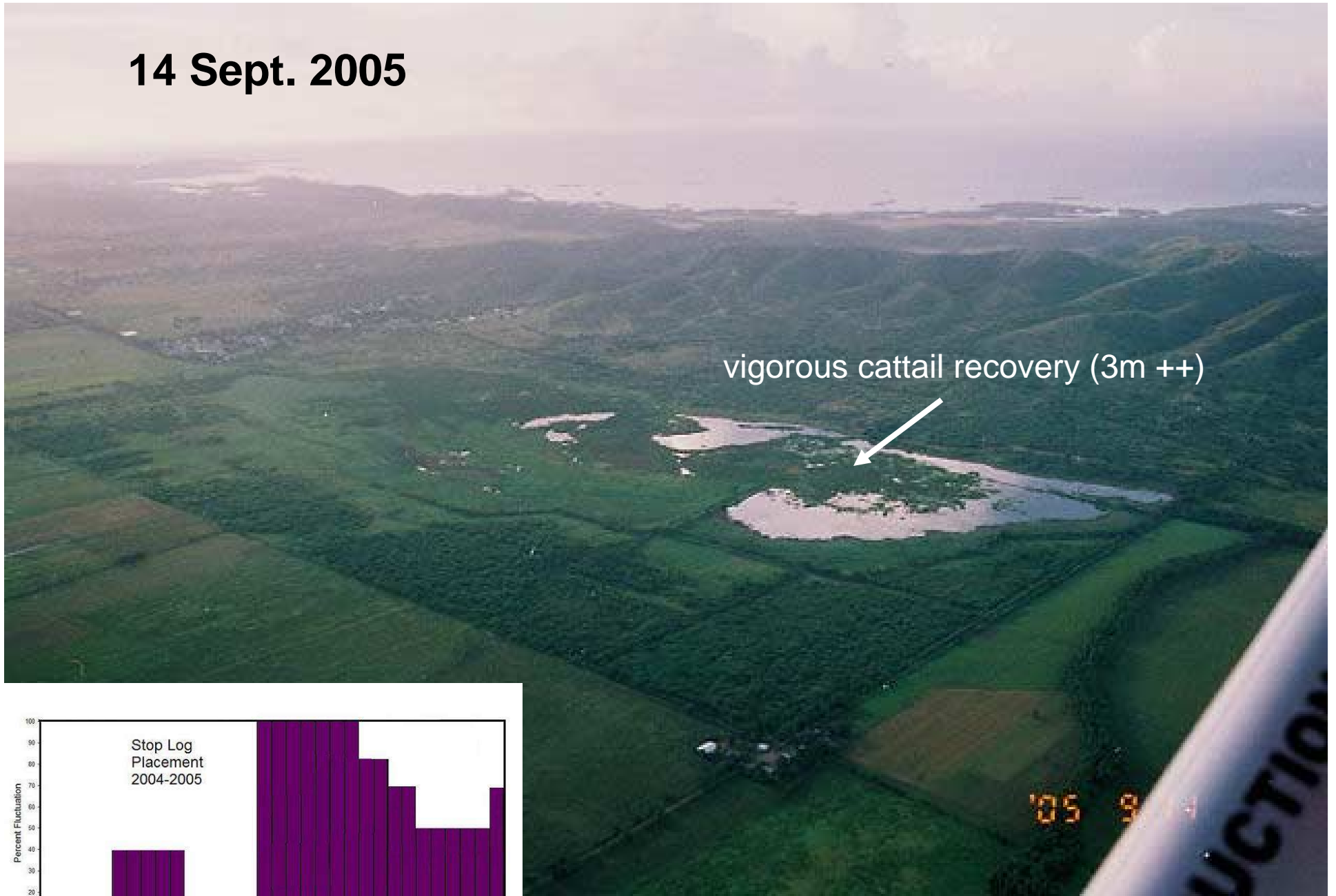


*F. C. Schaffner, 2005*

18 June 2005

'05 6 18

14 Sept. 2005



'05 9

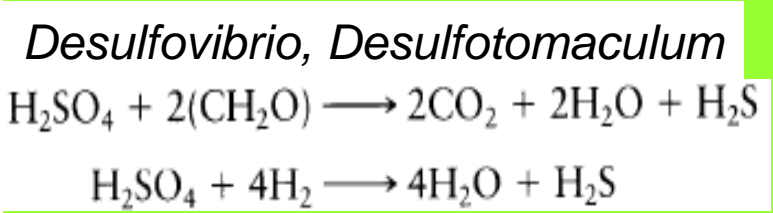
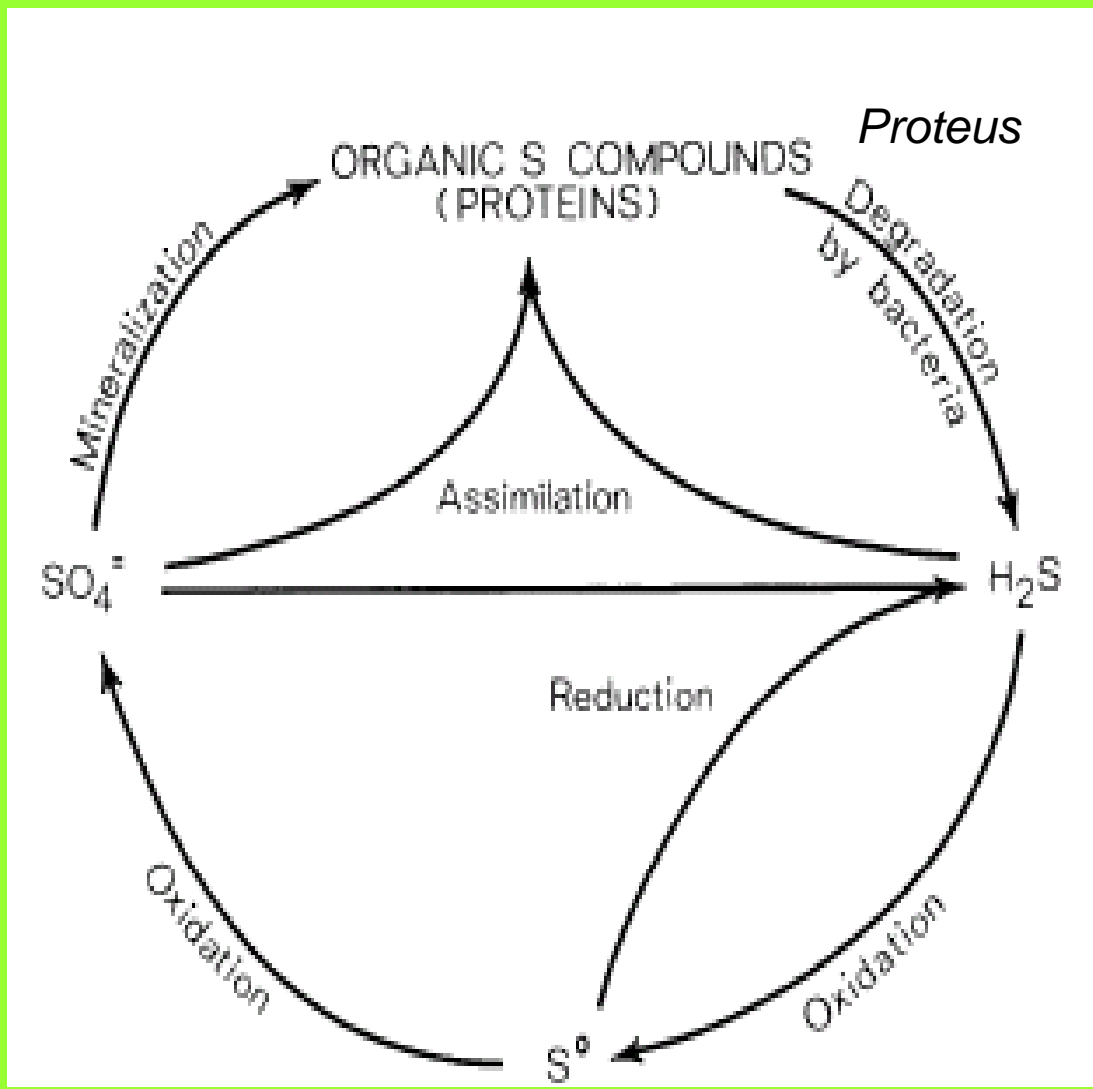
UNCTION



25 Sept 2005







$\text{Fe}^{+2}$

FeS to anaerobic sediments

Toxicity of  $\text{S}^{-2}$ ?



*Beggiatoa, Thiobrix*





*Plecostomus* sp., Laguna Cartagena, 2005-02-20