Use of Wetlands for Stormwater and Wastewater Treatment




Speakers
Jim Bays/ CH2M HILL
Larry Schwartz/ SFWMD
Chris Keller/Wetland Solutions Inc.

Florida Chamber's

2015 Environmental Permitting Short Course

Orlando, Florida

July 9-10 2015

Topic Briefings

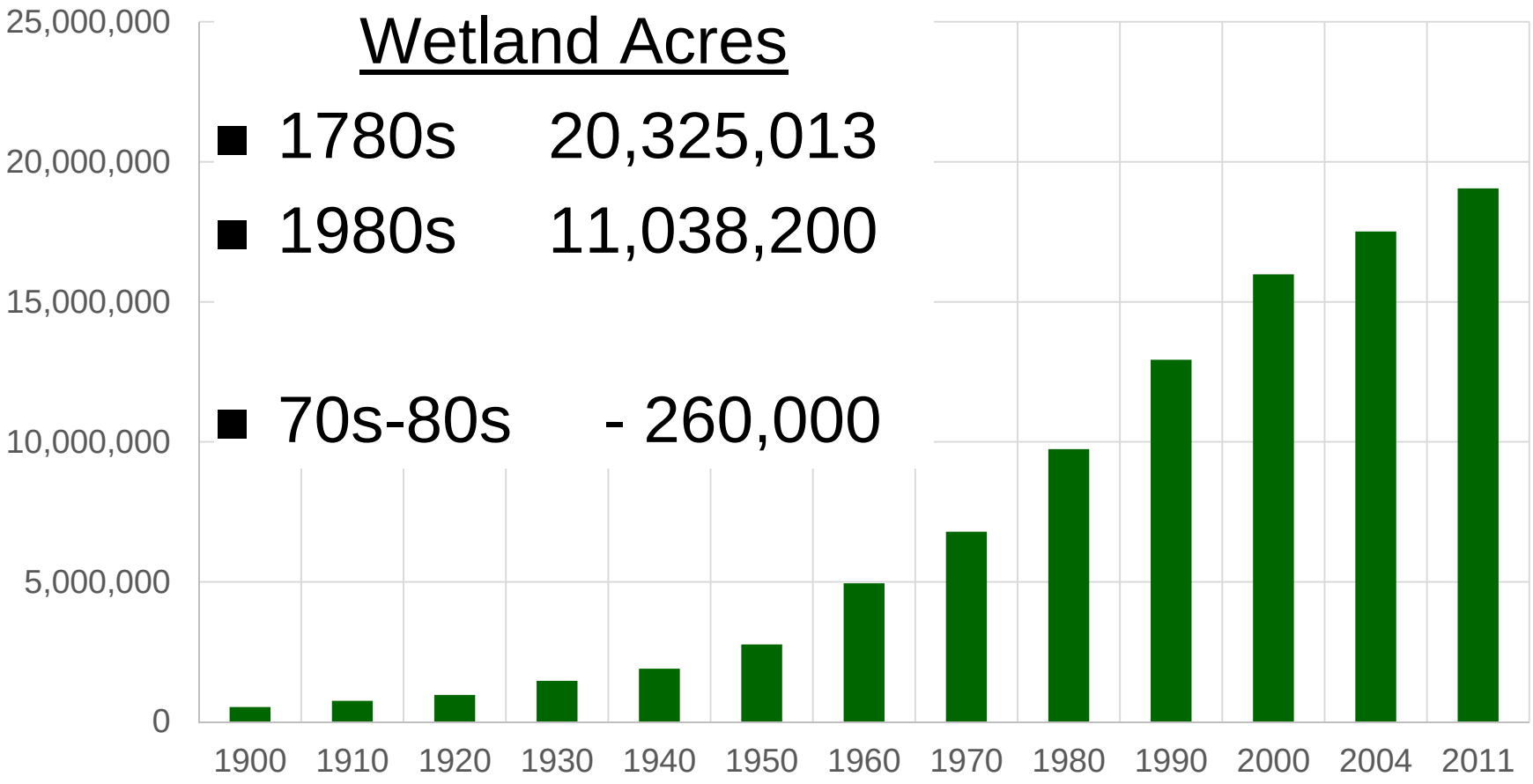
- ✓ Treatment Wetlands
  - ✓ Jim Bays/CH2MHILL
- ✓ Wetland Application Rule and Everglades Science Plan Overview
  - ✓ Larry Schwartz/SFWMD
- ✓ Stormwater Wetlands
  - ✓ Chris Keller/Wetland Solutions Inc.
- ✓ Q&A

Copies of presentations on Conference Web Site

Treatment Wetlands

- Design Overview
  - Ecological Basis
  - Sizing
  - Hydrology and Hydraulics
  - Planting Design
  - Public Use
  - Operation and Maintenance
- Selected Case Histories and New Applications

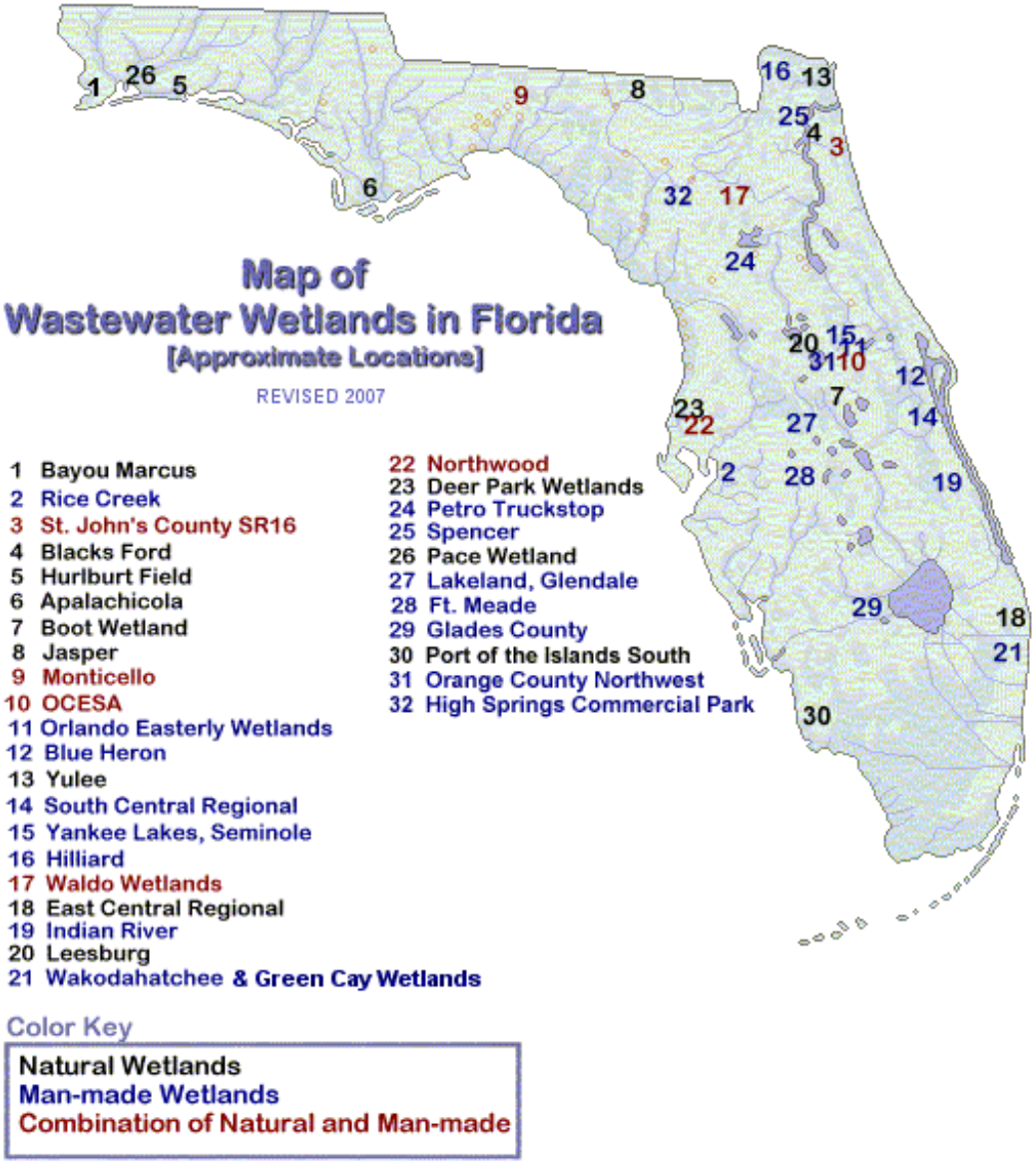
Florida 46% Historic Wetland Loss in Response to Population Growth



http://www.epa.gov/owow/wetlands/vital/epa_media/usa.gif

Legislation Counters Wetland Losses Using Effluent and Stormwater As Wetland Water Source

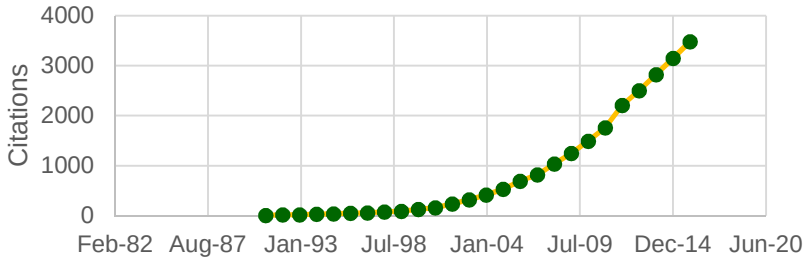
- Experimental Exemption for Wastewater Recycling 1979
- Warren Henderson Act 1984 (ERP)
- Wetlands Application Rule 1986
- Everglades Forever Act 1994
- Reuse Rule 1989 (last update 2007)
  - 10 systems, 33.4 mgd, 5440 acres (FDEP 2014)



http://www.dep.state.fl.us/water/wastewater/dom/wetmap.htm

Wetlands for Water Treatment: Florida Origins and History

- 1970s
  - Center for Wetlands (**Odum**)
  - Houghton L MI (Kadlec)
- 1980s
  - Arcata Marsh CA
  - **1984 – Henderson Act**
  - **1986 – Wetlands Application Rule**
  - 1987 – Lakeland, Orlando
- 1990s
  - EPA: TW Data Base
  - SFWMD: **EFA**, ENRP
  - SJRWMD: L Apopka Flow-way
  - SWFWMD: Rushton research
- 2000s –Implementation



Definitions

Wetland:

- An ecosystem characterized by extended periods of ***saturation***, resulting in ***hydric soils*** and dominated by ***vegetation*** adapted to such conditions

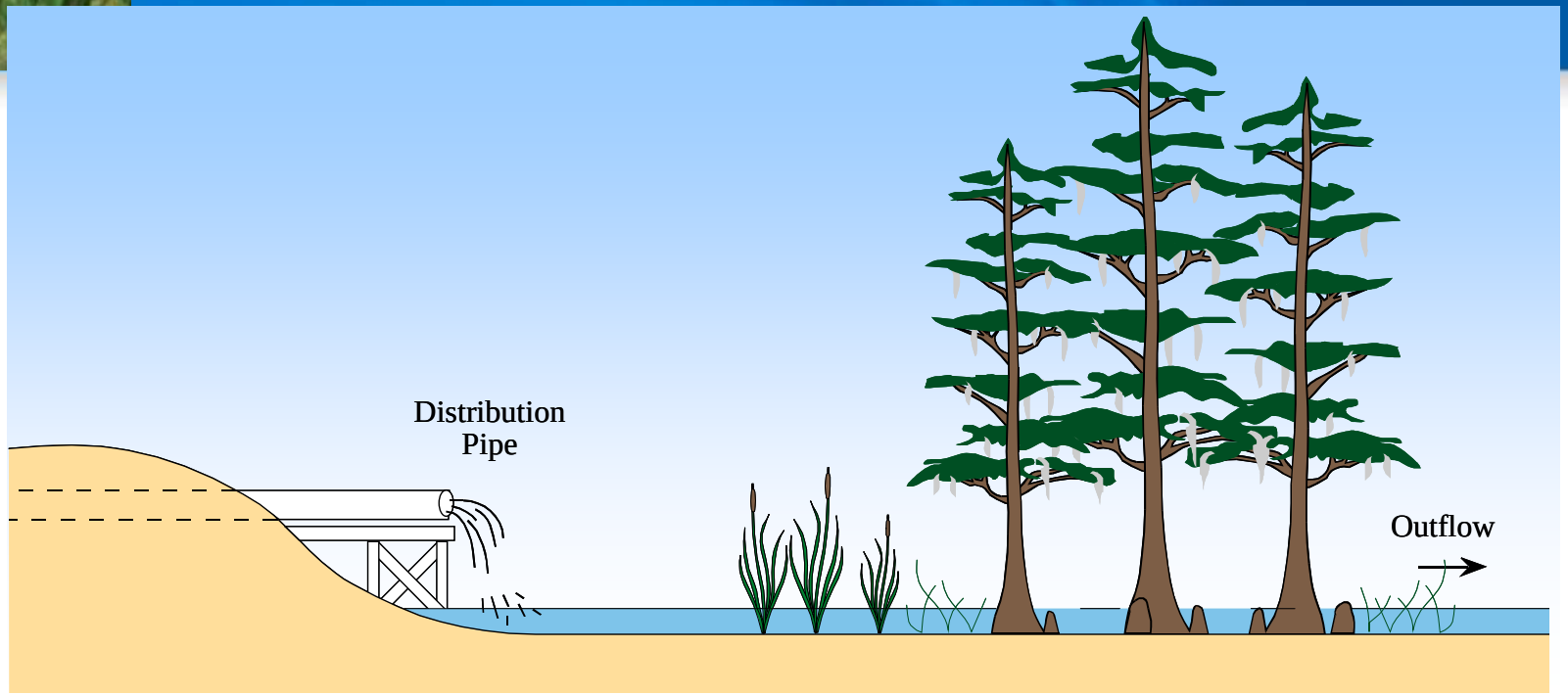
Constructed wetland:

- a ***manmade*** system designed to replicate the physical and ecological components of a natural wetland ecosystem

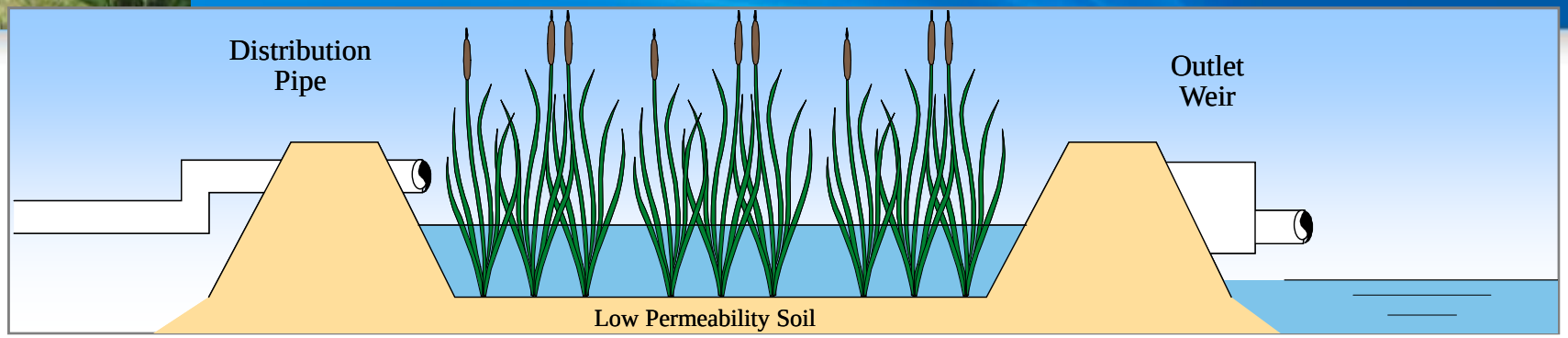
Treatment wetland:

- a ***natural or constructed*** wetland system engineered to ***reduce contaminants*** from water

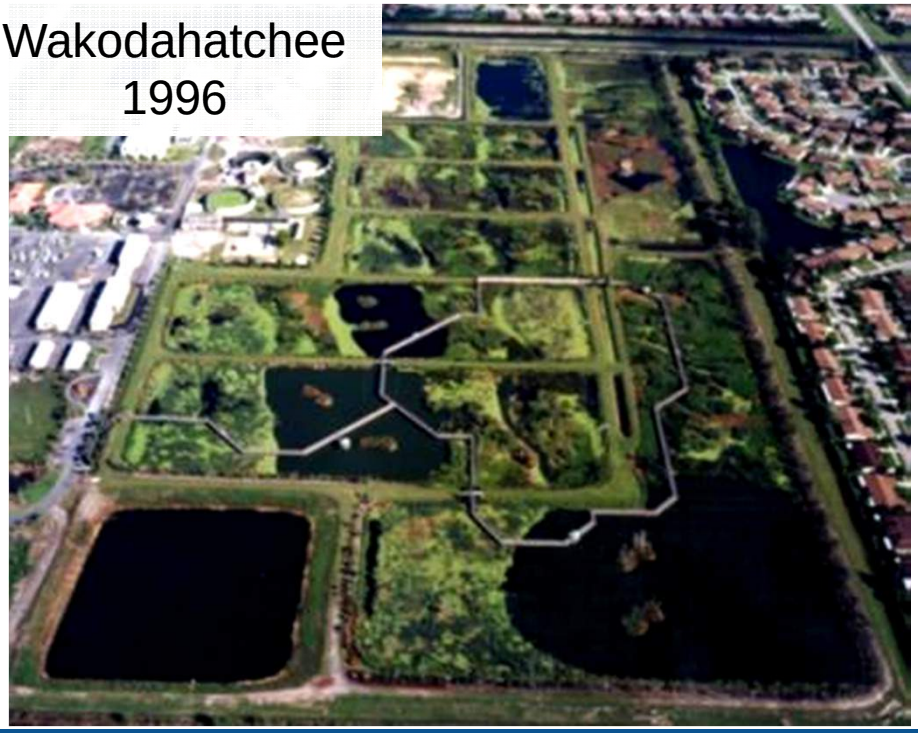
Natural Wetlands for Treatment



Surface Flow Constructed Wetlands



Wakodahatchee
1996



Other Natural Treatment Systems

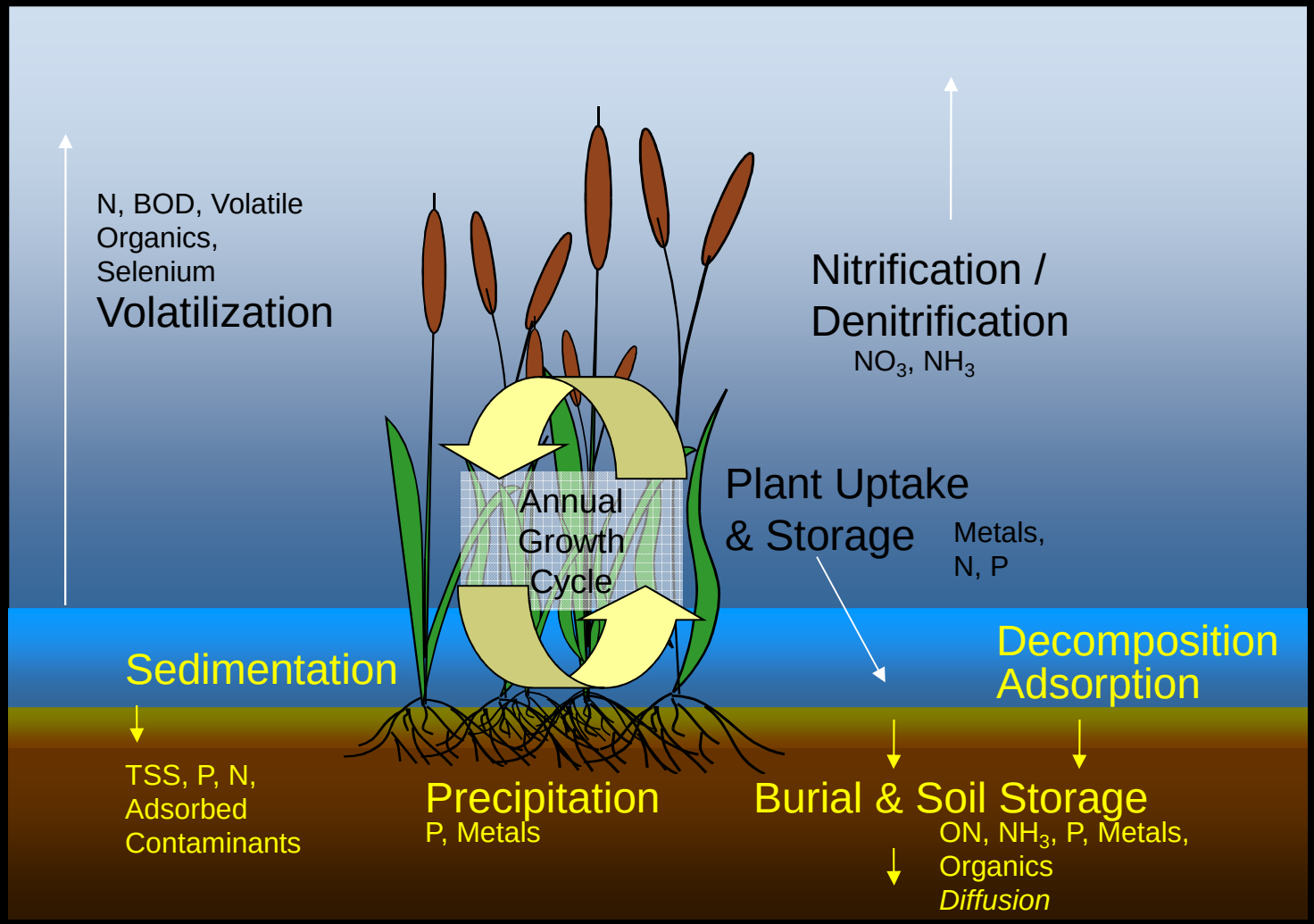
Floating Aquatic Plant Systems

Floating Wetland Islands

Periphyton/SAV

Green Infrastructure = Wetlands Plus

Wetlands Affect Water Quality Naturally

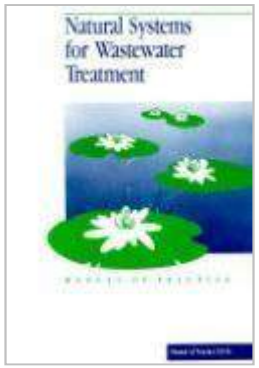


Surface Water

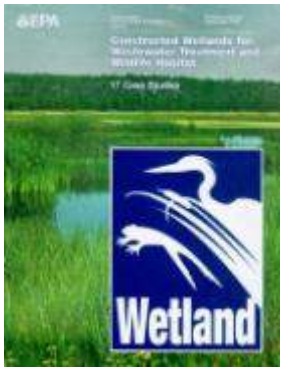
Detritus

Sediments

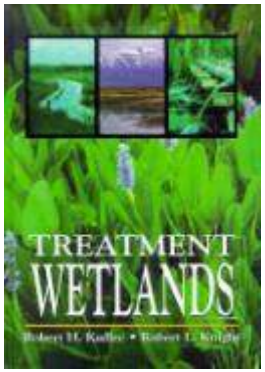
Steady Progress in Treatment Wetlands Design



1989

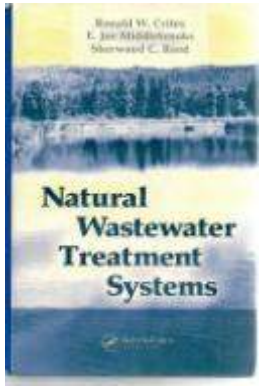


1993

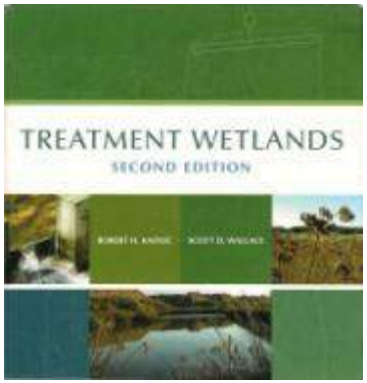


1996

2000



2006

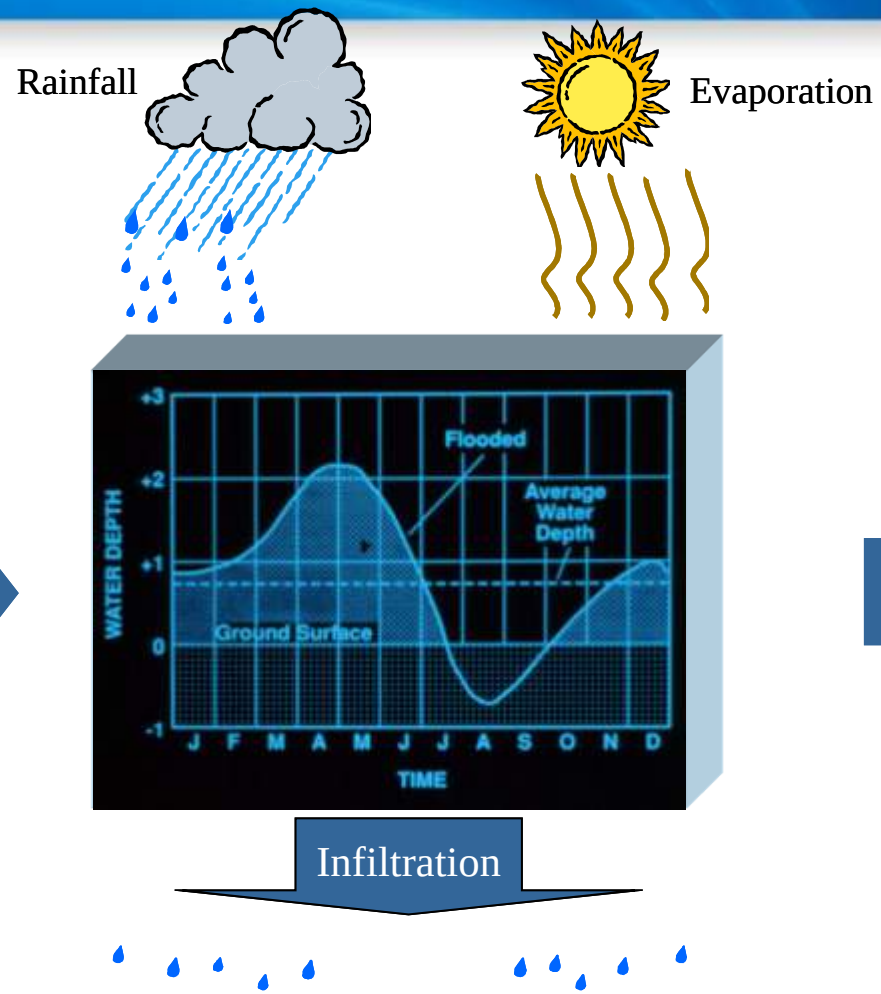


2009

Annual South Florida Environmental Report

1990 2000 2010

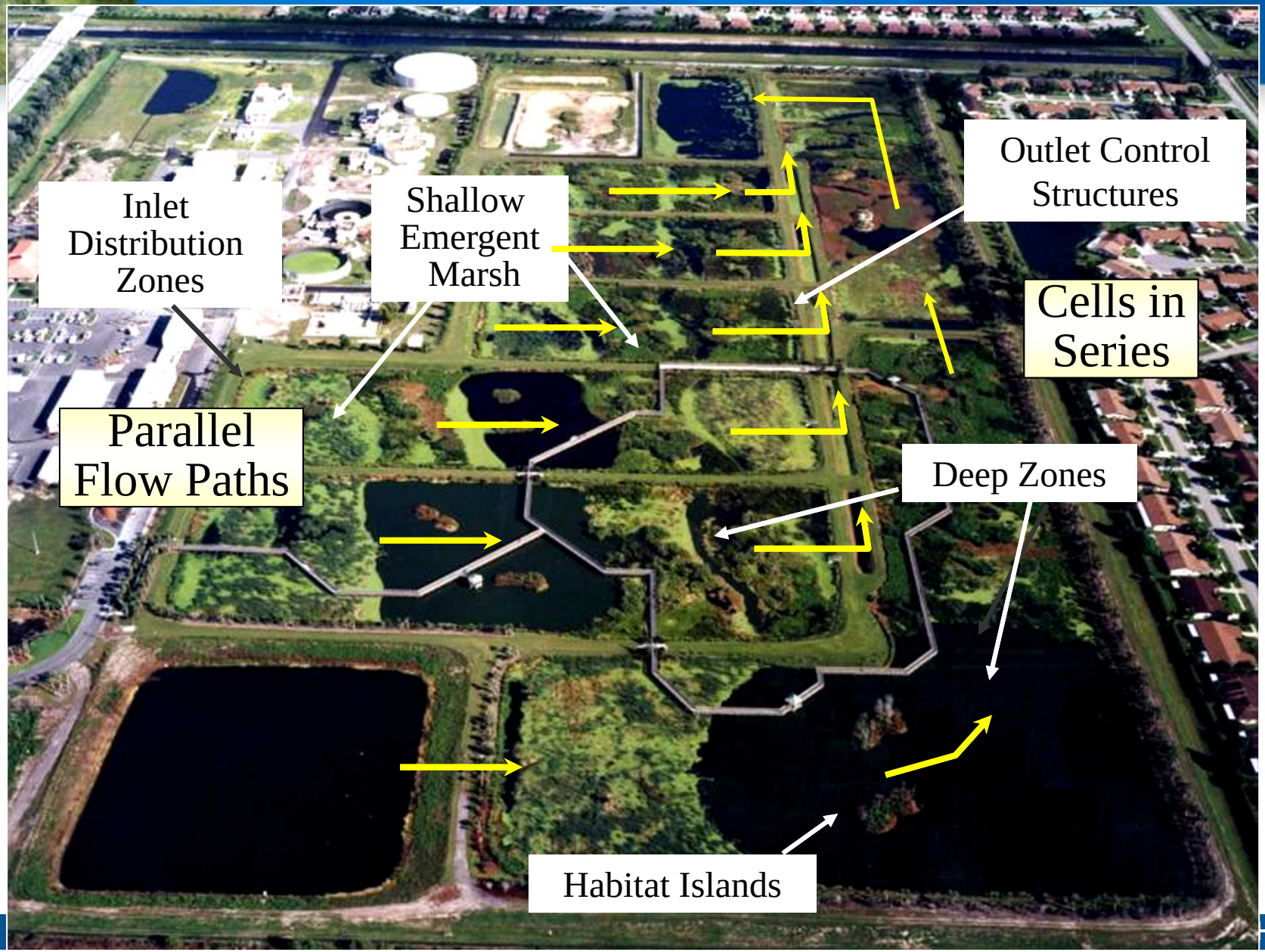
A Preliminary Water Balance Is Needed to Ensure Adequate Water to Maintain Wetlands



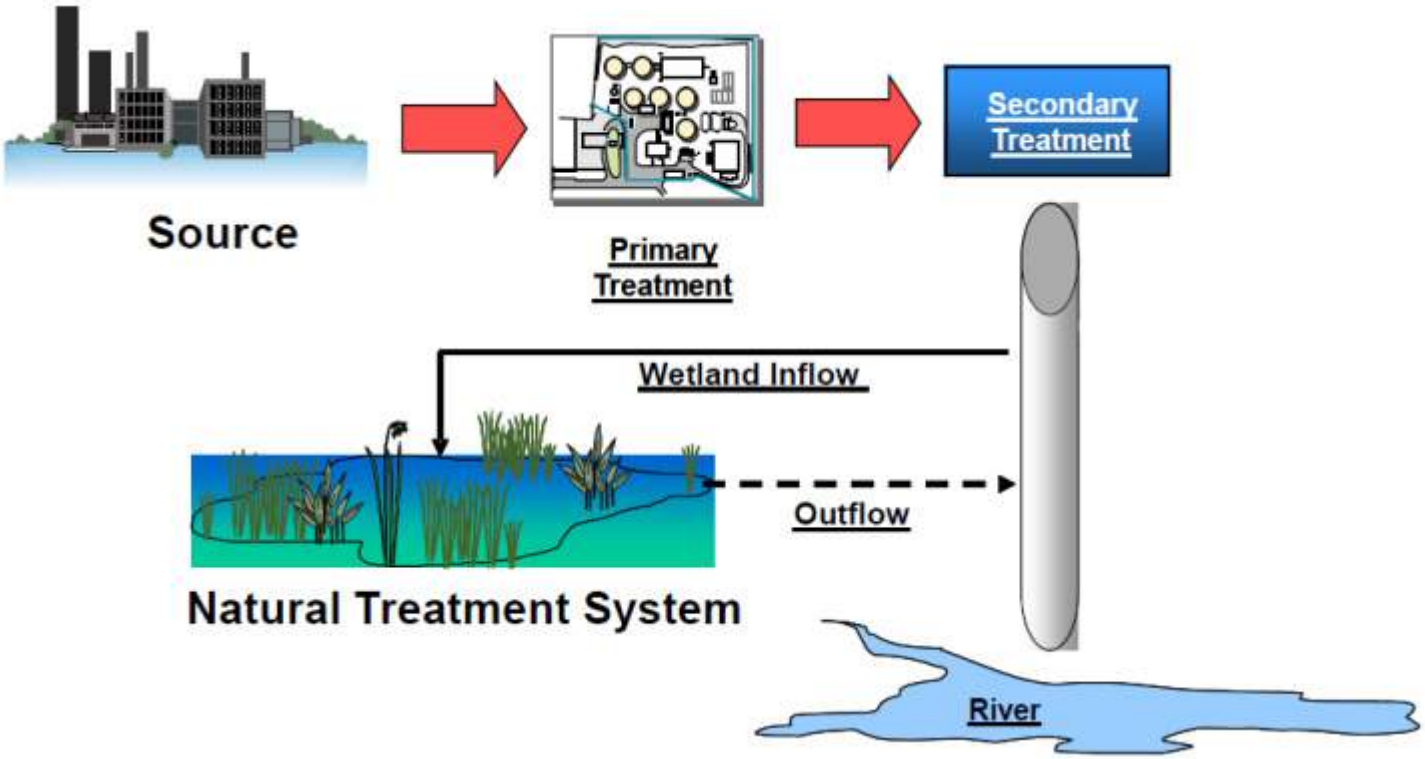
Use vegetative indicators to establish target SHWL, NP elevations

Infiltration can be a planning objective

Compartments in Treatment Wetlands Aid System Hydraulics and Performance



Effluent Treatment Wetland: Pretreatment Requirements



Surface Water/Stormwater Wetland: Pretreatment Requirements

Runoff and Load Generation → Conveyance and Pretreatment → Additional Treatment and Attenuation → Final Treatment and Attenuation

- ✓Source Controls
- ✓Public Education
- ✓Erosion Control
- ✓Roof Runoff
- ✓Florida Yards
- ✓LID

- ✓Swales
- ✓Catch Basins
- ✓Filter Inlets
- ✓Oil/water Separators

- ✓Storage Tank
- ✓Sediment Sump
- ✓Alum

- ✓Retention
- ✓Detention
- ✓Wetlands
- ✓Alum

!!

http://www.co.broward.fl.us/Stormwater/

http://www.co.broward.fl.us/Stormwater/

CH2MHILL.

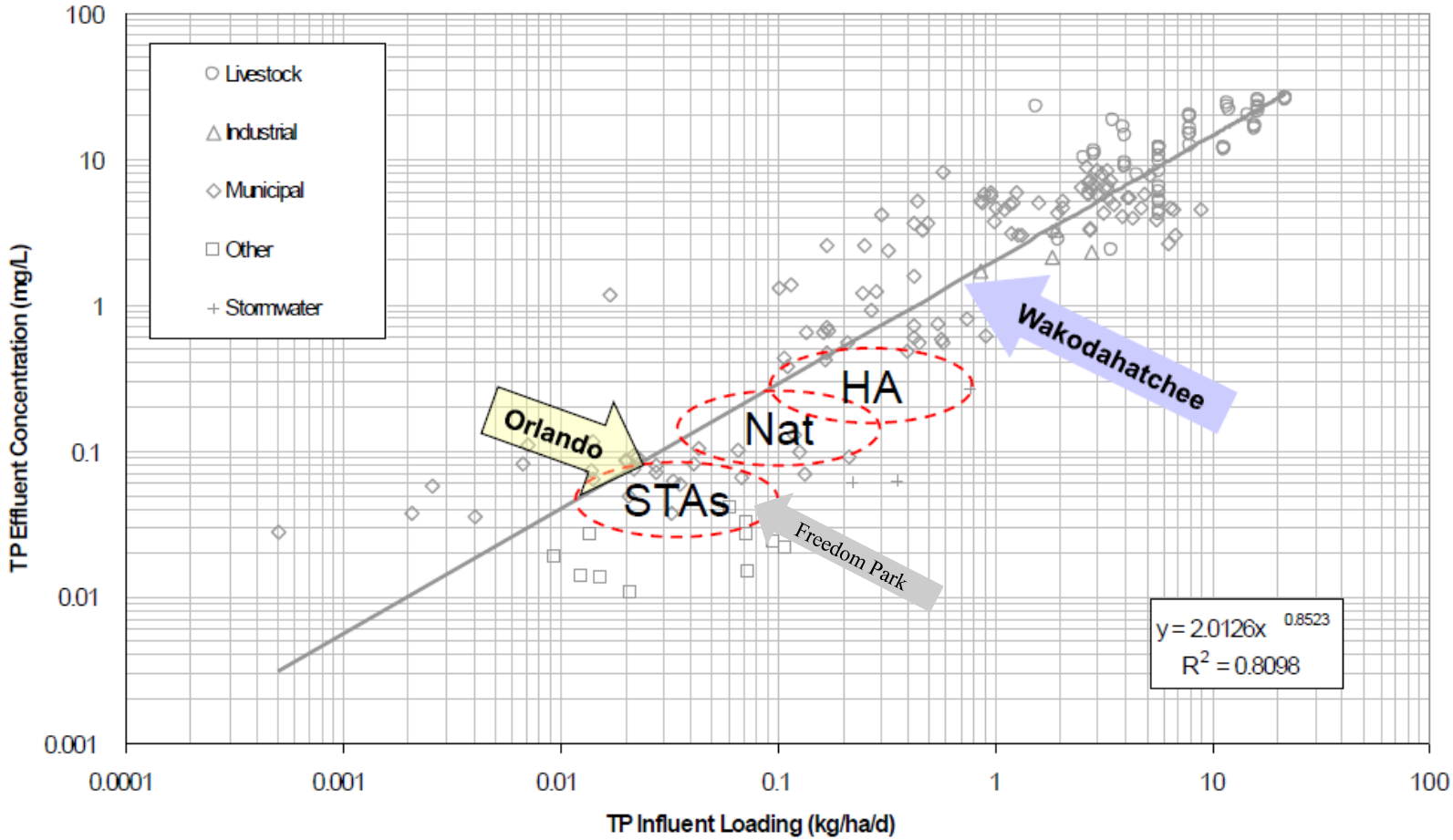
General Performance Results Set General Expectations

Parameter	Removal Efficiency	Limit
BOD	50 – 90%	2 – 10 mg/L
TSS	50 – 90%	2 – 10 mg/L
TN	40 – 90%	1 – 3 mg/L
TP	10 – 90%	<1 mg/L
Fecal Coliforms	80 – 99%	<100 – 1,000 col/100 mL
Metals	50 – 90%	Below Detection

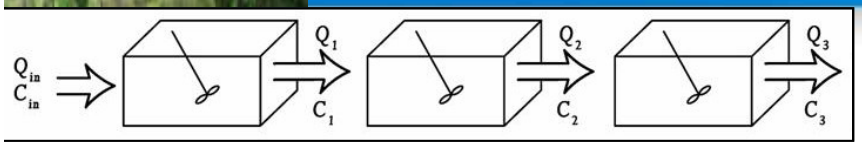
0.004 mg/L

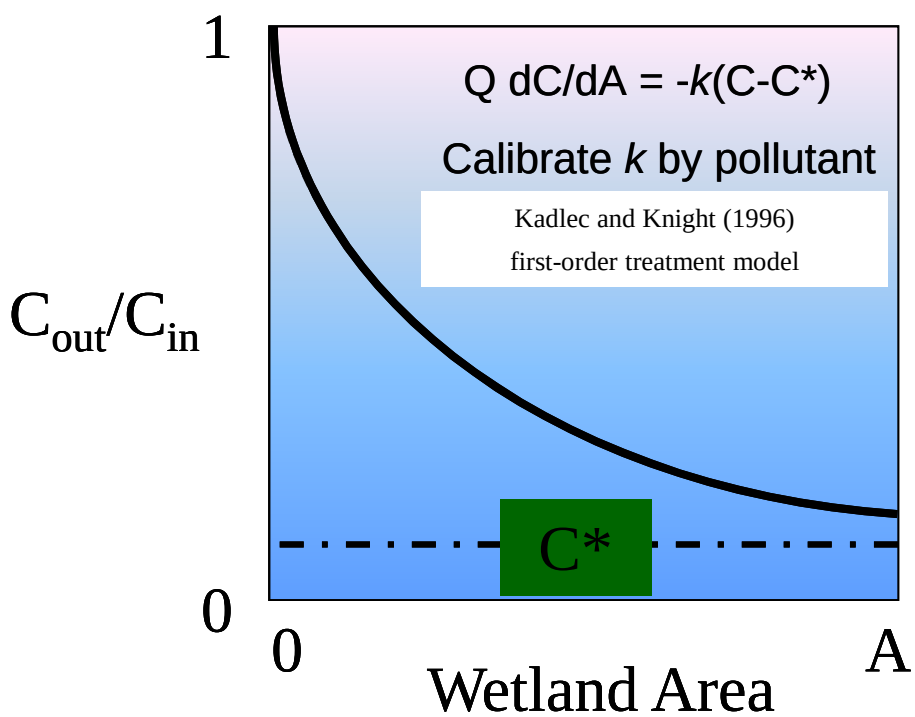
[a] Removal efficiencies and effluent concentrations are very dependent upon influent concentration and hydraulic loading rate.

Loading Coordinate Graph Establishes, Confirms Performance

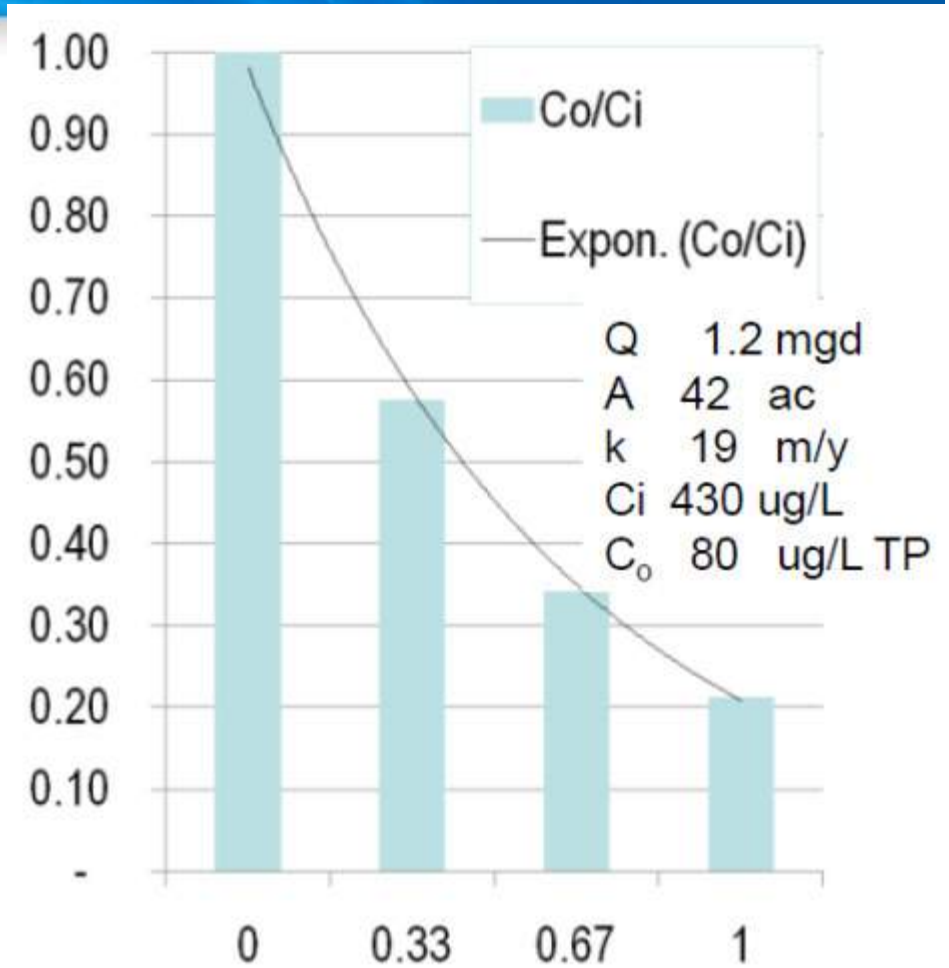


Wetland Treatment Performance Described by First-order Model





$$\left(\frac{C - C^*}{C_i - C^*}\right) = \frac{1}{(1 + k/Pq)^P}$$



Example Wetland Performance

Orlando Wetlands Park FL: AWT Wetland Milestone

	In (mg/L)	Out (mg/L)
TN	2.4	0.8
TP	0.28	0.06
BOD	1.5	1.8
TSS	<1.0	<1.0

1,220 ac

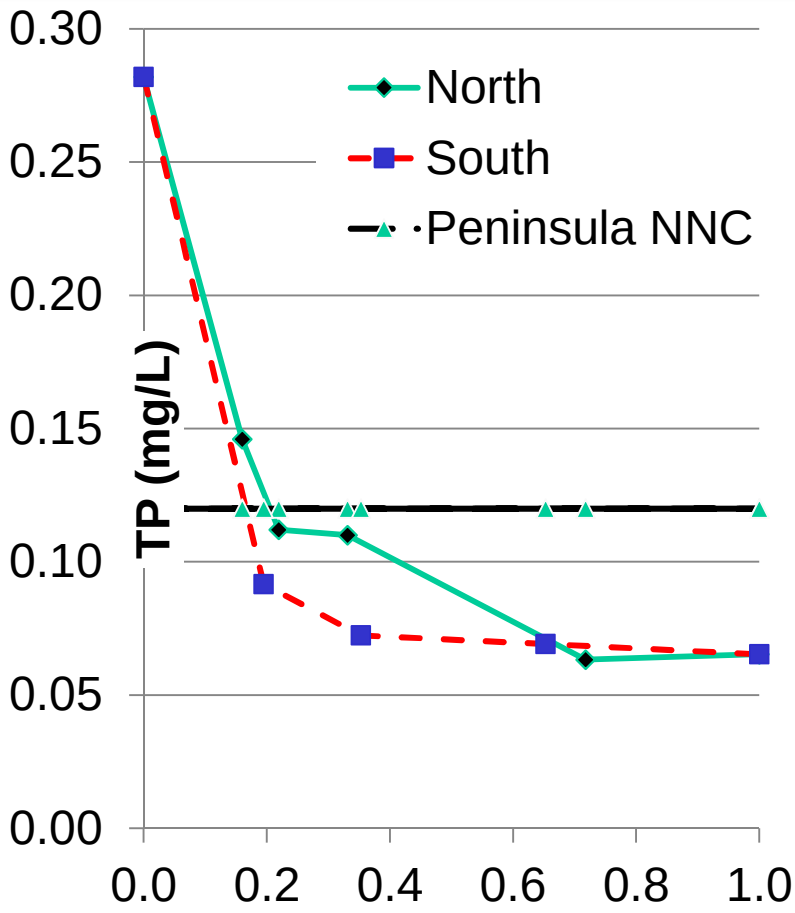
12 cells

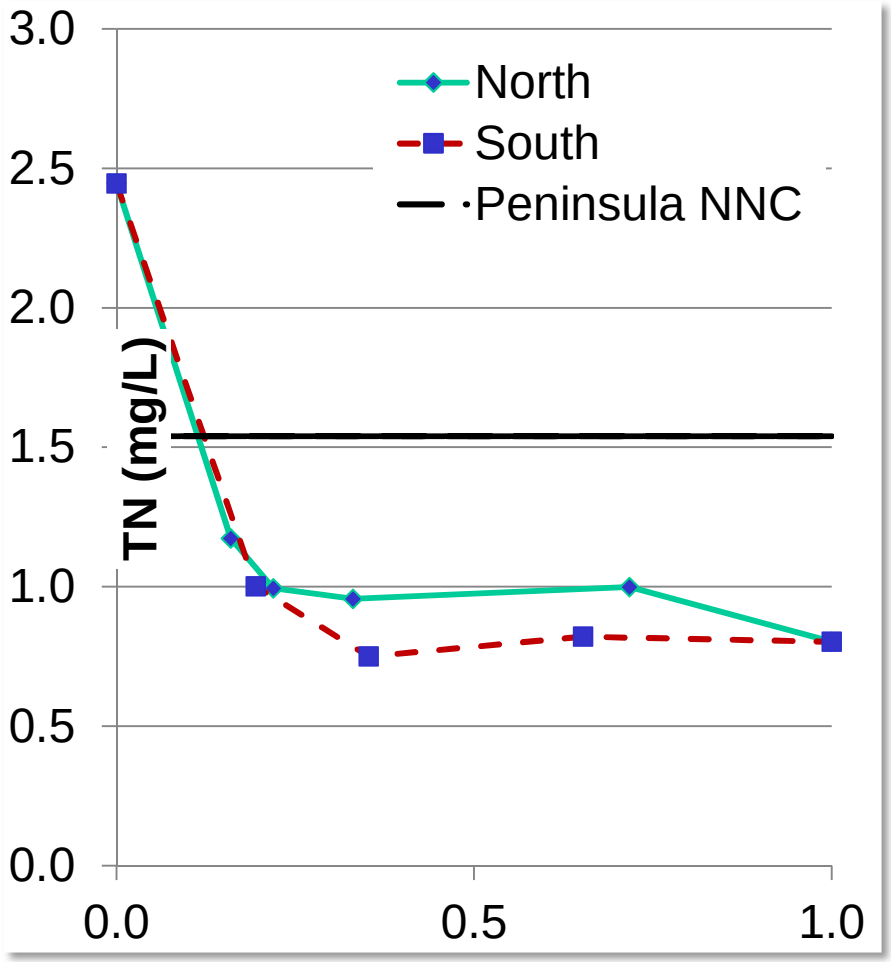
3 flow paths

20 mgd

>30 d HRT

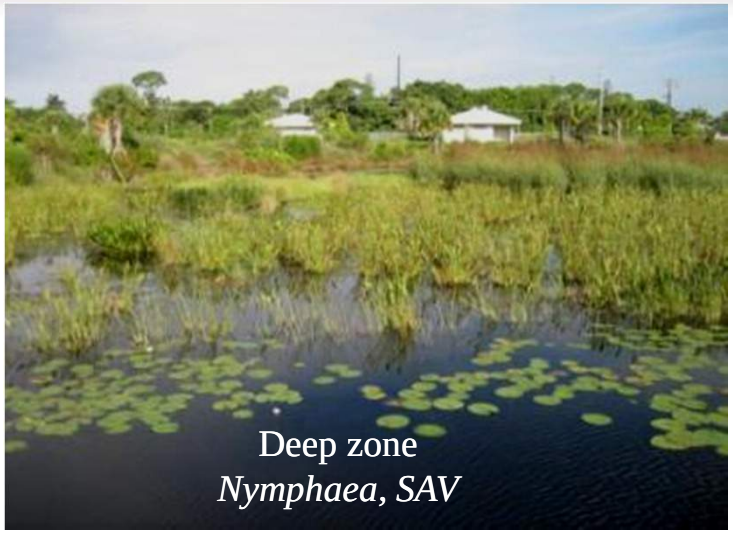
Orlando Wetlands Meet Proposed Numeric Nutrient Criteria





Source: Sees, 2005

Install and Manage Vegetation for Biomass, Diversity, Aesthetics, Flow



Treatment Wetlands Operations: Track Performance and Monitor Flow

- Water Quality
  - Monitoring
  - Constituent Loading
- Hydraulic Operation
  - Water Level and Flow Control
  - Flow Path Rotation
- Vegetation Management
  - Aesthetics and Exotics
  - Replacement for Hydraulics, Performance, Herbivory
  - Harvesting? No
- Control of Nuisance Conditions

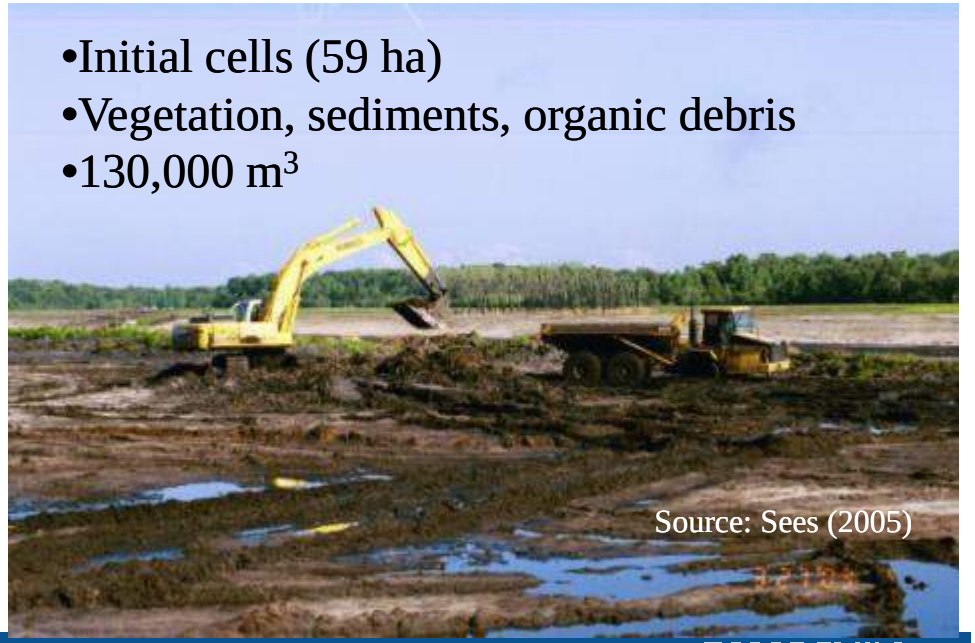
Sediment Removal FAQ

An Uncommon Practice

- Decades of Storage
- Slow Accretion Rate
  - 0.1 – 0.5 in/yr
  - Near inlet
  - Build in storage in deep zones
  - Water level adjustment
- Stormwater Considerations
  - 5 – 10 year cycle: clean out forebay/inlet deep zone

Orlando Wetlands (2002-03)

- Disposed on-site
- 160,000 bulrush installed
- Areal efficiency increased from 0.34 to 0.74.

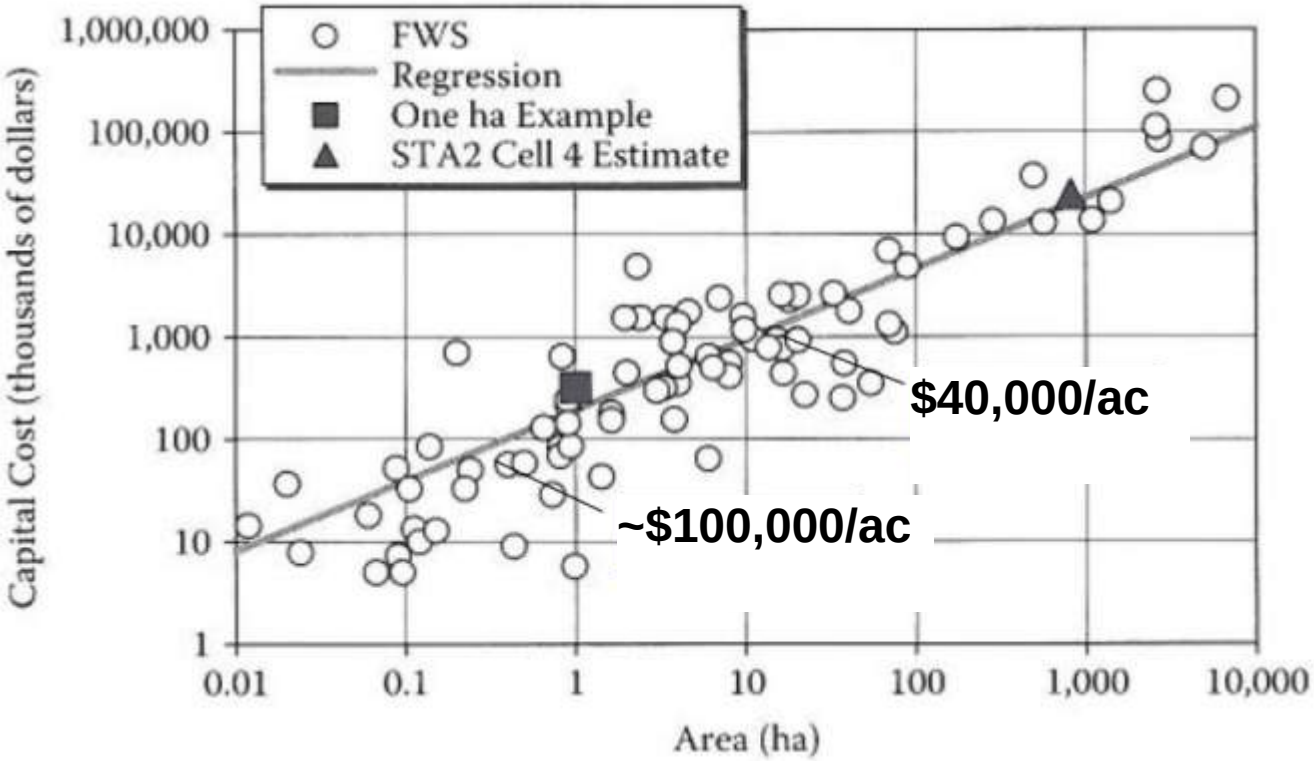


Public Recreational Use Can Exceed Expectations

Wakodahatchee
"Created Waters"
Delray Beach, FL

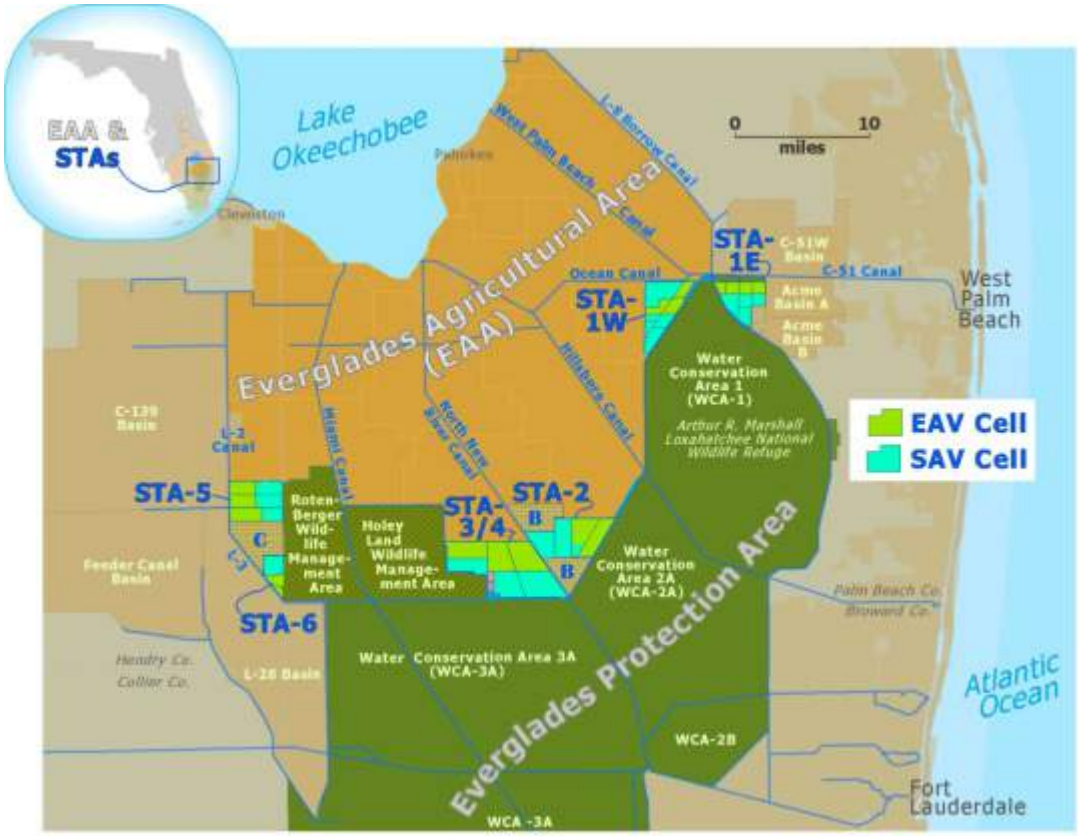
- Parking lot expanded from 10 to 50 in first year; still low.
- Available records indicate visitors increased from 165 in 1997 to conservatively *125,000* per year.
- Dec, Jan, Feb: 600 people per day.
- Birders, photographers, fitness walkers, and multi-generational groups.
- Featured in local and national media.
- Google "Wakodahatchee":
  - 50 in 2004
  - 510 in 2013

Capital Cost Considerations



Source: Kadlec & Wallace (2009)

Everglades Construction Project: World's Largest Treatment Wetlands



- 57,000 ac STA area
- 1,874 MT TP retained since 1994
- 75% TP Reduction
- FWM 34 ppb TP outflow
- 1994 ECP = $913 MM
  - $714 MM state
  - $199 MM Federal

WY 2014

- 1,300,000 ac-ft treated
- 81% TP Reduction
- FWM TP outflow 21 ppb
- 147 MT

Sources: SFER 2015

Freedom Park, Naples:
Stormwater Treatment, Restoration, Recreation
Treatment Wetlands Sustain Native Diversity

- 50-ac: since 2009
- 200 Million Gallons of SW Flow into Naples Bay Treated per Year
- Nitrogen Reduced By **39%** to 0.8 mg/L (background)
- Phosphorus Reduced By **82%** to 30 ppb (nr. backgr.)
- Metal Concentrations Reduced to Background Levels
- Critical Component of County's Stormwater Improvement Plan

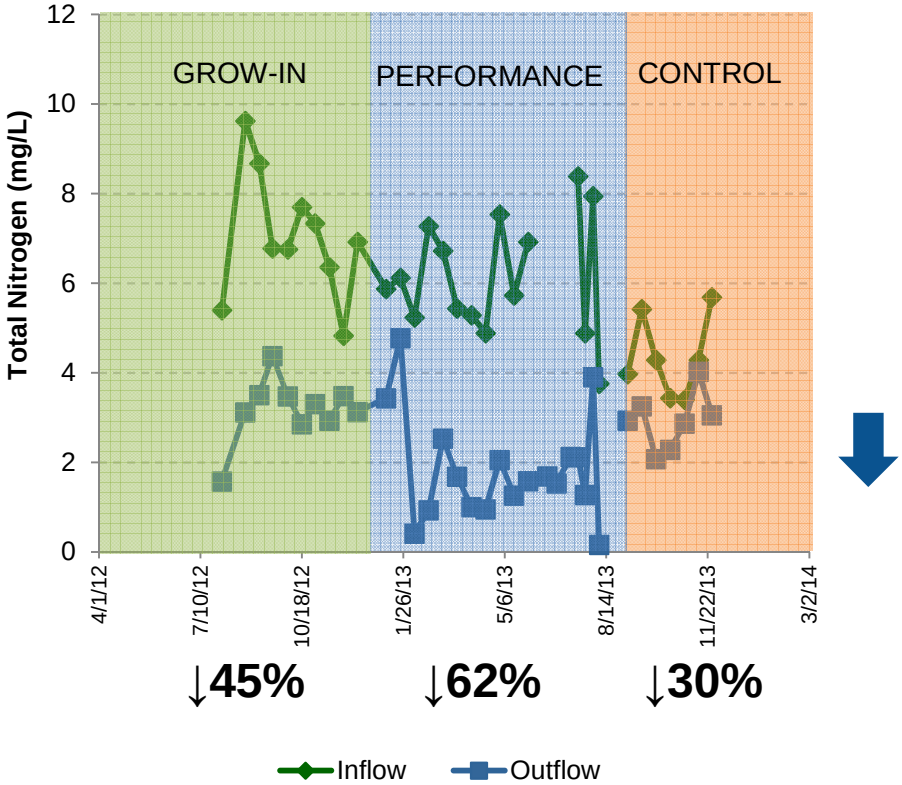
Collier County

CH2MHILL.

Floating Wetland Islands: A Strategy for Nitrogen Reduction in Reclaimed Water

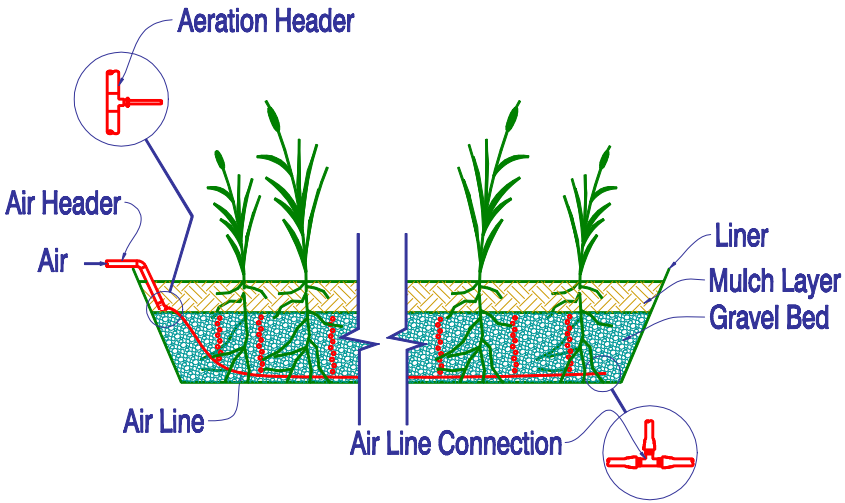
FWIs: After 1.5 years

Presence of Islands Improved TN Reduction



Enhanced Wetlands ("Intensification") and System Integration Can Help Meet TMDLs

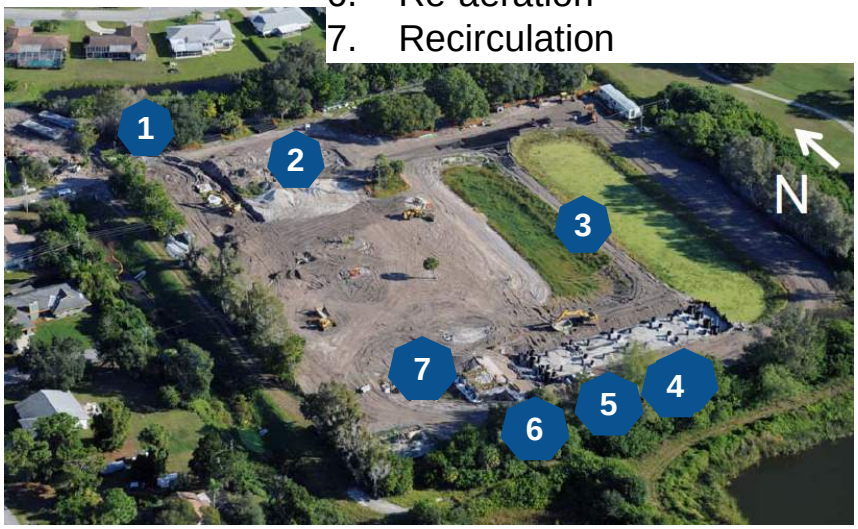
Forced Bed Aeration



Integrated Media Filtration

Alligator Creek Treatment Train:

1. Flow diversion (pump)
2. Forebay settling
3. Wetland treatment (2 cells)
4. Downflow gravel filtration
5. Upflow media adsorption
6. Re-aeration
7. Recirculation



Wanielista & Flint 2012

Wetlands for Water Treatment: Perspective

- Versatile
  - Mass removal, concentration
  - New applications
- Passive, low energy, low O&M, stores nutrients
- Well-understood, good record
- Conserves land, creates habitat

Freedom Park, Naples FL

Jim.Bays@ch2m.com

Chapter 62-611 FAC Wetlands Application

Larry N. Schwartz Ph.D., P.W.S.

- Presentation Format
  - History of the Rule
  - Content of the Rule
  - Recommended Rule Changes

Chapter 62-611 FAC Wetlands Application

- History
  - Exemption for the Experimental Use of Wetlands
  - Warren S. Henderson Wetlands Protection Act of 1984:

    Rules for the use of wetlands to receive wastewater with protection of their type, nature and function
  - 1st rule adoption 1986: 17-6.055 FAC
  - 2nd rule adoption 1988: 62-611 FAC

Chapter 62-611 FAC
Wetlands Application

- 62-611.100 Scope/Intent/Purpose
  - Landward extent of waters of the state
  - As additional data becomes available the department will reevaluate the rule

Reevaluation language eliminated from the rule but research and performance data indicate changes are warranted

Chapter 62-611 FAC Wetlands Application

- 611-110 Applicability
  - Rule only applies to domestic wastewaters
  - Prohibitions
    - Class I & II waters
    - Herbaceous wetlands except if dominated by cattail

Need to allow use of herbaceous wetlands with high quality reclaimed water

Chapter 62-611 FAC Wetlands Application

- 62-611.200 Definitions
  - Herbaceous and woody wetlands

Chapter 62-611 FAC Wetlands Application

- **62-611.200 Definitions**
  - **Treatment Wetland - wastewater treated to secondary levels with nitrification**
  - **Receiving Wetland - wastewater treated to advanced wastewater treatment (AWT) levels**
    - **AWT**

$CBOD_5$	5 mg/l	TSS	5 mg/l
TN	3 mg/l	TP	1 mg/l

Chapter 62-611 FAC Wetlands Application

- 62-611.200 Definitions
  - Man-made Wetlands
    - constructed in uplands
    - not constructed for mitigation

Referred to as constructed in the literature

Rule should be changed to promote use for waste treatment especially in conjunction with receiving wetlands

Chapter 62-611 FAC Wetlands Application

- 62-611.200 Definitions
  - Hydrologically Altered Woody Wetlands
    - drainage resulting in substantial and continuing encroachment in upland species
  - Hydrologically Altered Herbaceous Wetlands
    - drainage resulting in substantial and continuing reduction in water levels

- Definitions limiting and difficult to demonstrate

- Many wetlands could be rehydrated and this use should be promoted

-The use of wetlands with invasive non-native species could be promoted

Chapter 62-611 FAC Wetlands Application

- 62-611.300 General Qualitative Design Criteria
  - Minimize channelized flow
  - Maximize sheet flow
  - Minimize erosion
  - No adverse effect on T&E

Chapter 62-611 FAC
Wetlands Application

- 62-611.350 General Quantitative Design Criteria
  - Minimize alteration of natural hydroperiod
  - Annual average hydraulic loading rate shall not exceed 2 inches/week
  - Except in hydrologically altered wetlands where it shall not exceed 6 inches/week

Higher average hydraulic loading rates are appropriate in many wetland, lower average hydraulic loading rates are appropriate in certain wetlands

Therefore: consider establishing average hydraulic loading rates by wetland type

Chapter 62-611 FAC Wetlands Application

- 62-611.450 Discharge Limits from Treatment and Receiving Wetlands
  - Annual Average TN = 3 mg/l
  - Annual Average un-ionized ammonia = 0.02 mg/l
  - Annual Average TP = 0.2 mg/l
  - Superseded by Numeric Nutrient Criteria

Chapter 62-611 FAC Wetlands Application

- 62-611.500 Standards within Treatment and Receiving Wetlands
  - Exemption from certain general water quality standards; DO, nutrients, injury to plants, turbidity
  - Exemption from certain Class III water quality standards; DO, total coliform, biological integrity, transparency
    - Revised DO standard: Levels of dissolved oxygen including daily and seasonal fluctuations shall be maintained to prevent violations of the biological quality standards

Chapter 62-611 FAC Wetlands Application

- 62-611.500 Standards within Treatment and Receiving Wetlands
- Wetland Biological Quality

  Research has demonstrated that the application of treated wastewater to wetlands does not reduce biological quality, therefore available indices to assess wetland functions should be used instead of these standards

Chapter 62-611 FAC
Wetlands Application

- 62-611.650 Man-made Wetlands
  - Most of the provisions of the rule do not apply to man-made wetlands
  - Minimum (free-from) surface water quality standards do apply
  - General and Class III standards do not apply, except for metals
  - A wetland created for mitigation can not be used as a treatment wetland, but can be used as a receiving wetland

Chapter 62-611 FAC Wetlands Application

- 62-611.700 Monitoring Requirements
  - Unaltered treatment wetlands
  - Hydrologically altered or man-made treatment wetlands
  - Receiving wetlands
  - Length of baseline monitoring, specified parameters, frequency, number of stations
  - In general the numbers of parameters should be reduced as well as the monitoring frequency

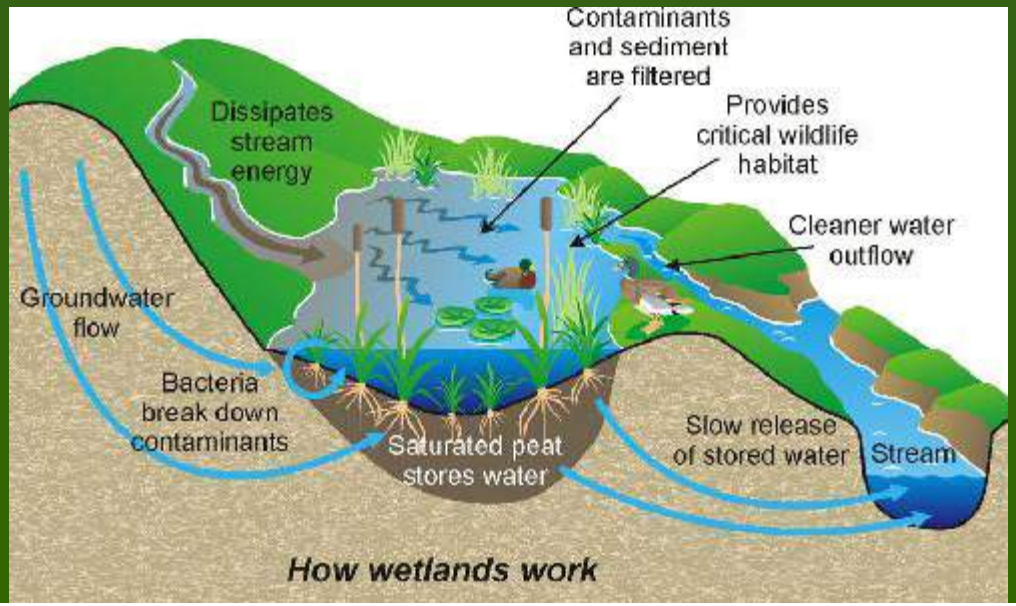
Environmental Permitting Summer School
July 2015

Stormwater Treatment Wetlands

Chris Keller, P.E.
Wetland Solutions, Inc.

Why Wetlands?

- Wetlands are the natural stormwater management systems in the landscape
- Wetlands remove or transform a wide range of pollutants found in urban runoff (BOD, TSS, N, P, pathogens, metals, hydrocarbons, etc.)



Stormwater Wetland Rules

- Constructed wetlands can be used for new development or retrofit projects
  - Provide reasonable assurance that volume and water quality criteria can be met
  - There is no design guidance provided in WMD or FDEP SWERP manuals
  - There was no design guidance provided in the draft statewide stormwater rule manual

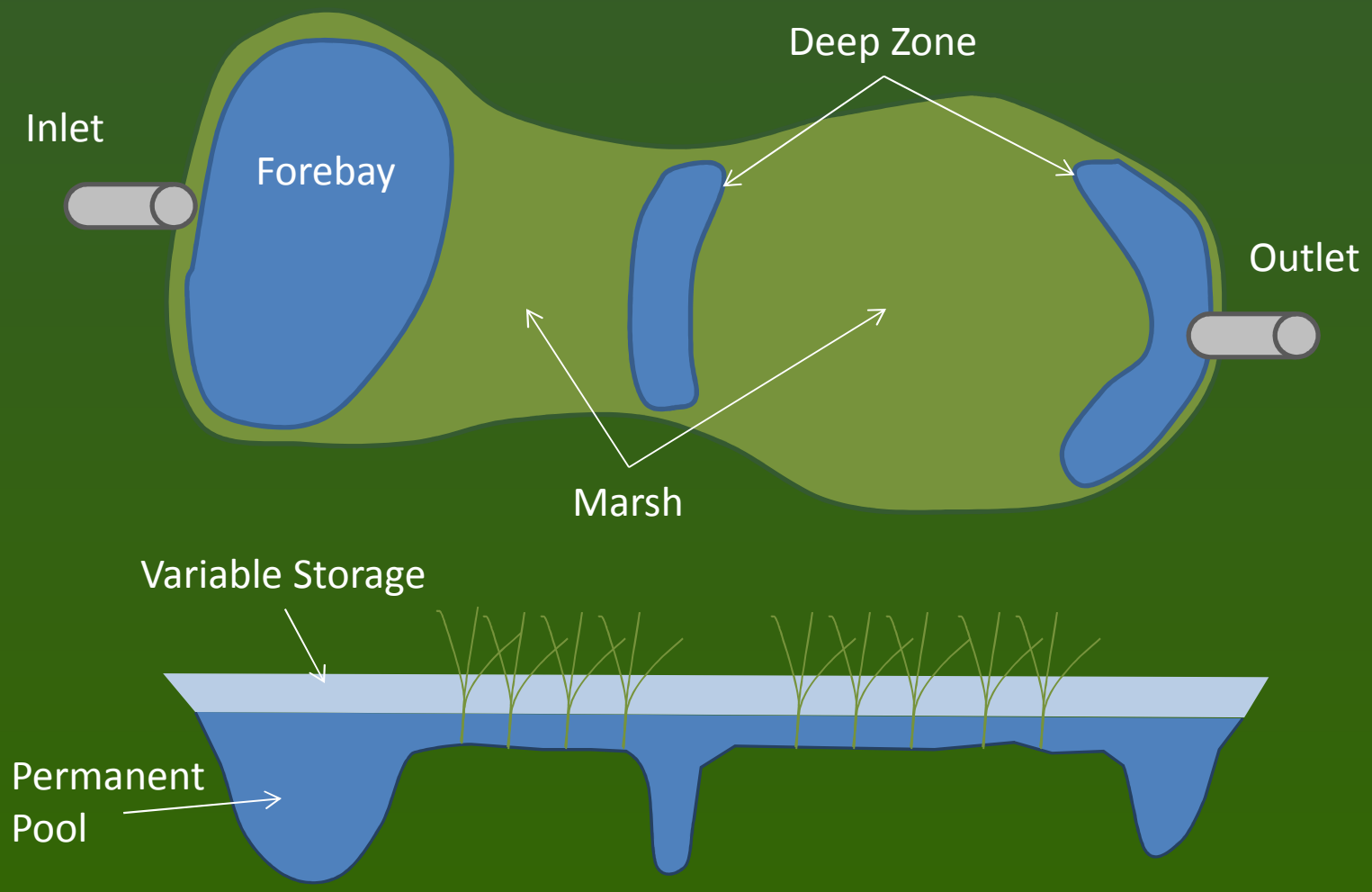
Stormwater Wetland Rules

- Isolated (Natural) Wetlands
  - Wholly owned or controlled by the applicant may be used for flood attenuation
  - Can be used as wet detention when not in conflict with environmental or public use considerations
    - If the required treatment volume cannot be detained with in the limits of the wetland boundaries and natural water levels, expansion of the wetland will be allowed when it can be shown that the excavation will not adversely impact the wetland
    - The treatment volume cannot adversely impact the wetland so that it fluctuates beyond the range of natural water levels. The available volume is determined based on site specific conditions and an analysis of the isolated wetland to be used.
    - Provisions must be made to remove sediment, oils and greases from runoff entering the wetland. This can be accomplished through incorporation of sediment sumps, baffles and dry grassed swales or a combination thereof. Normally, a dry grassed swale system designed for detention of the first ¼" of runoff with an overall depth no more than 4" will satisfy this requirement.

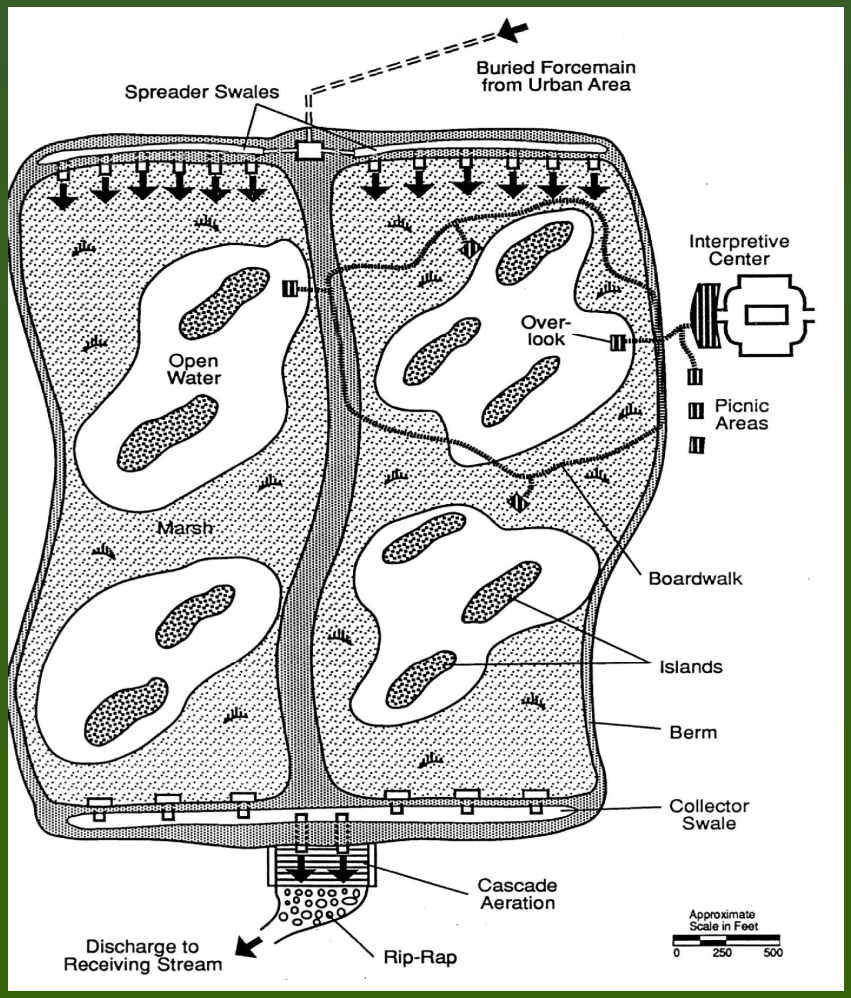
Stormwater Wetland Plant Communities

- Similar planting palette as wastewater wetlands
- Potentially wider range of hydrologic tolerance required
- Salt tolerance necessary in brackish/coastal systems

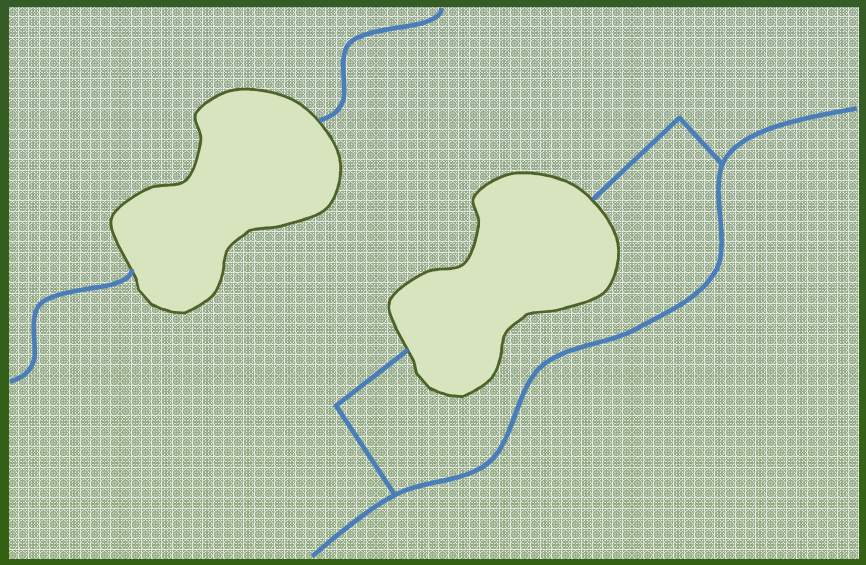
Typical Stormwater Wetland Layout



Conceptual Design for Multiple Benefits



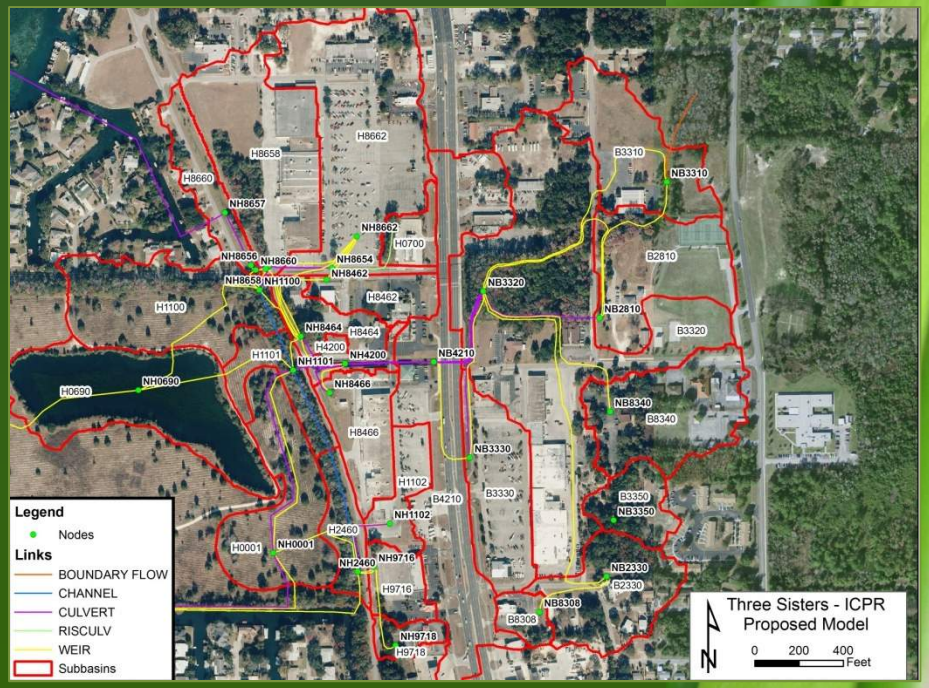
Design Considerations



- System Location
  - In-line
  - Off-line
- Flow Delivery
  - Gravity
  - Pumping
- Outlet Design
  - Flexibility is important
- Wetland Hydrology
  - Too dry = soil oxidation, nutrient export, transitional/upland vegetation
  - Too wet = pond

Stormwater Design Basis

- Flow Characteristics
  - Rainfall
  - Infiltration
  - Runoff
- Pollutant Loads
  - Watershed characteristics
  - Estimated concentrations
  - Direct measurement
- Design Methods
  - Wetland:watershed area
  - Design storm detention
  - Annual averaging
  - Dynamic modeling



Method 1: Wetland/Watershed Area

- Measure area of drainage basin
- Apply selected Wetland to Watershed Area Ratio (WWAR), typically 2 to 5%
- Allocate wetland surface area to 20% pool and 80% marsh

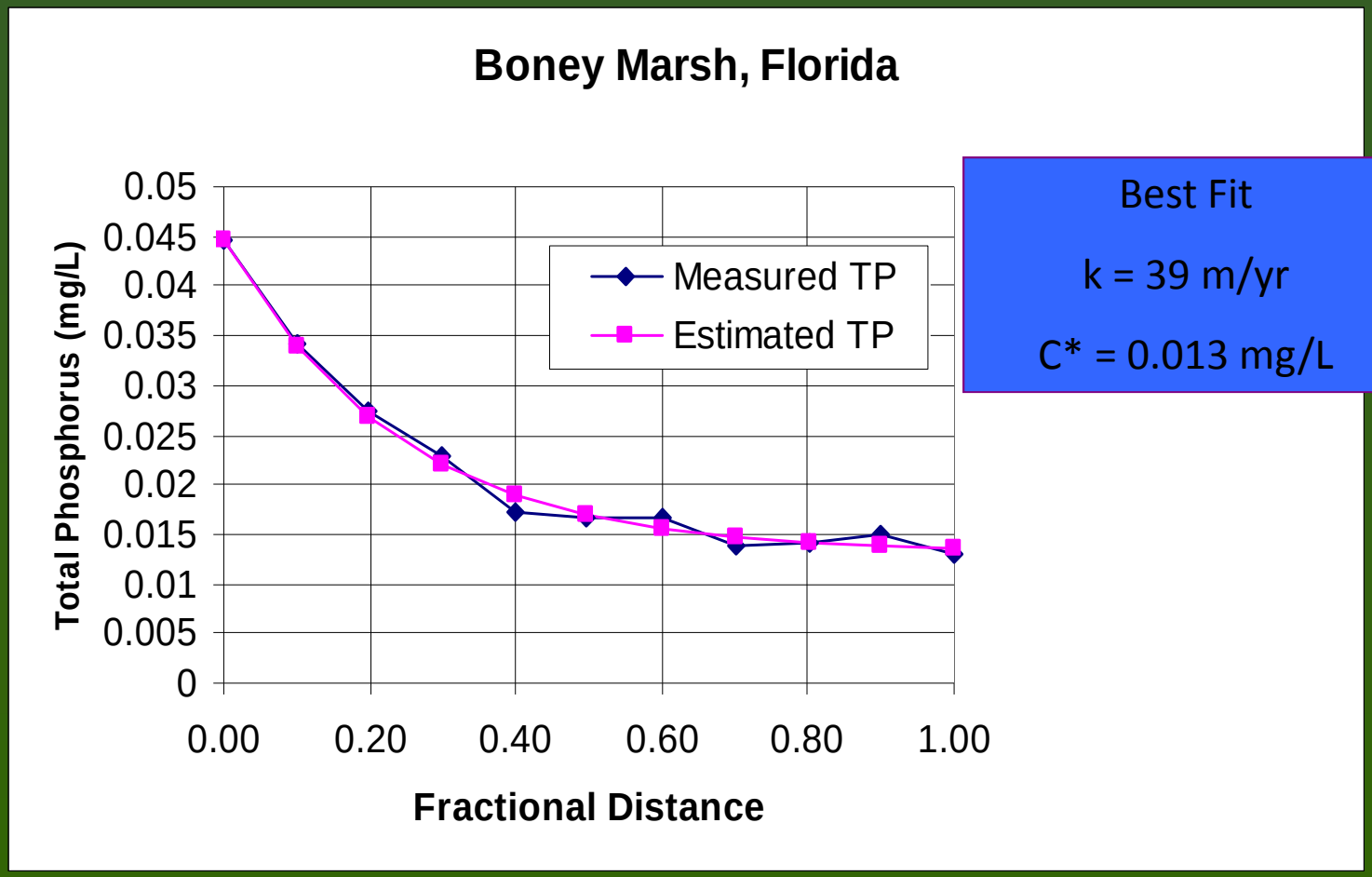
Method 2: Design Storm Detention

- Determine design storm requirement
- Calculate design runoff volume
- Allocate wetland volume 40% pool and 60% marsh
- Allocate wetland surface area to 20% pool and 80% marsh (marsh depth = 0.3 x pool depth)

Method 3: Annual Averaging

- Estimate event mean concentrations of pollutants
- Compute HLR to meet water quality target using first-order equation
- Estimate runoff coefficient
- Calculate design annual runoff volume
- Allocate wetland surface area to 20% pool and 80% marsh and select appropriate water depths

Method 3: k-C* Model Fit to Boney Marsh, FL TP Data



Best Fit

k = 39 m/yr

C* = 0.013 mg/L

Method 4: Dynamic Modeling

- Only available for TP
- Construct daily time series for flow, inflow concentration, rainfall, and ET
- Adjust wetland area in DSMTA Version 2 (www.wwwalker.net) to meet desired load or concentration reduction
- Future release of DMSTA for nitrogen species
- Phosphorus removal is often the area-controlling parameter in wetlands, so goals for BOD, TSS, TN may be met by default

Method 4: DMSTA Version 2 Phosphorus Balance

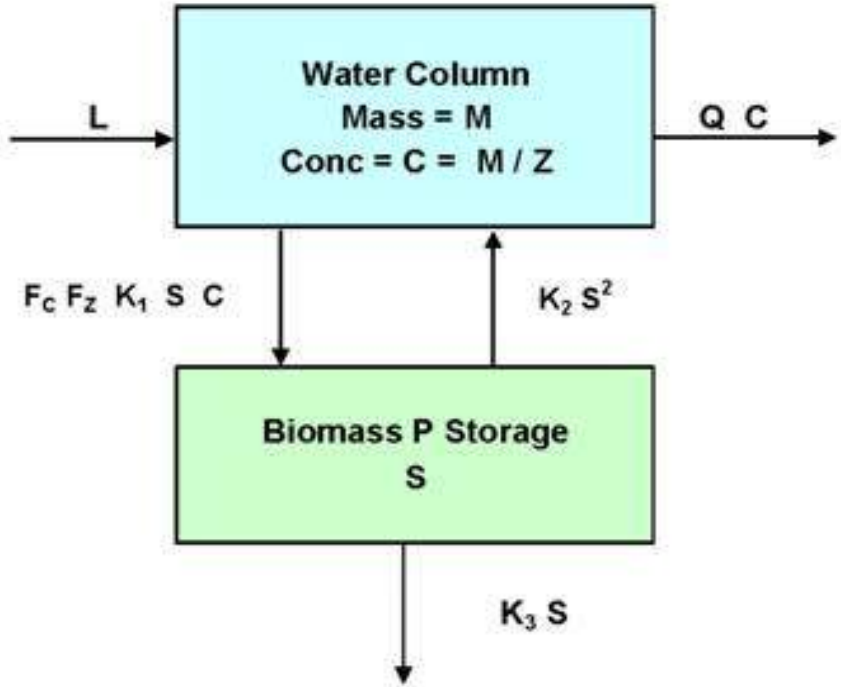
One CSTR at Steady-State

Unit Area Storage & Fluxes

Concs in mg/m3

Fluxes in mg/m2-yr

Storage in mg/m2



F_Z = Depth Multiplier

F_C = Conc Multiplier

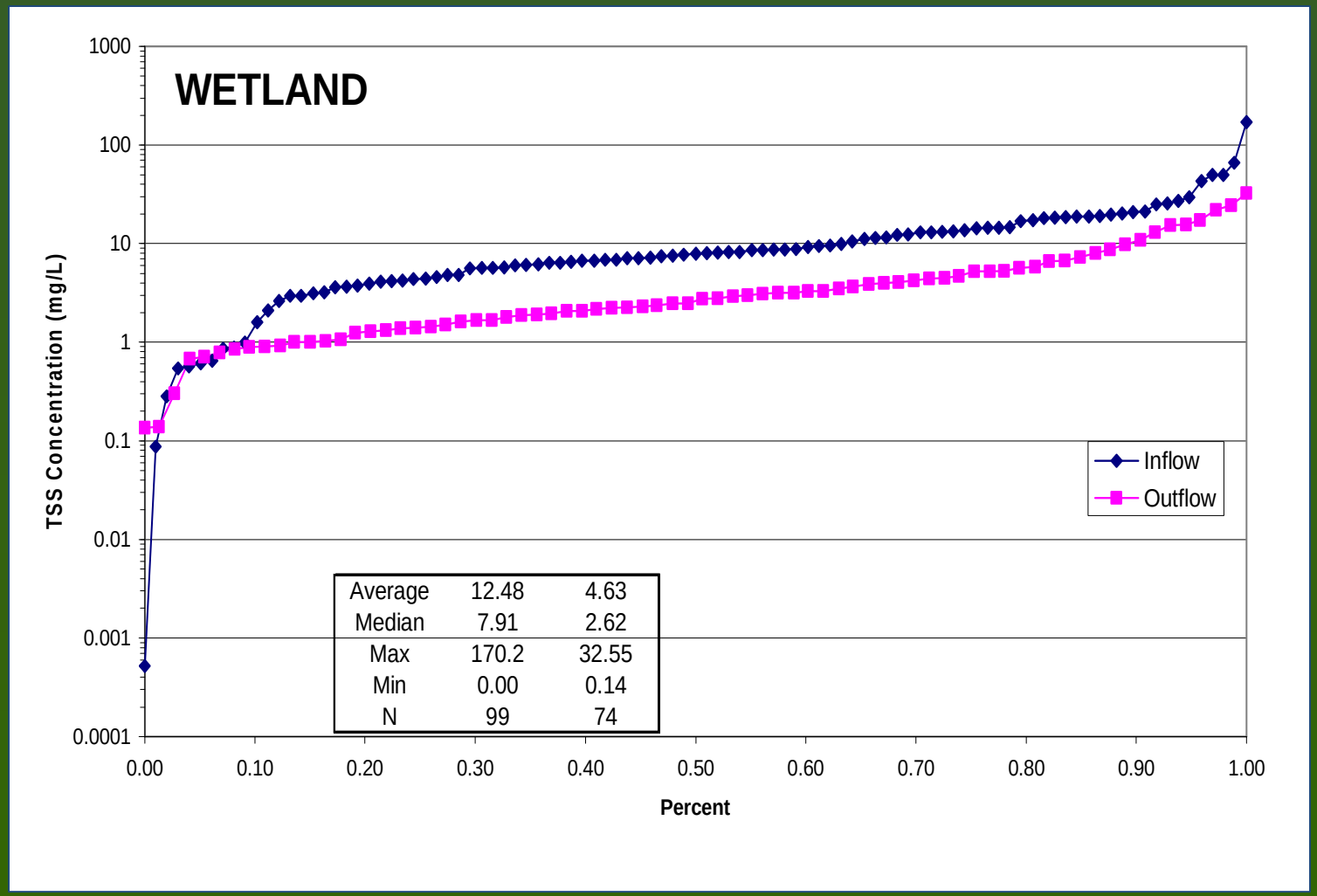
State Variables:

M	Water Column P Storage	mg/m^2
S	Temporary P Storage in Biota, etc.	mg/m^2
Z	Water Column Mean Depth	m

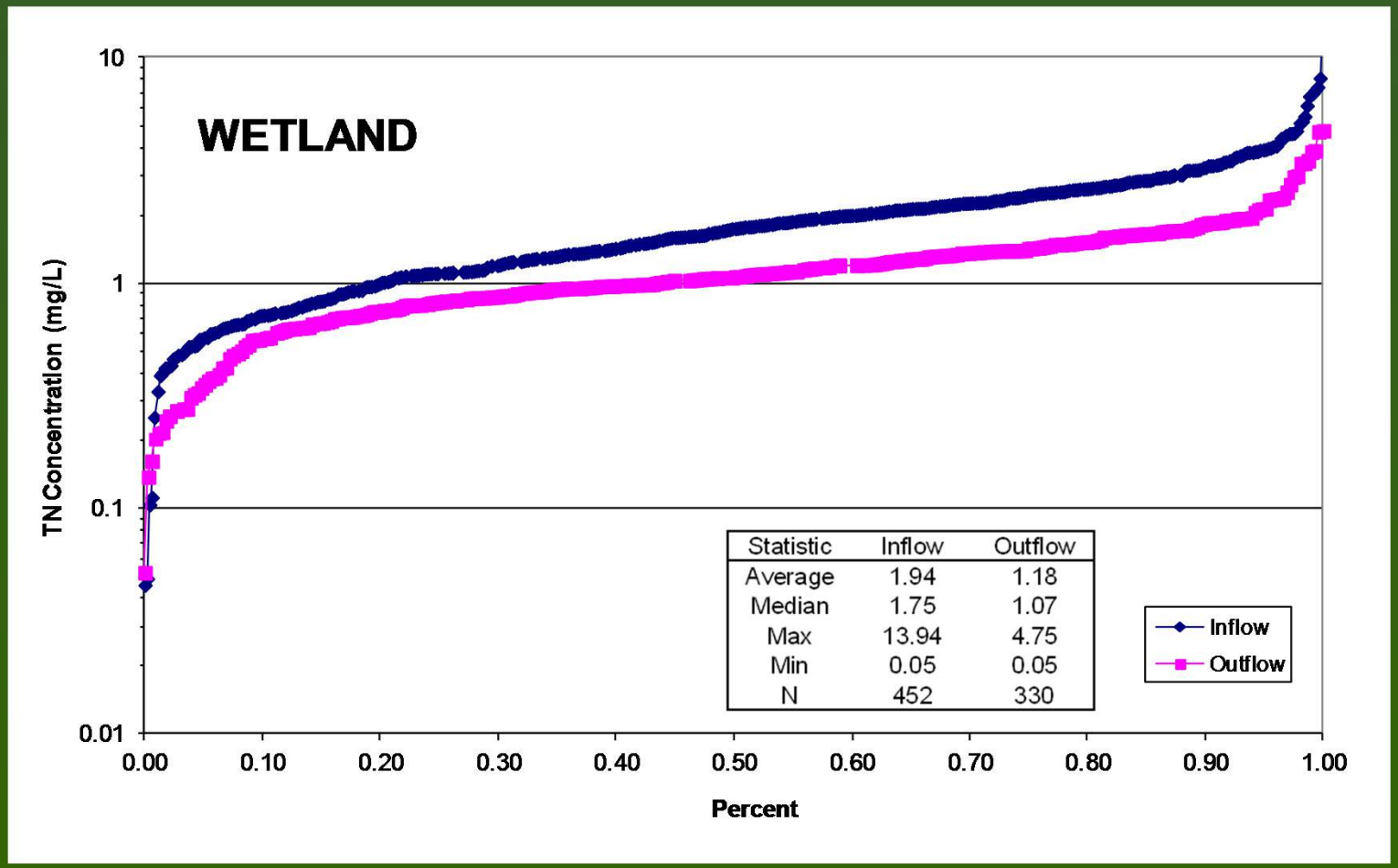
Keys to Maximize Water Quality Benefits

- Hydraulic design depends on project goals
  - Load Reduction
  - Concentration Reduction
- Maximize internal hydraulic efficiency
- Minimize water depths in marsh
  - 6-12” for permanent pool
  - 18-24” during design storm event
- Limit open water to 10-20% of total surface area

FL Stormwater Wetland TSS Data

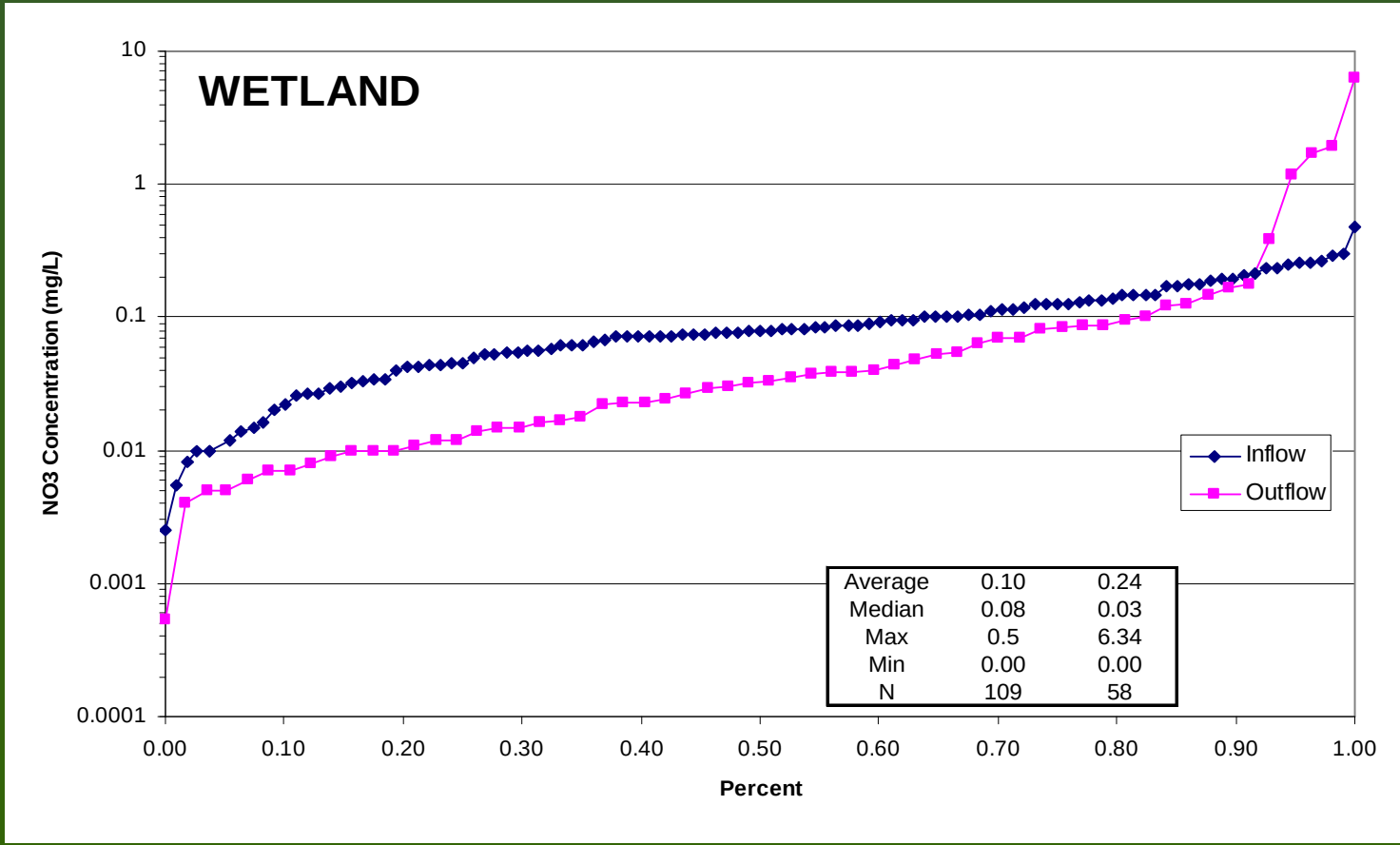


FL Stormwater Wetland TN Data

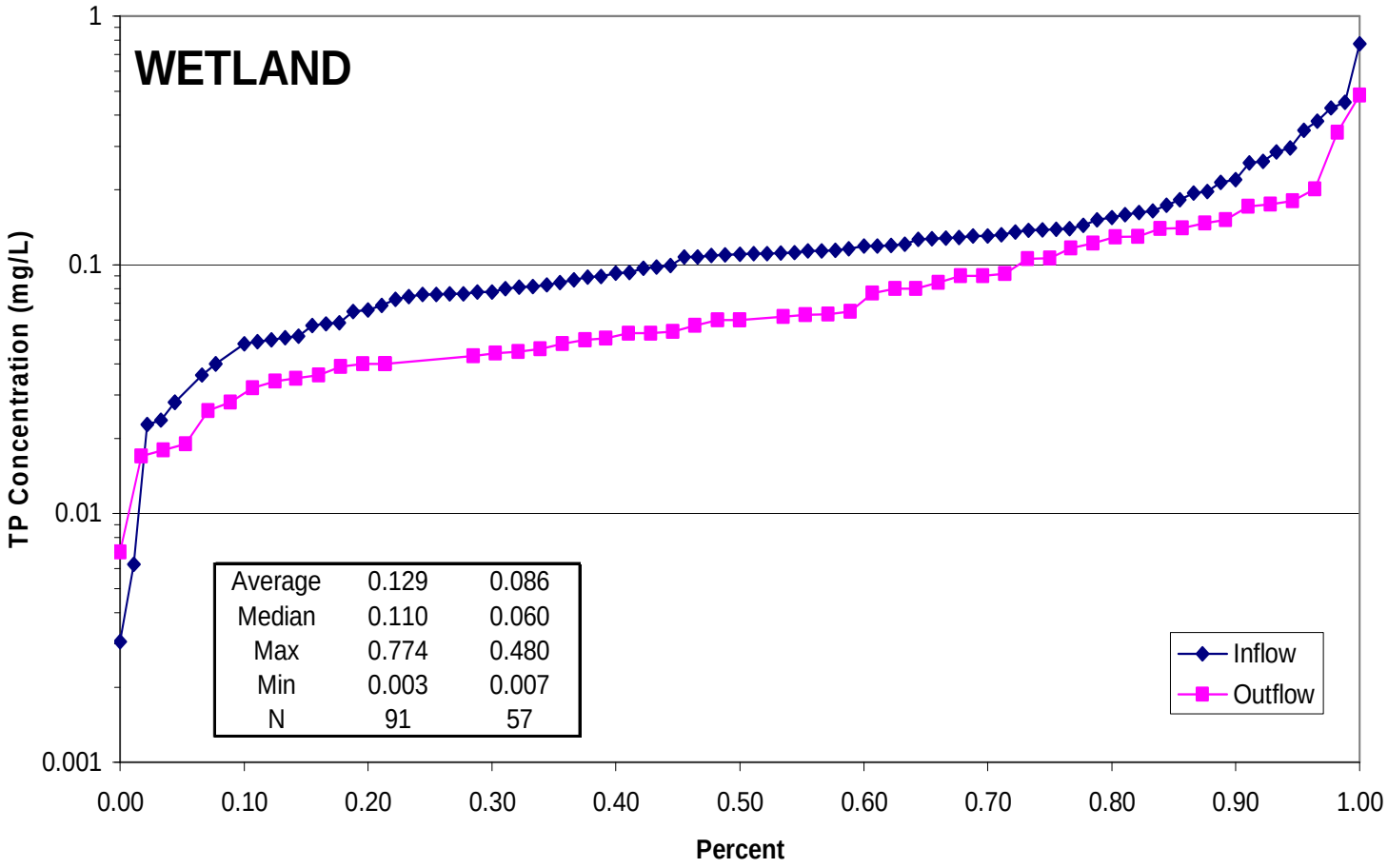


Statistic	Inflow	Outflow
Average	1.94	1.18
Median	1.75	1.07
Max	13.94	4.75
Min	0.05	0.05
N	452	330

FL Stormwater Wetland NOX Data

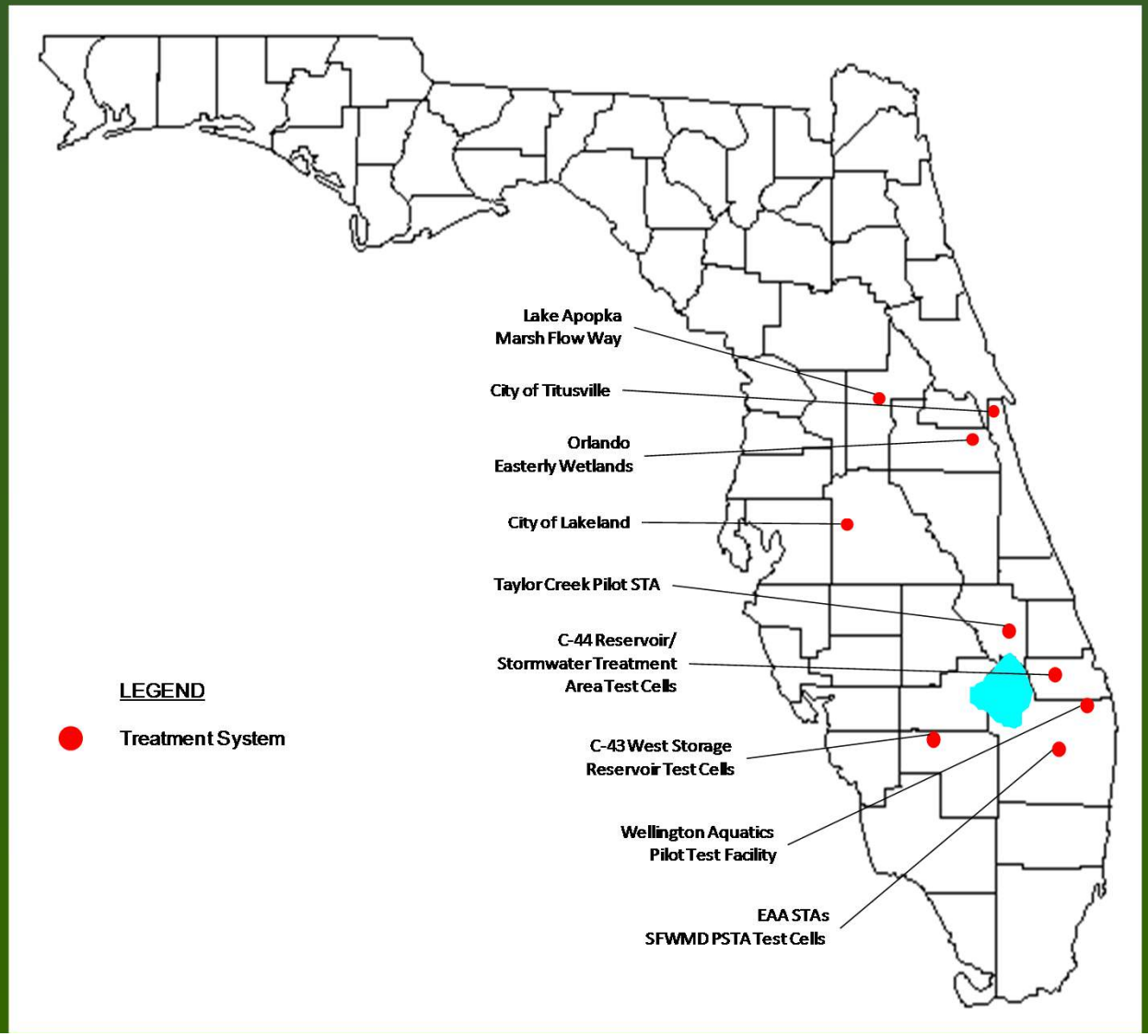


FL Stormwater Wetland TP Data

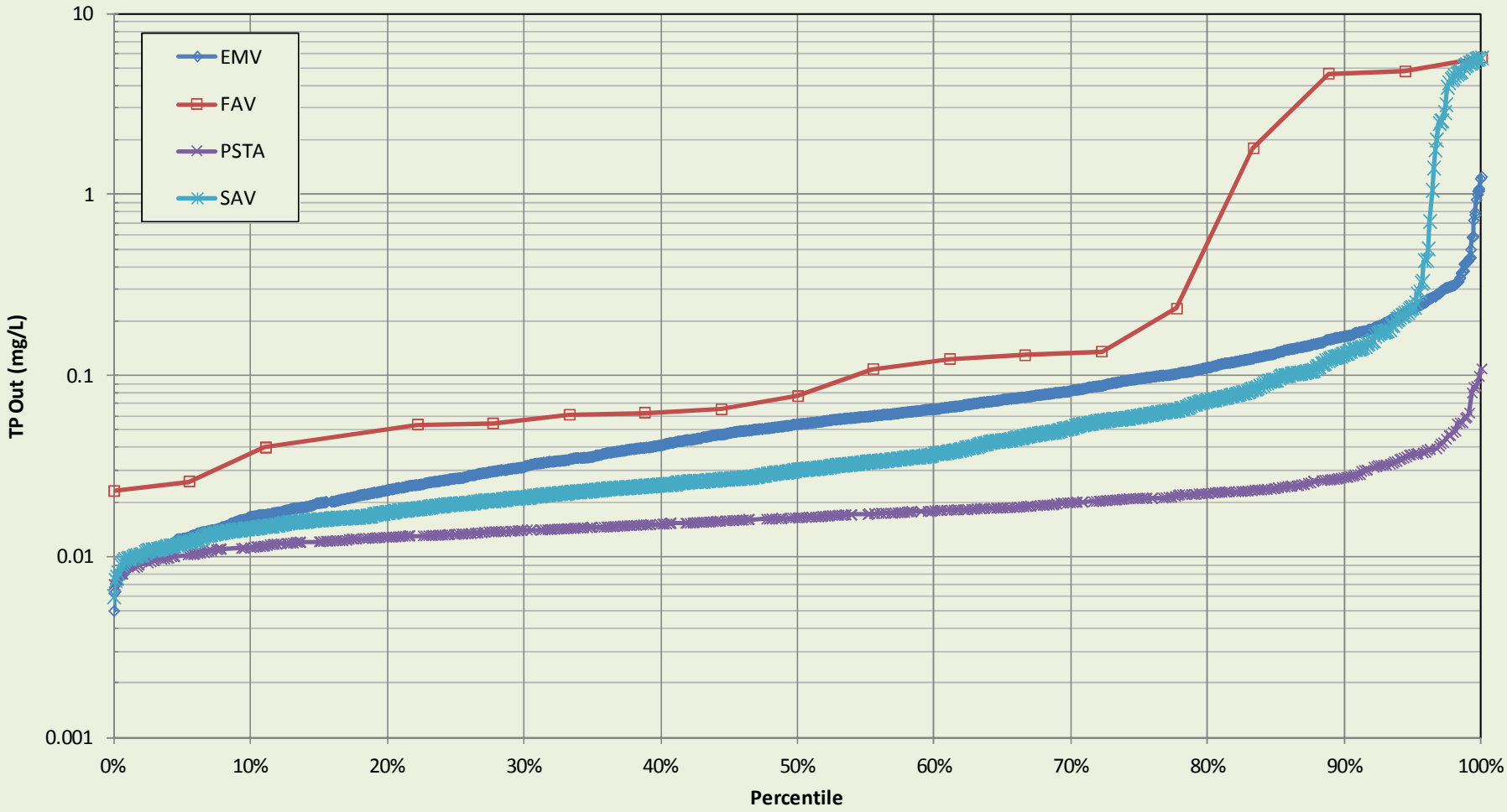


Average	0.129	0.086
Median	0.110	0.060
Max	0.774	0.480
Min	0.003	0.007
N	91	57

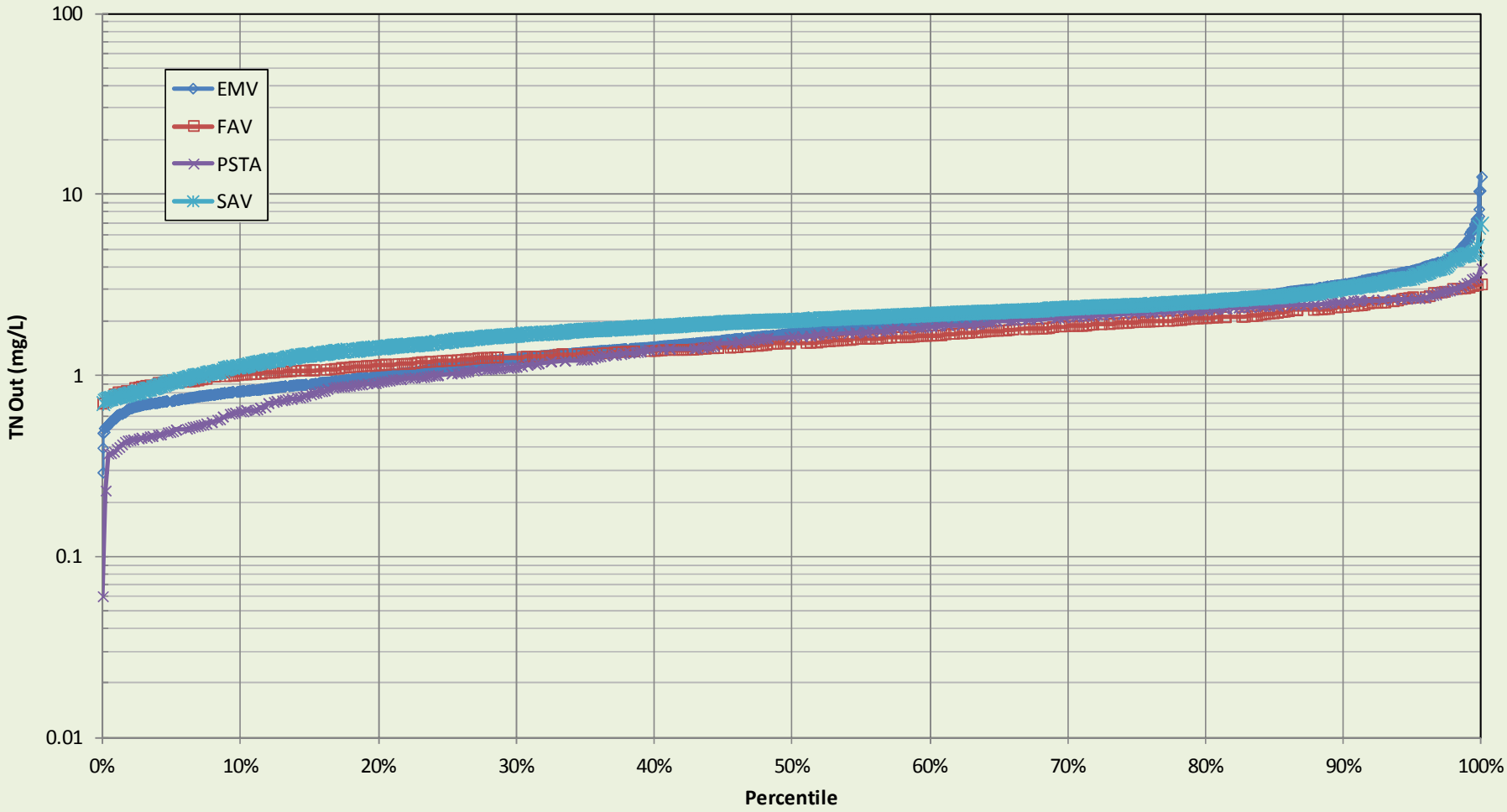
Detailed Study by Vegetation and Substrate Type



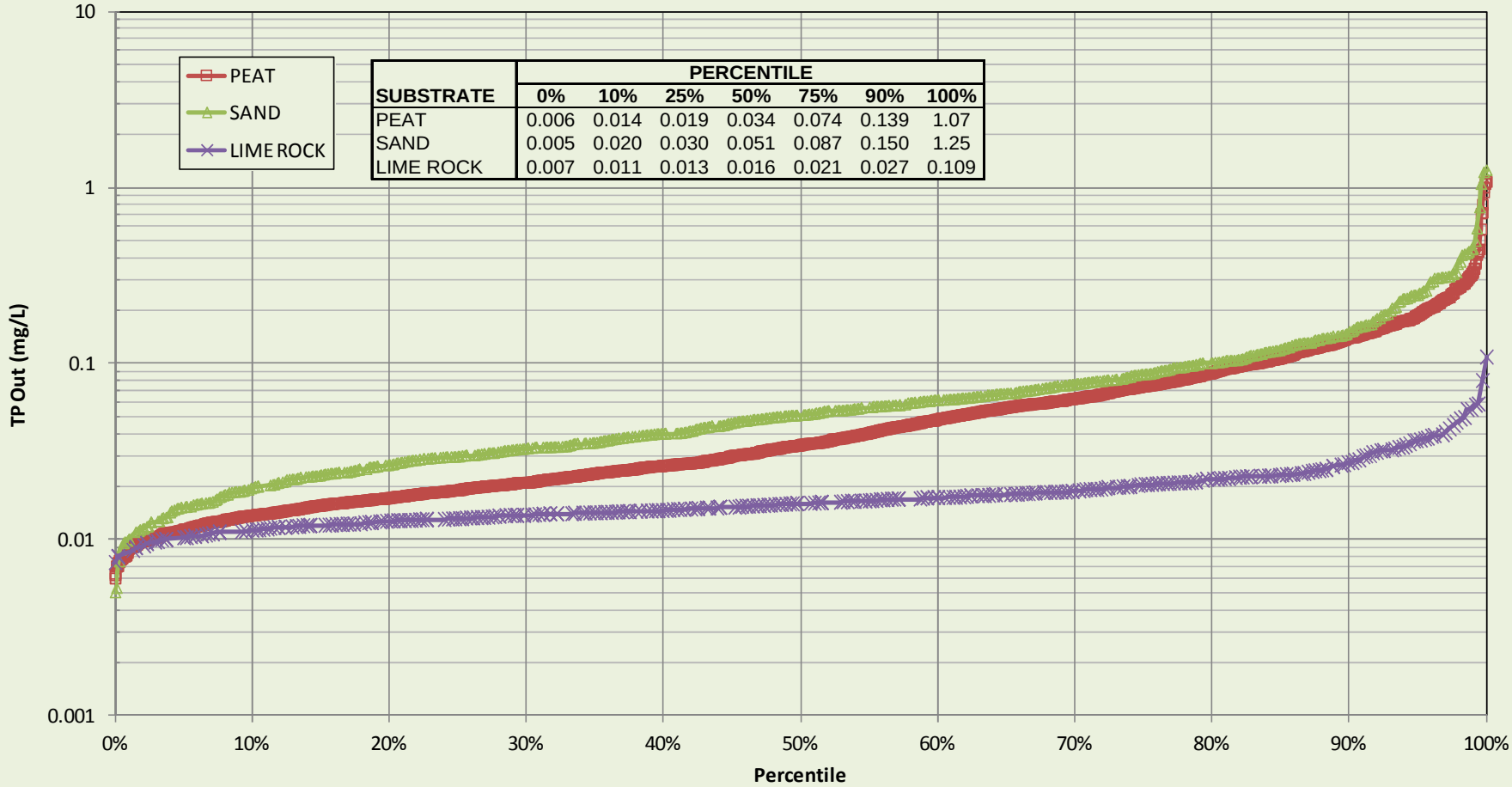
Outlet TP vs. Vegetation Type



Outlet TN vs. Vegetation Type

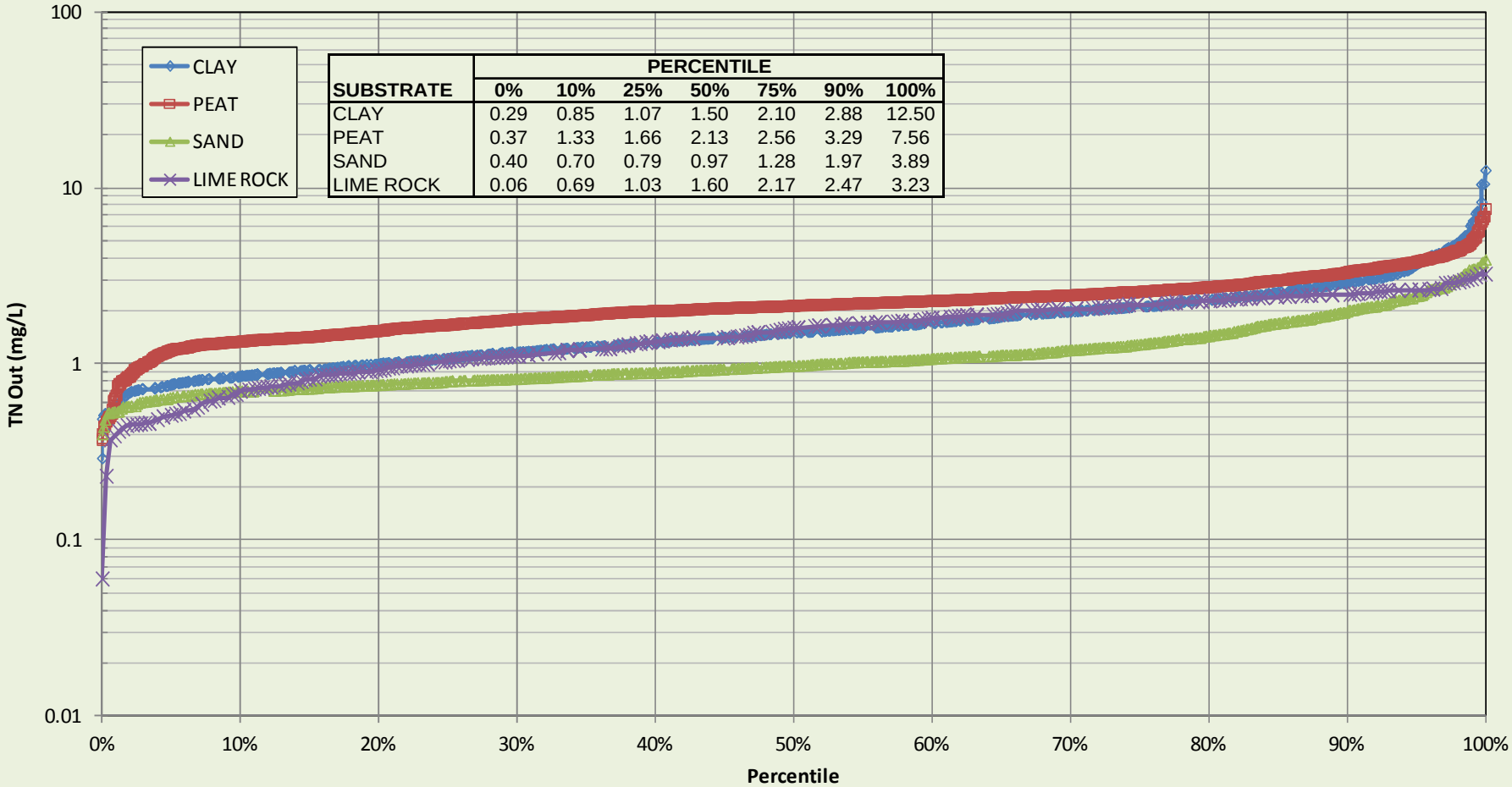


Outlet TP vs. Substrate Type



SUBSTRATE	PERCENTILE						
	0%	10%	25%	50%	75%	90%	100%
PEAT	0.006	0.014	0.019	0.034	0.074	0.139	1.07
SAND	0.005	0.020	0.030	0.051	0.087	0.150	1.25
LIME ROCK	0.007	0.011	0.013	0.016	0.021	0.027	0.109

Outlet TN vs. Substrate Type



SUBSTRATE	PERCENTILE						
	0%	10%	25%	50%	75%	90%	100%
CLAY	0.29	0.85	1.07	1.50	2.10	2.88	12.50
PEAT	0.37	1.33	1.66	2.13	2.56	3.29	7.56
SAND	0.40	0.70	0.79	0.97	1.28	1.97	3.89
LIME ROCK	0.06	0.69	1.03	1.60	2.17	2.47	3.23

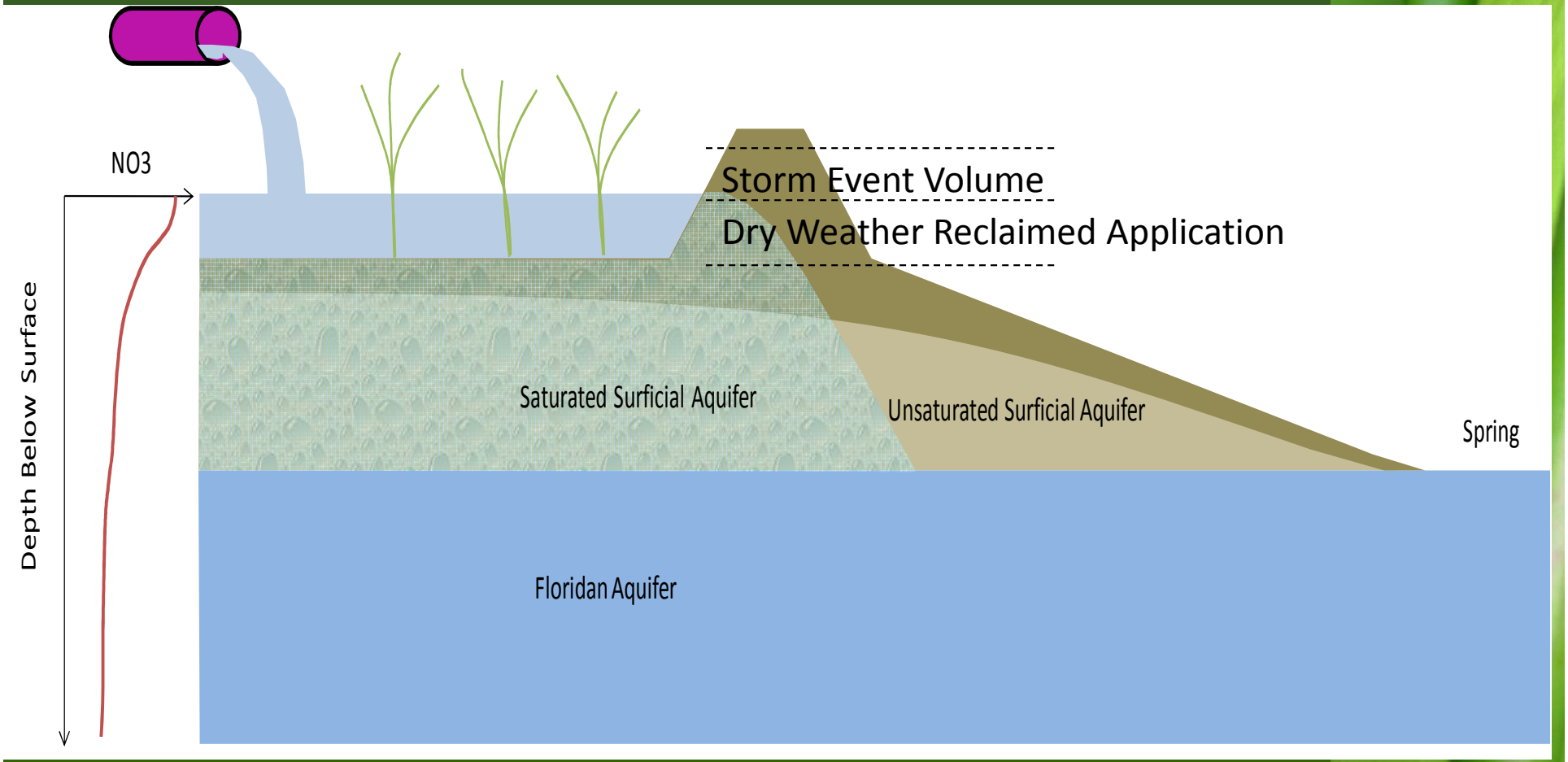
Expansions of SW Wetland Technology

- Floating wetlands as add-ons in wet detention ponds
- LID modular systems
- Hybrid chemical treatment/wetland systems
- Soil amendments

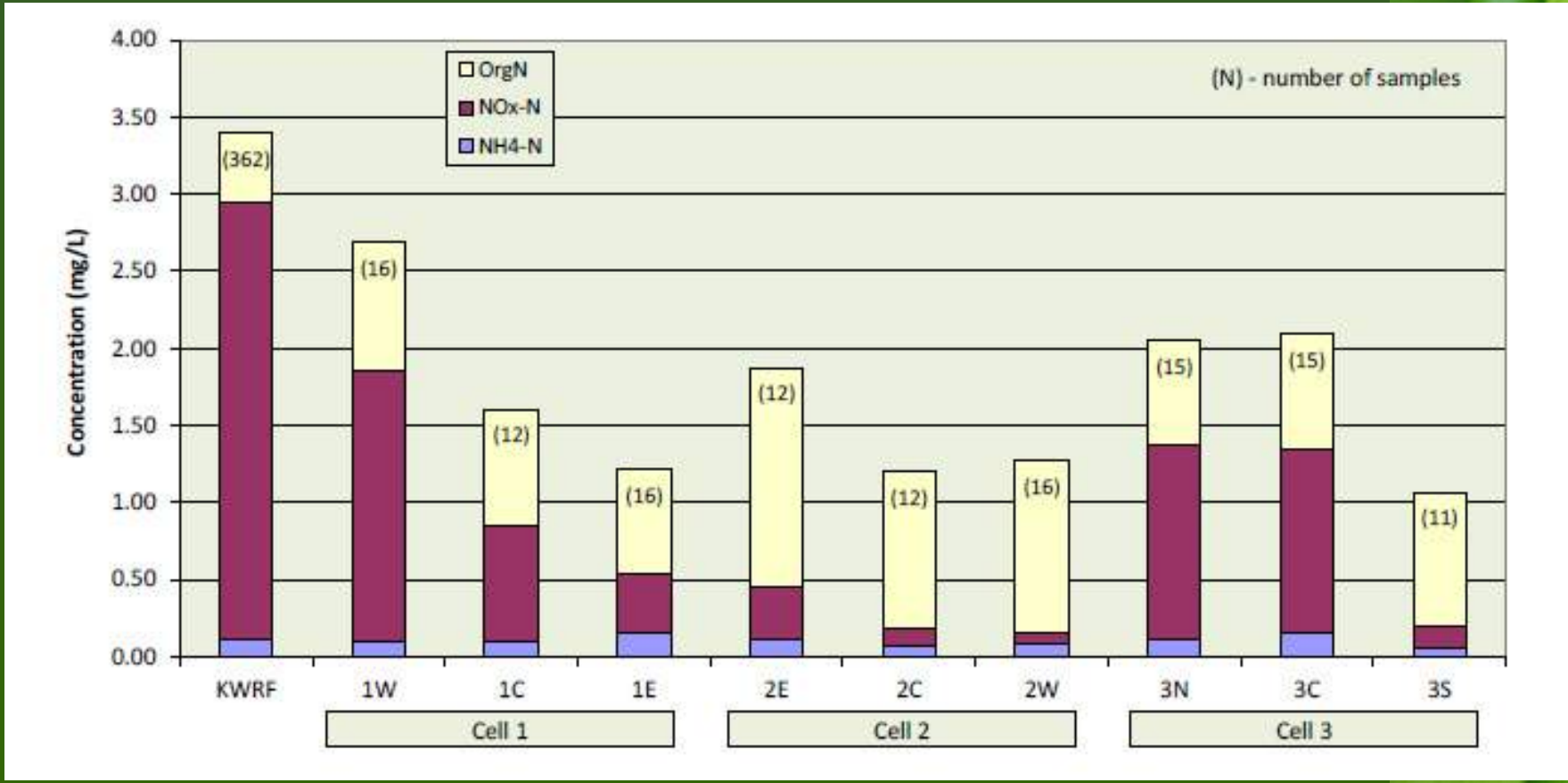
Emerging SW Issues

- Effects of reclaimed water irrigation on stormwater systems (Harper 2012)
  - 2/3 of WWTP's produce secondary quality reclaimed water (TN: 2-15 times stronger than runoff; TP: 8-60 times stronger)
  - 1/3 of WWTP's produce tertiary quality reclaimed water (similar to high density residential runoff)
  - Tendency by homeowners to over-irrigate
- Dry retention favored in many areas but presumption of 100% load reduction is questionable

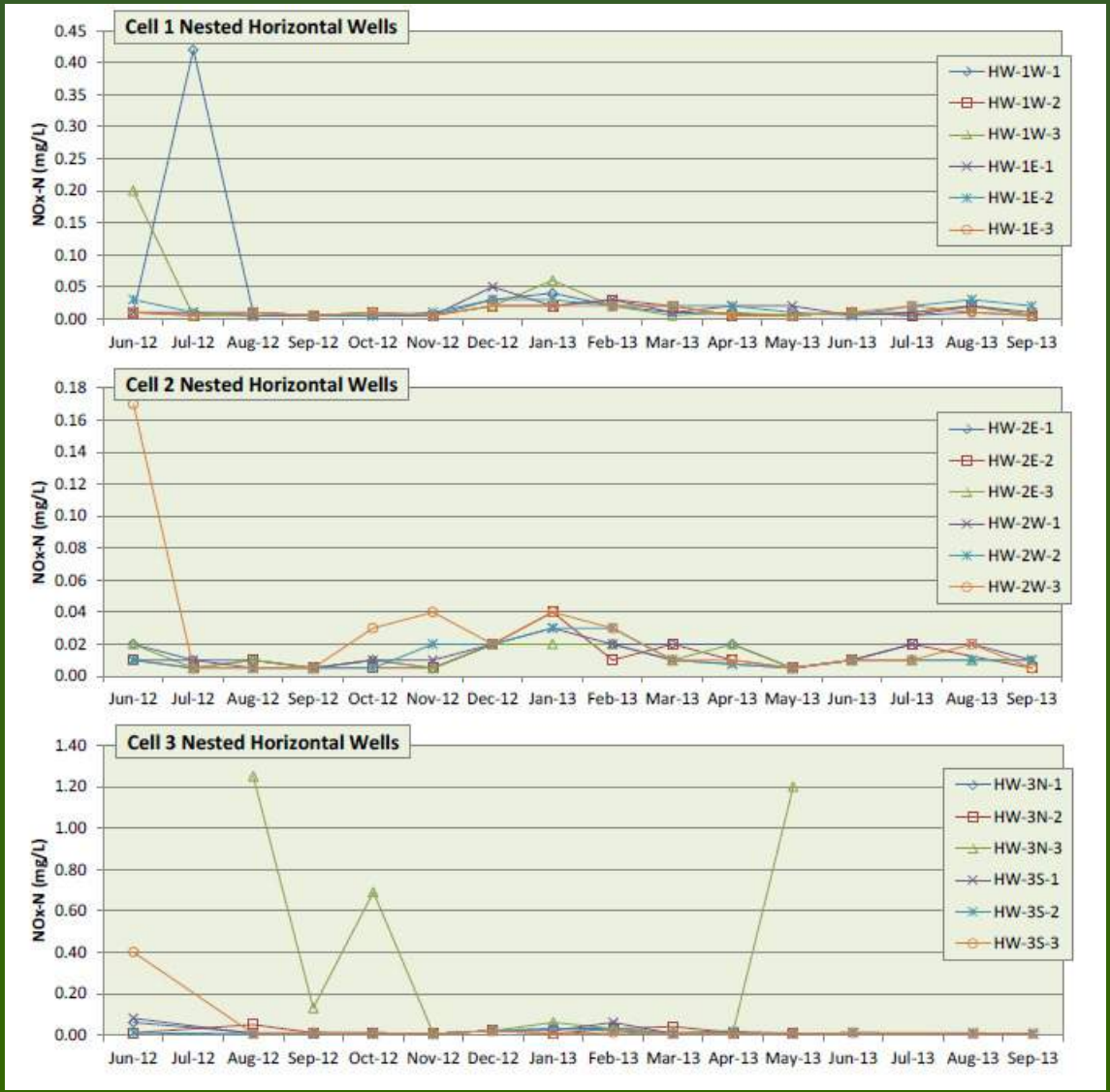
Dry Retention – Wetland Conversion for Nitrate Removal



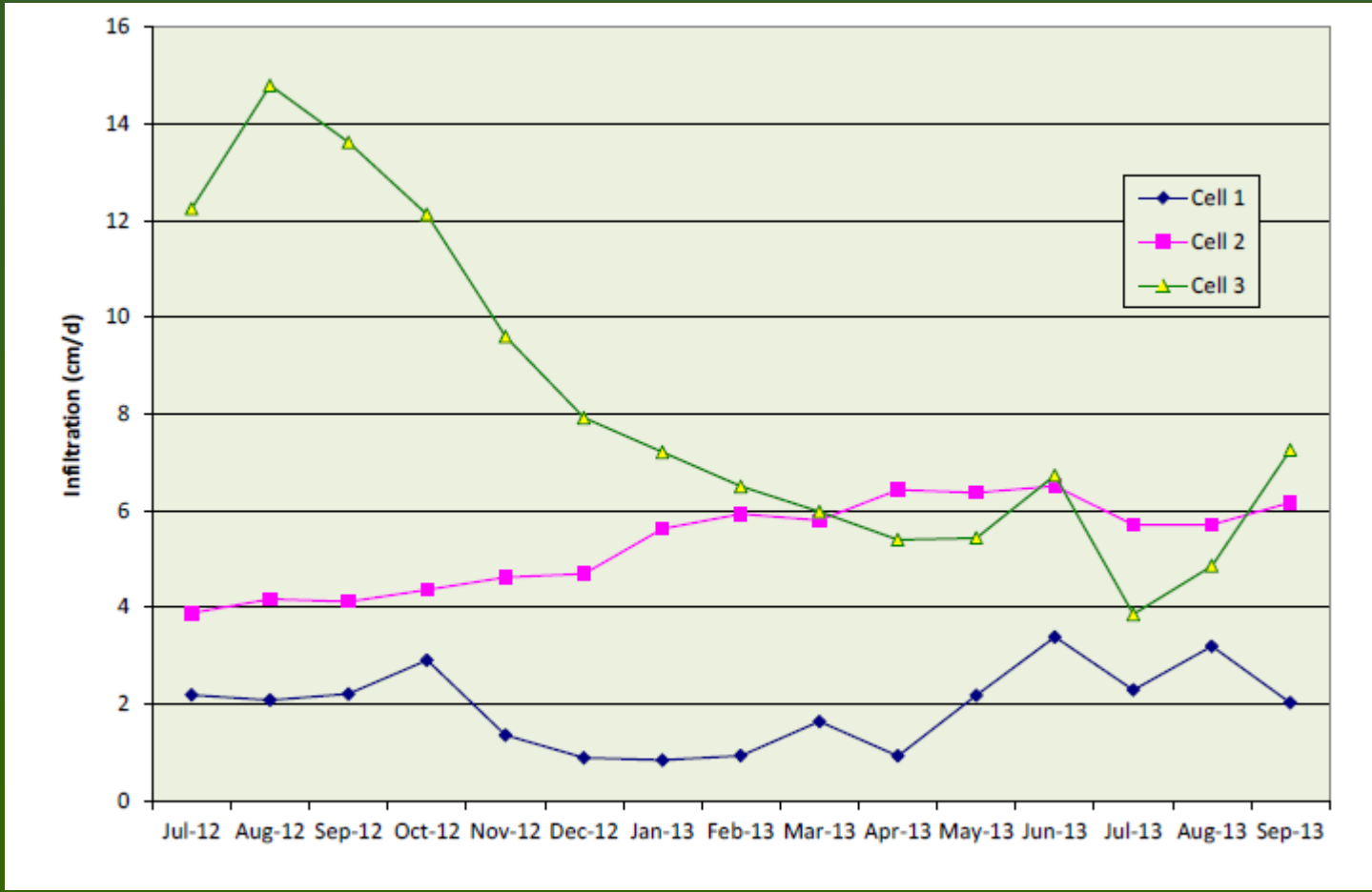
Infiltrating Wetland Surface Water Nitrogen Concentrations



Infiltrating Wetland Shallow Groundwater Concentrations



Infiltration Rates



Questions