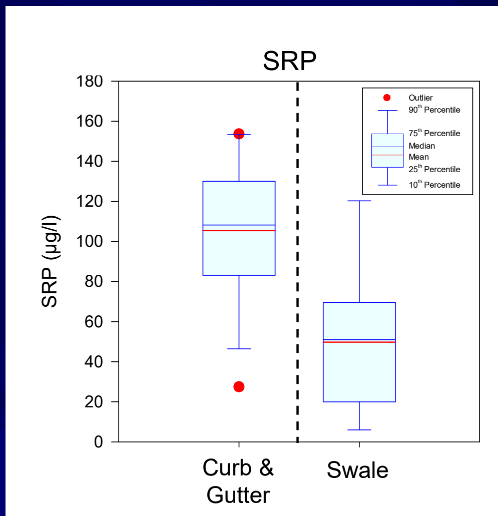
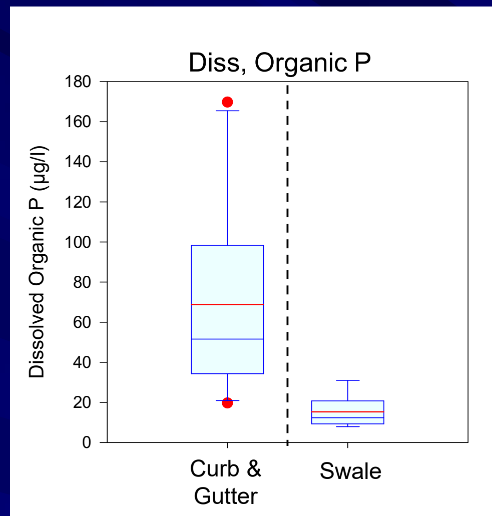
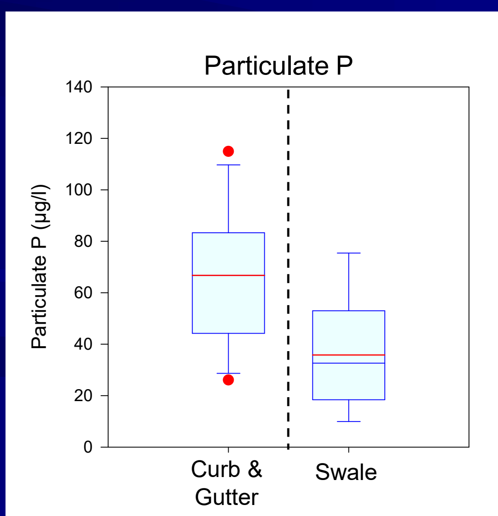
Significance of Concentrations on BMP Performance

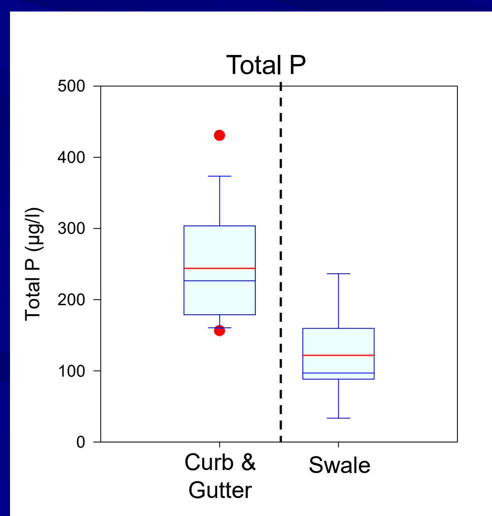
By: Harvey H. Harper

January 2026









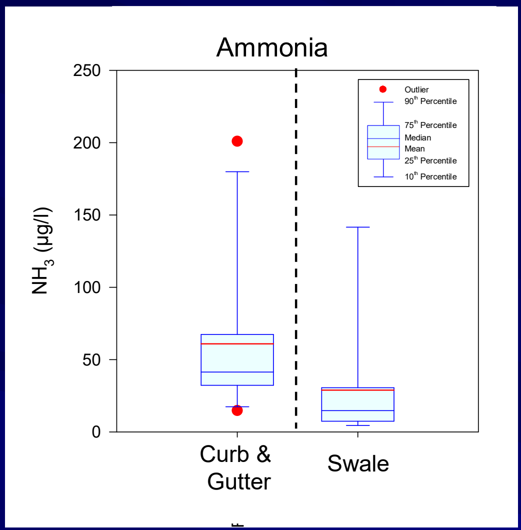
1. Runoff Concentrations

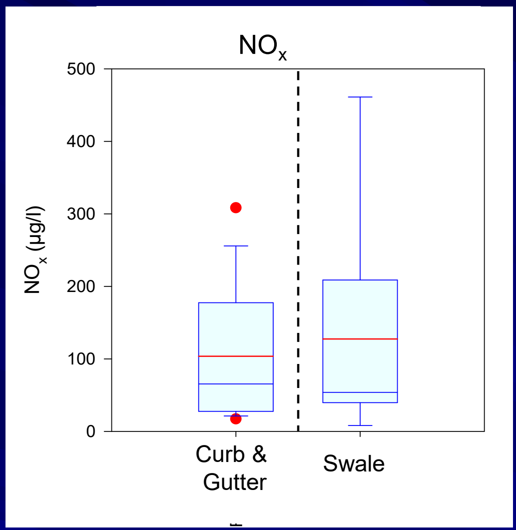
Typical Phosphorus Concentrations in Florida Residential Runoff

Curb & Gutter
vs. Swale
(n=10 sites)

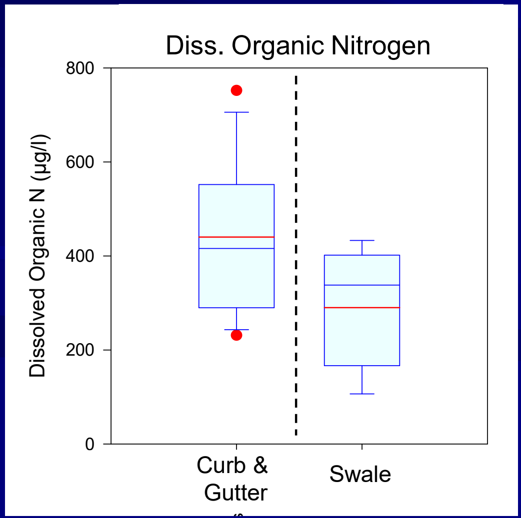
- Concentrations of all phosphorus species are lower in swale runoff than in curb & gutter systems
- Swales provide good pretreatment of runoff

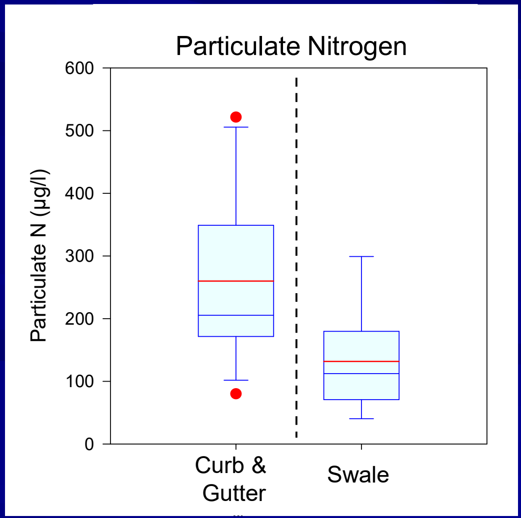
Typical Nitrogen Concentrations in Florida Residential Runoff

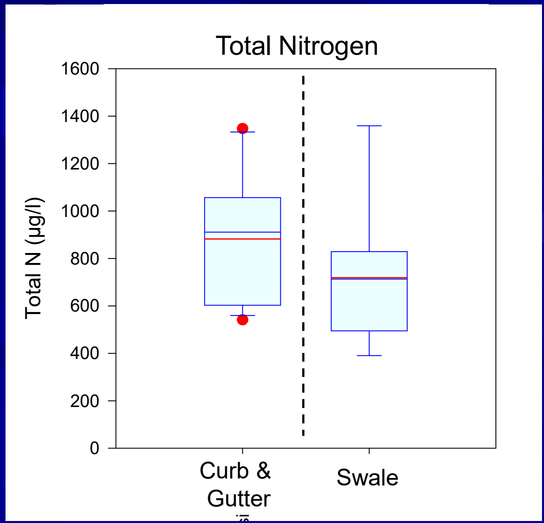




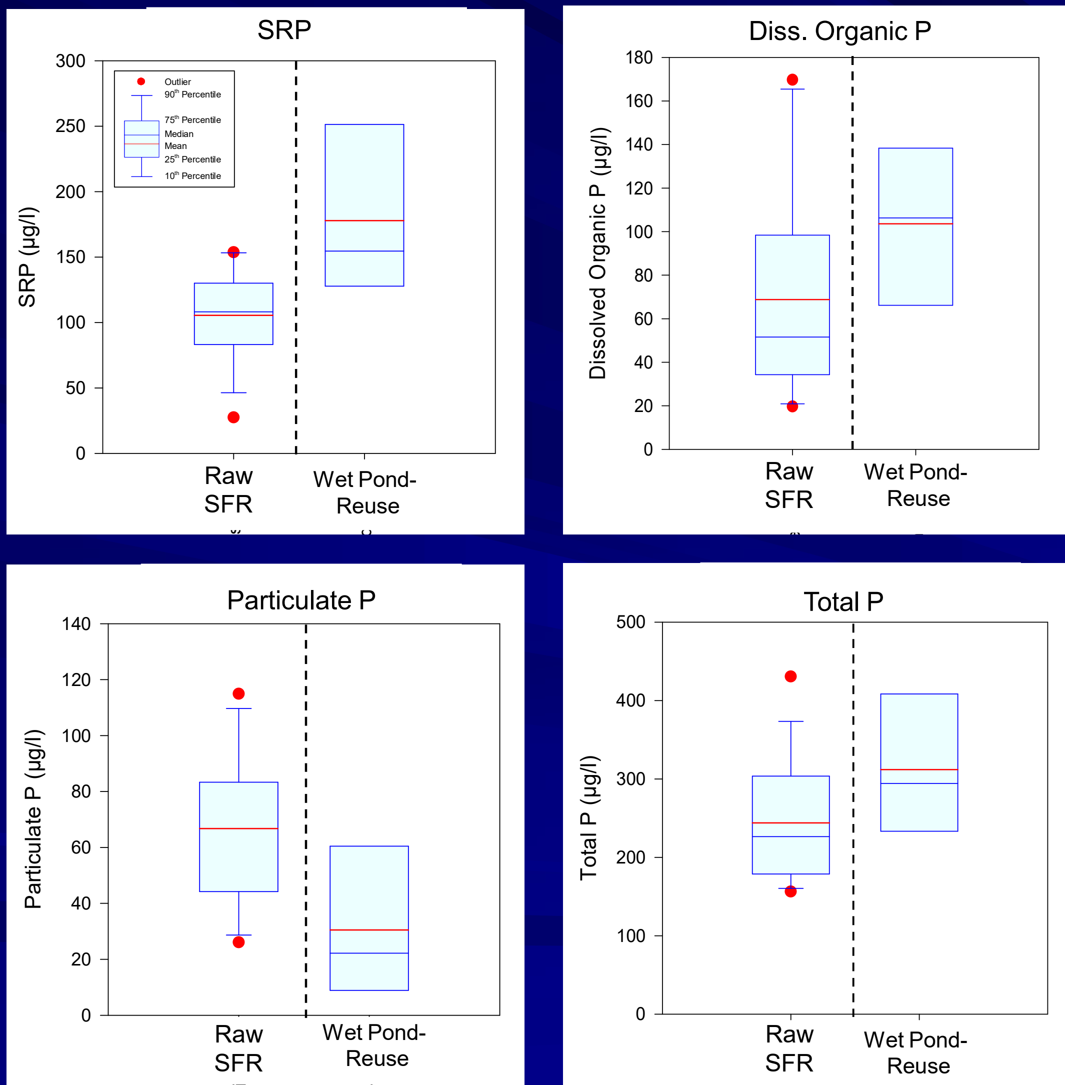
Curb & Gutter vs. Swale (n=10 sites)







- Concentrations of all nitrogen species are lower in swale runoff than in curb & gutter systems

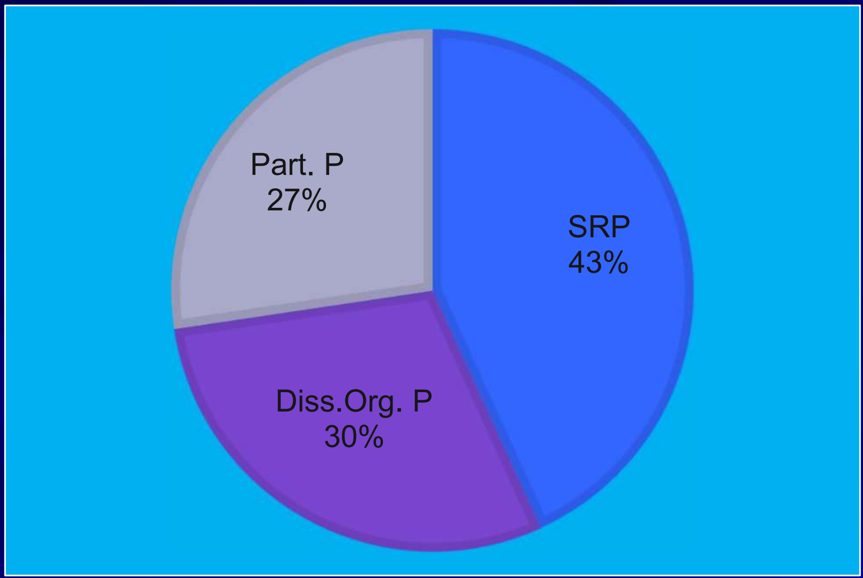


Wet Detention Pond Discharges in Watersheds with Reuse Irrigation

Total P

- Phosphorus concentrations for most parameters in the pond discharge are higher than typical raw residential runoff
- Requires a much larger runoff treatment volume to achieve post<pre
- Reuse may not be compatible with the new Stormwater Rule

Typical Distribution of Phosphorus Species in Residential Runoff



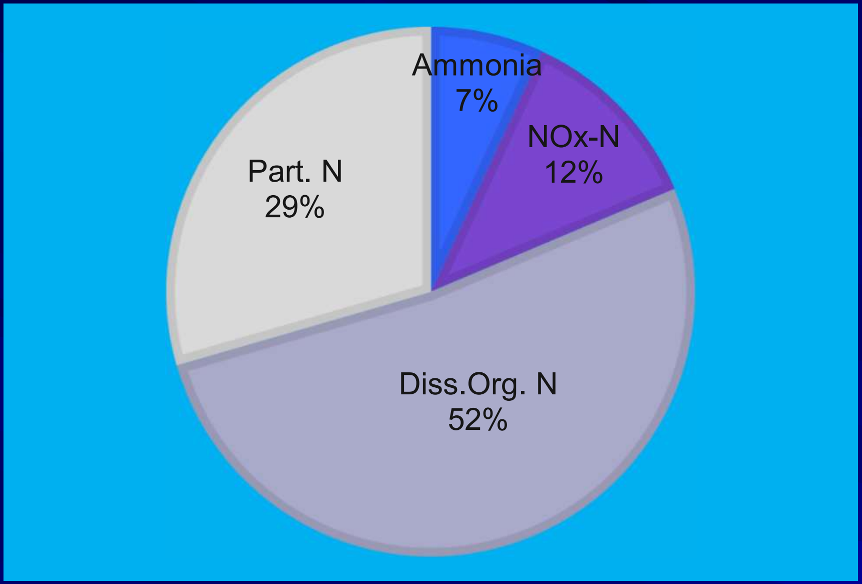
Typical Residential Runoff Phosphorus Concentrations

Parameter	Concentration (µg/L)
SRP	105
Diss.Org. P	72
Part. P	67
Total P	244

Fate of P in Wet Detention Ponds

- Removeable species include SRP and particulate P ~ 70%
- Dissolved organic P is removed through biological processes at a slow rate
- If 85% of removeable species are removed, then TP removal is (70% x 0.85) = 60% which is similar to the maximum TP removal achieved in wet ponds with typical detention times
- At long detention times (~ 180 days) a portion of the dissolved organic P may also be removed

Typical Distribution of Nitrogen Species in Residential Runoff



Typical Residential Runoff Nitrogen Concentrations

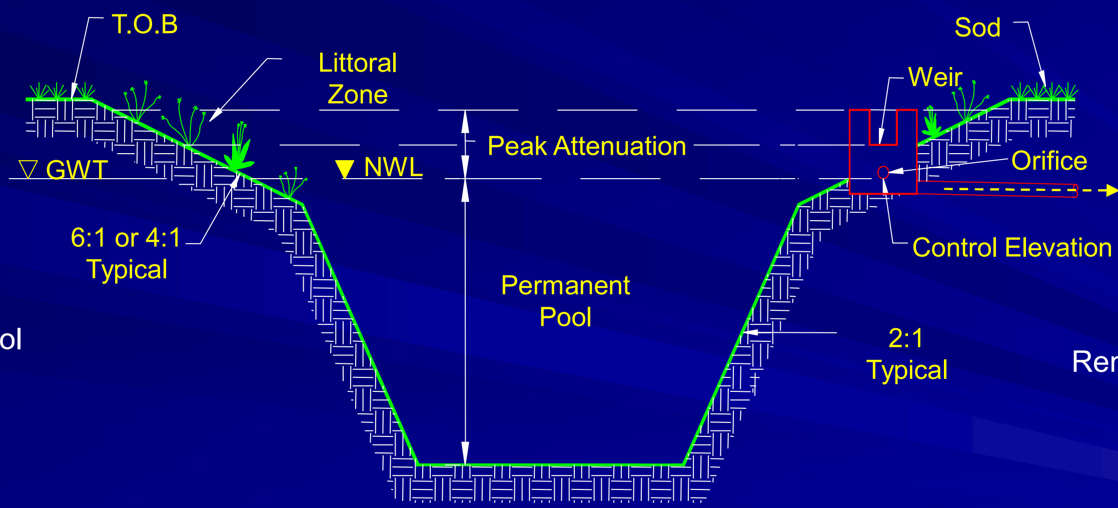
Parameter	Concentration (µg/L)
Ammonia	61
NOx	104
Diss.Org. N	457
Part. N	260
Total N	882

<u>Fate of N in Wet Detention Ponds</u>

- Removeable species include ammonia, NOx, and particulate N – 48%
- Dissolved organic N is removed through biological processes at a slow rate
- If 85% of removeable species are removed, then TN removal is (48% x 0.85) = 41% which is similar to the maximum TN removal achieved in wet ponds
- At long detention times (~ 1+ yr) a portion of the dissolved organic N may also be removed
- Even at extremely long detention times, TN removal in wet ponds cannot exceed 40-50%

Wet Detention Ponds

- Essentially man-made lakes
- Subject to all physical, biological, and chemical processes in surface waters
- Highly predictable performance



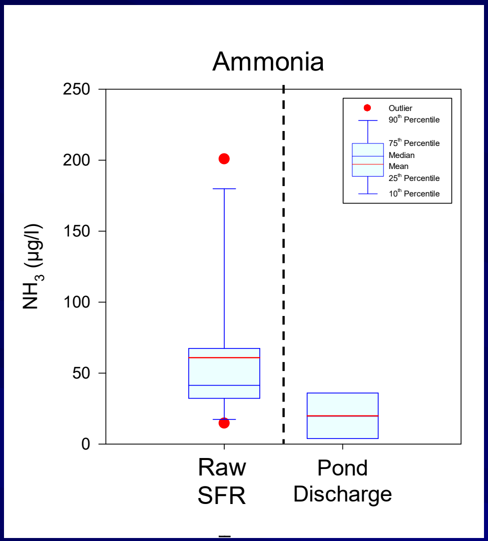
Pollutant removal processes occur within the permanent pool volume

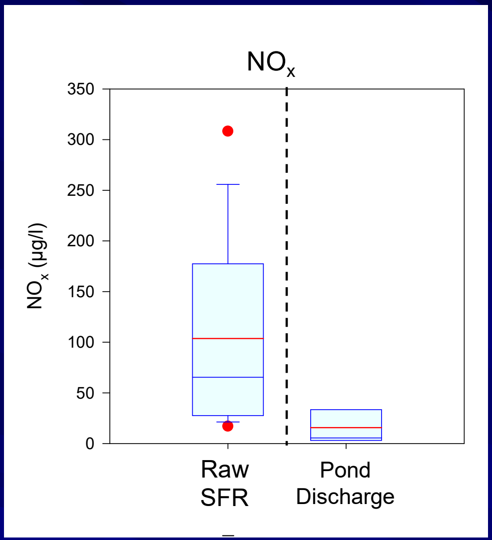
Removal efficiency is a function of residence time

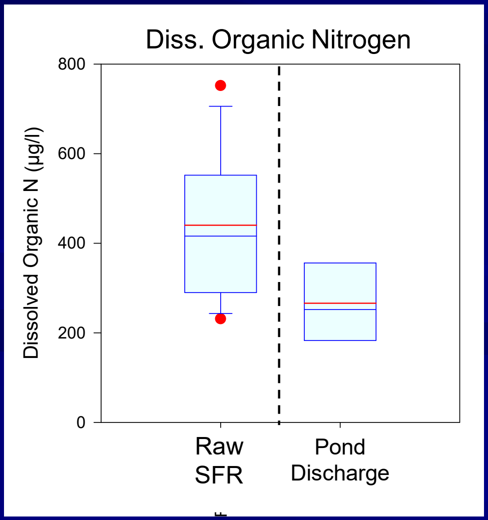
- Physical Processes
  - Gravity settling – primary physical process
    - Efficiency dependent on pond geometry, volume, residence time, particle size
  - Adsorption onto solid surfaces
- Biological processes
  - Uptake by algae and aquatic plants
  - Metabolized by microorganisms
- Chemical processes
  - Co-precipitation by metal oxides

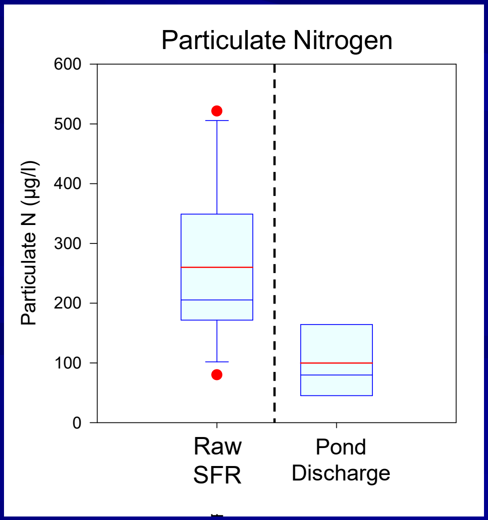
Comparison of Residential Runoff and Wet Detention Pond Discharges

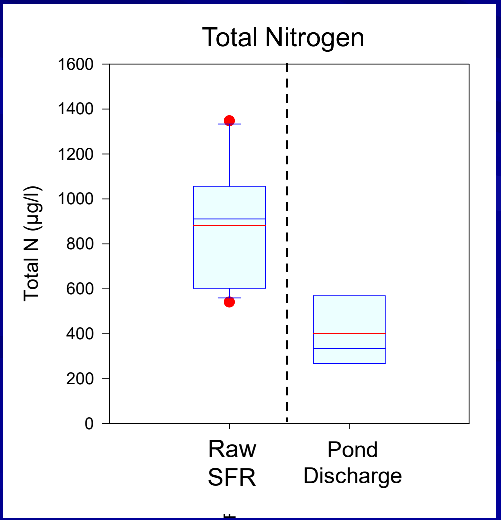
Total N



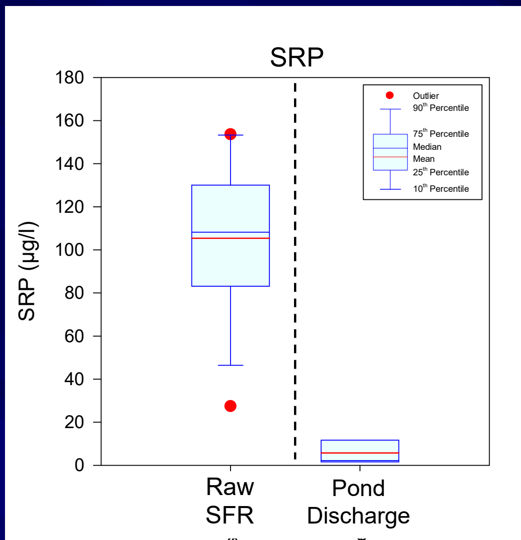


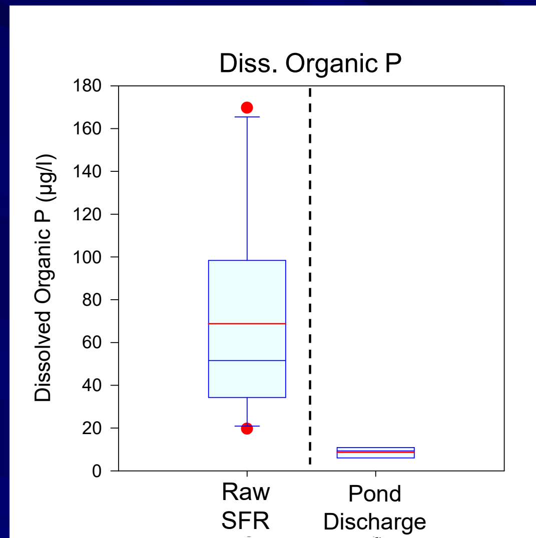






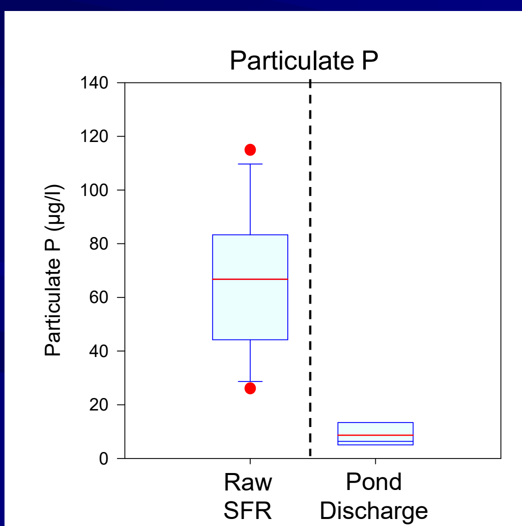
- Concentrations of all nitrogen species are reduced in wet ponds, especially for inorganic nitrogen (ammonia + nitrate) due primarily to biological assimilation

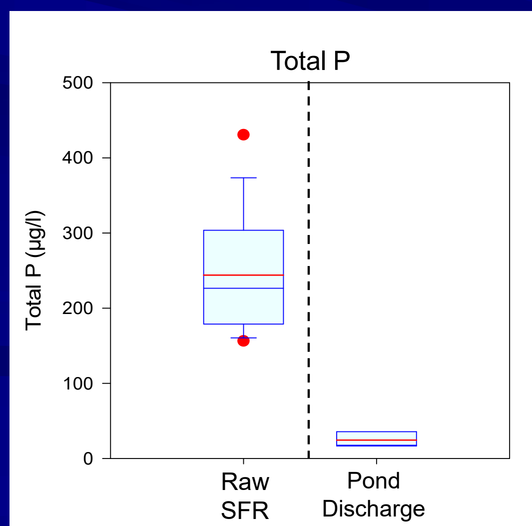




Comparison of Residential Runoff and Wet Detention Pond Discharges

Total P





- Most ponds in data had longer detention times (> 100 days)
- Concentrations of all phosphorus species are reduced in wet ponds

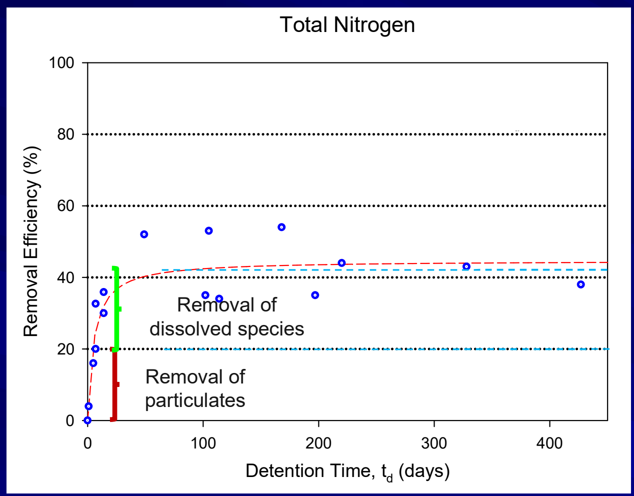
Wet Detention Pond Concentrations

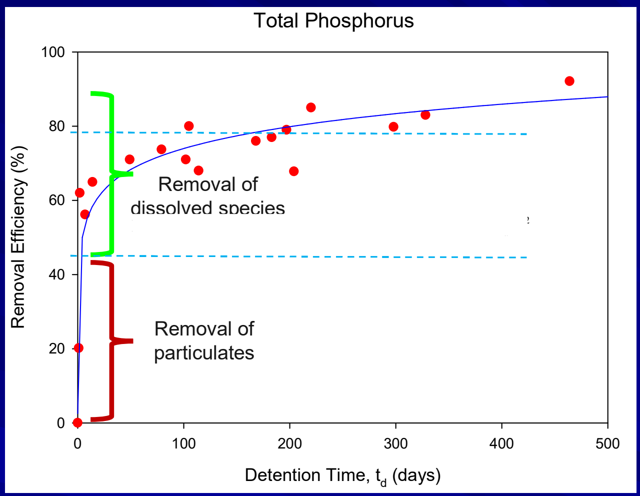
Parameter	Units	Pond Discharge
pH	s.u.	6.87
Alkalinity	mg/L	43.4
Conductivity	µmho/cm	151
Ammonia	µg/L	20
NOx	µg/L	16
Diss.Org. N	µg/L	266
Part. N	µg/L	100
Total N	µg/L	401
SRP	µg/L	6
Diss.Org. P	µg/L	9
Part. P	µg/L	9
Total P	µg/L	24
Turbidity	NTU	2.0
TSS	mg/l	2.3

- Extremely low concentrations of inorganic nitrogen
  - Ammonia and NOx concentrations near limit of uptake
- Diss. Organic N is the largest remaining nitrogen species
- Extremely low concentrations of SRP
  - Near limit of uptake ability
- Low concentrations of TSS
- Nutrient concentrations too low for any significant additional removal
  - Irreducible concentrations
    - Total N ~ 400 ug/l
    - Total P ~ 10-15 ug/l

Nutrient Removal Relationships for Wet Ponds

Nutrient Removal is Primarily a Function of Detention Time





- These relationships were developed for <u>untreated</u> runoff only
- The relationships do not apply when the runoff gets pre-treatment
- Removal of dissolved pollutants is a function of concentration
  - Removal rates decrease as the water column concentration decreases
  - Removal stops when Irreducible concentration is reached
    - TN = 350 µg/L
    - TP = 10 µg/L

Wet Detention Enhancement - Floating Islands

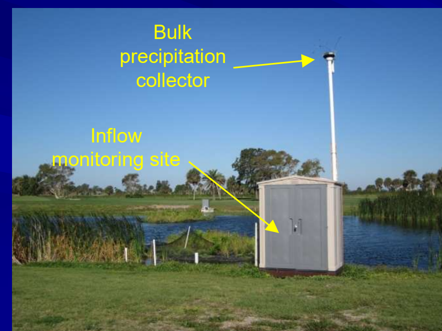
Adding plants to mats

Dragging mats to selected location

Grown plants in mat

Root mass at end of study

Root mass under mat at end of study



Inflow monitoring site

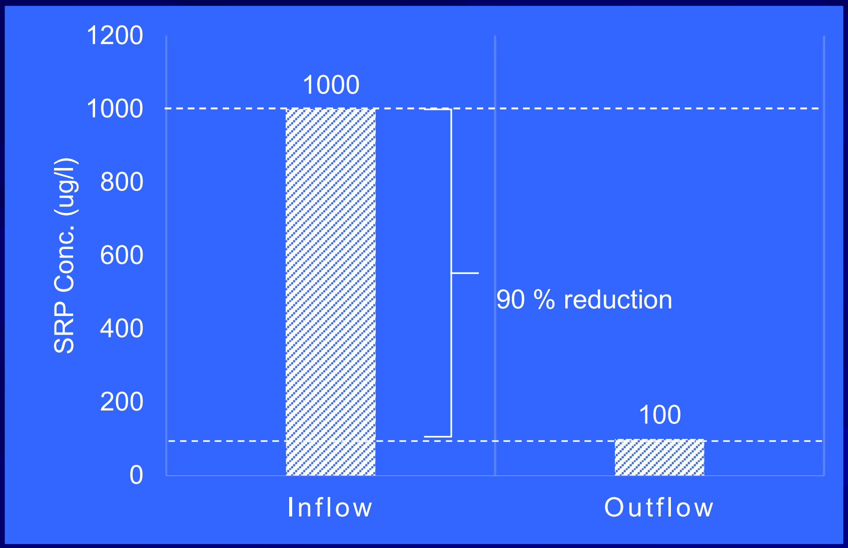
- Elevated water column nutrient concentrations due to reuse irrigation
- Achieved ~ 10% concentration reduction for TP and 12% increase for TN
- Best for applications with elevated nutrients or in watersheds with reuse irrigation

Typical Wet Pond Concentrations

Parameter	Units	Pond Discharge
Ammonia	µg/L	20
NOx	µg/L	16
Diss.Org. N	µg/L	266
Part. N	µg/L	100
Total N	µg/L	401
SRP	µg/L	6
Diss.Org. P	µg/L	9
Part. P	µg/L	9
Total P	µg/L	24

- Available inorganic nutrient concentrations are too low for additional uptake
- Minimum nutrient uptake concentrations
  - SRP: > 10 ug/l (0.01 mg/l)
  - Nitrogen: >130 ug/l for TIN

Manufacturer's Removal Claims



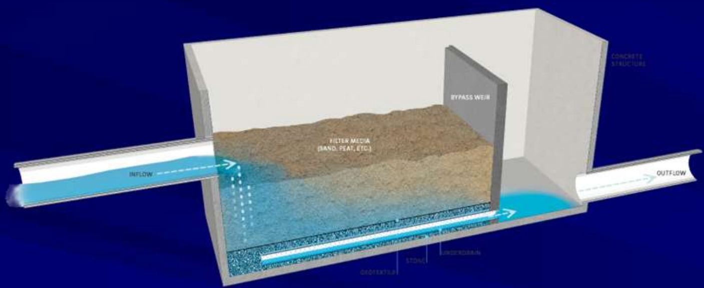
- Many product testing studies are conducted using concentrations much higher than observed in runoff
  - Wastewater technologies
  - Agriculture
- Product efficiency claims are commonly based on the most favorable testing results
- Products which work for wastewater or other high nutrient streams may not work on runoff
  - Generally, runoff concentrations are an order of magnitude lower than wastewater
- When evaluating a new product always ask for information on the concentrations used in the testing

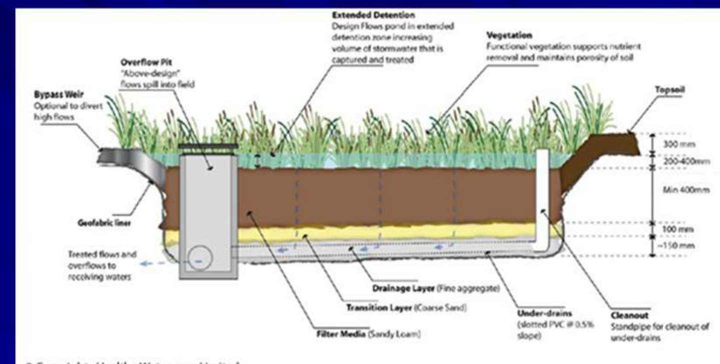
Initial Conc. (ug/l)	Final Conc. (ug/l)	Removal Eff. (%)
5,000	100	98
2,500	100	96
1,000	100	90
500	100	80
250	100	60
100	100	0

- For the example above, a 90% SRP reduction was achieved in product testing
- Actual removal would be near zero

Source	SRP (µg/L)
Raw Runoff	105
Swale	50
Wet Pond	6

Adsorption Media





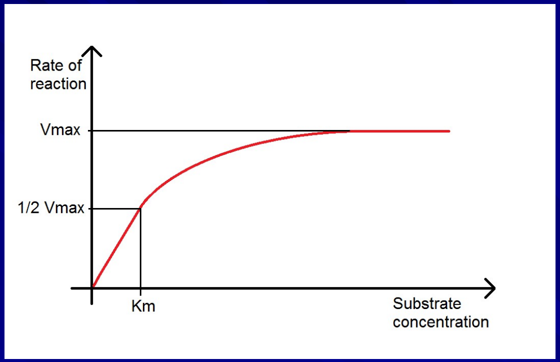
(Construction and Establishment Guidelines V1.1 April 2010; Image 3.1, Typical cross section through a bioretention system)

Description

- Removal of stormwater pollutants by sorption onto solid surfaces
- Removal of particulate matter by entrapment
- Media are developed to maximize removal of target pollutants
- Evaluated media include
  - Sand
  - Clay
  - Carbon sources (compost, sawdust, cardboard, paper, agricultural residue, etc.)
  - Lime rock
  - Manufactured media

Adsorption Media – con't.

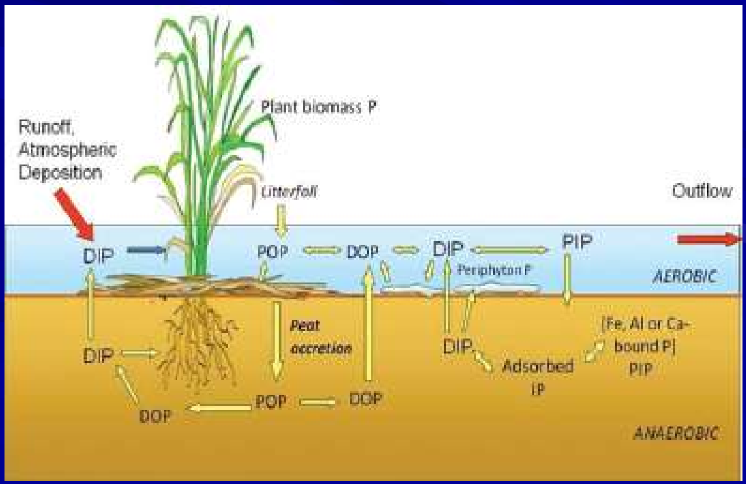
- All sorption processes are concentration based
  - Sorption rates increase as concentrations increase
  - At low concentrations, the rate decreases until it stops
  - Minimum uptake concentrations vary depending on media type and constituent to be removed
  - All media have a minimum required concentration
- Manufacturer's efficiency claims often lack info on the range of concentrations treated
- Common media is UCF Bold & Gold
  - Original media composition
    - 50% sand in natural soil
    - 30% tire crumb
    - 20% sawdust
  - Current version – CTS24 –
    - Developed specifically for highway runoff
      - Expanded clay
      - Tire crumb
      - Sand



Parameter	Inflow Conc. (ug/l)	B&G Outflow Conc. (ug/l)	Wet Pond Discharge (ug/l)
Ammonia	476	126	20
NOx	306	1,328	16
Diss. Org. N	169	397	266
Particulate N	127	245	100
Total N	1,078	2,096	401
SRP	164	8	6
Total P	189	85	24

Shallow Hardwood Wetlands

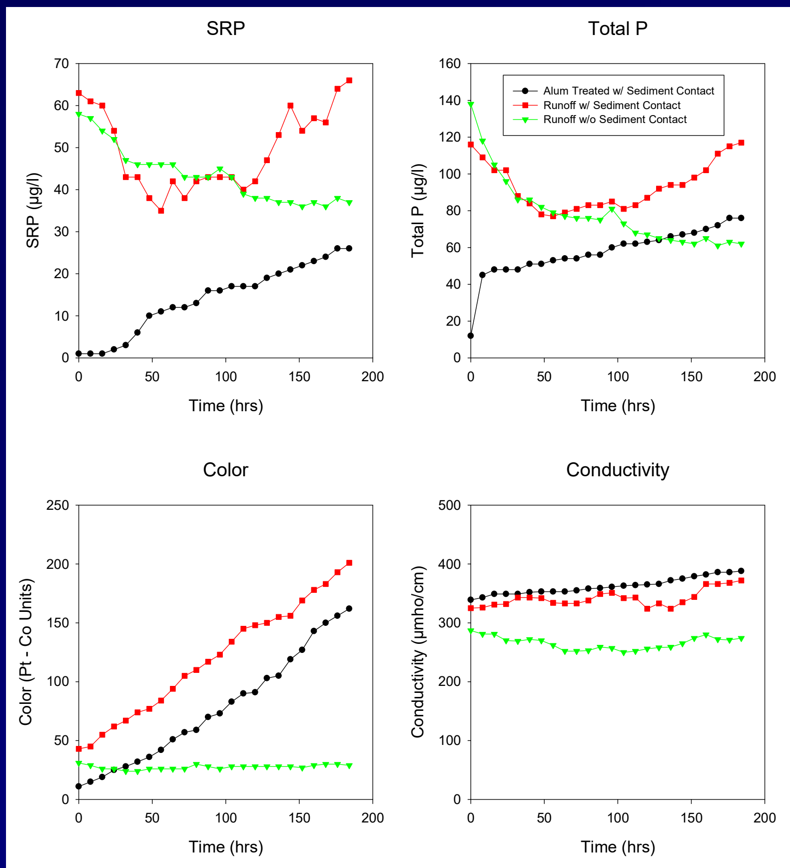
- Shallow waterbody with nutrient rich, acidic, and typically anoxic soils
- Water quality of wetland discharges is based primarily on an equilibrium between the soils and the water column
  - First-order reaction rate based on concentration
  - Equilibrium reached in 3-4 days
  - High concentrations will be reduced
  - Low concentrations will be increased

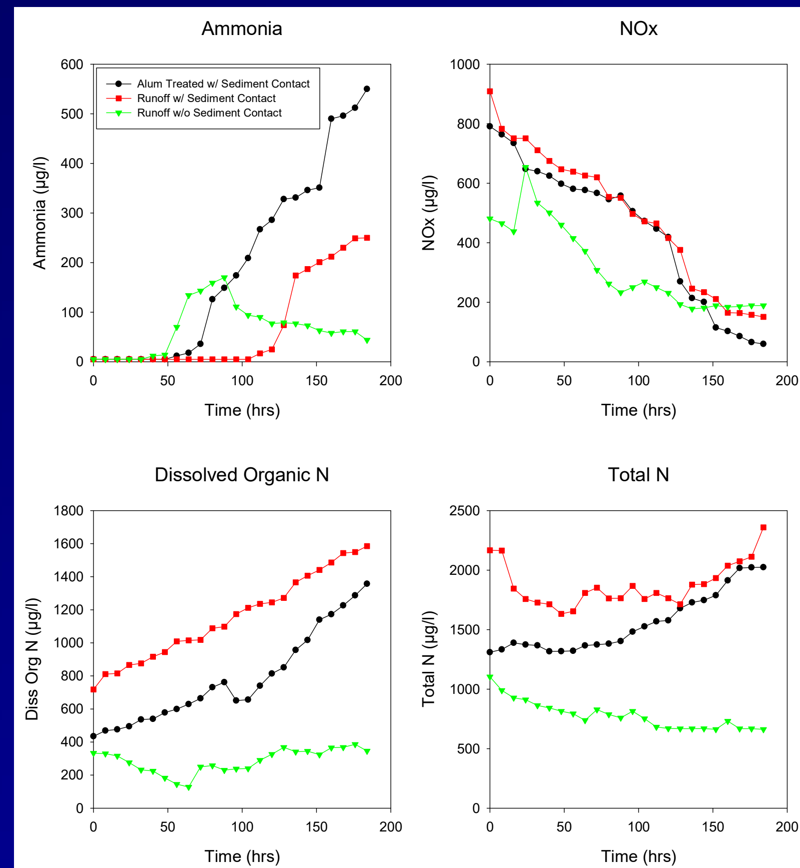


Nutrient Equilibrium in Hardwood Wetlands

- Nutrients inputs reach equilibrium with wetland soils
  - Total P - ~ 0.100 mg/L (100 ppb)
  - Total N - ~ 1 – 2 mg/L (1,000 ppb)

Nutrient Equilibrium in Hardwood Wetlands





- Nutrients inputs reach equilibrium with wetland soils
  - Total P - ~ 0.100 mg/L (100 ppb)
  - Total N - ~ 1 – 2 mg/L

Wetland "Polishing"

Wet Detention

TP = 250 ug/L
TN = 1,500 ug/L

Removes solids and dissolved nutrients

Hardwood Wetland

TP = 100 ug/L
TN = 1,000 – 2,000 ug/L

Little uptake by vegetation; water reaches equilibrium with soils

Wet detention efficiency will be reduced by substantial amount

Nutrient Equilibrium in Herbaceous Wetlands

- Shallow waterbody with dense herbaceous vegetation
- Vegetation provides a large amount of structure which supports a large population of algae, bacteria, and micro-organisms
- Form dense gelatinous layer on stalks referred to as zoogleal
- Water meanders around stalks
  - Provides large opportunity for uptake processes
- Soils are anoxic, but the have little contact with water
  - Sediment release of TP is minimal

Shallow Herbaceous Wetland

Treatment Train

TP = 250 ug/L
TN = 1,500 ug/L

Wet Detention

TP = 35 ug/L
TN = 750 ug/L

Removes solids and dissolved nutrients

Shallow Herbaceous Wetland

TP = 15 ug/L
TN = 400 ug/L

Significant uptake by vegetation and biology attached to plant stalks

- Efficiency of initial pond is calculated using the removal curves
- Wetland will remove additional nutrients from treated pond effluent

Wet detention efficiency will be increased

Summary

- In selecting a BMP it is important to match the concentration reduction capabilities to the source water concentrations
- Removal processes observe first order rate kinetics
  - Removal rate increases and decreases as concentrations increase and decrease
  - Biological, physical, and chemical processes require minimum concentrations to initiate
  - Likely concentrations of target pollutants must be considered when selecting a BMP
- Beware of manufacturer’s marketing claims
  - Literature removal efficiencies are often based on elevated nutrient concentrations where removals are greatest
  - Ask about product performance at typical stormwater concentrations

Summary – cont.

- Product removal efficiencies have little meaning
  - Manufacturers can increase the removal efficiency by increasing the initial concentration
  - The accepted removal efficiency for a BMP should state the concentration ranges used in the testing
- Minimum achievable concentrations for the BMP are much more important
- Techniques which are successful in wastewater may not be transferable to stormwater
  - Wastewater nutrient concentrations are about 1 order of magnitude greater than stormwater
- Field testing is essential prior to implementing retrofit BMPs
  - Testing should be conducted under actual field conditions

Significance of Concentrations on BMP Performance

By: Harvey H. Harper

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ERD Water Quality Engineering

Florida Department of Environmental Protection

University of Central Florida