Engineered Wetlands

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BAE 495: Applications of Ecological Engineering
Spring 2009

Name 3 types of Engineered Wetlands

Lecture Outline

- Types of Engineered wetlands
  - Treatment Wetlands
  - Stormwater Wetlands
  - Restored/Created Wetlands

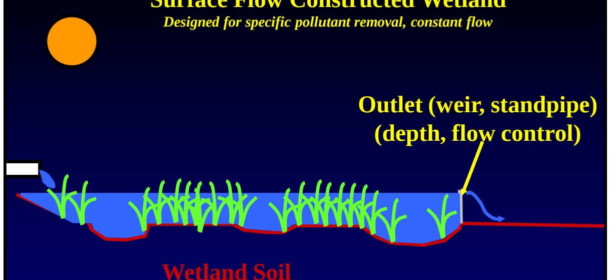
Treatment wetlands

Treatment Wetlands

- Use of CWs come from early use in treating municipal wastewater
- CWs can be designed to provide and inexpensive and easily operated system for treating and storing other pollutant streams (ex. Ag runoff)
- For maximum effectiveness, CWs must be used as part of an overall pollutant management system

Surface Flow Constructed Wetland

Designed for specific pollutant removal, constant flow



Wastewater treatment wetland

Goldsboro, NC
Groundwater contaminated by hog lagoon seepage

PA = acid mine drainage

Constructed wetlands can be used as a tool to help protect downstream water quality and overall watershed health

- Good stream health…
  - Maintains ecosystem function
  - Helps ensure human health
  - Protects fishing industry
  - Enhances tourism industry

Pollutants of concern
Where can these come from?

Biochemical Oxygen Demand (BOD) (proteins/carbohydrates, agrichemicals, oils/grease)	**Nitrogen** (organic-N, NH_4-N, NO_3-N)
Solids (sediment, algae, debris)	**Phosphorus** (organic, inorganic)
Pathogens (bacteria, viruses, protozoa)	**Metals** (Cu, Zn, Pb, Se, etc.)

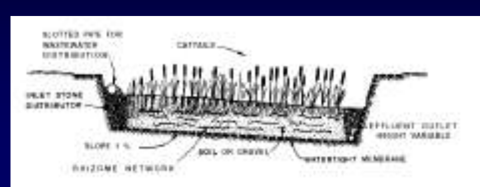
Wetland Pollutant Removal Mechanisms

- **Physical** – slow water down, and retain water for a period of time. (Ex. Sedimentation, adsorption)
- **Biological removal**– metabolic processes (Example- plant and microbial uptake of pollutants, pathogen die-off)
- **Biogeochemical transformations** – conversion of some contaminants to forms that may be retained or released harmlessly to the atmosphere (Ex. Denitrification, precipitation)

Constructed wetlands

Advantages	Limitations
Properly designed – can offer high level of pollutant treatment	Wastewater may require pre-treatment, and system may require large land area
Natural energy inputs, limited "concrete and steel"	Plants are sensitive to high pulses of pollutants (example – Ammonium)
Inexpensive to build and operate	Operate better with a continuous water source
Largely self-maintaining	Do not perform as well in cold seasons
Can handle some variability in wastewater loadings	Improperly designed systems can attract vectors (example – mosquitoes)

Considering wetlands for treatment of agricultural wastewater? You must understand how they work and what they need to treat



To reduce the mass of influent pollutants, a treatment system must:

- Reduce concentration of pollutant in effluent water

  OR
- Reduce volume of water exported

  OR
- Reduce pollutant concentration and volume of water exported

- Properly designed wetlands can do this!

Mass = Concentration x volume of water

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How can volume be reduced?

ET

Exfiltration

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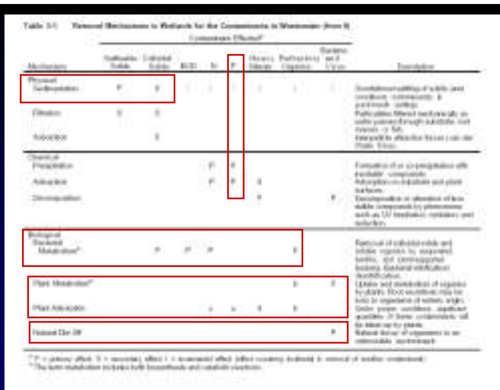

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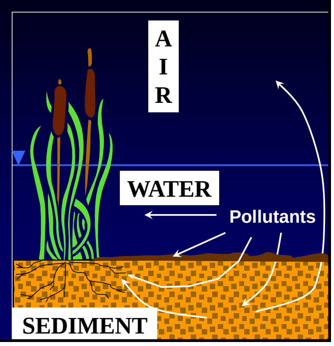
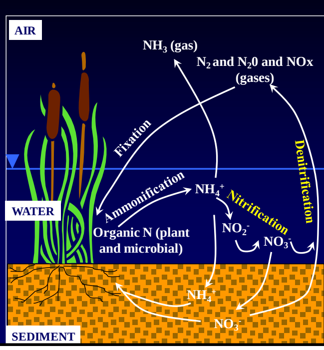
Pollutant reduction

- Sedimentation/Sorption
- Uptake
- Transformation
- Microbial degradation
- UV (pathogens)



Simplified Wetland Nitrogen Cycle

(after Kadlec and Knight , 1996)



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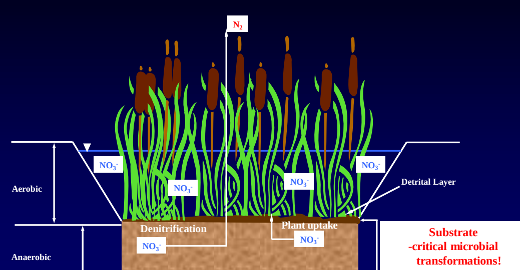
Wetland Denitrification Review

(Requires NO_3^- + Anaerobic + C source)



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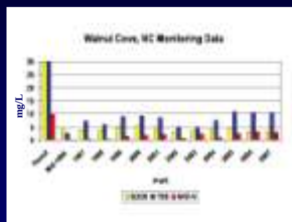
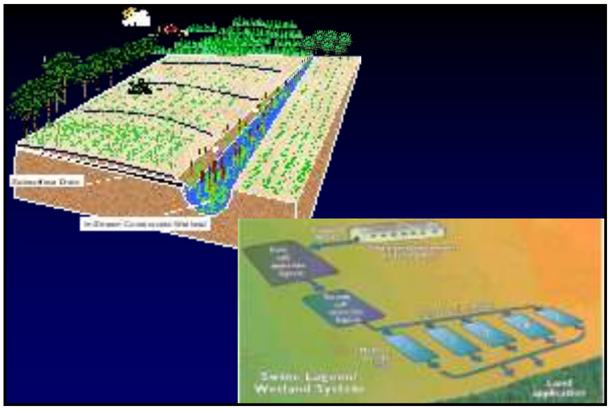
Walnut Cove, NC

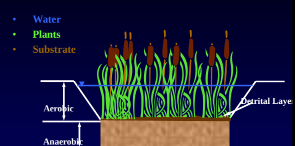




Wetland Design

Treatment wetland design

- Must design wetland components based on goals for pollutant removal
- Sizing -
  - Based on hydraulic retention time (HRT) required to treat target pollutant(s)
- Vegetation selection
  - Biomass production
  - Climate
  - Max Water Depth
  - Tolerance to pollutants
  - Habitat or no habitat?
- Soils
  - Permeability
  - Carbon content
  - Stability
  - Fertility

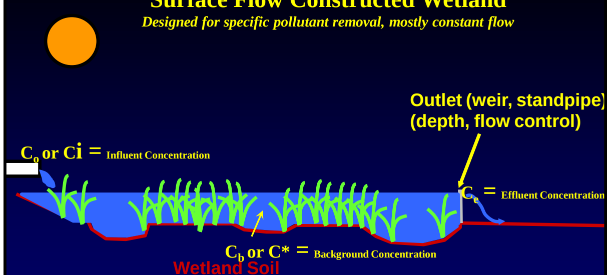


Sizing – do you have enough area?

- Various pollutants will require different areas for treatment
- Design wetland for pollutant that will require the largest area!

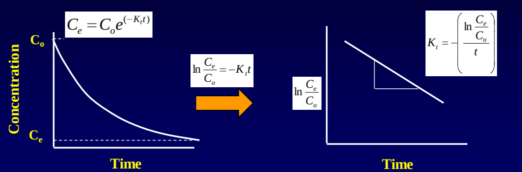
Surface Flow Constructed Wetland

Designed for specific pollutant removal, mostly constant flow



Microbial Growth Kinetics

Since breakdown of contaminants are microbially driven, most researchers agree degradation of nitrogen species in wetlands and other treatment systems are considered 1st order, based on Monod equation (bacterial growth based on limiting substrate)



Co = Nitrogen inflow conc. (mg/L) Ce = Nitrogen effluent conc. (mg/L)
K = 1st order kinetic removal rate constant t= time within the wetlands (HRT) d^{-1}

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Design Methods - Kinetic

Reed

$$\frac{C_e}{C_o} = e^{(-K_t t)}$$

- C_o = Influent nitrogen concentration (mg/L)
- C_e = Effluent nitrogen concentration (mg/L)
- K_t =temperature dependant rate constant (d^{-1})
- d = average depth of water in wetland (m or ft)
- n = porosity in the wetland cell (% as a decimal)
- t = hydraulic residence time =LWdn/Q=Adn/Q (days)

Kadlec

$$\frac{C_e - C_b}{C_o - C_b} = e^{\left(\frac{-K_t}{HLR}\right)}$$

- Coefficients as above except:
  - C_b = Internal nitrogen concentration (mg/L)
  - K_t =temperature dependant rate constant (m/d)
  - HLR = Hydraulic loading rate = Q/A (m/d)
- Only minor difference in results when attempting to predict effluent quality of an existing treatment wetland

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CW Performance Expectations

- Percent removal of contaminants found in wetlands databases are variable
- Reasons for variability include:
  - Size of wetland
  - Hydraulic loading rate - HLR
  - Hydraulic retention time - HRT
  - Climate (temperature/precipitation/evapotranspiration)
  - Influent contaminant concentration

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Example of % removal variability

- Wetland 1
  - Influent NH_3-N = 243 mg/L
  - Effluent = 68 mg/L (175 mg/L less)
  - (243-68)/243 x 100% = 72% removal
- Wetland 2
  - Influent NH_3-N = 15 mg/L
  - Effluent = 7 mg/L (8 mg/L less)
  - (15-7)/15 x 100% = 53% removal
- Which wetland performs better?

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Inlet structures

- Distribute flow evenly across the width of the wetland
- Orifices should be large enough not to clog
- Gravel to dissipate energy

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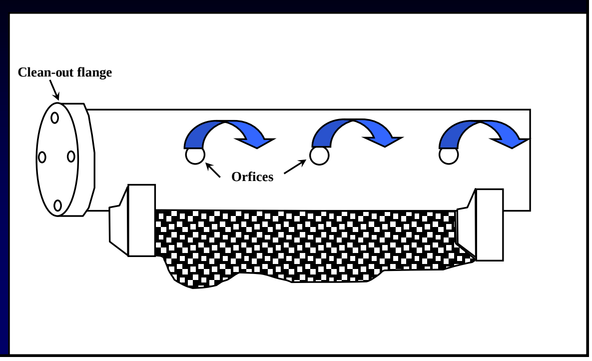
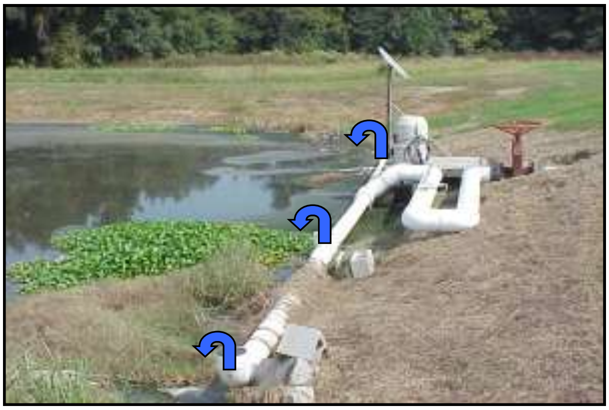
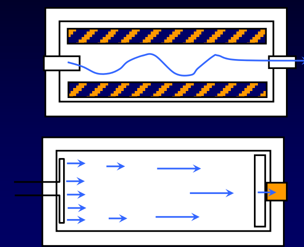
Inlet Distribution System





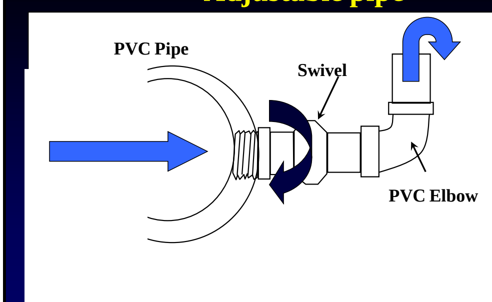
Inlet distribution is very important
to use the entire wetland treatment area



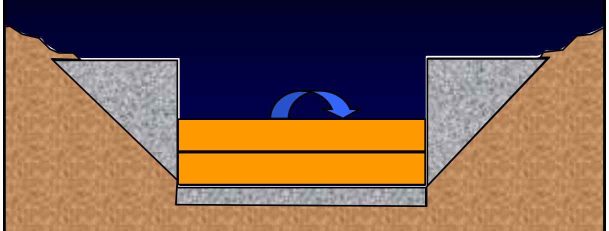
Outlet structures

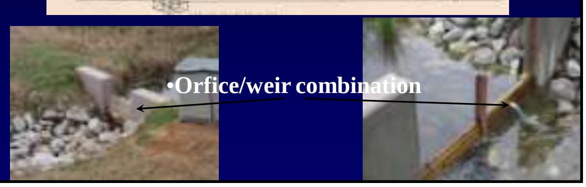
- Be designed to maintain design HRT
- Should be adjustable to increase/decrease water levels
- Systems should have emergency spillways
- Clogging can be an issue
- Cascading can re-aerate effluent if needed

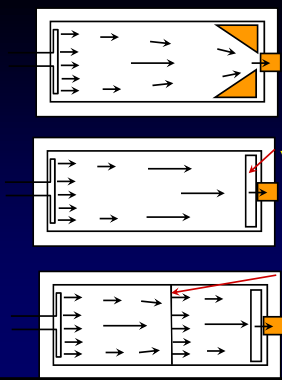
Adjustable pipe



Flashboard weir outlet







Deep water area near outlet
will encourage even flow across wetland

Multiple wetland cells or level spreader in the middle of the wetland
will encourage even flow across wetland

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Vegetation

- Roots for microbial activity (O_2)
- Provide soil stability
- Evapotranspiration
- Shading (reduce algae0
- Unlimited supply of organic carbon that make wetlands pollutant sinks

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Planting

- Use native plants
- Recommend at least 60 cm spacing
- 27,000 plants/ha
- Fertilize?
- Maintain low water levels during establishment

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Scirpus, Typha, Schoenoplectus and *Phragmites* (Europe)

Woolgrass and cattail

Bulrush

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Construction Guidelines

- Build to gravity flow
- Replace topsoil excavated or utilize soil amendments
- Compact wetland liner, but keep topsoil loose (limit heavy equipment on wetland surface)
- 3:1 bank slopes – stabilize with grass and erosion control fabric

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Post Construction Guidelines

•Allow plants time to establish before high water or pollutant loads

•Maintenance of outlets/inlets/ berms

•Nutria *Myocastor coypus* Burrows and Herbivory

•Monitoring (flow (water balance), water quality, plant survival

   

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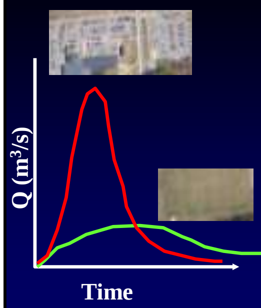
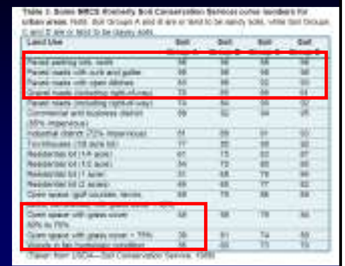
Stormwater wetlands

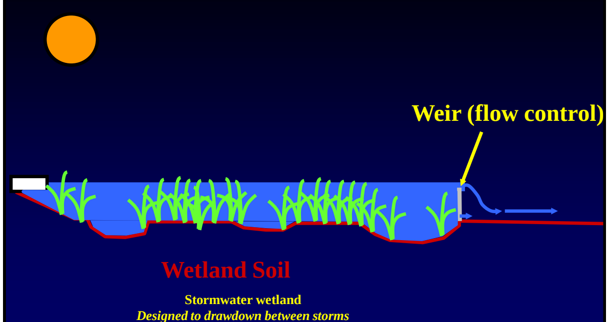
Stormwater runoff

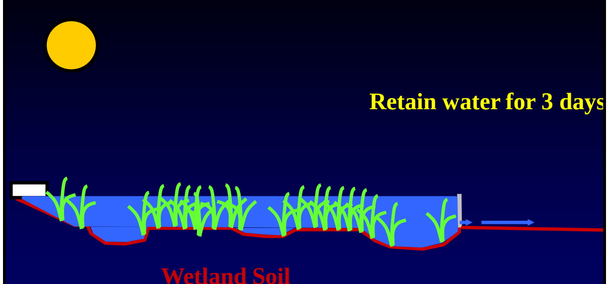




Stormwater vs. treatment wetlands

- Size limited
- HRT less, alternating wet/dry conditions
- Sized on peak runoff from storms, watershed size
- Inflow pollutant concentrations lower
- Variable water depths (temporally and spatially)
- Diverse plants community
- By pass excess flow (storms>1.5 in runoff)

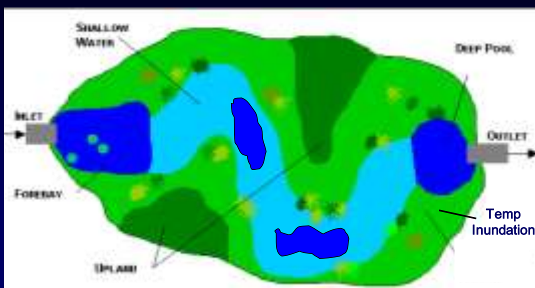




Stormwater BMPs
Stormwater Wetlands

- How do they work?
- **Retention** – hold water for a longer period of time than a pipe, ditch or stream
- **Physical** – slow water down, allow sediment to be retained
- **Biological** – plant uptake of pollutants
- **Biogeochemical transformations** – conversion of some contaminants to forms that may be retained or released harmlessly to the atmosphere

Typical Plan View

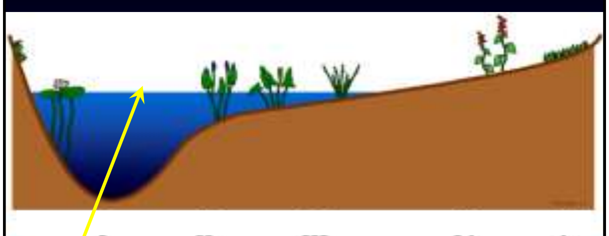


"Entry" Deep Pool is the Forebay

1. Slow H_2O
2. Capture Sediment & Solids

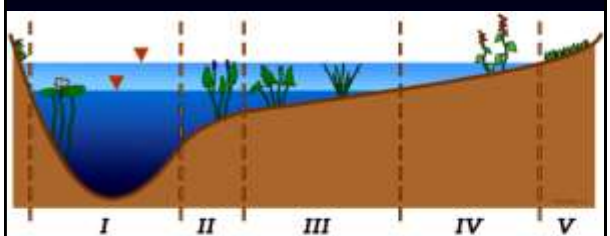
2 Purposes…

Normal pool

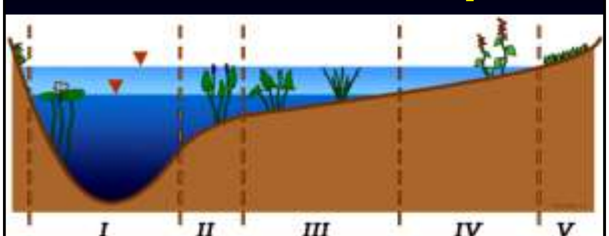


Elevation of the stormwater outlet (an orfice 12-18 in below overflow)

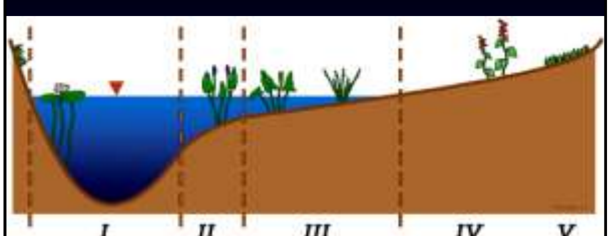
Stormwater enters!



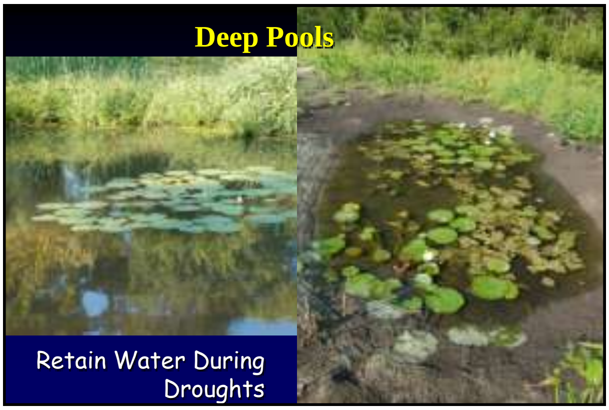
Stormwater drains to normal pool

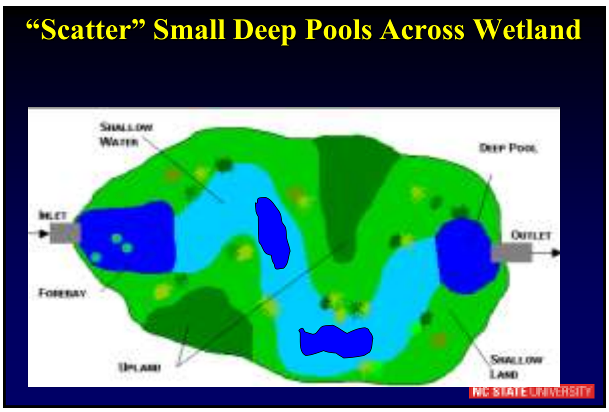


Stormwater Wetland Zones



I – Deep Pool – Exceeds 45 cm Depth





Select Wetland vegetation based on wetness tolerance

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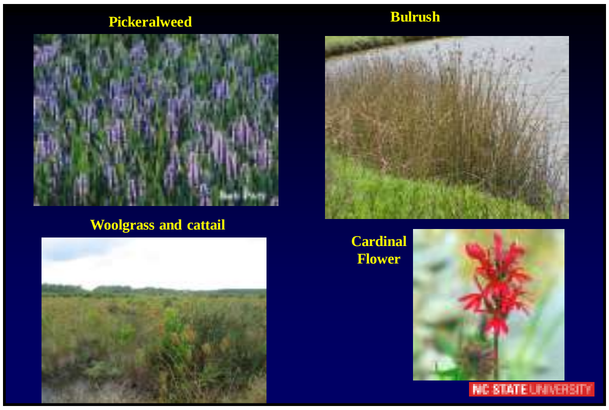
Pickeralweed
Bulrush
Woolgrass and cattail
Cardinal Flower
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Swamp Rose
Duck Potato
Water Lillies
Arrow Arum
Lizard's Tail
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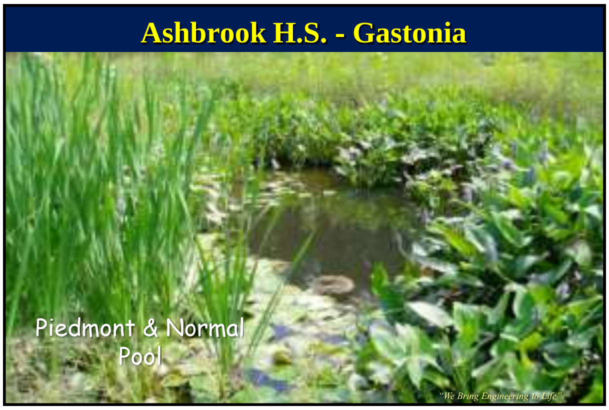
Spring Lake – Cumberland Co.
Established
"We Bring Engineering to Life"


Mary Bridger's - Wilmington
Newly
"We Bring Engineering to Life"


Moss Planing Mill - Washington
Large & Eastern
"We Bring Engineering to Life"


NC Arboretum - Asheville
Small & Western
"We Bring Engineering to Life"


Ashbrook H.S. - Gastonia
Piedmont & Normal Pool
"We Bring Engineering to Life"


Smithfield Selma HS
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August 2005
July 2006
Laney HS – Wilmington, NC
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May 2007
Laney HS – Wilmington, NC
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Golf Course Stormwater Wetlands


Unnamed Failure
"We Bring Engineering to Life"

CE wetland - Shallow Water Too Deep

How big are stormwater wetlands?

Wetland Treating a Parking Lot Drainage Area < 0.4 ha

Depends on watershed size and characteristics

How Well Do Stormwater Wetlands Work?

According to NC DENR….

Pollutant	Removal Efficiency
TSS	85%
TN	40%
TP	35%

Fecal Coliform? Temperature? Metals?

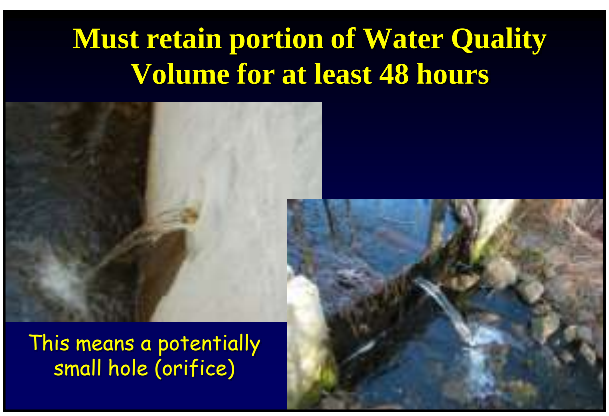
Outlet Structures


Flashboard Riser


Water Level Can Be Adjusted by Replacing,
Removing, or Adding Flashboards


Flashboard Riser Variations


Removal of All Boards aids in Maintenance or Planting
Recommend that all zones but Zone I are able to be drained.
"We Bring Engineering to Life"


Must retain portion of Water Quality Volume for at least 48 hours
This means a potentially small hole (orifice)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Next time

- **Focus on Wetland Restoration/Creation factors**

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