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The Case (and Challenges) for expanding the use of constructed wetlands to treat rural wastewater

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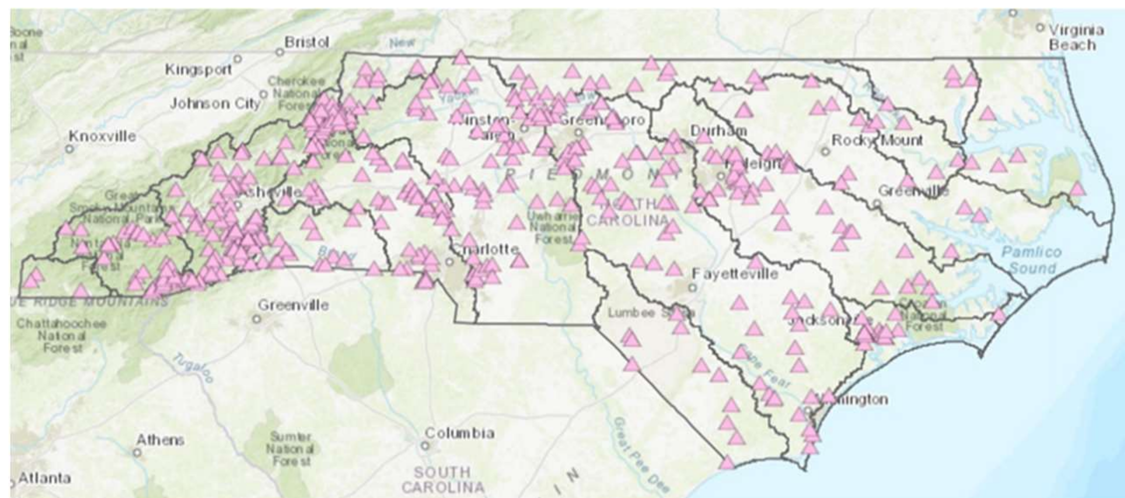
Sea Grant
North Carolina

To reduce nitrogen loads to watersheds the usual suspects of N discharge have been the focus

- Large WWTPs
- Ag (row crop and CAFOs)
- Urban stormwater/development

But what about numerous rural areas with smaller on-site wastewater treatment that are permitted to discharge higher concentrations of N?



Strategy for additional N treatment
Surface flow constructed wetlands

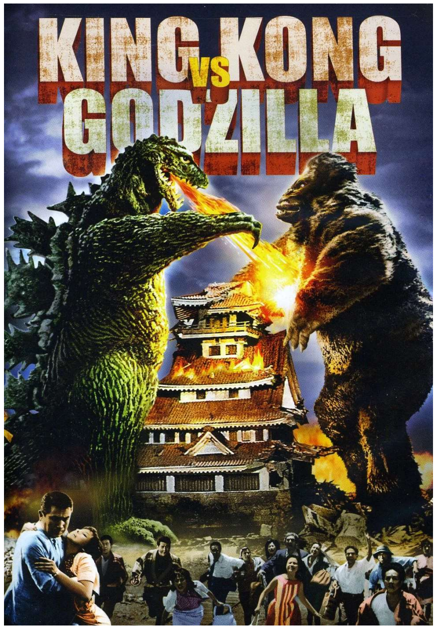
- Excellent example of Ecological Engineering
  - Most similar to emergent macrophyte wetlands
  - Uses natural energy sources, low fossil fuel inputs, generally low maintenance **(but not zero!)**
  - High plant and microbial activity, abundant C, and aerobic + anaerobic zones promotes **nitrogen removal via plant uptake and nitrification + denitrification**

Despite documented success – constructed wetlands are underutilized in many US areas to address N pollution

- We know how they work!
- Function best as secondary or tertiary treatment as a further step to reduce N content in effluent
- Efficacy in N treatment - well documented since the 1970s (particularly in early years of operation)
  - **NH_4 treatment** – variable, nitrification generally limited by low DO
  - **NO_3 treatment** – higher, anaerobic high carbon environment favors denitrification

Constructed treatment wetland vs. Stormwater wetland

Parameter	Stormwater Wetland	Treatment Wetland
Size	0.5 ha	0.5 ha
Depth	30 cm	30 cm
Flow type	Event Driven	Package plant
Watershed	10 ha	N/A
Influent inorganic N	0.5 mg/L	10 mg/L
Flow amount	60 cm runoff/yr	190 m^3/day
Treatment Eff/Rate	40%	200 mg N/m^2/d
N removed per year	**12 kg**	**350 kg**



One treatment wetland could remove 30x the N per year when compared to the same sized stormwater wetland.

If constructed wetlands are so great NC must have a bunch of them right?

Constructed wetlands in North Carolina

few in operation in NC – and those have not be managed well

Name	Location	Wastewater Source	Type	Size ha (ac)	Year Built
New Hanover Co. Landfill	Wilmington	Landfill leachate	Surface	2.3 (5.7)	1995
Aurora WWTP	Aurora	Municipal wastewater	Surface	0.6 (1.4)	1996
Walnut Cove WWTP	Walnut Cove	Municipal wastewater	Surface	1.7 (4.2)	1997
Caledonia Prison	Tillery	Prison wastewater/ food processing	Surface	4.9 (12)	2000
Goldsboro WWTP	Goldsboro	Municipal wastewater	Surface	17 (42)	2001

Current challenges to more widespread constructed wetland adoption

- Lack of operational data +
- Lack of operational and maintenance guidance +
- Lack of regulatory incentives or presence of disincentives +

- Lack of clear economic incentives (nutrient trading) +

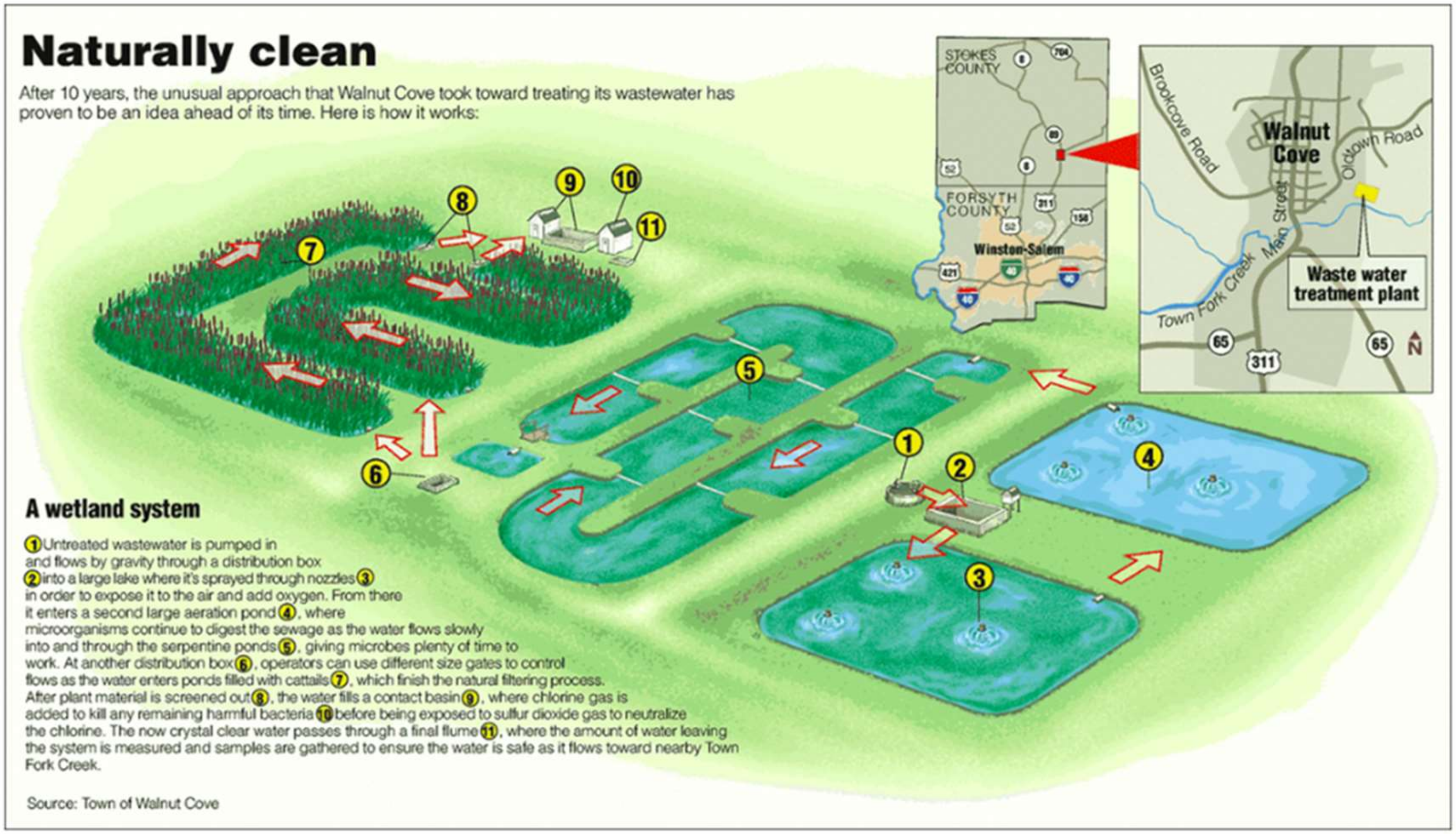
= Negative perception of constructed wetlands

Pre-treatment may limit performance of CWs at wastewater plants

- NO_3-N levels are often <1 mg/L entering wetlands if aeration is limited (or not existent) during **lagoon** pre-treatment
- Limits the ability of wetlands to completely remove N from the wastewater
- Would not be an issue for package plants

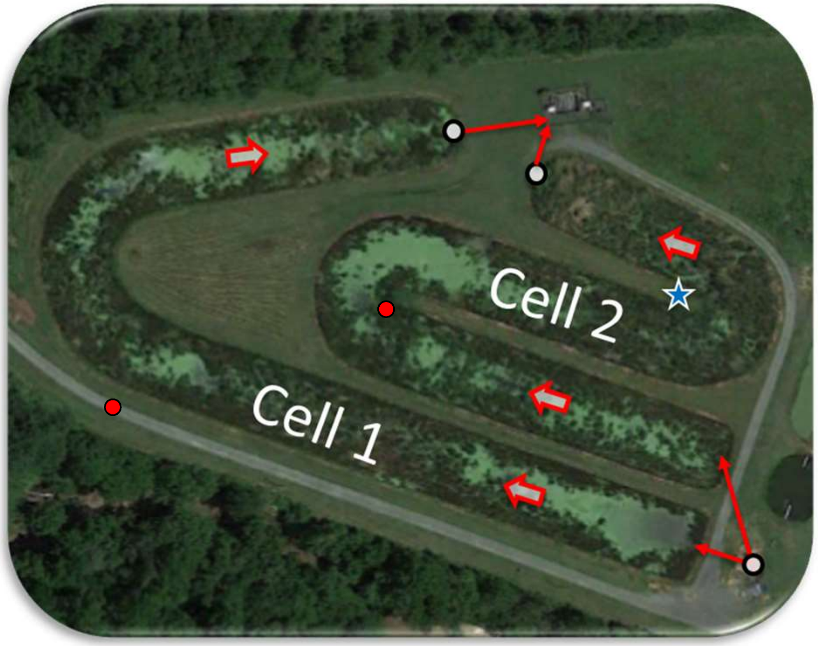
So what have we been doing about it?

Walnut Cove, NC case study

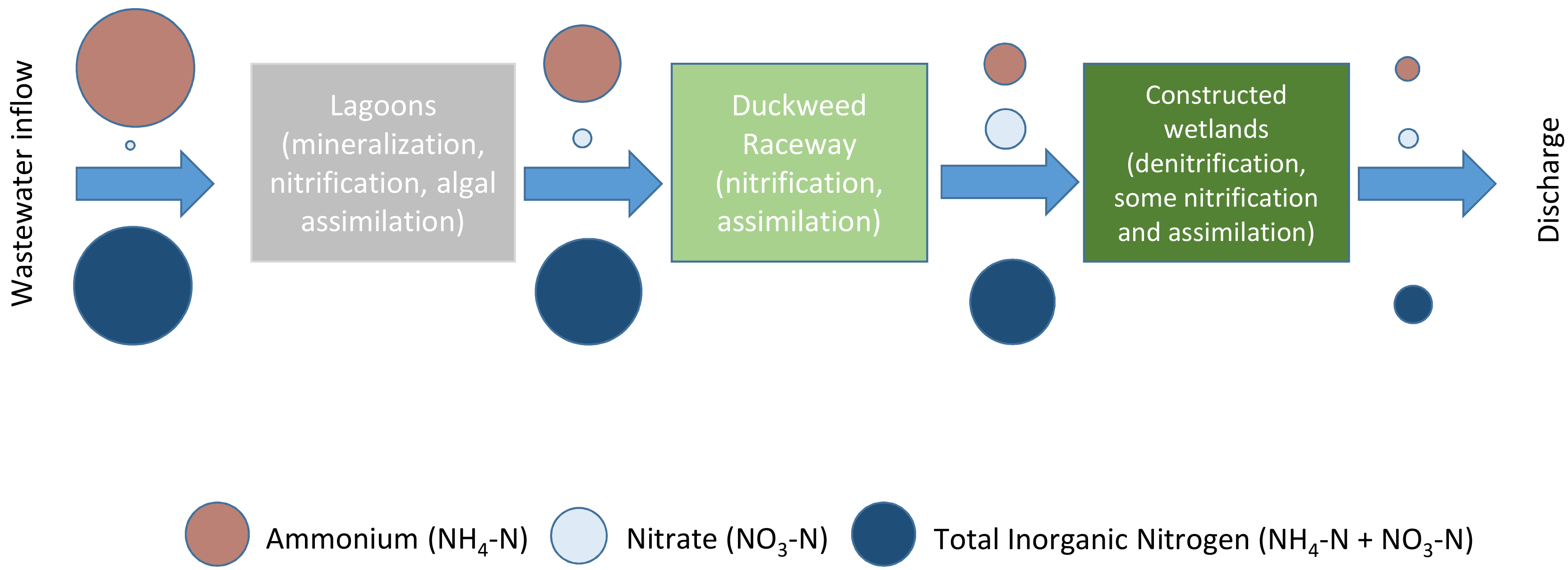


Research Monitoring

- Initialized in 2016
- Continuous in September 2018
- Inlet/Outlet Sampling & Flow
- WQ parameters (DO, pH etc.)
- On-site Weather Station



Walnut Cove designed N treatment strategy



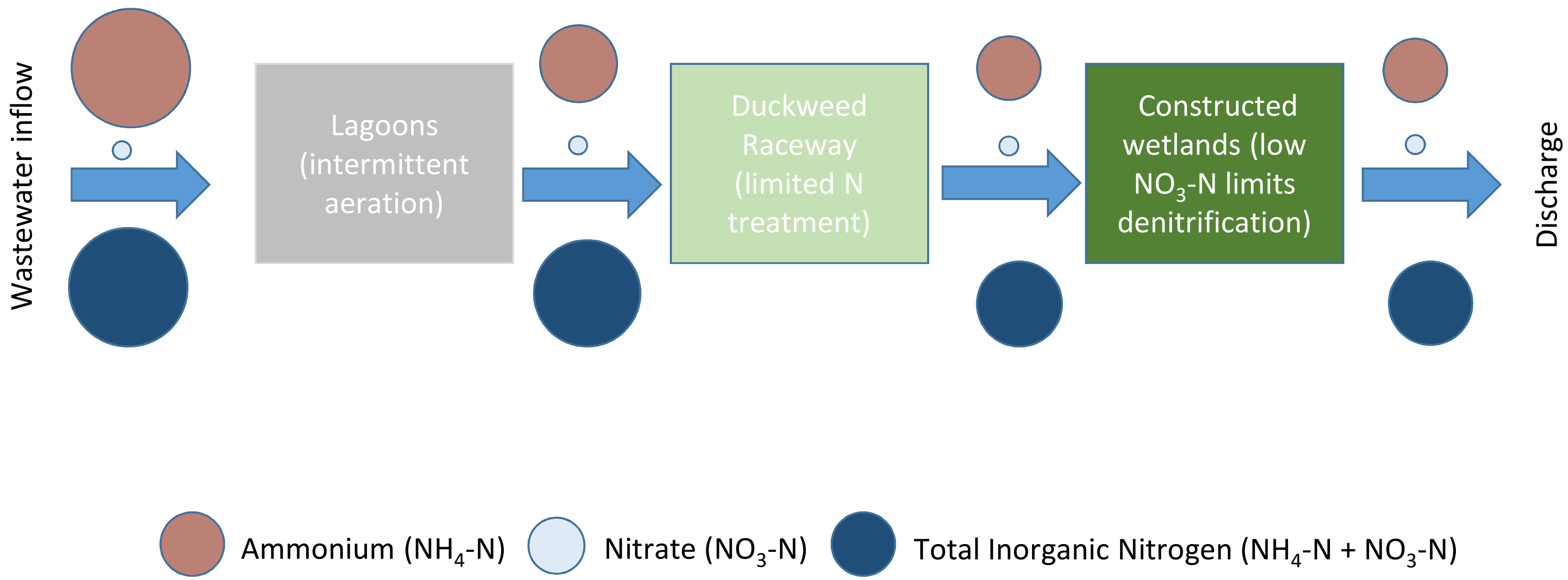
Mean N species at Walnut Cove (Fall 2018)

Location	NO_3-N mg/L	NH_4-N mg/L	Org –N mg/L	Tot-N mg/L
Inlet	0.14	8.3	2.4	10.9
Cell 1	0.11	8.3	1.8	10.2
Cell 2	0.05	8.3	1.7	10.1

No NO_3-N entering the wetlands (limited pre-treatment)

No net treatment of NH_4-N

Actual N Cycling at Walnut Cove

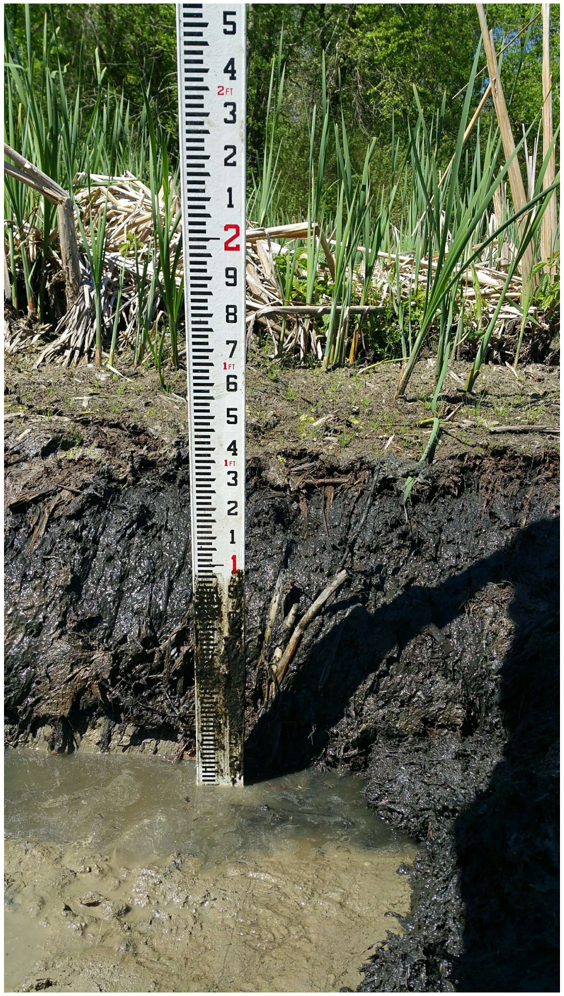


Two major Issues seem to plague this and other NC older systems

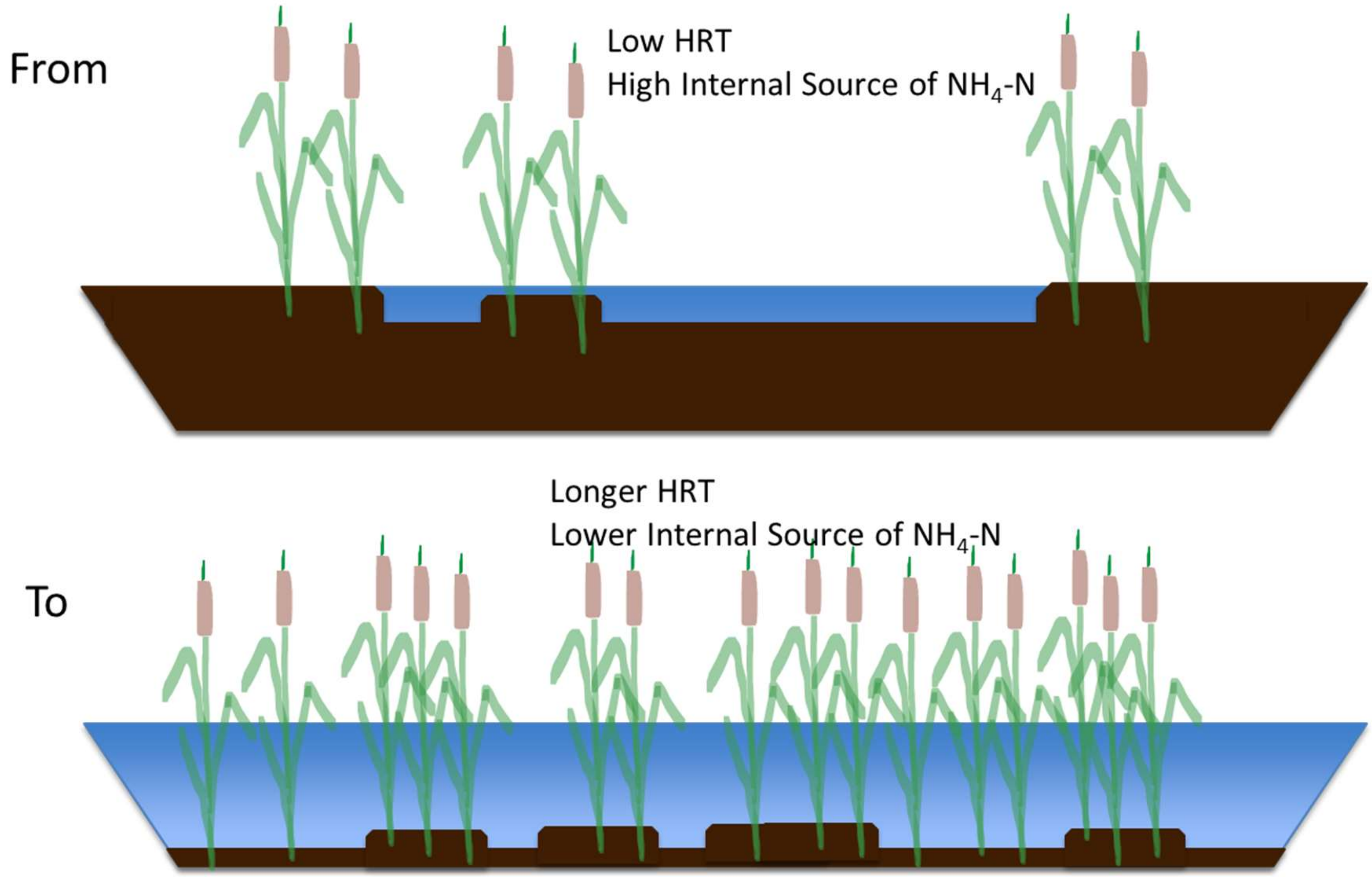
1. **Detrital Buildup**
   - Poor mixing and reduced retention time
   - Internal source of NH_4-N

2. **Lack of pretreatment of NH_4-N to NO_3-N** (nitrification) because of limited aeration

This limits potential performance!



Strategy 1: Maintenance - Remove detritus from Cell 1



Strategy 1: Cell 1 clean out method

- Cell taken offline to dry out
- Excavator with 60 ft boom used to work downstream to upstream
- Detritus pulled to the banks and allowed to dewater and stabilize
- 4-6 inches left in cell
- Clumps of cattail scooped and replanted on 4 ft centers
- 5 day process

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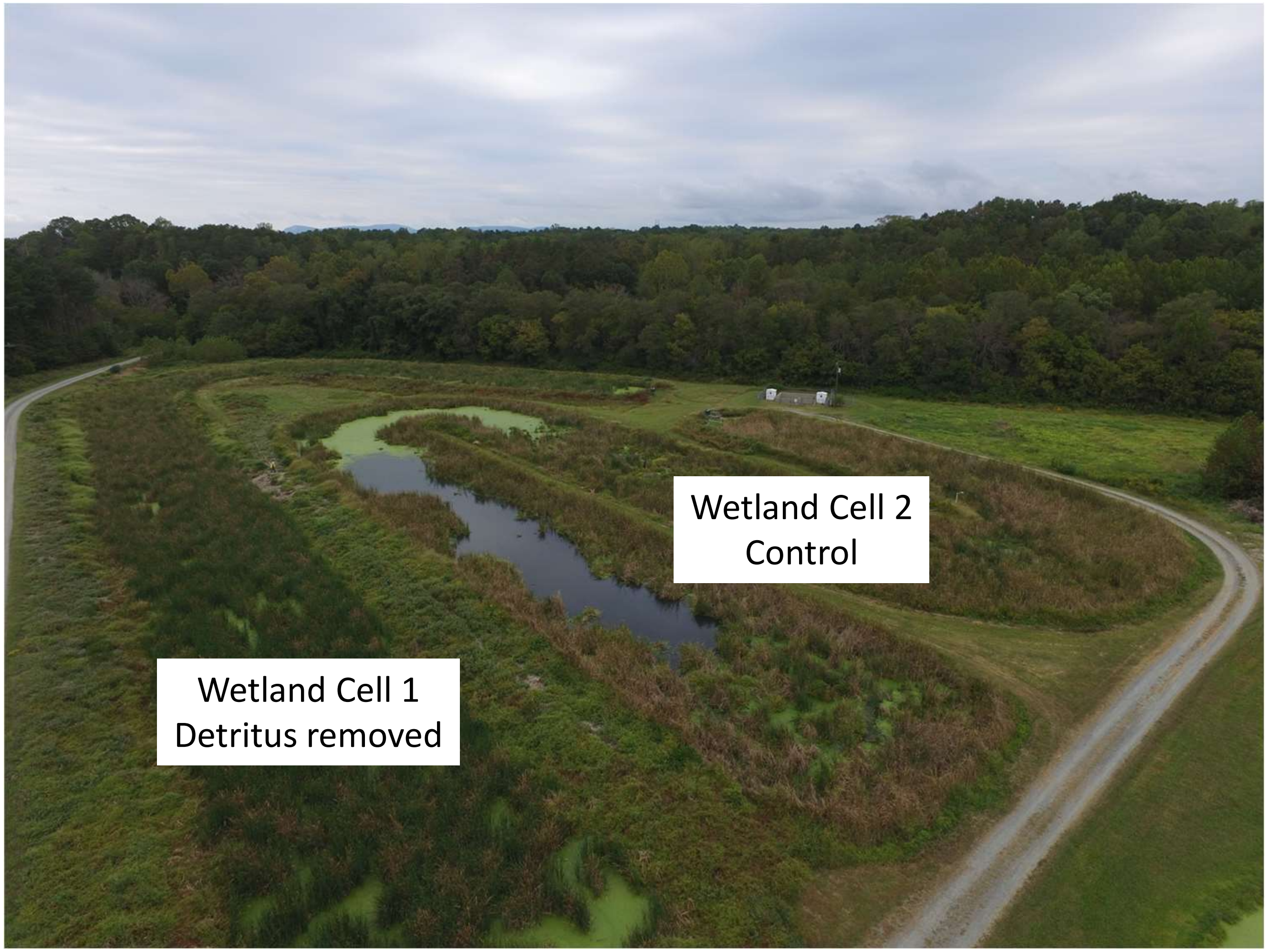

Vegetation Reestablishment

- Aerial photographs show that cell 1 was revegetated by the fall 2019

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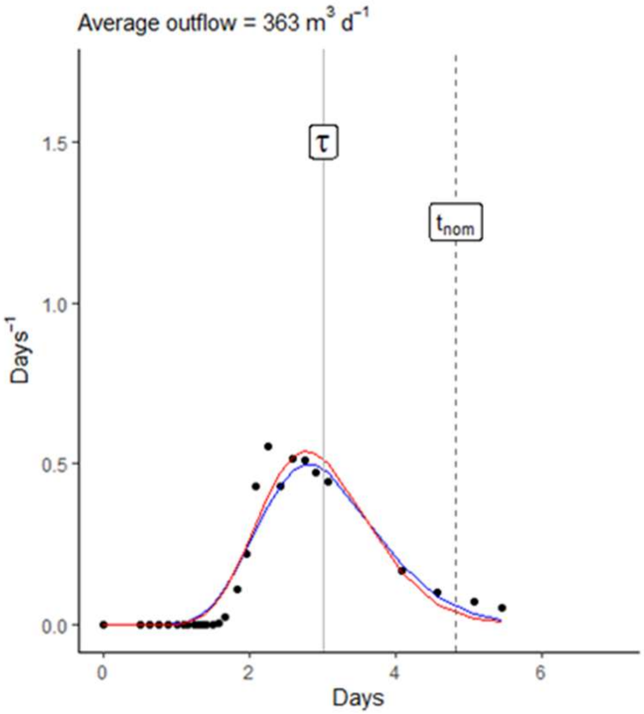
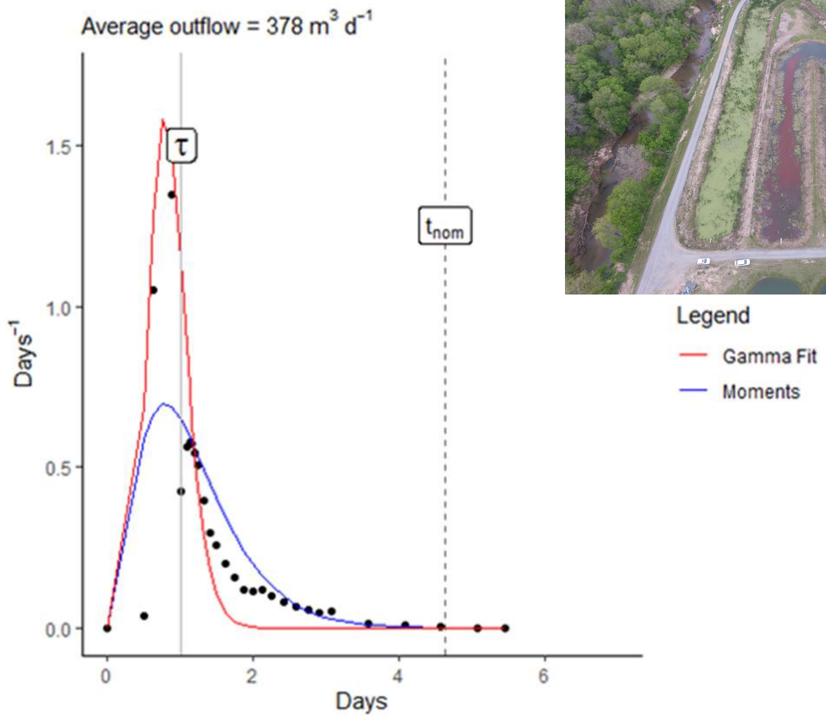
Post-Rejuvenation Hydraulics

Cell 1 (Detritus Removed)



Cell 2 (Control)



HRT increased to around 3 days in Cell 1

Example - Post-rejuvenation N Concentrations

Location	NO_3-N mg/L	NH_4-N mg/L	Org –N mg/L	Tot-N mg/L
Inlet	0.32	**5.34**	1.59	7.26
Wet1out	0.40	**3.88**	1.32	5.60
Wet2out	0.13	**6.24**	1.20	7.58

Mean values between May 2019 and January 2020

Cell	NO_3-N	NH_4-N	Org –N	Tot-N
Wetland 1	-25%	**27%**	17%	**23%**
Wetland 2	59%	**-17%**	24%	**-4%**

Wetland Performance (N Loading)

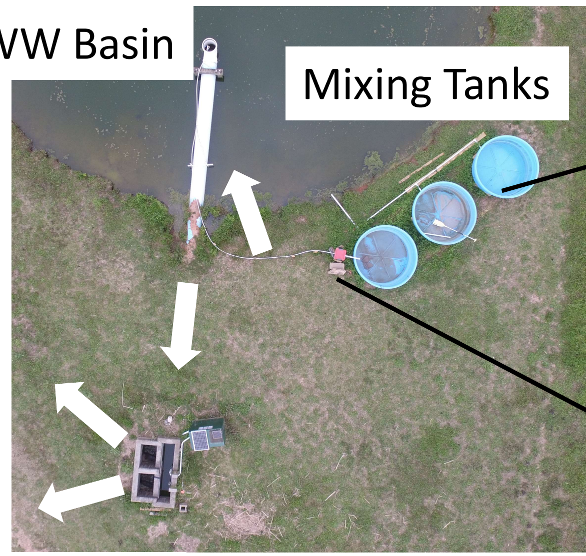
Wetland	Location	Tot-N kg	Tot-N removed, kg	Tot-N % removal
Cell 1	In	927.2	**136.1**	**15%**
	Out	791.1		
Cell 2	In	964.1	**-18.5**	**-2.0%**
	Out	982.6		

Based on mean monthly flow and concentration values between May 2019 and January 2020

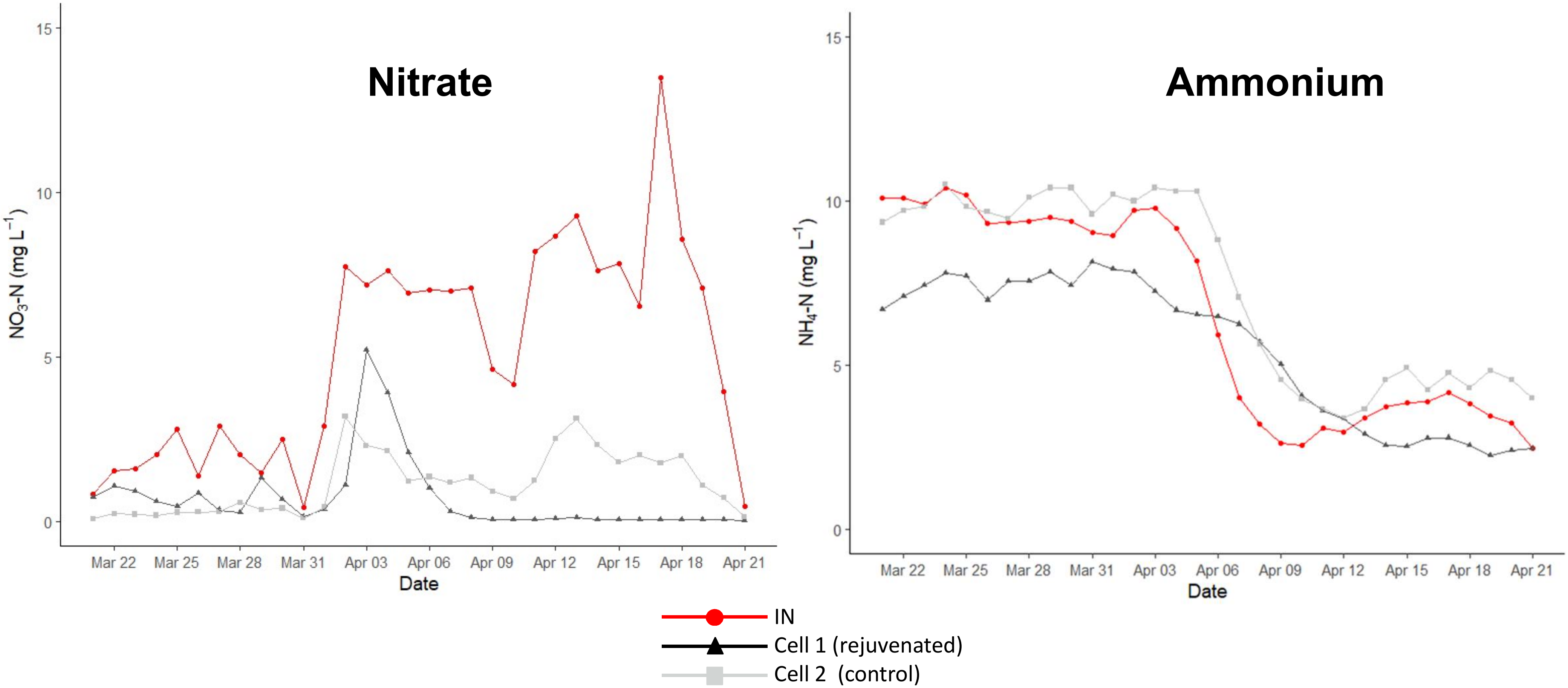
Since rejuvenation:
Wetland Cell 1: removal of TN
Wetland Cell 2: export of TN

Strategy 2: Demonstrate N treatment potential in a rejuvenated wetland cell that receives NO_3-N

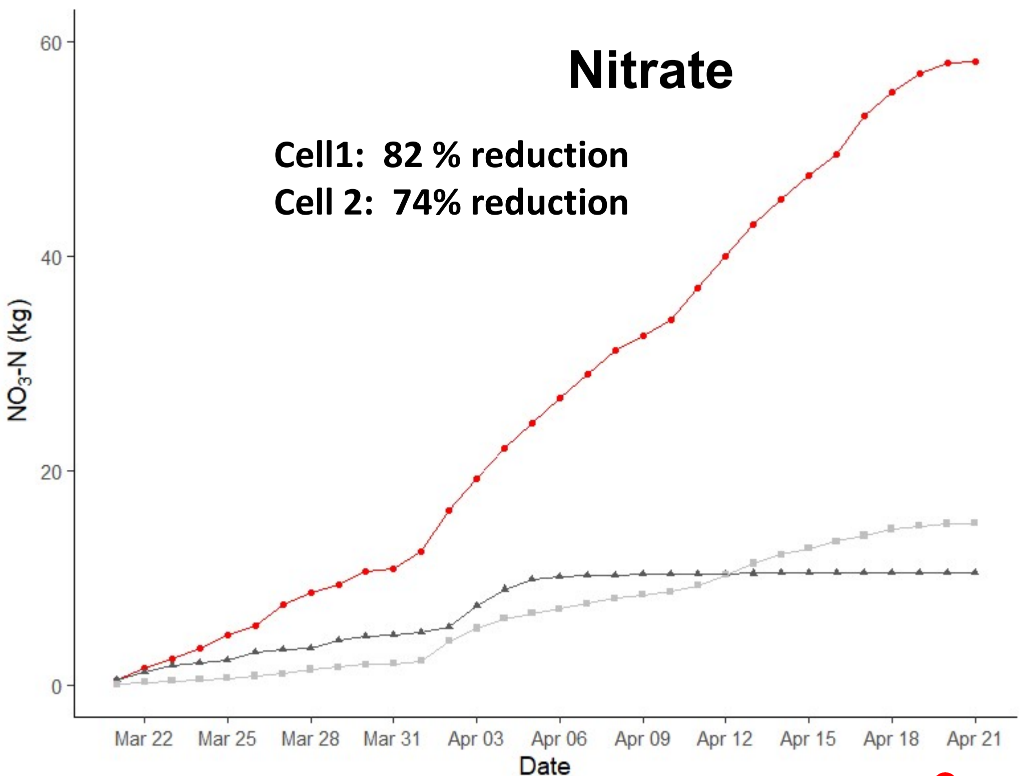
- Operators do not to continuously operate aerators for maximum nitrification pretreatment
- Conducted a 5 week nitrate dosing study in March-April 2021 to simulate pretreatment
- Water temperature 17°C (62 °F), early plant growth

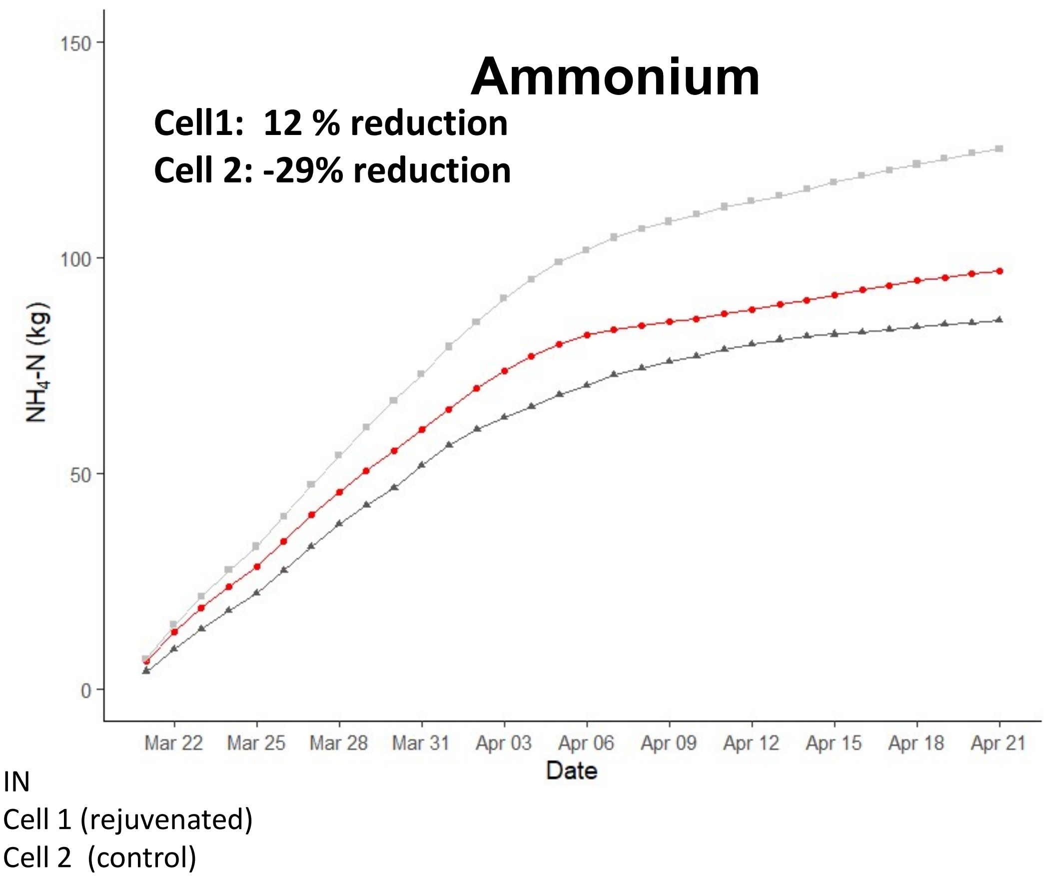


N Concentrations



Nitrogen Loads





Ok, big deal! You showed these wetlands treat NO_3-N *What do simple tests like this demonstrate?*

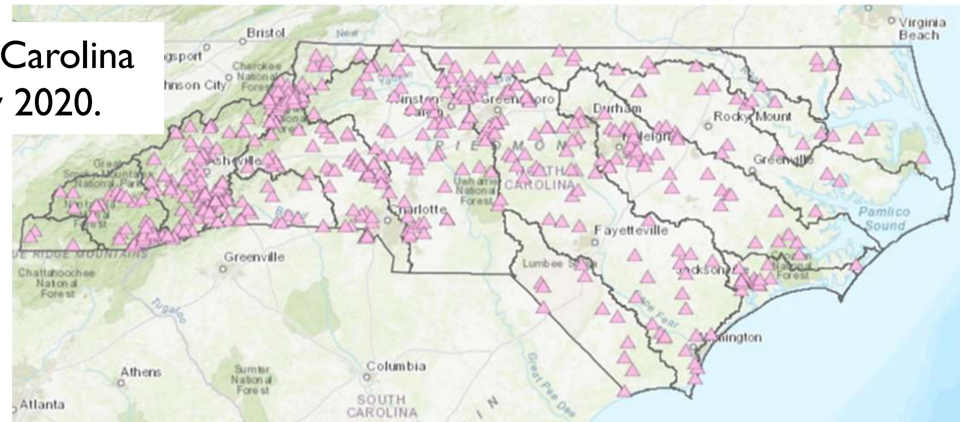
- Shows (again) how treatment wetlands most efficiently remove nitrogen – through denitrification

- Shows operators of existing wastewater plants with wetlands the importance of pretreatment (running existing lagoon aerators or adding aeration)
  - Converting 50% incoming NH_4-N to NO_3-N will can double potential DIN removal by the wetlands (good for the environment, nutrient trading?)
  - Additional treatment makes them safer from costly permit violations

- Shows both smaller rural towns operating package plants (that are required to treat only NH_4-N) and regulators, a full scale snapshot of how much additional N could be removed by adding downstream constructed wetlands

Constructed wetlands added to minor WWTP improve could really reduce N loads

All 483 minor WWTPs operating in North Carolina under active NPDES permits as of February 2020.



Discharge to

Less N to surface water

Example: Impact of wetland expansion?

- Studied a relatively small minor WWTP (activated sludge) with an average effluent flow of 180 m^3 per day (0.04 MGD)
- Treated NH_4-N well, only had to report this effluent loads
- Release approximately **800 kg-N (1800 lbs) of unaccounted-for NO_3-N in 2019**
- A 0.2 ha (1/2 acre) could easily remove 50% of this load (900lbs x $15N = $13,500/yr)

- At 200 minor WWTPs, CWs built to remove just 50% of this NO_3-N load could reduce nitrogen loads by 250,000 kg-N (550,000 lbs) per year in NC. ($8.2 M N credits?)

Conclusions and future work

- Constructed wetlands can serve as an important tool and strategic step in protecting watershed health - but it won't be easy
- **Strategic Plan:**
  - **Re-educate stakeholders** on the history, treatment potential, economics, maintenance, and lifespan of constructed wetlands
  - **Find funding** to study existing systems to improve their performance (***aerated wetlands?),*** apply lessons learned to new systems
  - **Encourage operators to document performance –** need inlet and outlet data
  - **Work with state officials** to promote common-sense approaches of how wetland discharges are regulated
  - **Evaluate incentives** (conservation grants, nutrient trading, nutrient offsets) to encourage communities to finance and maintain new wetlands to polish effluent

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THANK YOU – Lets Discuss!

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