Analyzing and Optimizing Denitrification Hot Spots in Minnesota's Surface Waters

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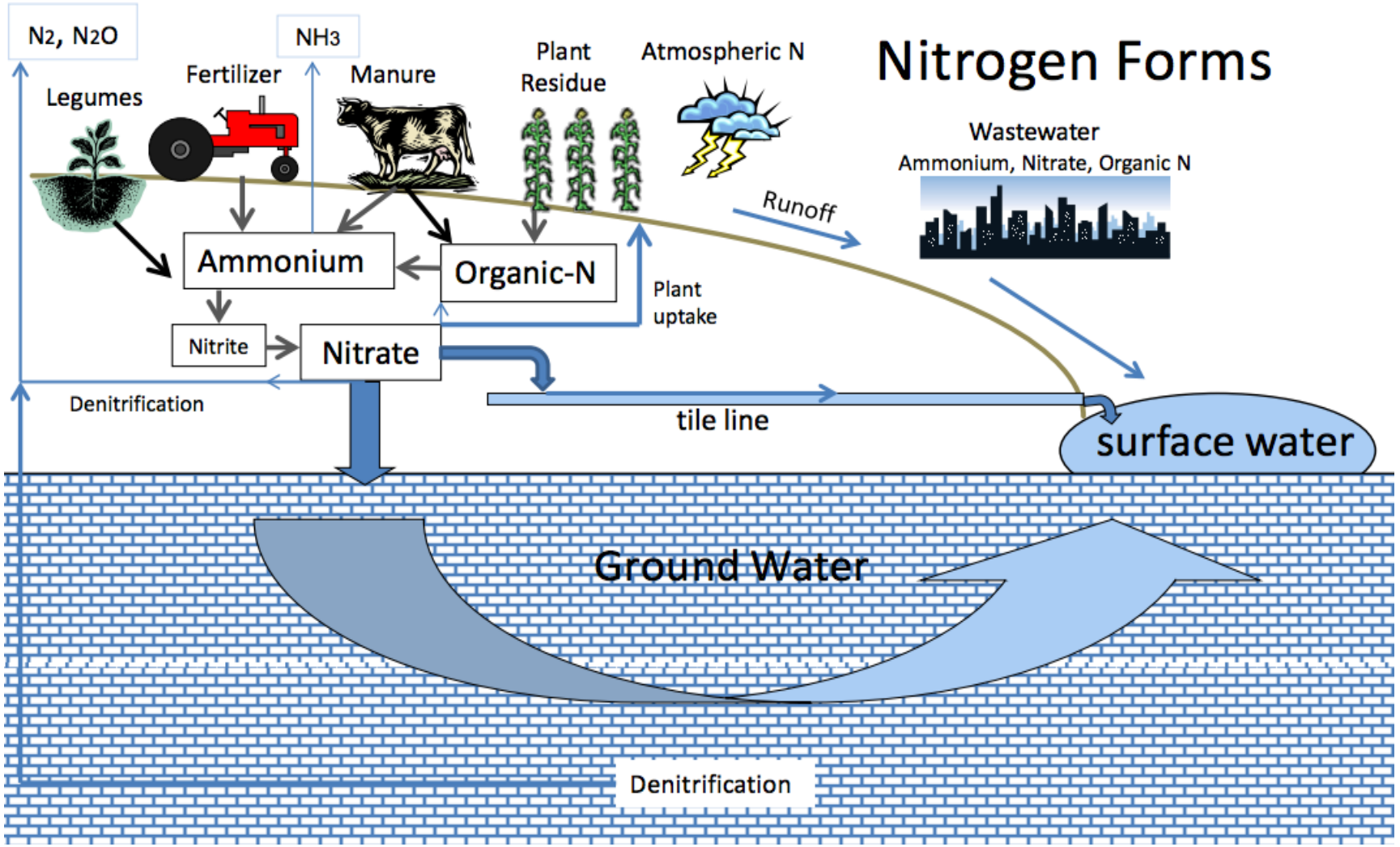
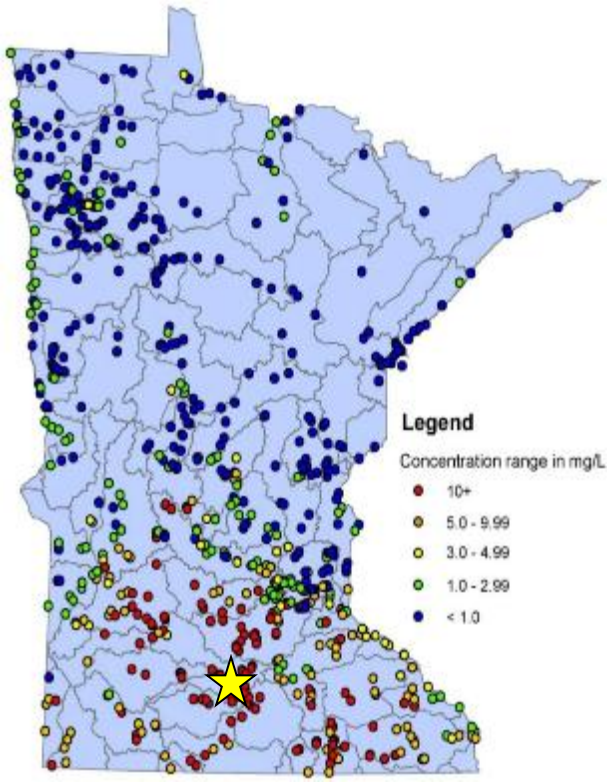


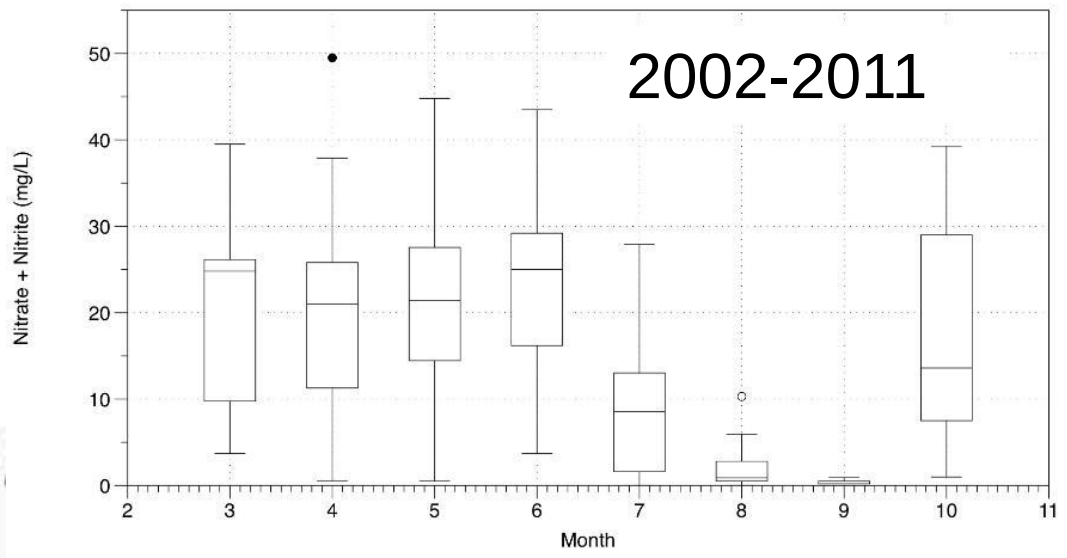
From: pca.state.mn.us

Nitrogen in Minnesota

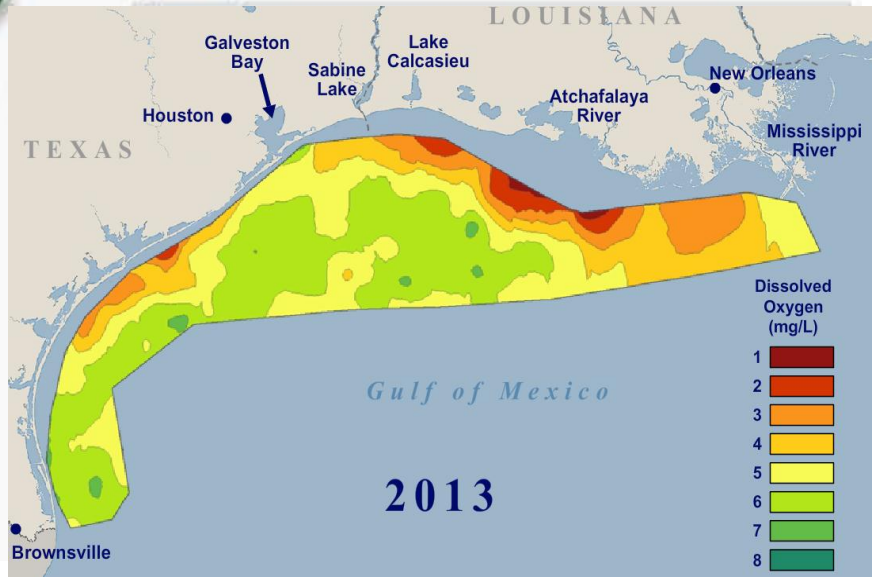


Nitrate concentrations
www.pca.state.mn.us

- Large amounts of nitrogen fertilizer applied to agricultural land in Southern MN
- More than 70% of nitrate in MN is coming from cropland
- MN is one of the largest exporters of nitrate to the Mississippi River
- High nitrate loads in the Mississippi River is a leading cause of the hypoxic dead zone in the Gulf of Mexico

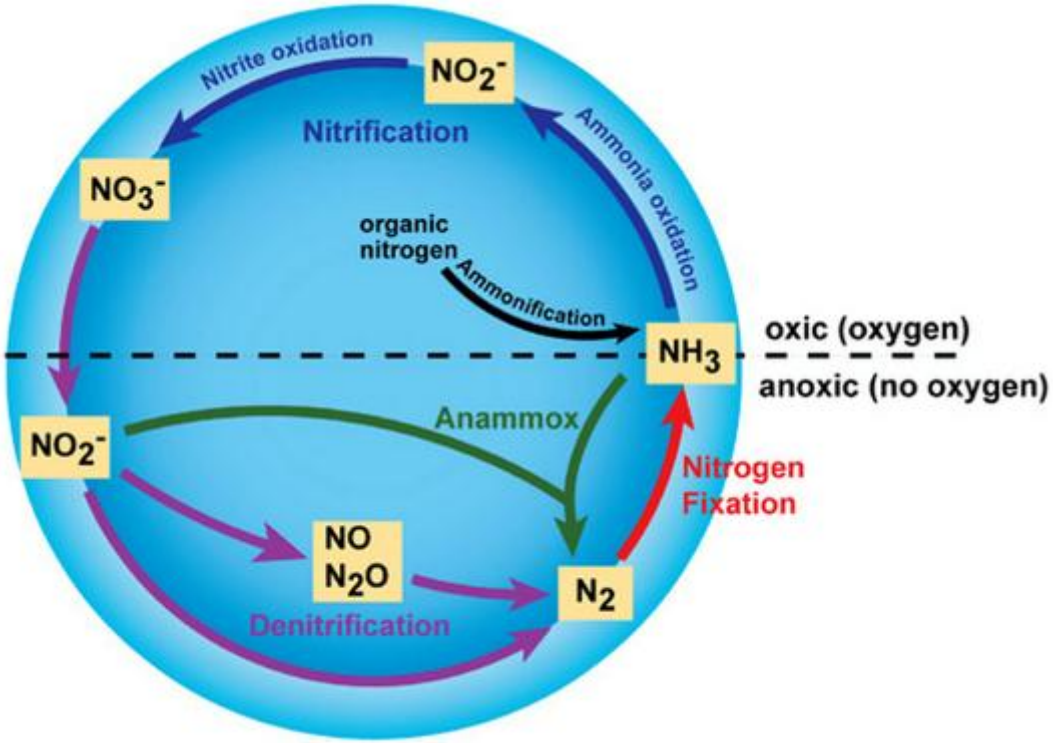

2002-2011
Nitrate + Nitrite (mg/L)
0
10
20
30
40
50
2
3
4
5
6
7
8
9
10
11
Month

Highest Risk Of


LOUISIANA
Galveston Bay
Sabine Lake
Lake Calcasieu
New Orleans
Houston
Atchafalaya River
Mississippi River
TEXAS
Dissolved Oxygen (mg/L)
1
2
3
4
5
6
7
8
Gulf of Mexico
2013
Brownsville

Microbial Denitrification

Complete denitrification acts as a nitrate sink in aquatic systems, releasing N_2 to the atmosphere



www.nature.com

Denitrification Hot Spots and Hot Moments

Patches/intervals of **increased denitrification rates** relative to surrounding regions/time periods

Hot spot formation formed by the convergence of ideal:

- Nitrate
- Organic carbon
- Anoxic sediments
- Fluid-flow residence time
- Established bacterial community

Overall Project Goals

- Identify and quantify the predominate parameters that control microbial denitrification
- Determine how these parameters affect the microbiological community and lead to denitrification hot spots
- Establish a set of management guidelines to promote denitrification hot spots

Denitrifying Gene Abundance

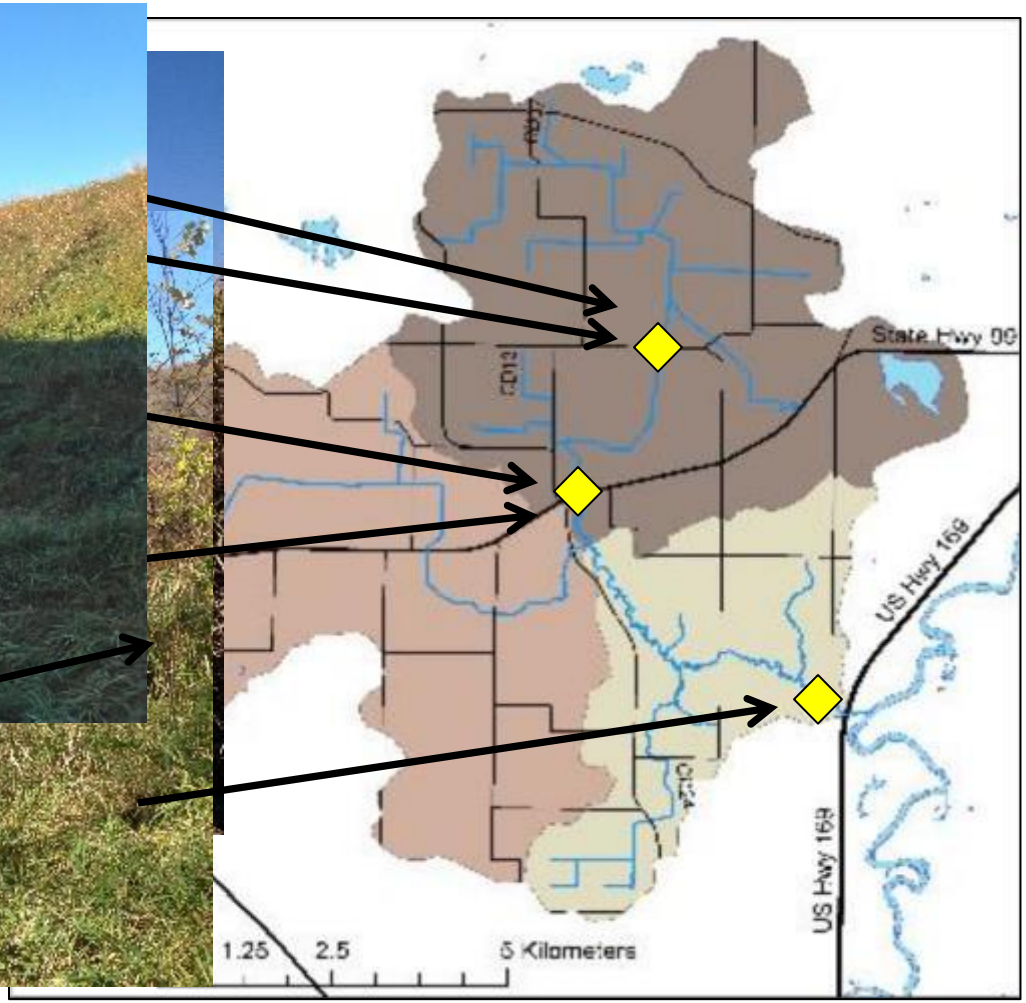
- DNA extraction and qPCR to quantify the amount of denitrifying genes in soil samples

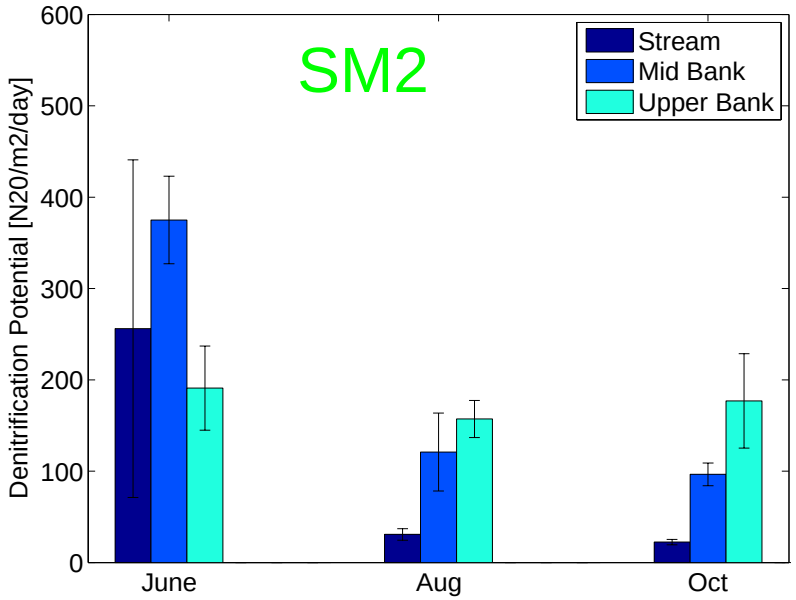
Max Planck Institute for Marine Microbiology, 2014

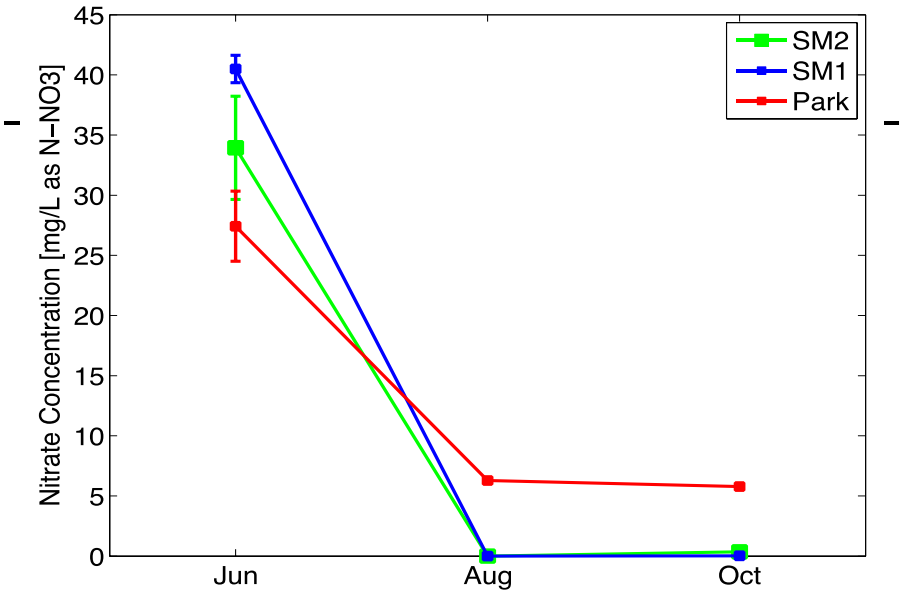
Measuring Denitrification Potential

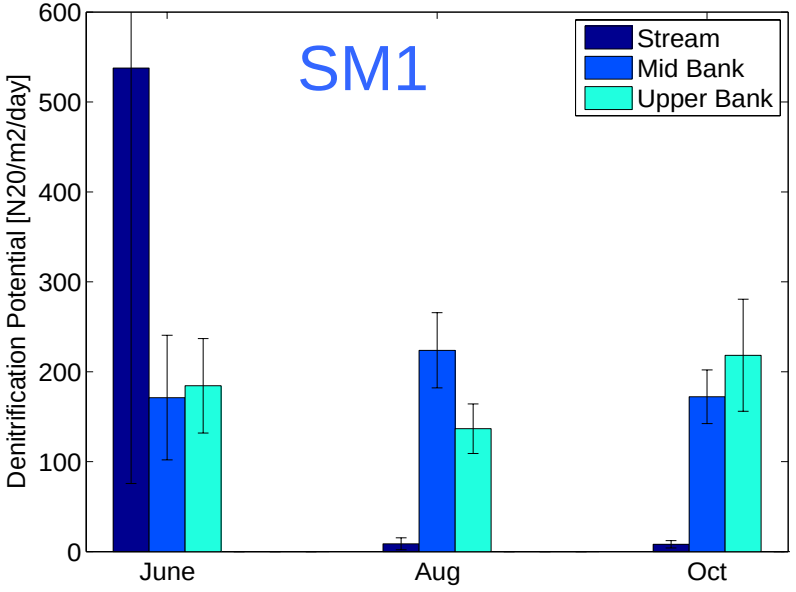
$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$$

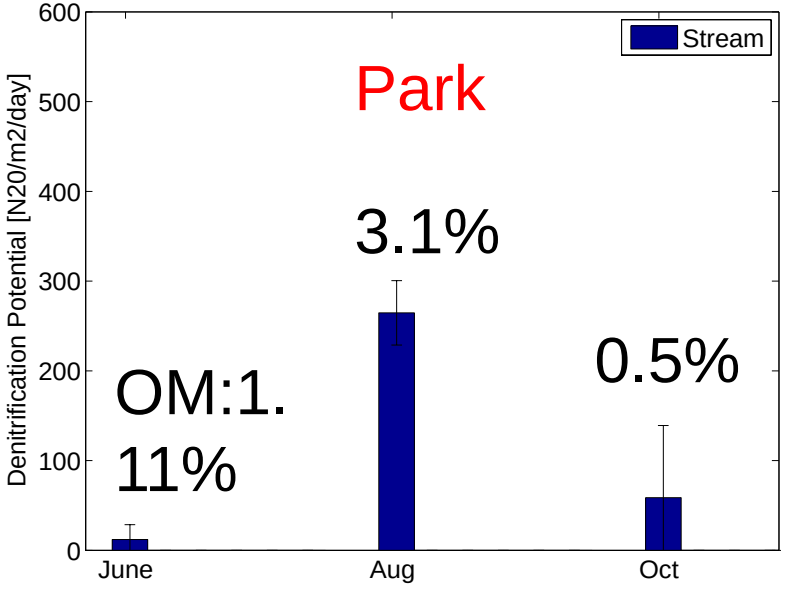
Seven Mile Creek




SM2
Stream
Mid Bank
Upper Bank
Denitrification Potential [N20/m2/day]
600
500
400
300
200
100
0
June
Aug
Oct


SM2
SM1
Park
Nitrate Concentration [mg/L as N–NO3]
45
40
35
30
25
20
15
10
5
0
Jun
Aug
Oct


SM1
Stream
Mid Bank
Upper Bank
Denitrification Potential [N20/m2/day]
600
500
400
300
200
100
0
June
Aug
Oct


Park
Stream
Denitrification Potential [N20/m2/day]
600
500
400
300
200
100
0
OM:1.
11%
3.1%
0.5%
June
Aug
Oct

SM2

June

October

Park

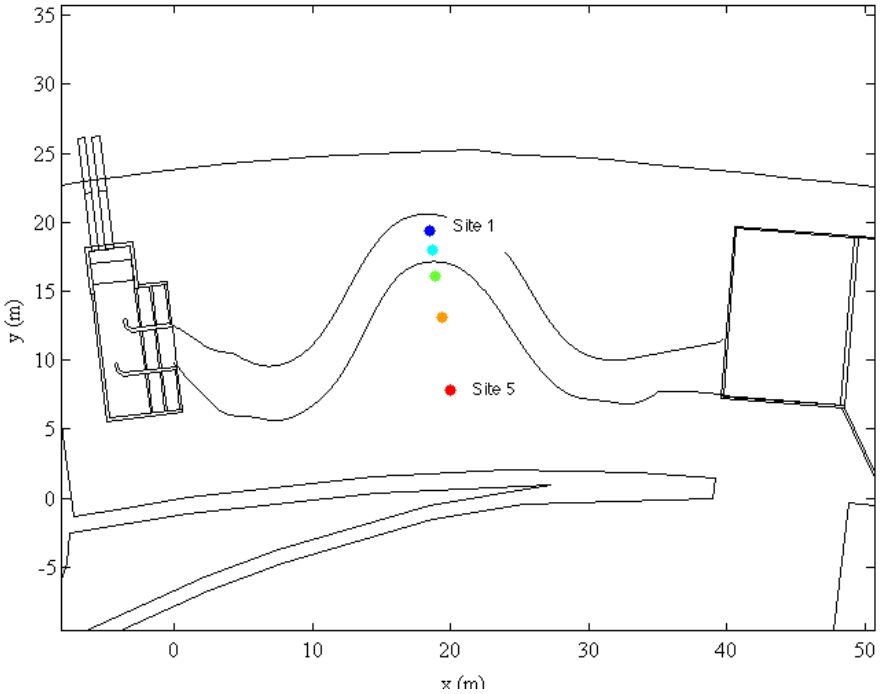
June

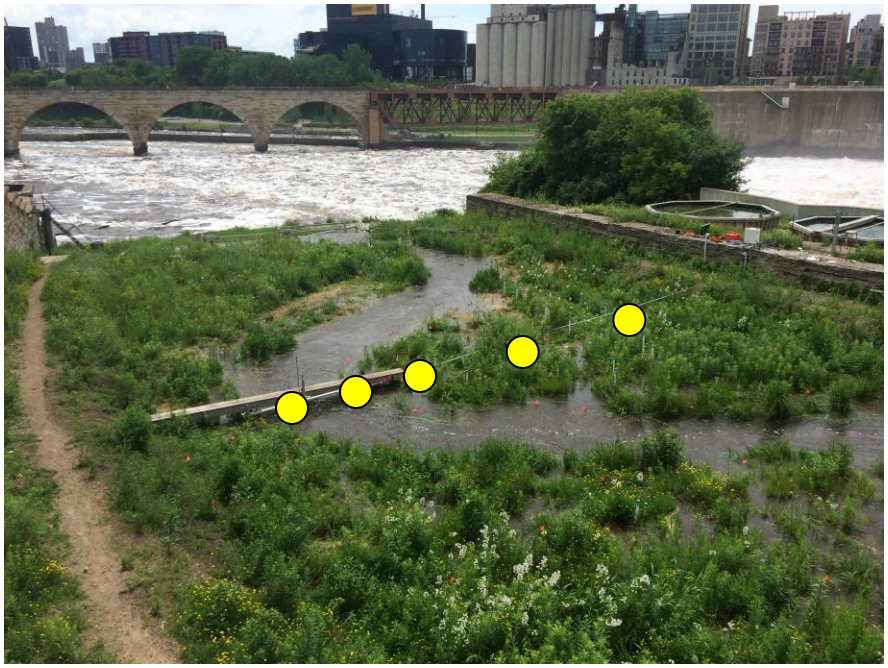
October

Outdoor StreamLab

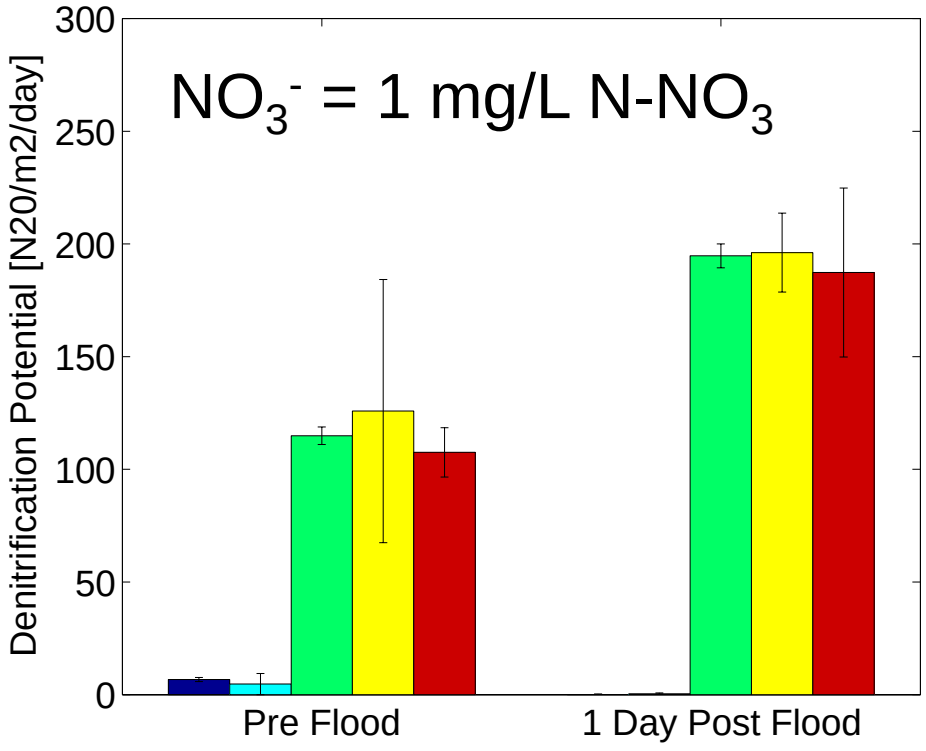
Outdoor StreamLab Experiments

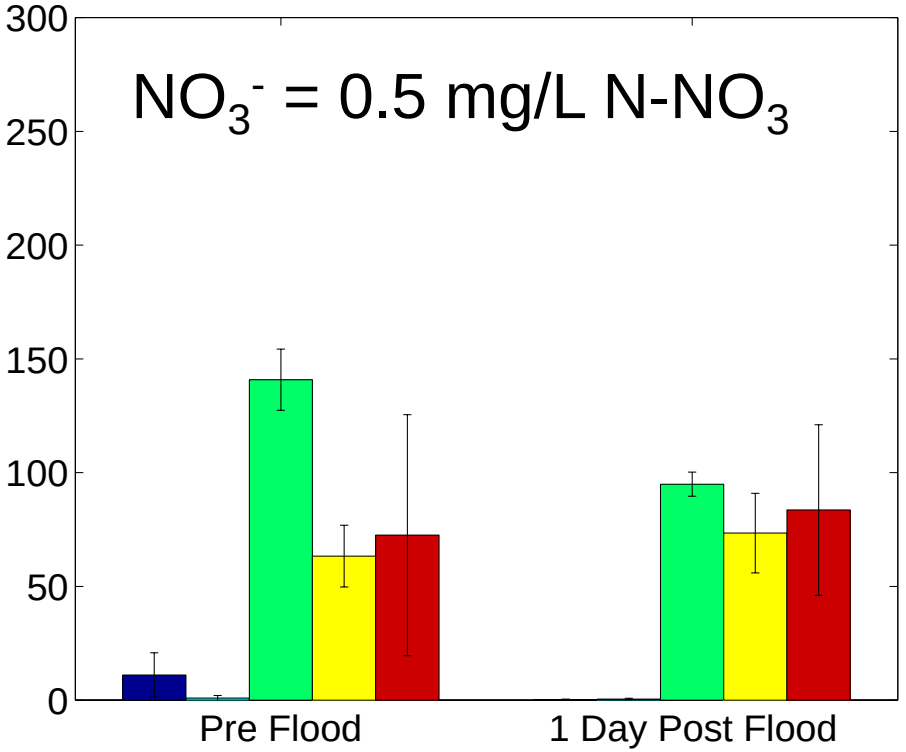
- Entire floodplain of OSL was flooded twice
- Samples taken immediately before flooding, immediately after, 1 day after and 3 days after

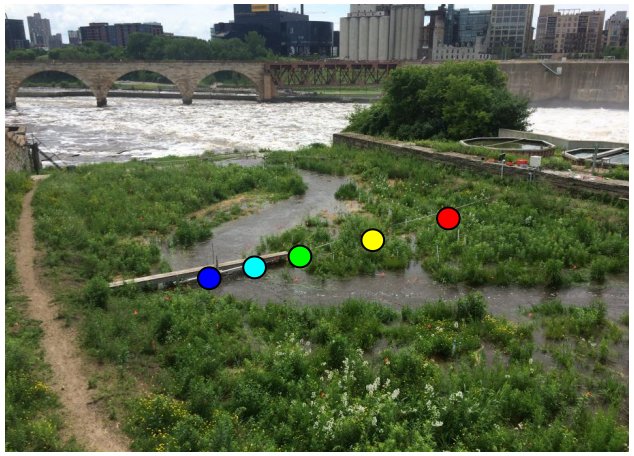




OSL Floods


NO_3^- = 1 mg/L N-NO_3
Denitrification Potential [N20/m2/day]
300
250
200
150
100
50
0
Pre Flood
1 Day Post Flood


NO_3^- = 0.5 mg/L N-NO_3
300
250
200
150
100
50
0
Pre Flood
1 Day Post Flood

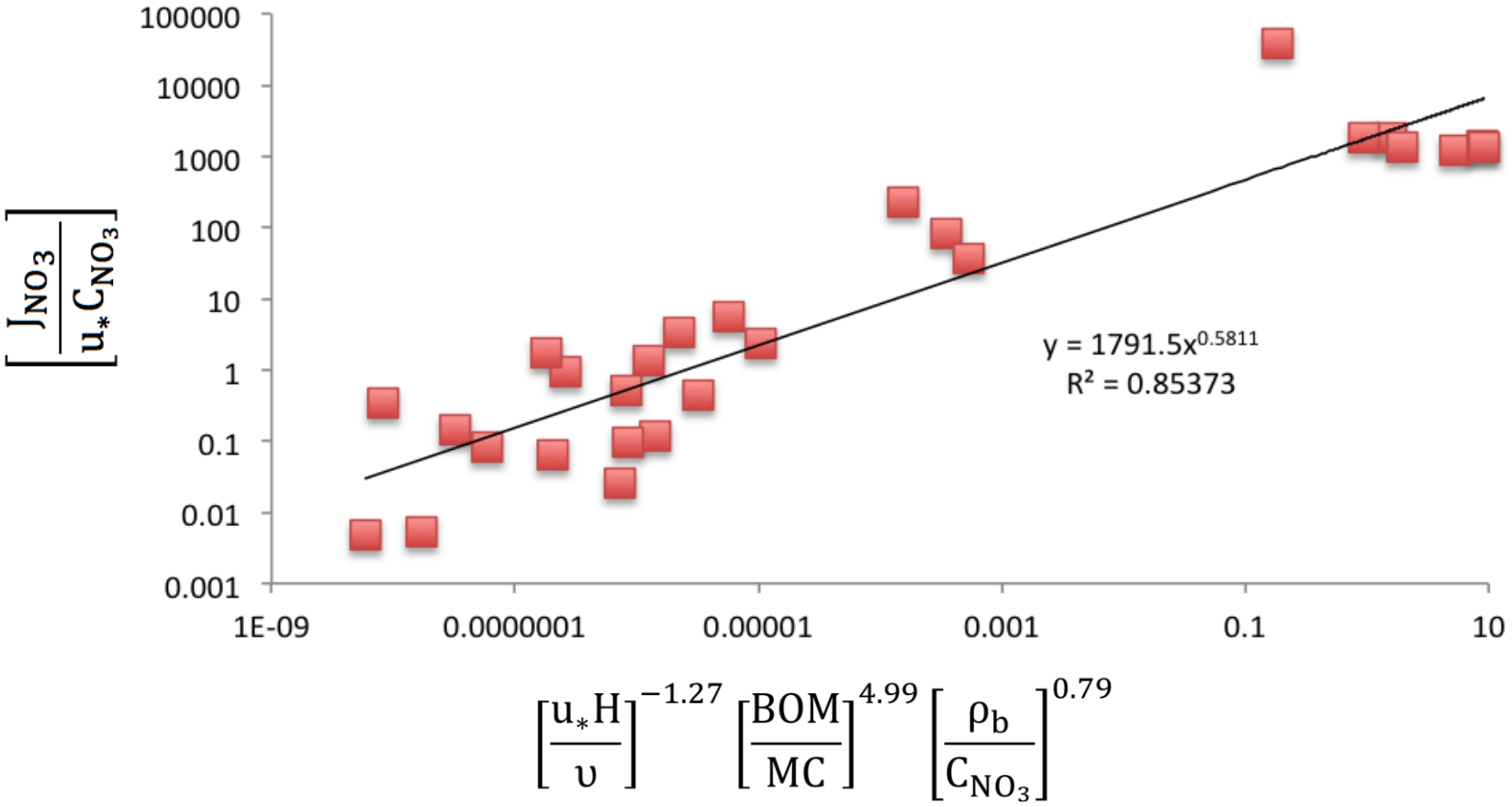


Bringing it all Together: Dimensional Analysis

	Bulk Density (ρ_b)	Organic Matter (BOM)	Moisture Content (MC)	Shear Velocity (u_*)	Nitrate Concentration (C_{NO3})
Potential Denitrification (J_{NO3})	-	+	+	-	+

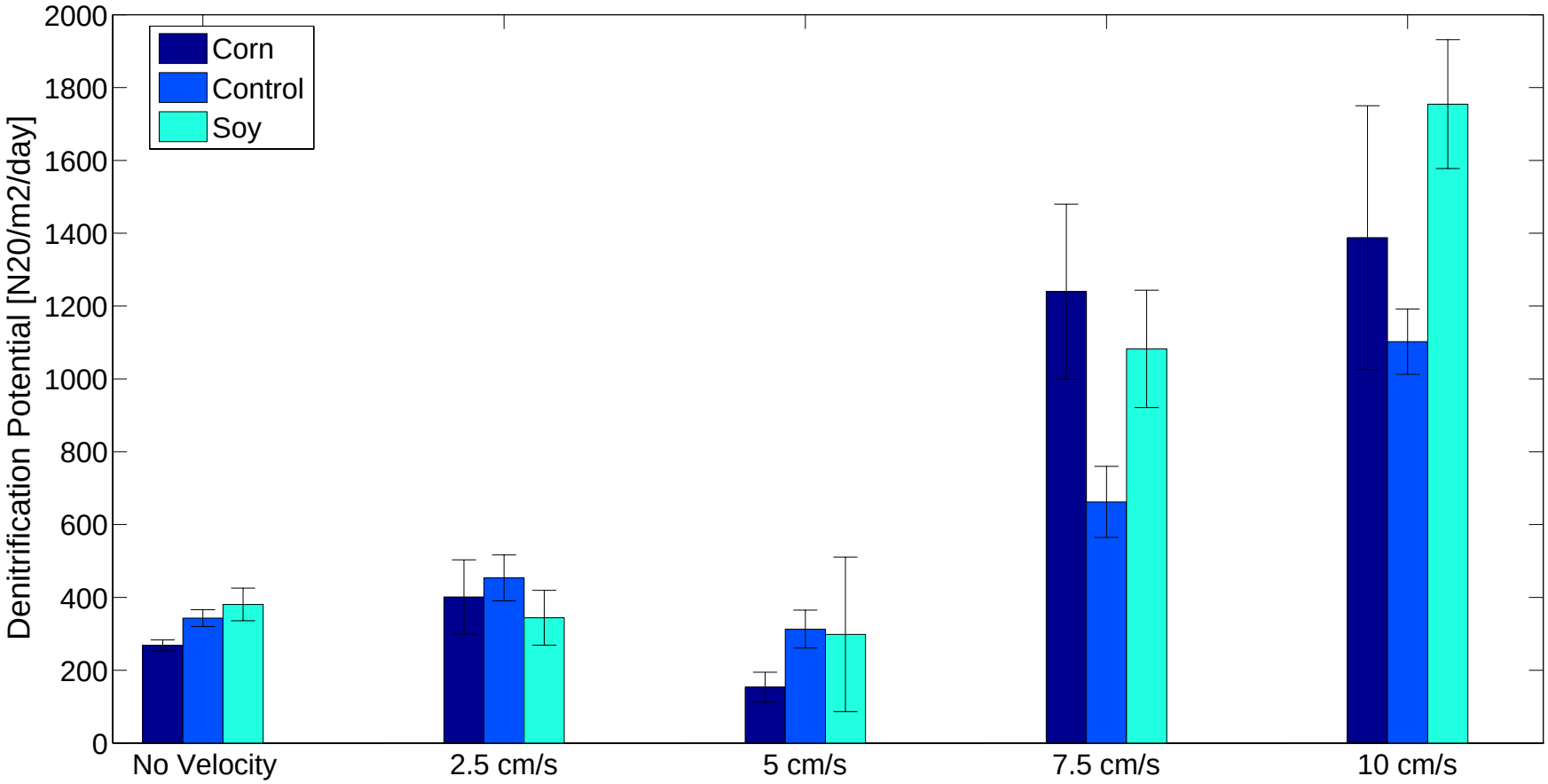
$$\left[\frac{J_{NO_3}}{u_* C_{NO_3}}\right] = 10^{3.25}\left[\left[\frac{u_* H}{\upsilon}\right]^{-1.27}\left[\frac{BOM}{MC}\right]^{4.99}\left[\frac{\rho_b}{C_{NO_3}}\right]^{0.79}\right]^{0.58}$$

Overall Relationship



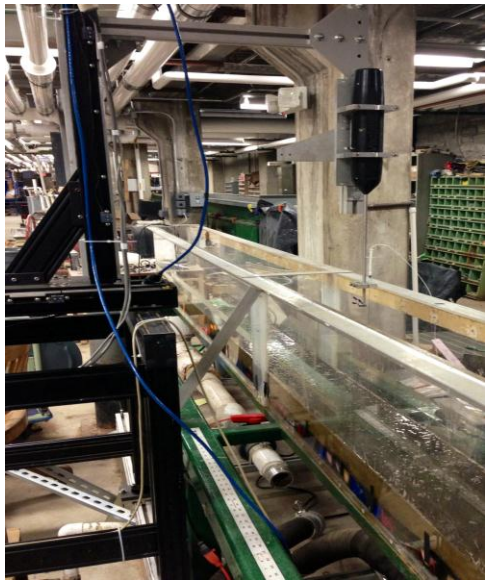
$$\left[\frac{u_* H}{\upsilon}\right]^{-1.27} \left[\frac{BOM}{MC}\right]^{4.99} \left[\frac{\rho_b}{C_{NO_3}}\right]^{0.79}$$

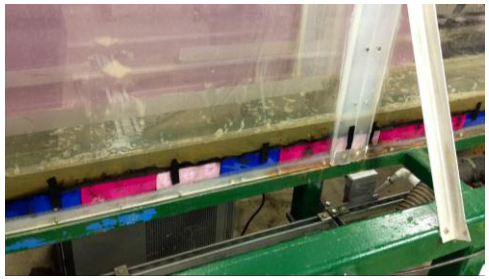
Potential Denitrification - Flume



Future Work

- Microbial work
- Laboratory flume experiments
- More field data collection
- Additional OSL flood experimets
- Small-scale basin studies in OSL





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- Laboratory: Sandy Brovold, Kurt Spokas and Martin du Saire

Questions?

Please contact me with questions or comments!

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