Assessment and restoration of riparian processes in urban watersheds

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and

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Outline:

- Urbanization effects on riparian zones.
- Are detention basins the new riparian zone?
- Does stream and riparian restoration have a nitrogen benefit.
- Evaluating riparian zones at the watershed scale.

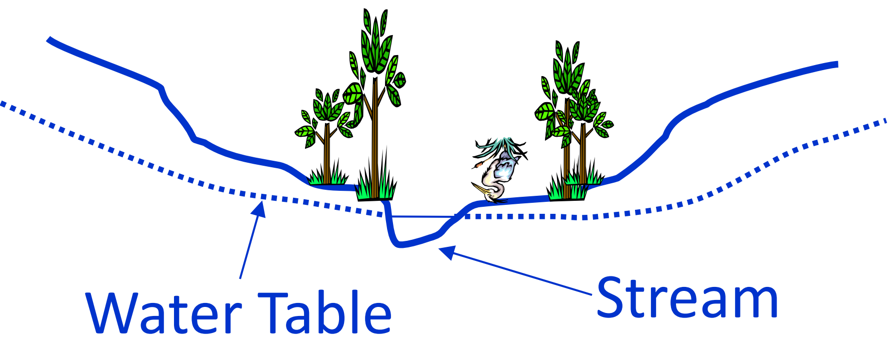
RIPARIAN ZONES:

- Critical interface between terrestrial and aquatic components of a watershed.

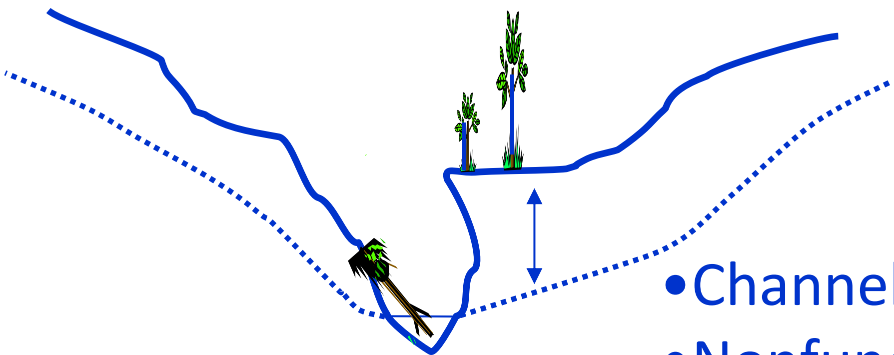
- Demonstrated ability to prevent pollutant movement from upland land uses into streams.

- Most work on groundwater nitrate, in agricultural watersheds.

Natural Channel



Channel with Incision Due to Increased Runoff

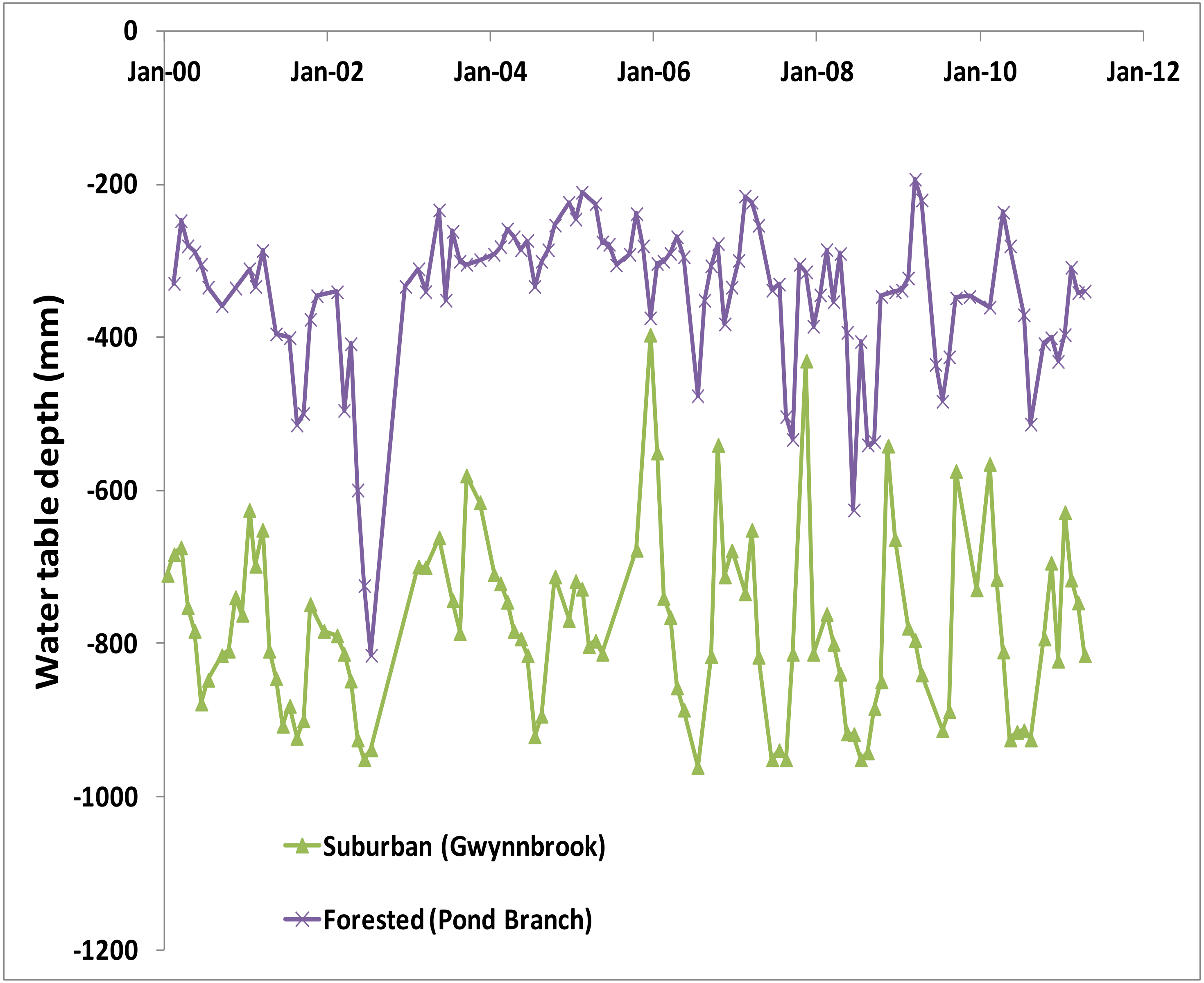


- Channel Erosion
- Nonfunctional Floodplain
- Dry Riparian Soils

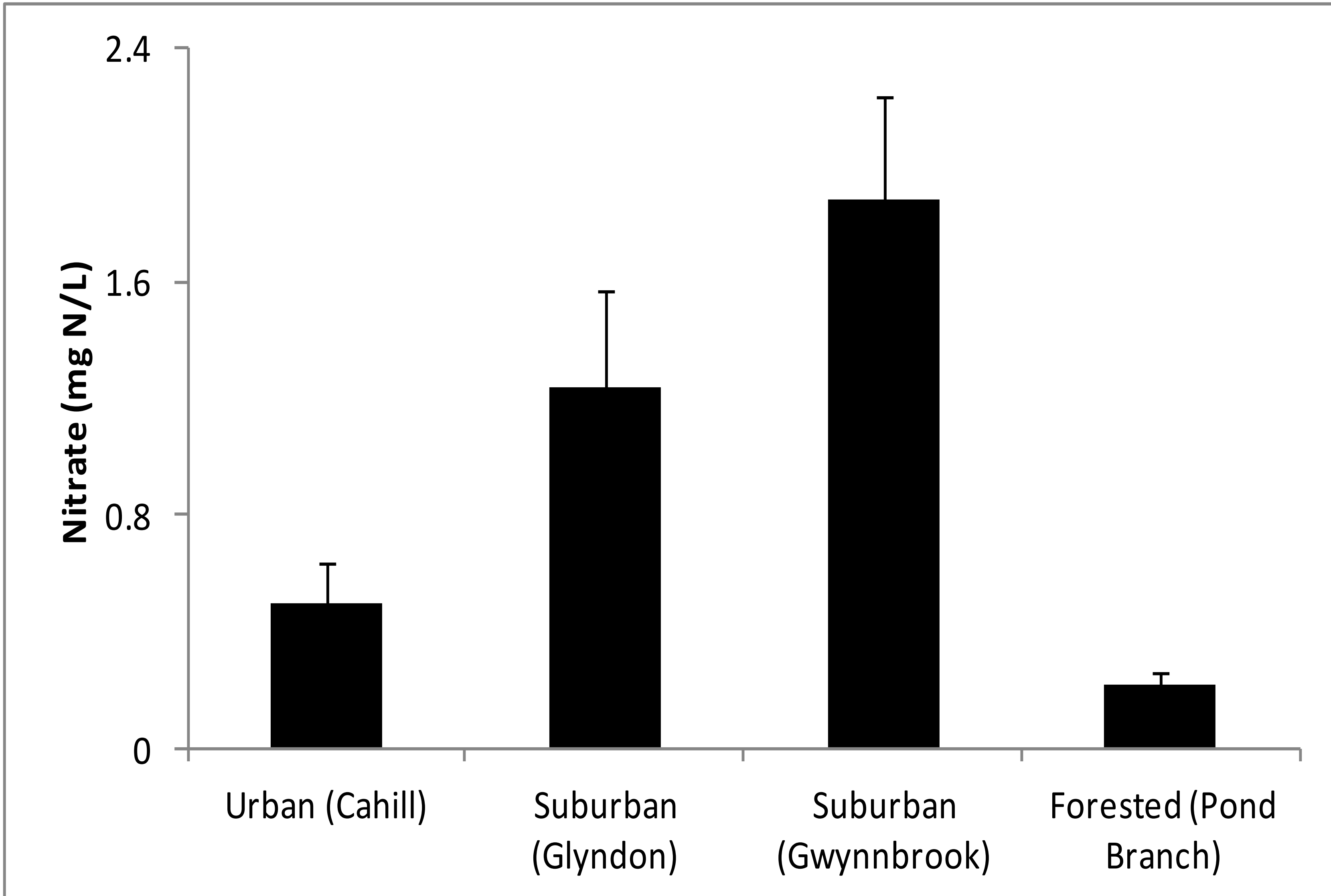
- Urban stream syndrome:
  - High storm flows.
  - Incised channels.
  - Drier riparian zones with lower water tables.

Urban stream syndrome:

Urban stream syndrome results in drier soils and lower water table in riparian zone:



Urban stream syndrome results in higher groundwater nitrate in riparian zone:



Denitrification

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

- Anaerobic
- Heterotrophic (requires organic C)

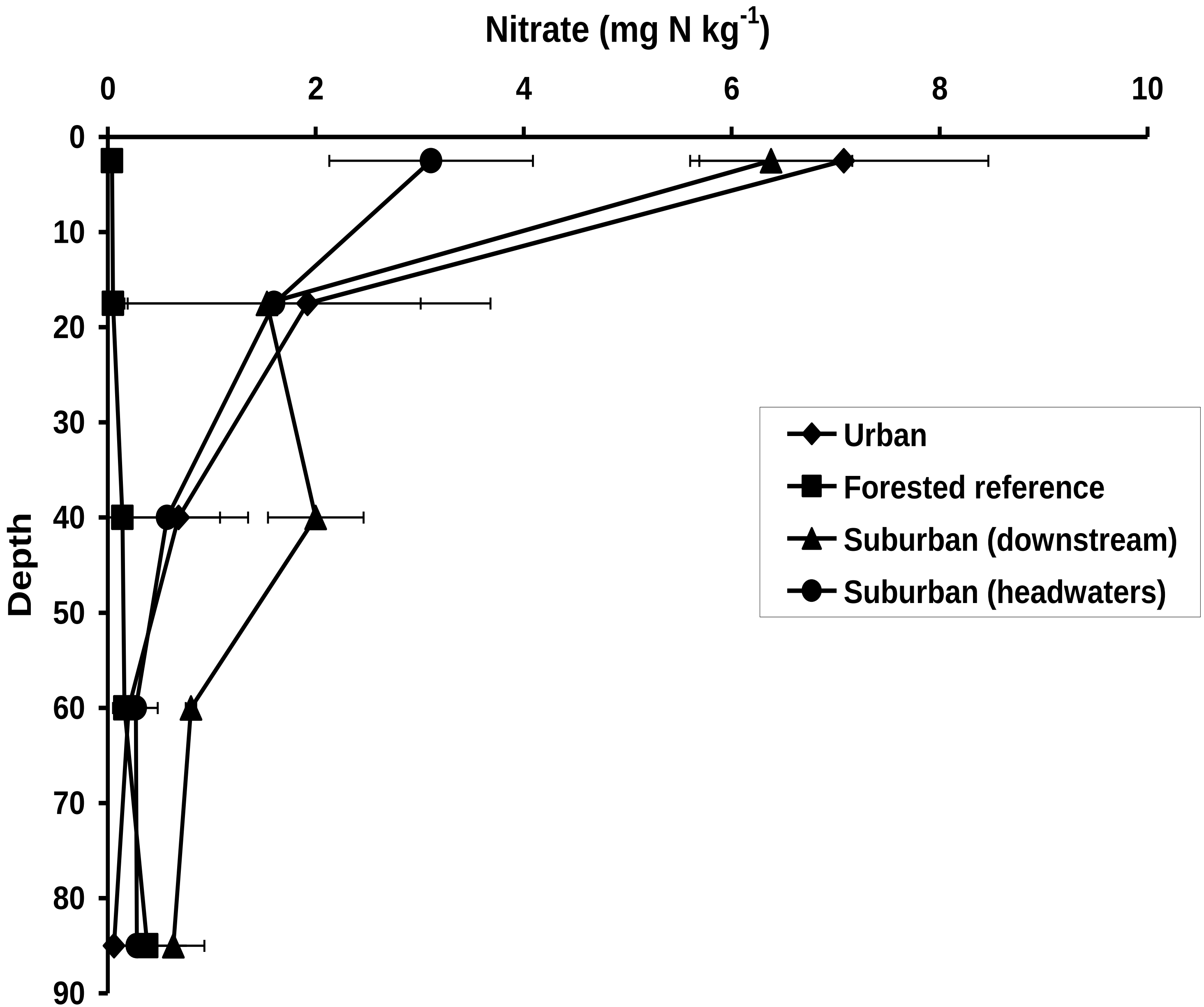
- Expect high rates in wetland soils.
- Key component of the water quality maintenance function of riparian zones.

Nitrification

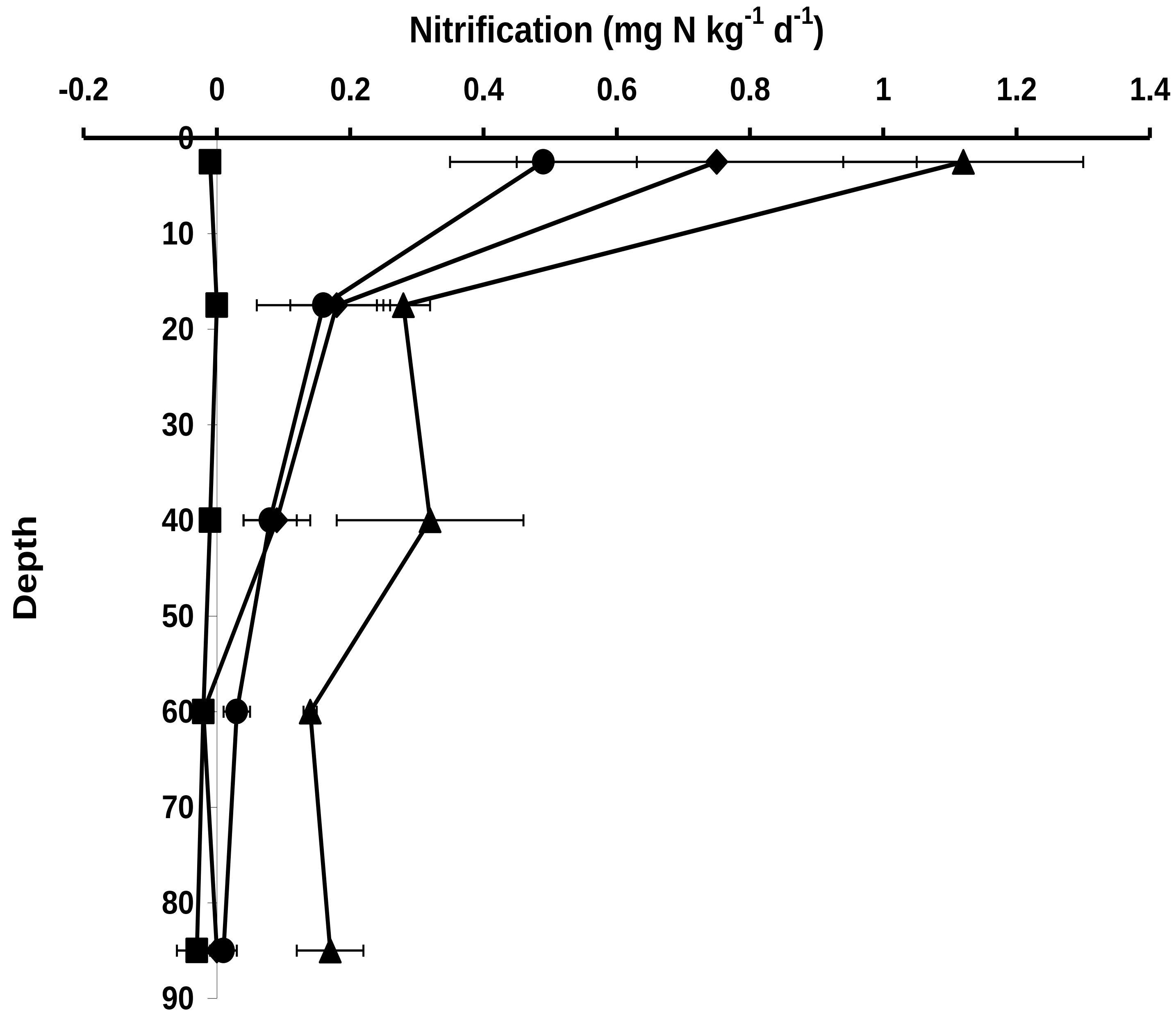
$NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$

- Aerobic
- Substrate driven (need high NH_4^+)

- Important internal source of nitrate in an ecosystem.
- Symptom of N richness or N saturation.



Source: Groffman et al. (2002)



Source: Groffman et al. (2002)

Are detention basins the new riparian zone?

- Stormwater structures (detention basins) are engineered to mitigate impact of impervious surfaces on stream discharge.
- Their impact on nutrients (especially nitrogen) in unclear.

Can you find the detention basins in this suburban landscape?

½ mile x ¾ mile area

Source: Neil Bettez

Can you find the detention basins in this suburban landscape?

½ mile x ¾ mile area

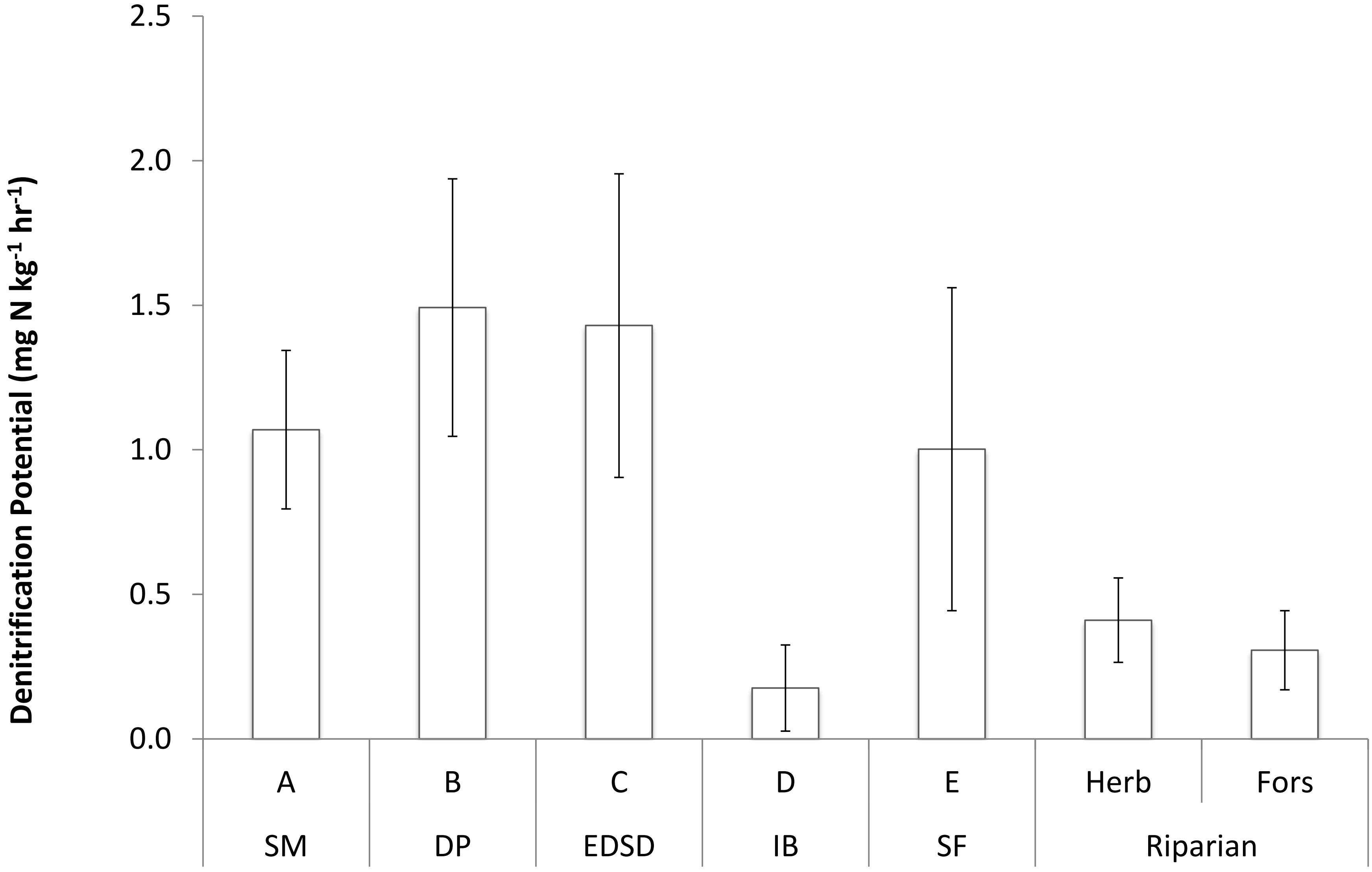
Source: Neil Bettez

Storm water Management Structures in the Gwynns Falls

Type	Structure Type (TN removal efficiency)	Count	Percent of total	Percent of Drainage Area	Area weighted removal	Type of Structure
A	Wet Ponds and Wetlands (30%)	23	3%	1	0.33	shallow marsh Retention Pond
B	Dry Detention & Hydrodynamic structure (5%)	275	33%	10	0.48	Bay Separator Oil & Grit Separator Still Basin Underground storage Detention Pond
C	Dry Extended Detention (30%)	272	33%	8	2.39	Dry Ext Detention Pond Ext Det Pond
D	Infiltration Practices (50%)	90	11%	0.34	0.14	Porous Pavement Swale Infiltration Trench Infiltration basin
E	Filtering Practices (40%)	167	20%	1.79	0.72	Dry Well BIO-Retention Sand filter

(Stormwater workgroup: BMP Pollutant Removal Efficiencies.PDF)

Denitrification potential higher in detention basins than in natural riparian zones:



Bettez and Groffman (2012)

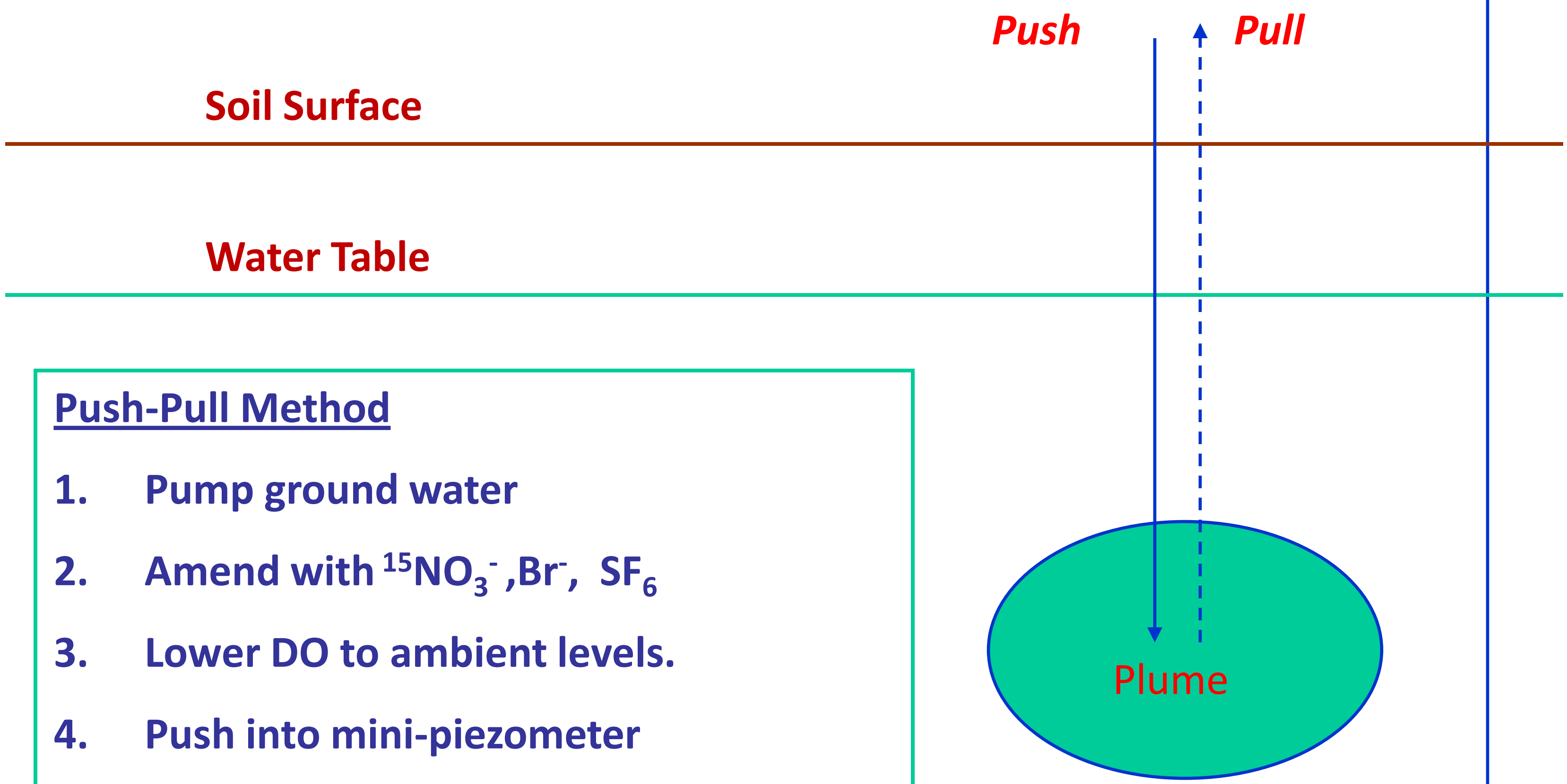
Is there a nitrogen benefit to stream and riparian restoration?

Restored Urban Stream: Early Stage

Restored Urban Stream: Developed Stage


Stable, unconnected floodplain


“ConnectedFloodplain

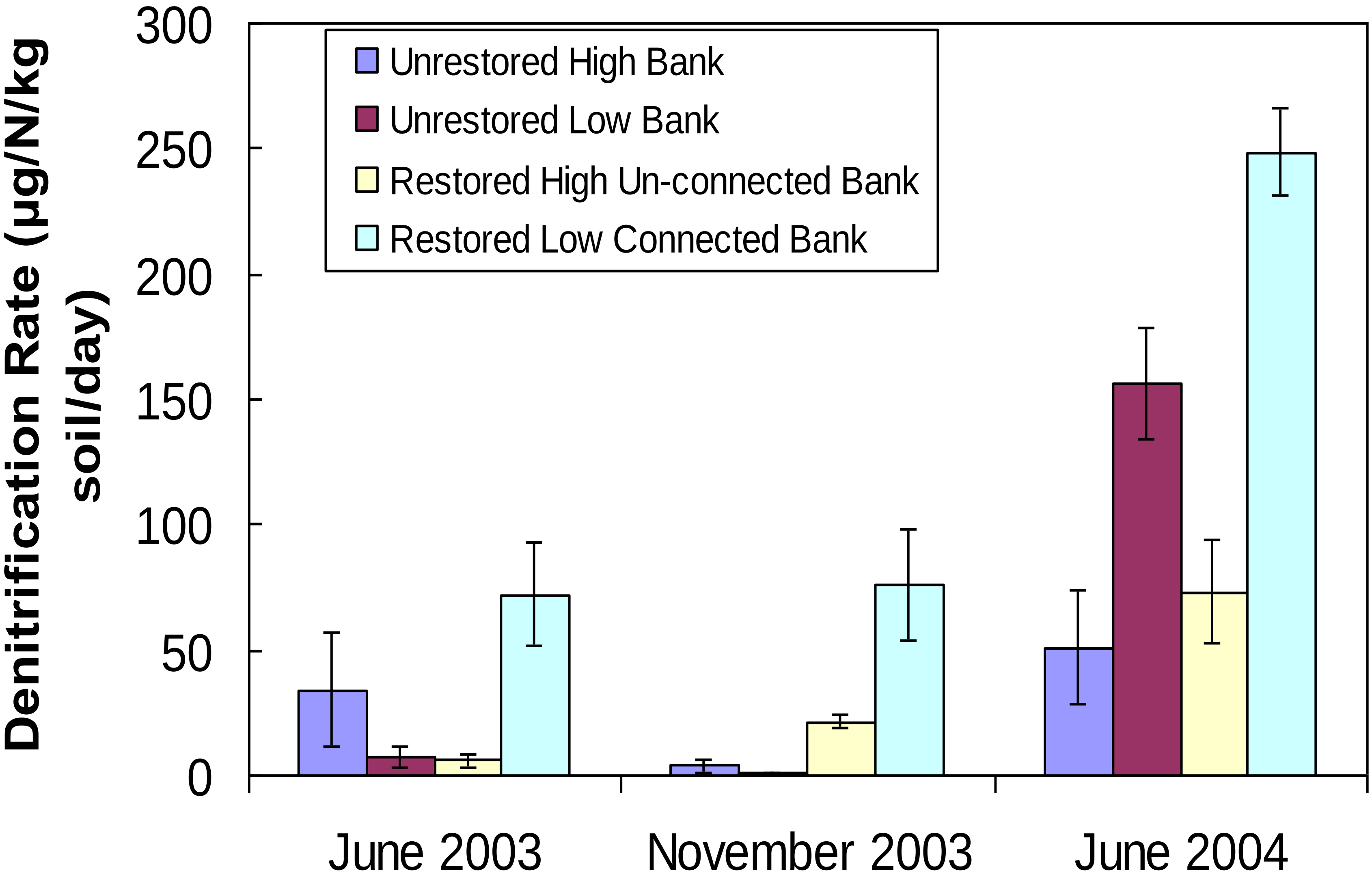


<u>Push-Pull Method</u>

1. **Pump ground water**
2. **Amend with $^{15}NO_3^-$, Br^-, SF_6**
3. **Lower DO to ambient levels.**
4. **Push into mini-piezometer**
5. **Incubate for 4 hours**
6. **Pull from mini-piezometer**

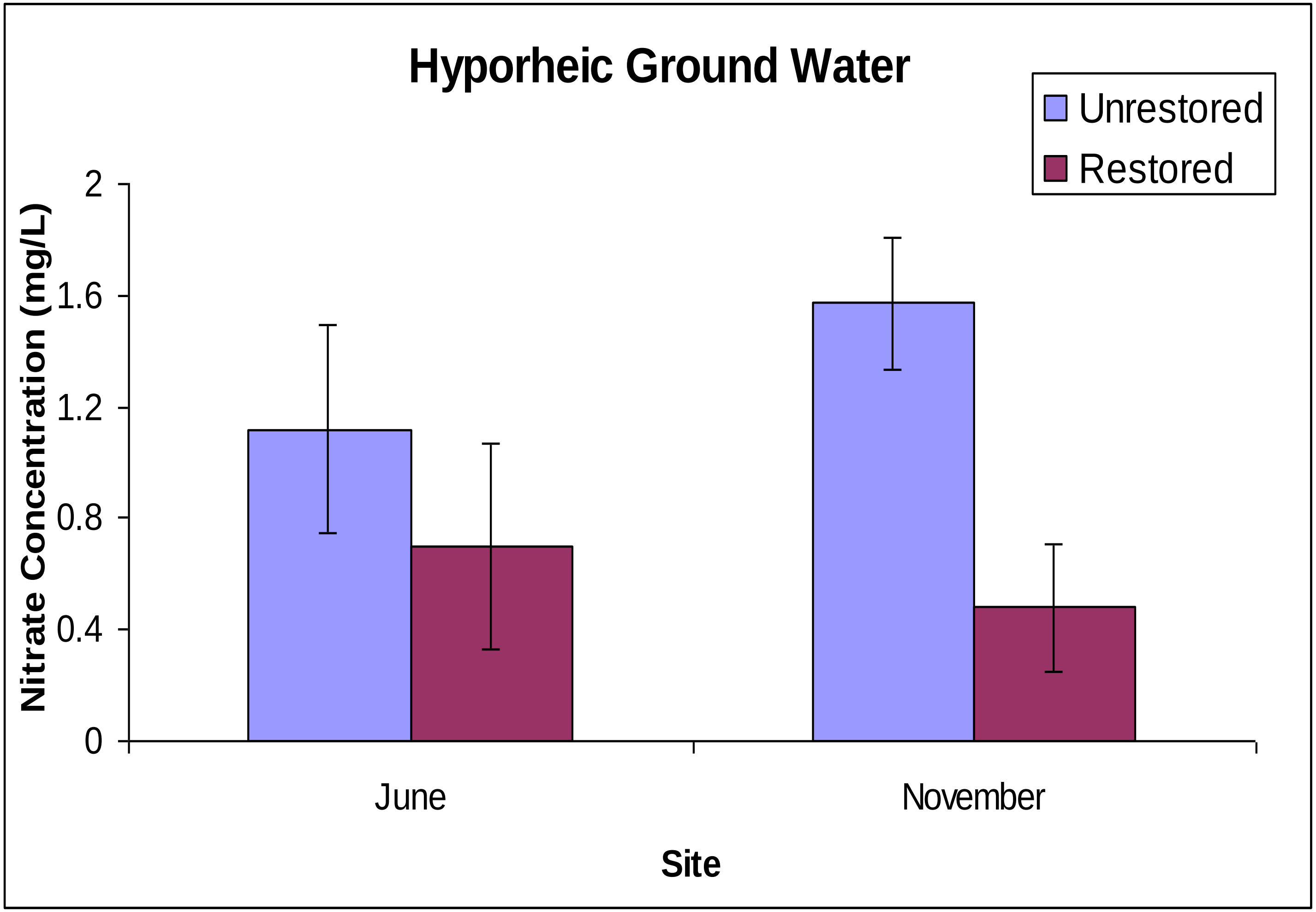
Addy et al. (2002)

Denitrification higher in restored, connected riparian zones:



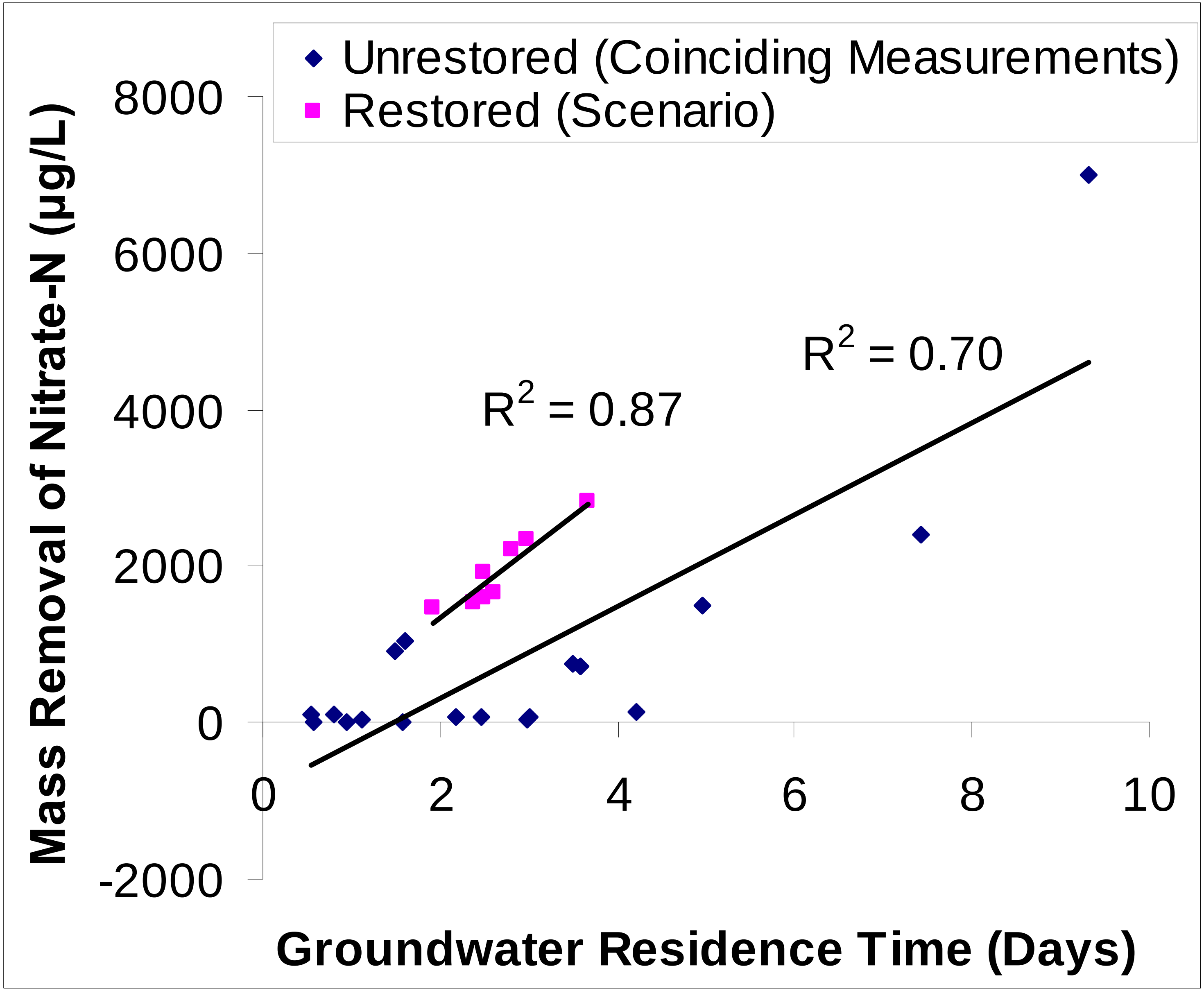
Kaushal et al. (2008)

Nitrate concentrations lower in restored hyporheic zones:



Kaushal et al. (2008)

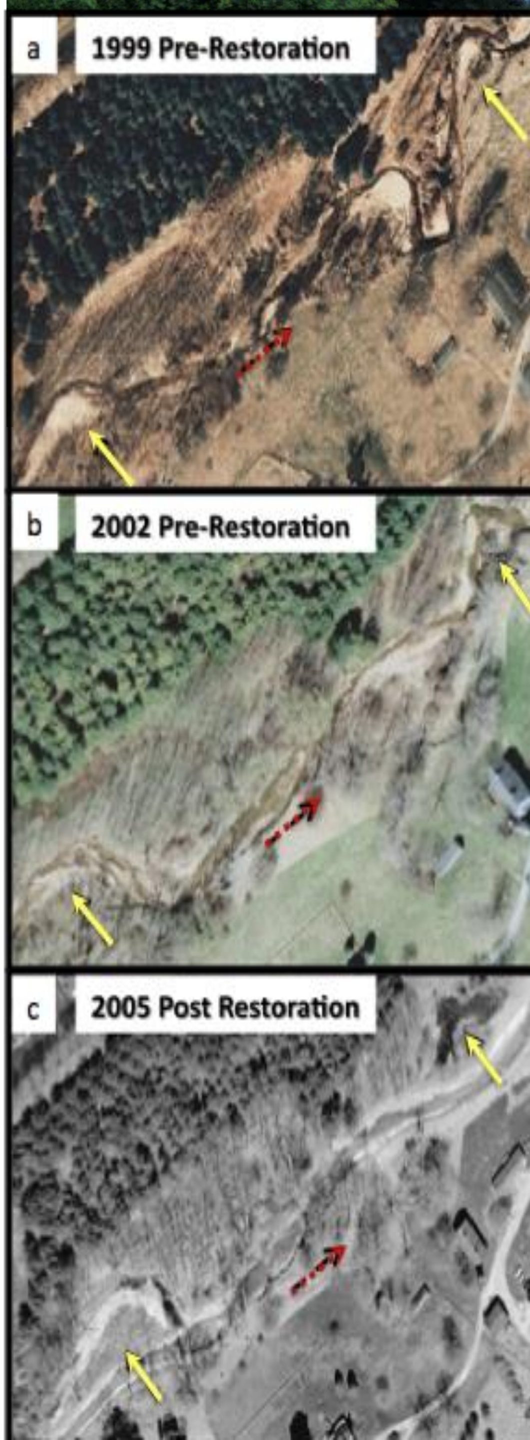
Nitrate dynamics improved in restored hyporheic zones:



Kaushal et al. (2008)

Can stream restoration create denitrification "hotspots" on the floodplain?

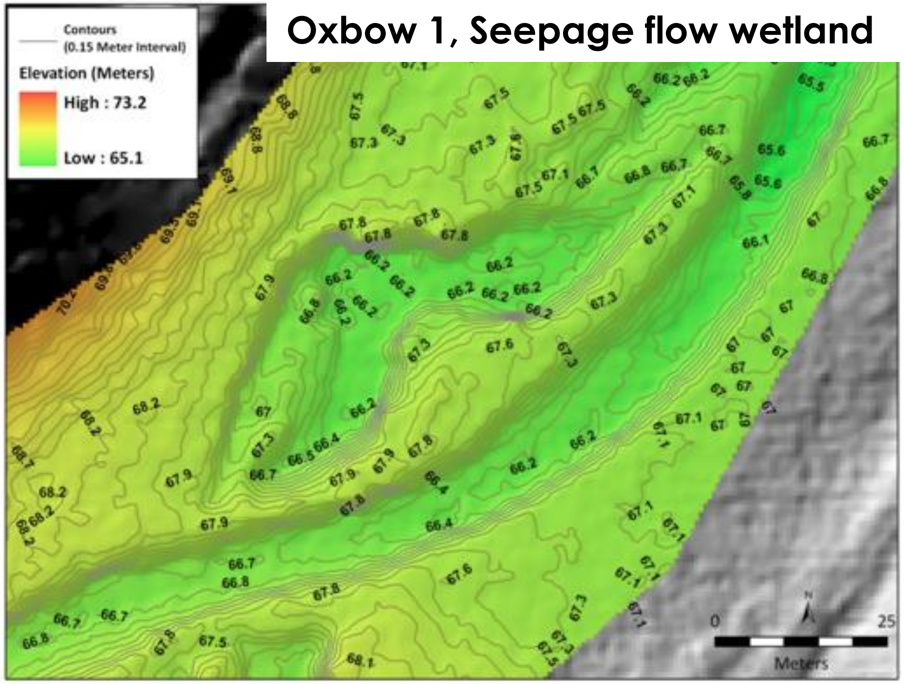
- Floodplain wetlands can be created deliberately or incidentally during stream restoration projects.
- These wetlands have the potential to serve as floodplain NO_3^- sinks if:
  - They process a significant amount of water.
  - With significant residence time.
  - With high denitrification.
  - With high plant (algae, macrophyte) uptake.

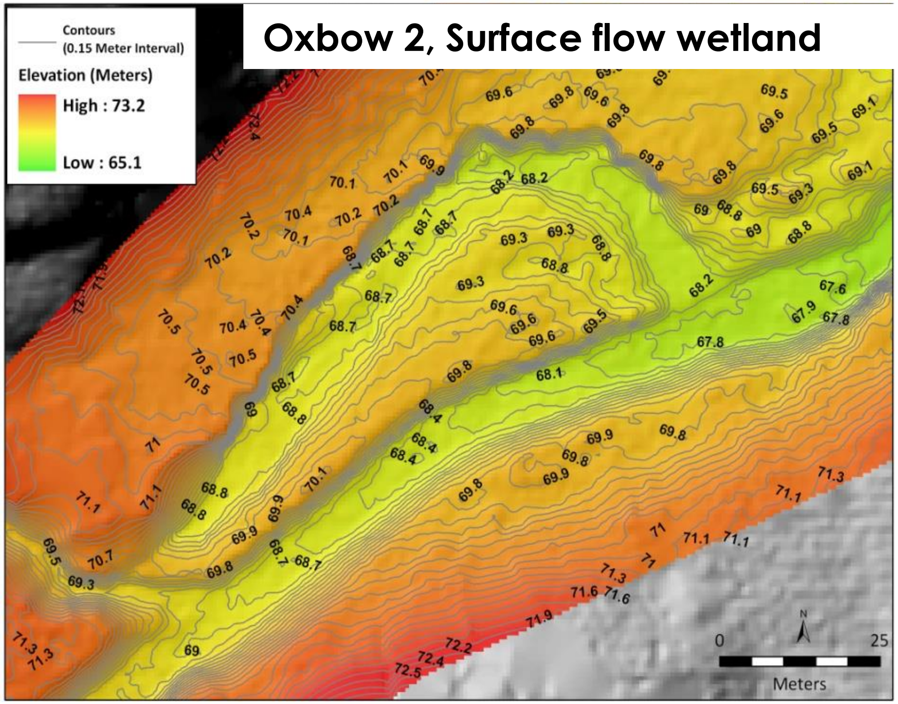


Minebank Run oxbow wetlands:

- Created incidentally during stream restoration.
- Vary in nature and extent of connectivity to the stream.
- Measurements of hydrology, denitrification, ^{15}N uptake by plants and algae, storm dynamics.

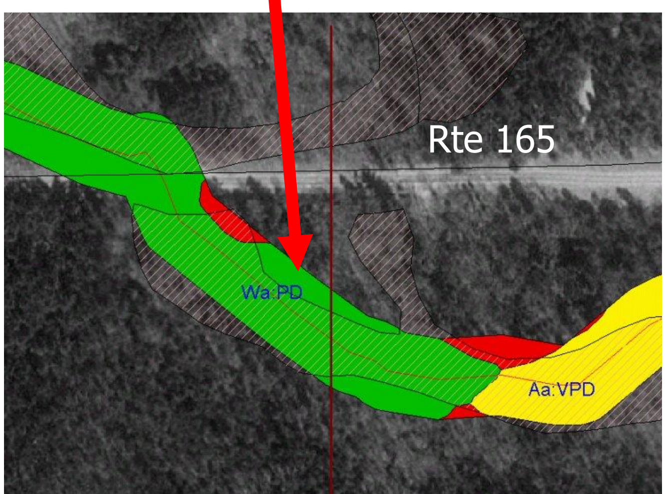
Harrison et al. (2011, 2012a,b, 2014)

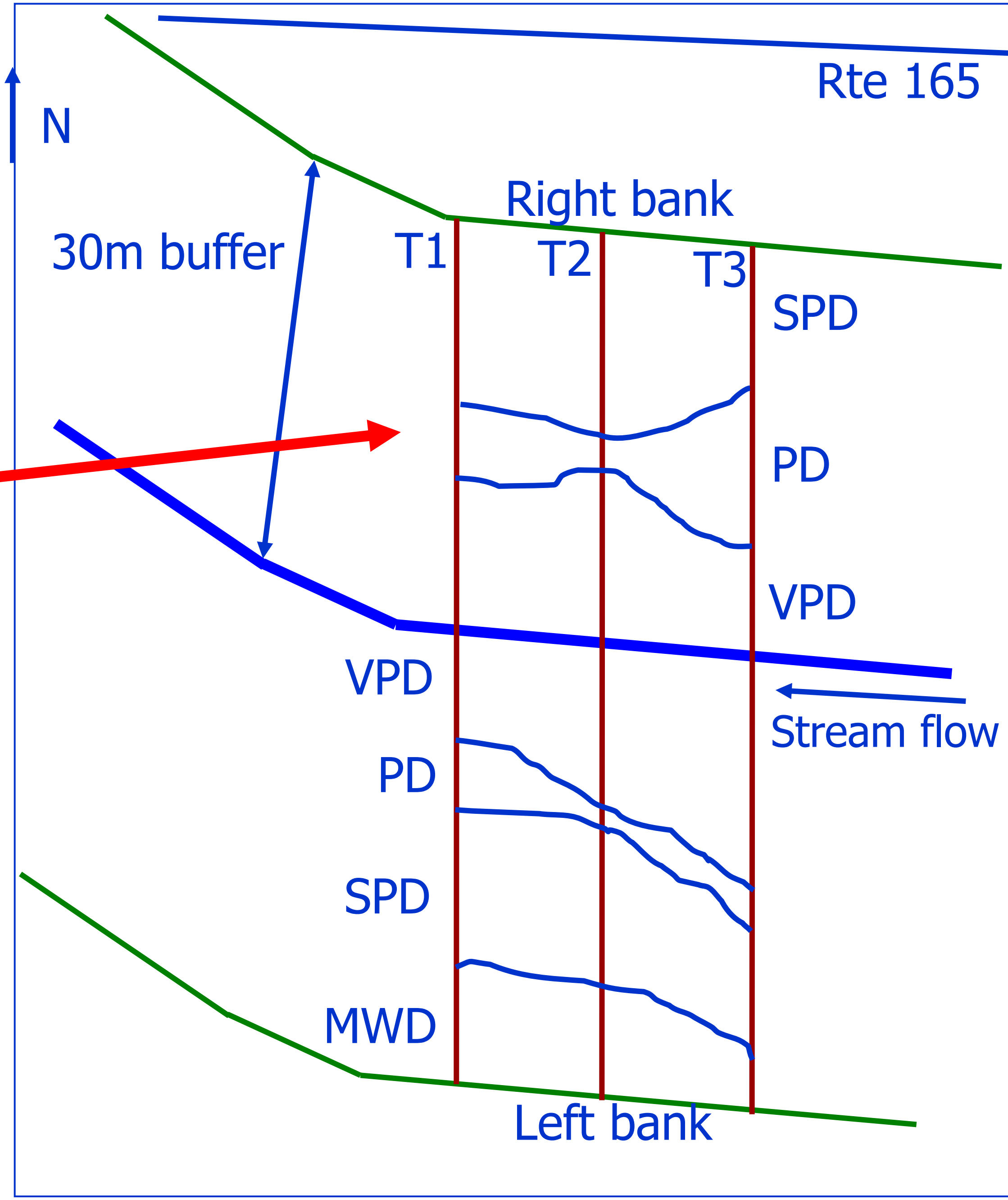




Can we assess riparian condition at the watershed scale:

- **Ground-truth map: 3-4 drainage classes**
- **Does SSURGO reflect this complexity?**

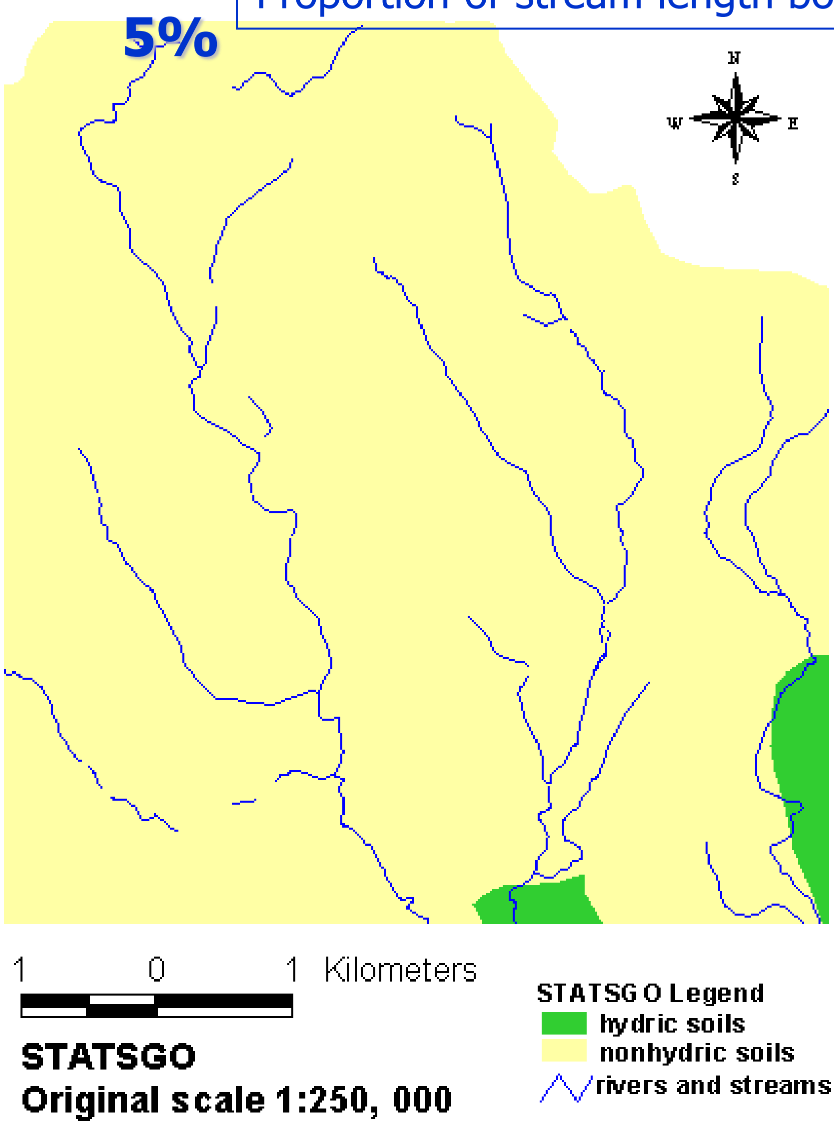


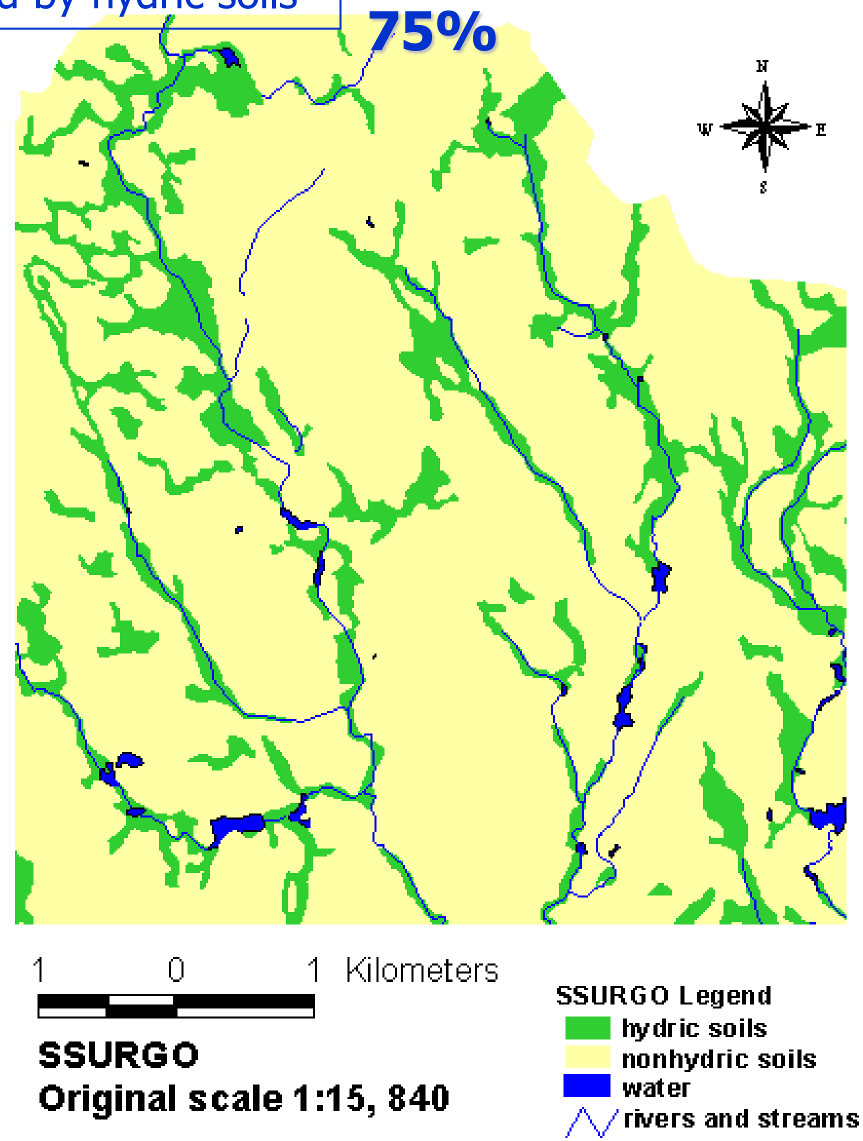


Source: Rosenblatt et al. (2001)

Original Scale of GIS Data Base Can Alter Inputs & Outputs to Watershed Models

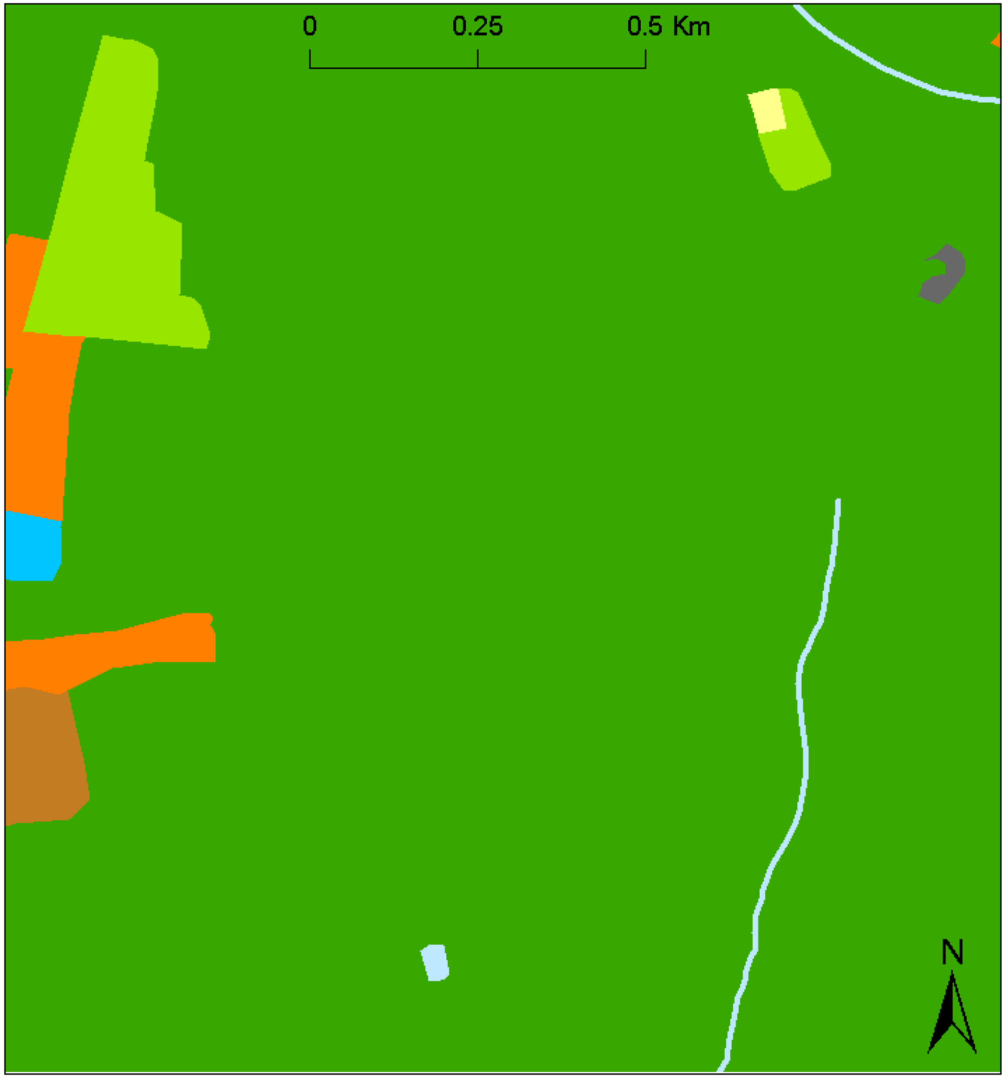
Proportion of stream length bordered by hydric soils





Source: Rosenblatt et al. (2001)

Scale/type of spatial data can mask or display pathways and sinks (*data: Kingston Quad-RI*)



Streams (1:24,000)

Ponds (1:24,000)

Forest / Open Space

Agriculture

Residential (low density)

Residential (med density)

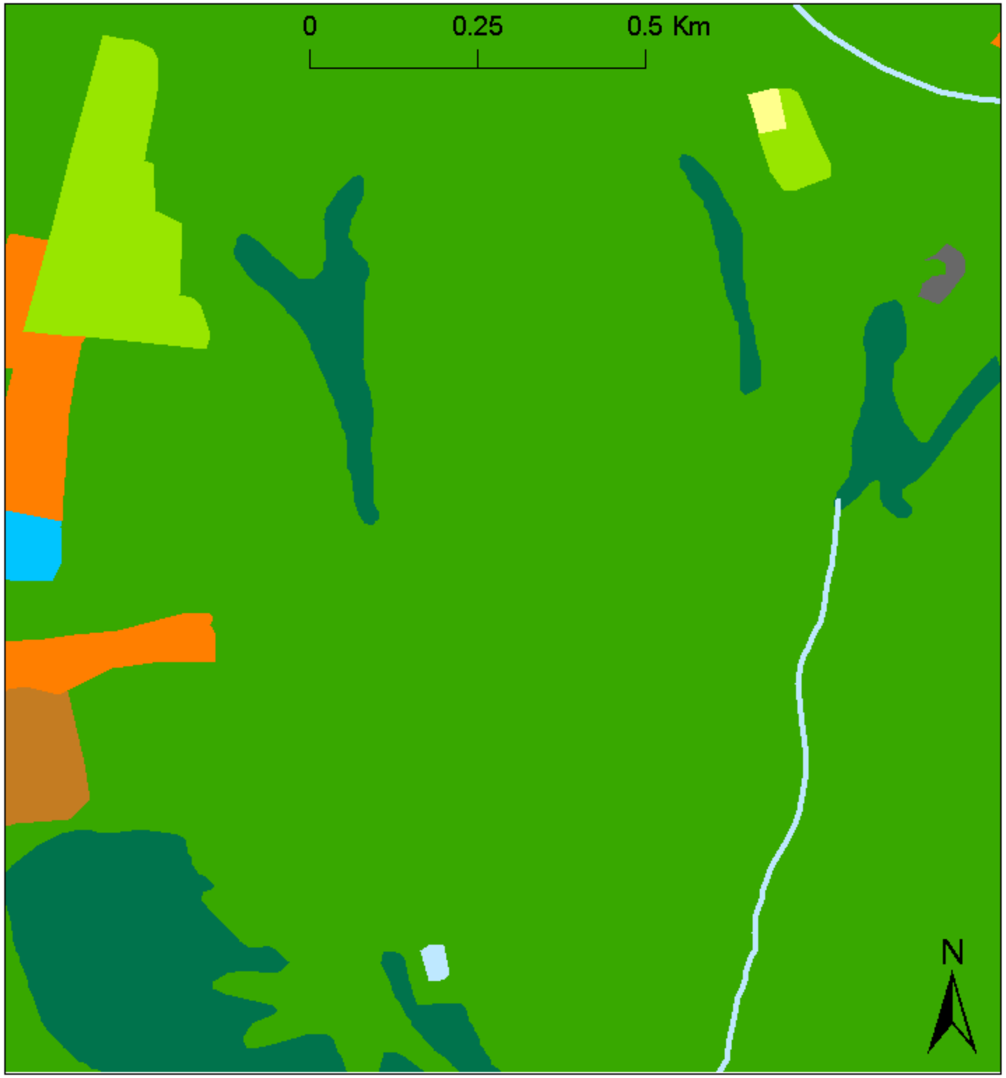
Res. (med high density)

Institutional

Gravel pits

Source: Groffman et al. (2009)

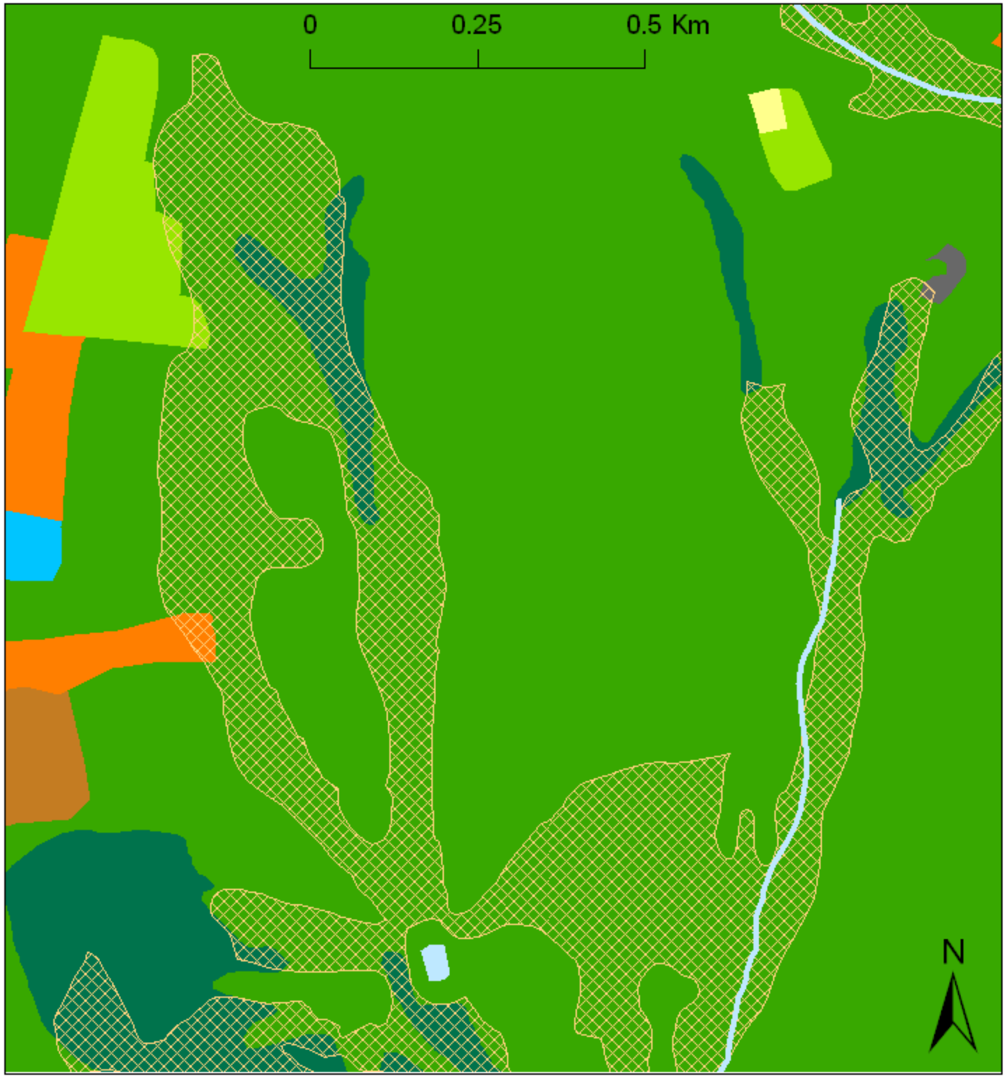
National Wetland Inventory (1:24,000) displays potential sinks



- Streams (1:24,000)
- Ponds (1:24,000)
- Forest / Open Space
- Agriculture
- Residential (low density)
- Residential (med density)
- Res. (med high density)
- Institutional
- Gravel pits
- **NWI Wetlands (1:24K)**

Source: Groffman et al. (2009)

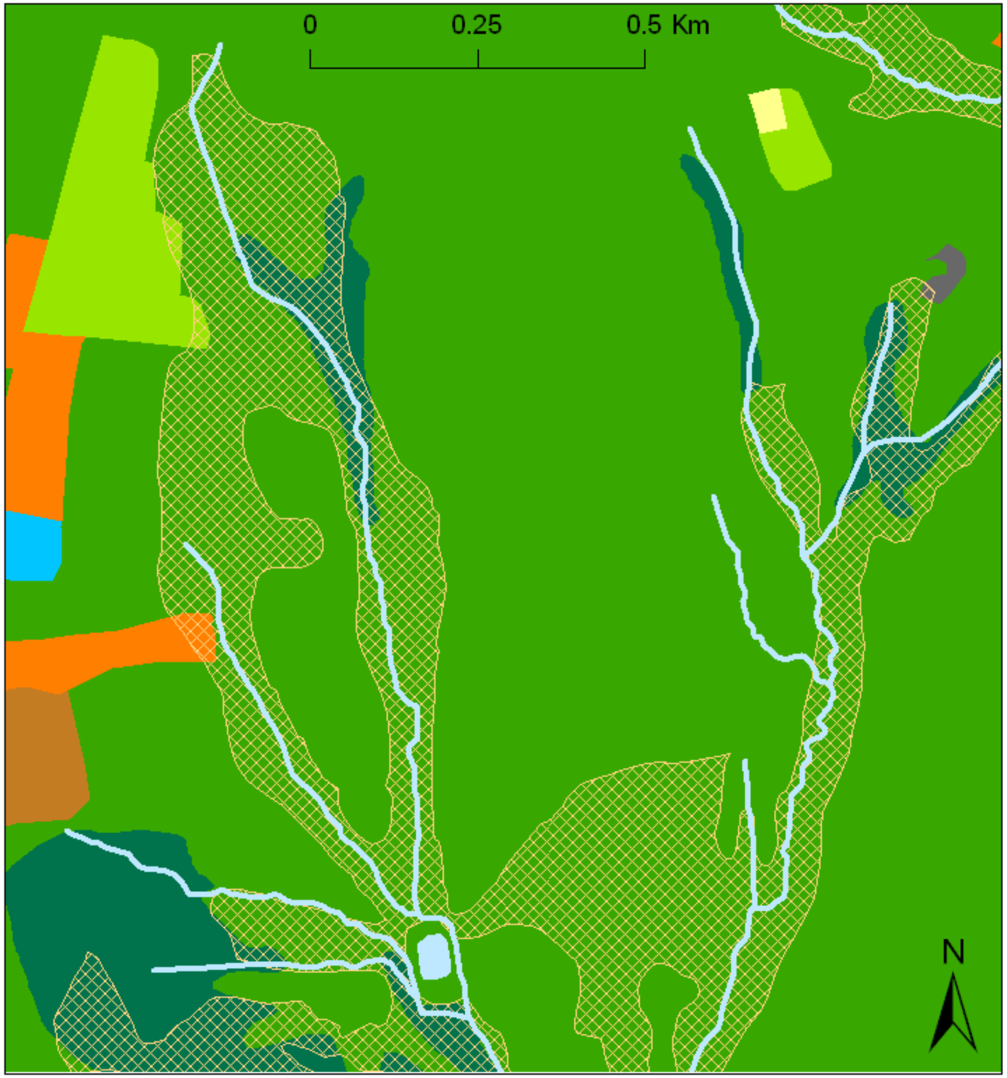
SSURGO Hydric Soils suggest wetlands and zero order streams connect source to stream



- Streams (1:24,000)
- Ponds (1:24,000)
- Forest / Open Space
- Agriculture
- Residential (low density)
- Residential (med density)
- Res. (med high density)
- Institutional
- Gravel pits
- NWI Wetlands
- **Hydric Soils (SSURGO) (1:15,840)**

Source: Groffman et al. (2009)

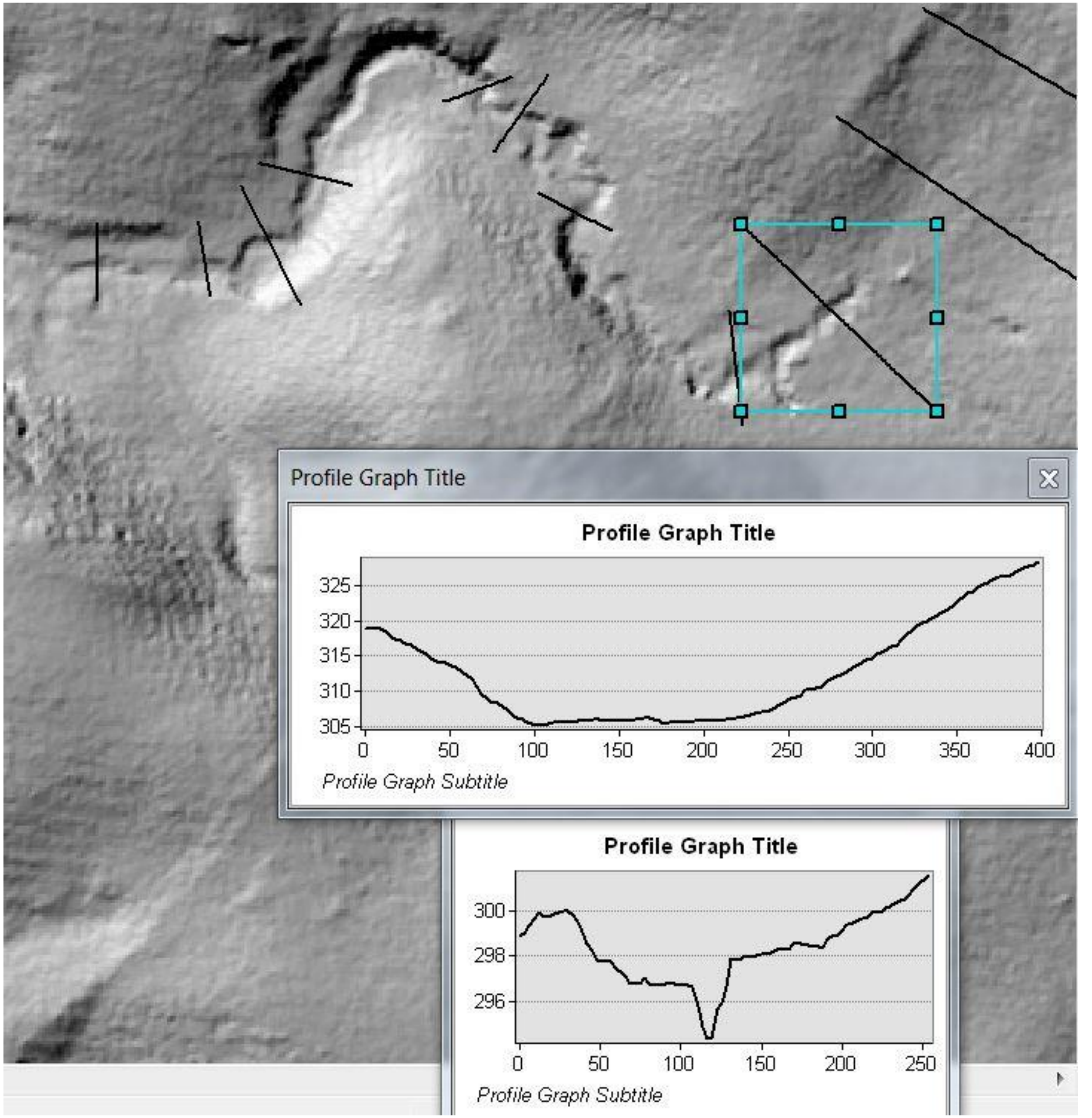
High resolution stream data and hydric soils display an active biogeochemical landscape



Streams (1:5,000)
Ponds (1:5,000)
Forest / Open Space
Agriculture
Residential (low density)
Residential (med density)
Res. (med high density)
Institutional
Gravel pits
NWI Wetlands
Hydric Soils (SSURGO) (1:15,840)

Source: Groffman et al. (2009)

Detecting riparian and stream condition with LiDAR:



Source: Andy Miller

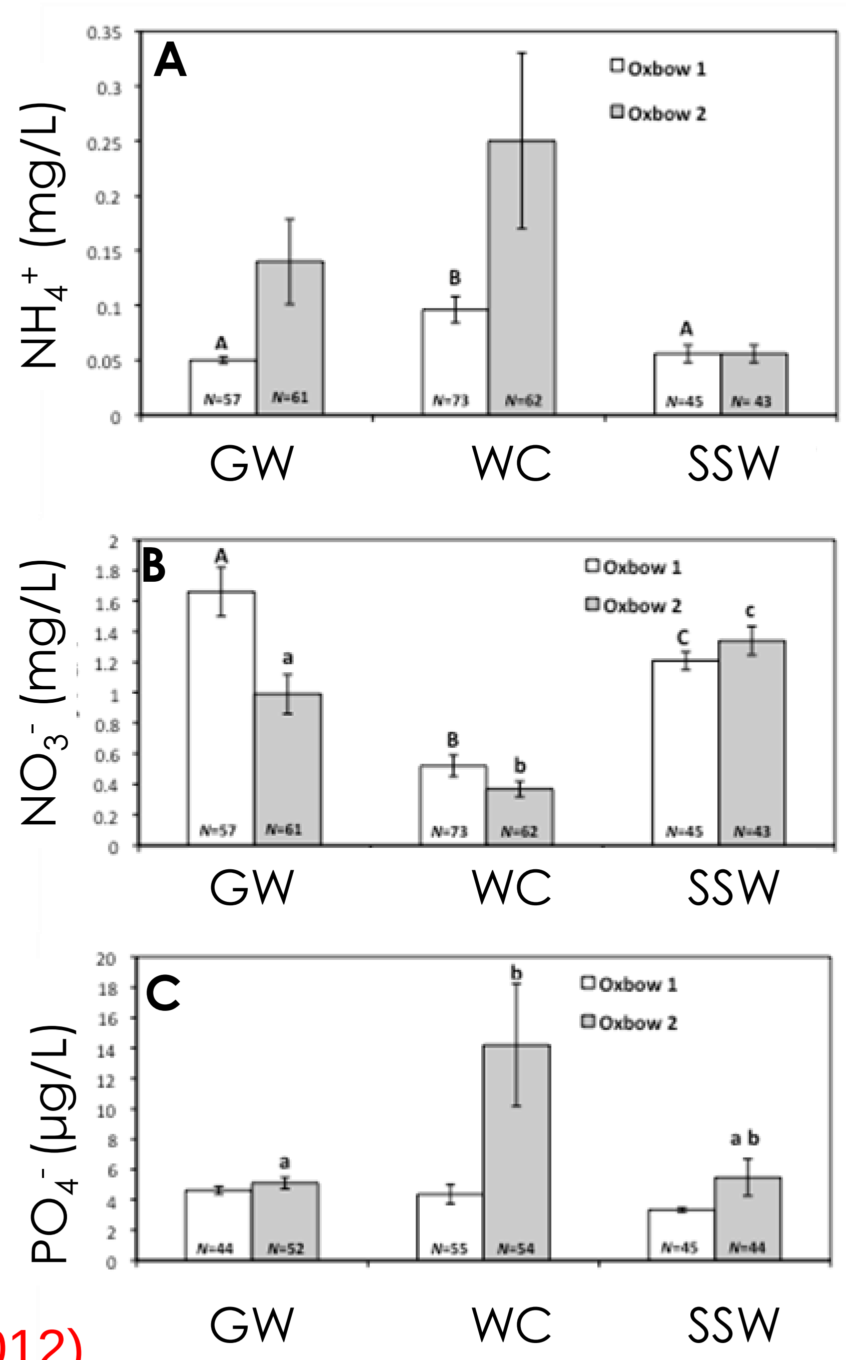
Key issues going forward:

- Urbanization disrupts riparian processing, converting riparian zones from sinks to sources of nitrogen.
- Stormwater control measures may restore the "lost" riparian effect.
- Stream and riparian restoration, especially those that "reconnect" streams and riparian zones should have a nitrogen benefit.
- Riparian evaluations at the watershed scale:
  - New tools such as SSSURGO and LiDAR.
  - Need monitoring at the watershed scale.

Minebank Run oxbow wetlands:

- Surface water has lower nitrate concentrations than groundwater and streamwater – suggests oxbows are “sinks” for nitrate.

- Surface water has higher phosphate concentrations than groundwater or streamwater, suggests oxbows are “sources” of phosphate.



Harrison et al. (2012)

Denitrification in urban floodplain wetlands:

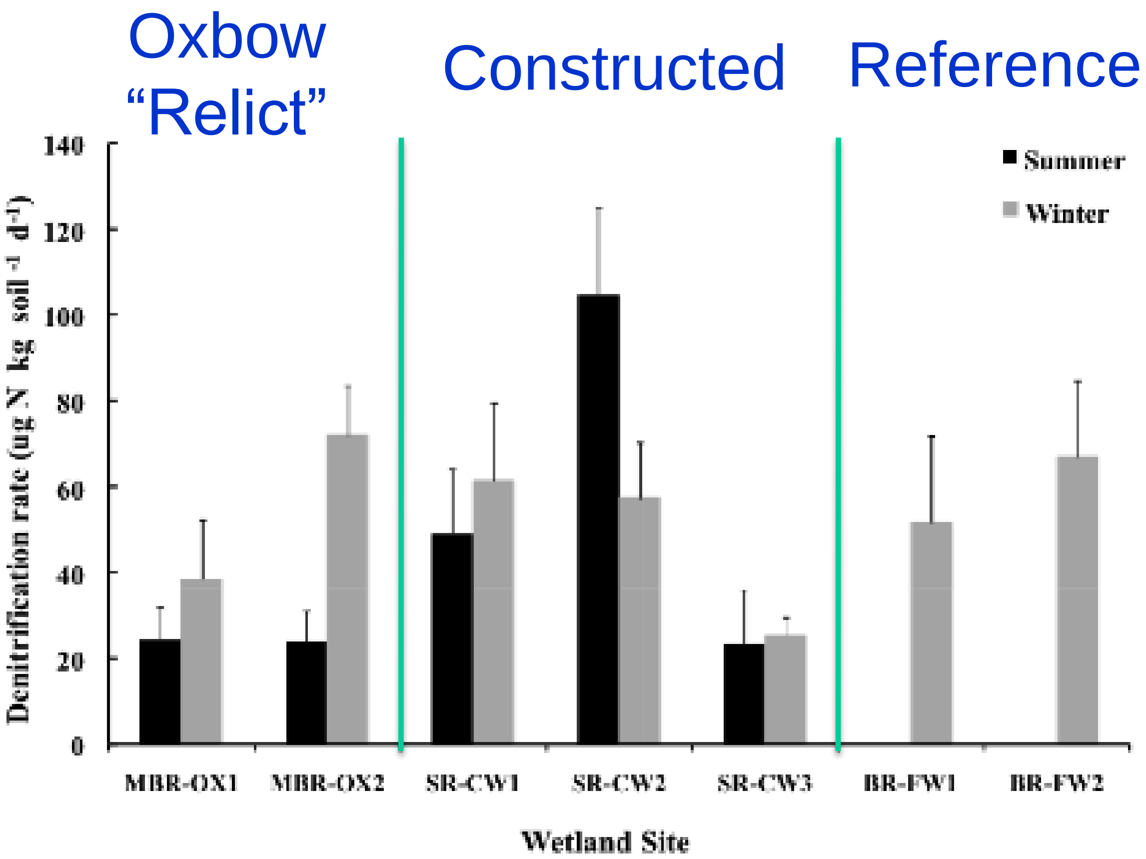
- Measured *in-situ* denitrification summer and winter 2008 using the ^{15}N-push pull method.
- Analyzed gas samples for N_2O and N_2

Constructed storm water wetlands

Oxbow *"relict"* wetlands

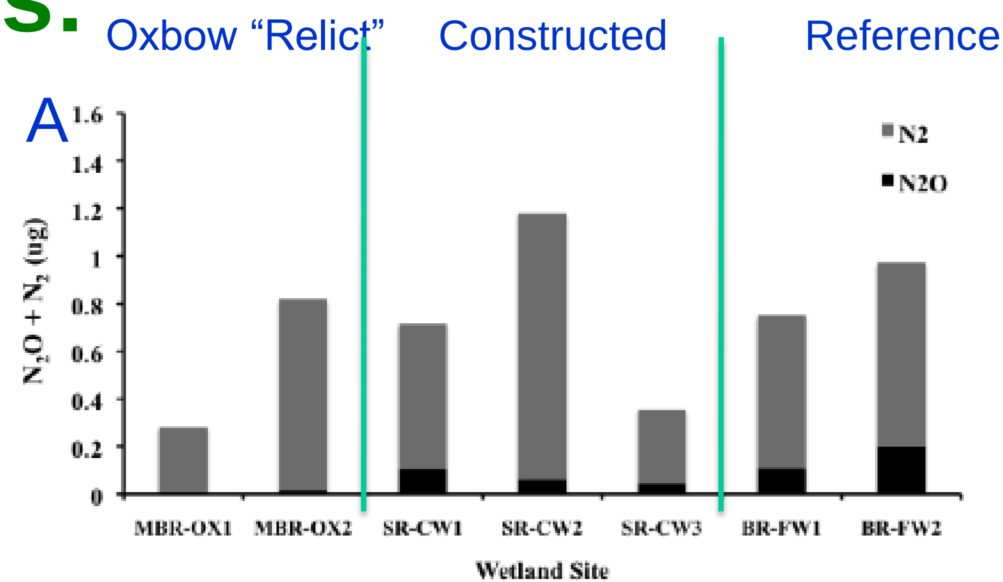
Denitrification in urban floodplain wetlands:

- Denitrification rates were high – a significant sink for nitrate.
- Rates were higher in winter than in summer.
- Denitrification similar across all wetland types.

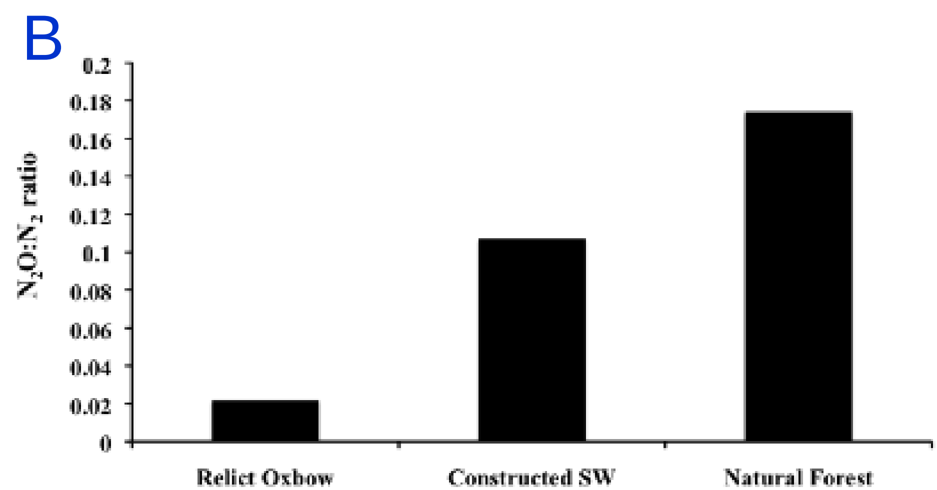


Harrison et al. (2011)

N_2O yield during denitrification in urban floodplain wetlands:



- N_2 was the dominant end-product at all sites.
- N_2O yield (N_2O:N_2 ratio) was low at all sites.



Harrison et al. (2011)

^{15}N mass-balance approach oxbow “relict” wetlands:

- Determine the fate of ^{15}N added to wetlands:
  - Algae
  - Macrophyes
  - Sediments
  - Denitrification (unaccounted for N)

- Two additions:
  - Mid growing season
  - Very early (almost dormant) growing season

^{15}N mass-balance approach in oxbow "relict" wetlands: Methods

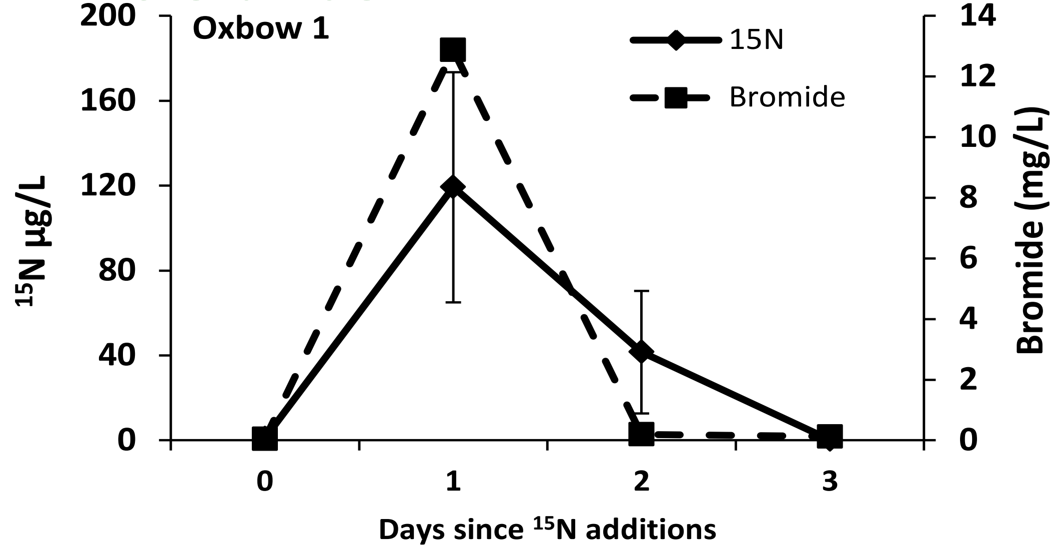
- Water column samples, algae, macrophytes, and sediment were collected before and after the six-day experiment to determine ^{15}N natural abundance.

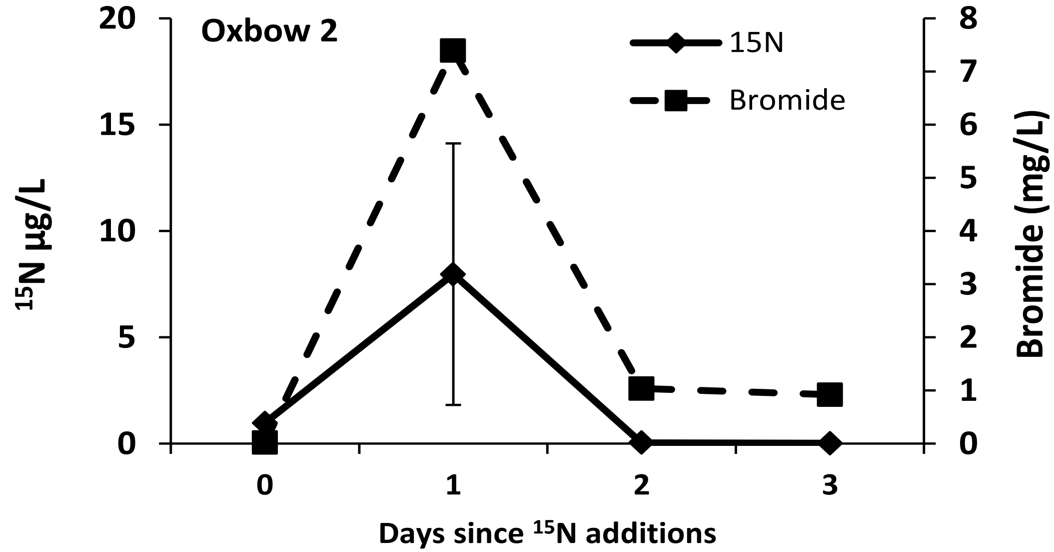
- ^{15}N-KNO_3^- and Br^- solution added summer 2009 and spring 2010.

- Water samples were collected six consecutive days in six discrete locations (inlet to outlet) in each oxbow.

^{15}N mass-balance approach in oxbow "relict" wetlands: Results

- Complete mixing of added ^{15}N by day 2.
- All added ^{15}N was processed by day 3.





Harrison et al.

^{15}N mass-balance approach in oxbow "relict" wetlands: Fate of ^{15}N