Managing agricultural watersheds and landscapes for environmental quality: The challenges ahead

Peter M. Groffman

Cary Institute of Ecosystem Studies

USDA United States Department of Agriculture
National Institute of Food and Agriculture

Landscape thinking: Connecting the dots

- Improvements at the field scale will not be enough. We need to "connect the dots" between pollutant sources and sinks in the landscape.
  - Riparian zones
  - Constructed wetlands
  - Tile bioreactors

Challenges to connecting sources and sinks of pollutants in the landscape:

- Mapping the interface: Need to be able to accurately depict soil and hydrologic conditions in the interface between the source and the sink.

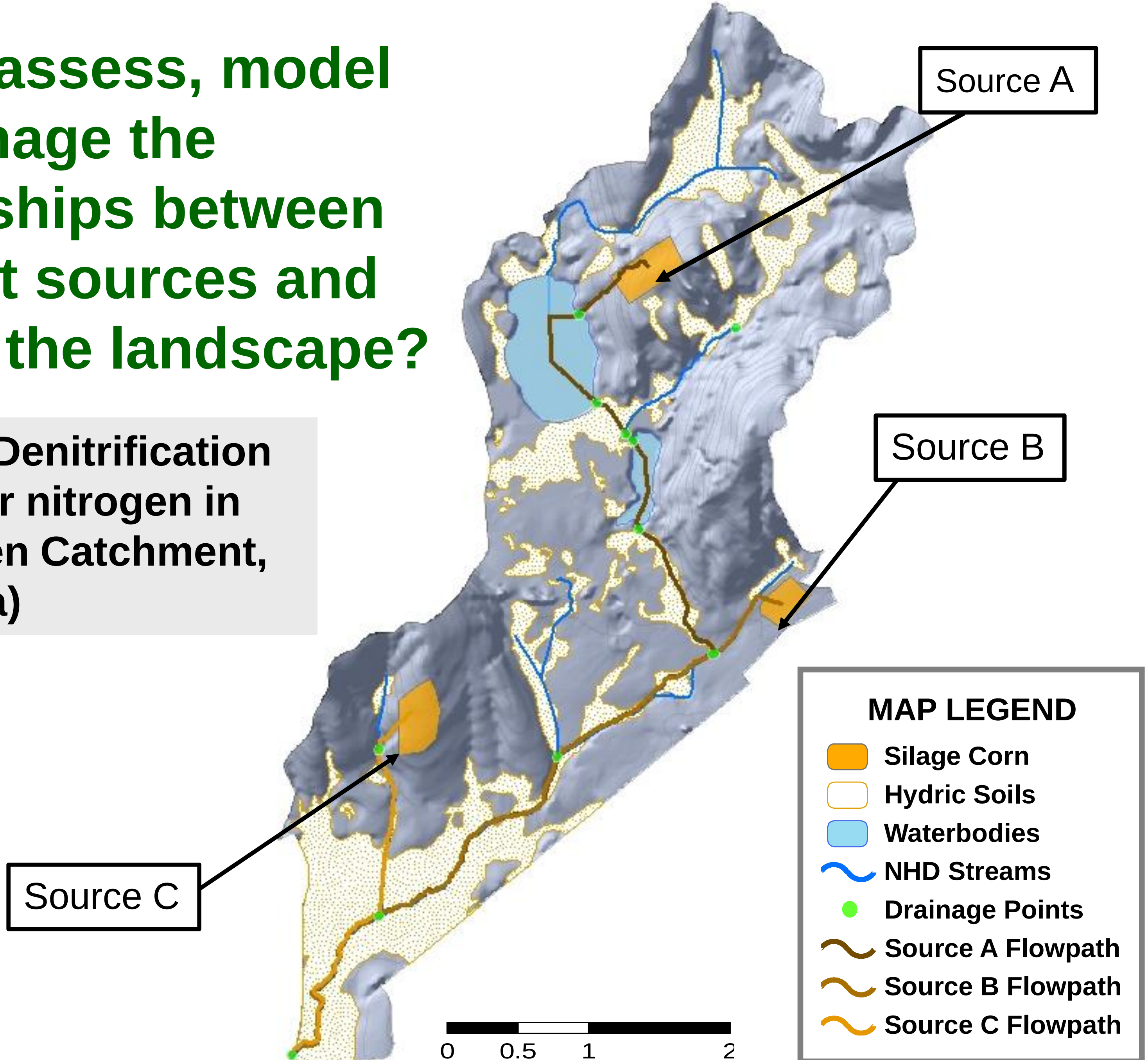
- Flowpaths: Need to be able to accurately depict flowpaths between sources and sinks.

- Emerging issues. What are the effects of sources on multiple ecosystem services in the sink ecosystem.

- Monitoring. How to see the effects of landscape intervations at the watershed scale.

Can we assess, model and manage the relationships between pollutant sources and sinks in the landscape?

Example: Denitrification as a sink for nitrogen in Chickasheen Catchment, RI (1740 Ha)



Source: Kellogg et al. 2010

Denitrification

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

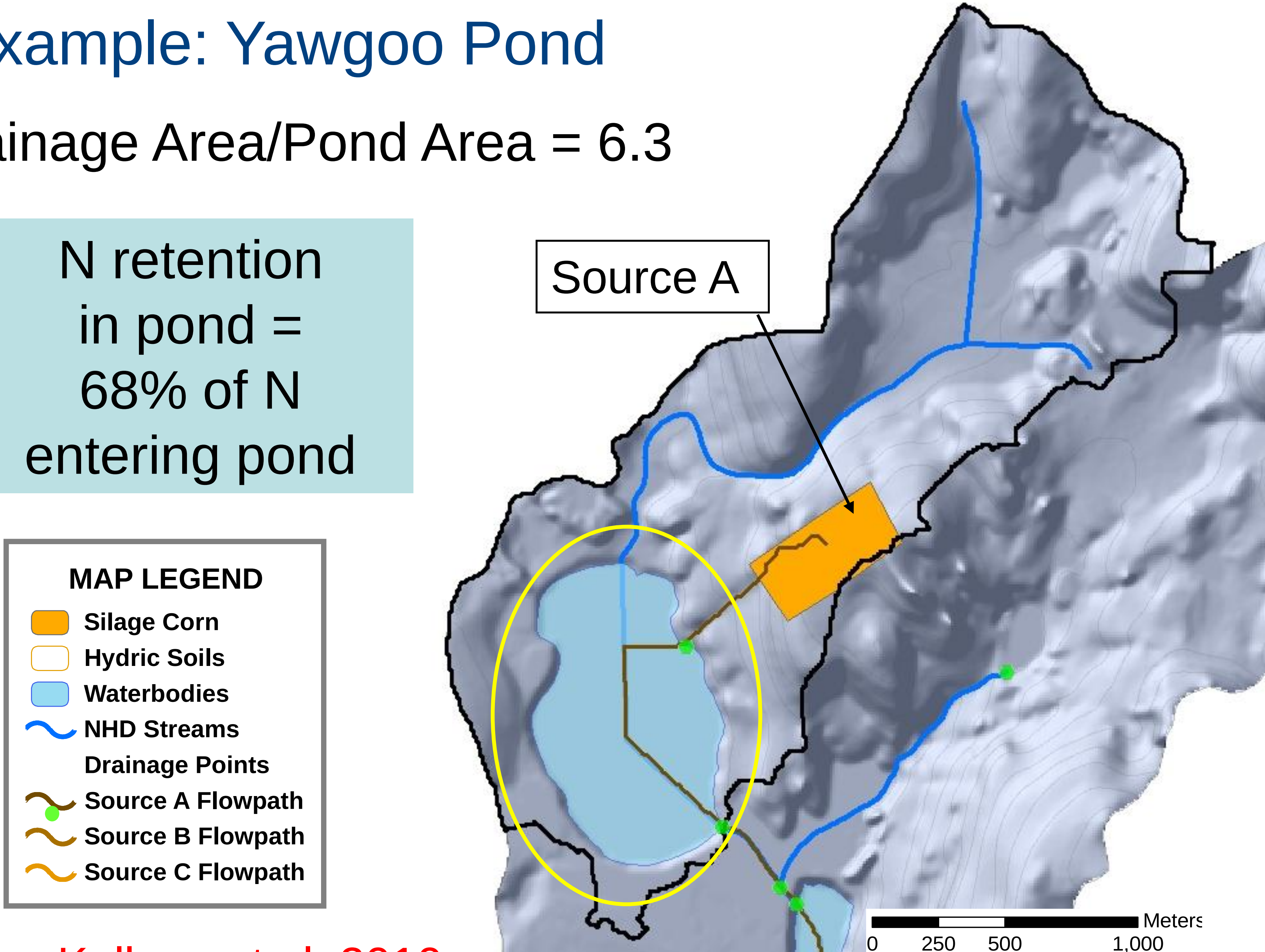
- Anaerobic
- Heterotrophic (requires organic C)

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

Example: Yawgoo Pond

Drainage Area/Pond Area = 6.3

N retention in pond = 68% of N entering pond



Source: Kellogg et al. 2010

Ponded Areas as N Sinks

From regression analysis of lake data from Seitzinger et al. (2002) we relate N removal to depth (D) / residence time (T) [m y^{-1}] ($r^2 = 0.81$):

$$\text{N Removal (\%)} = 79.24 - 33.26 * \log_{10}(D/T)$$

$$D = \text{Volume}/\text{Pond Area}$$

$$T = \text{Volume}/Q$$

$$D/T = Q/\text{Pond Area}$$

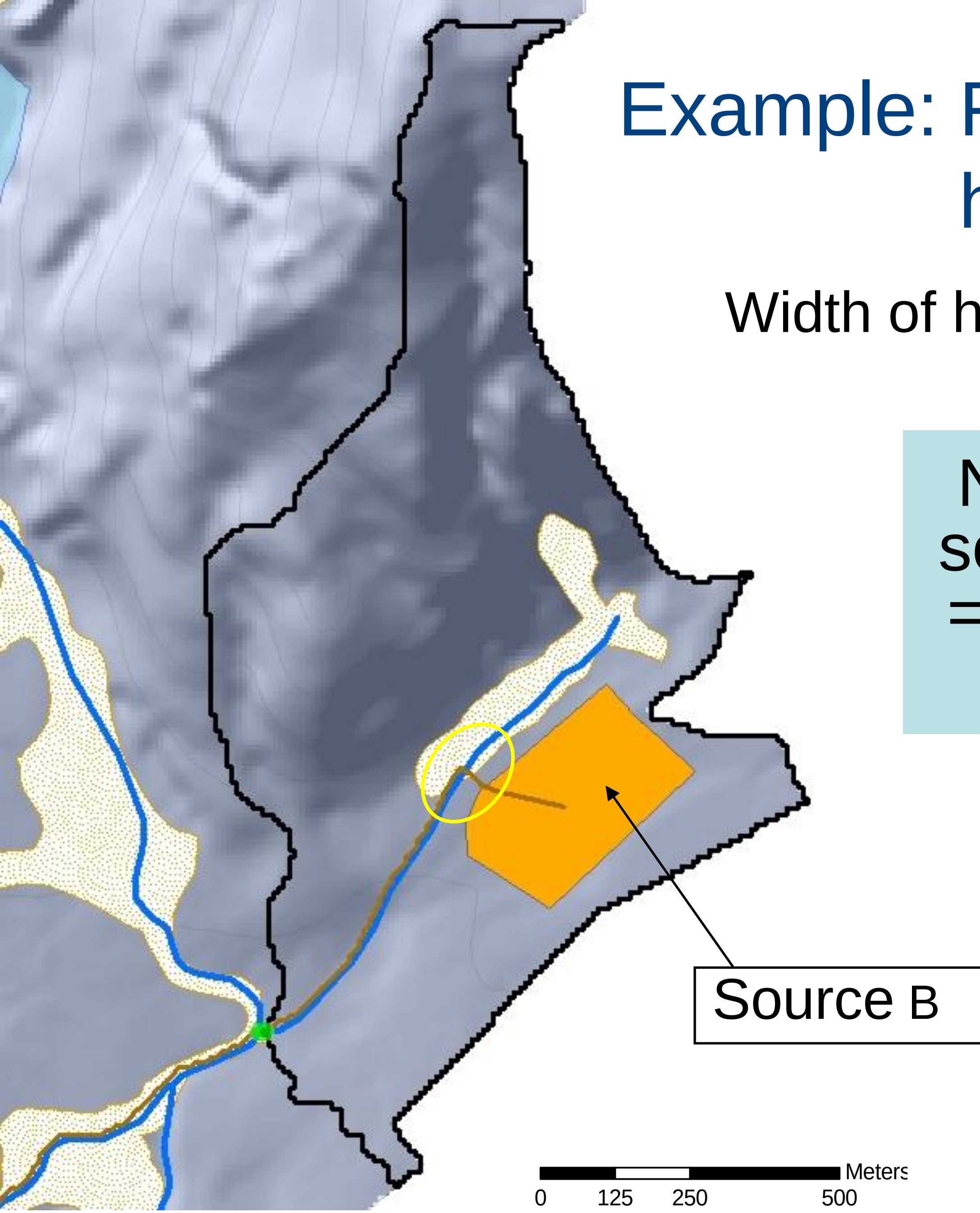
- Obtain Pond Area from GIS data

- Estimate flow rate into a pond, Q:

  - USGS has normalized regionally explicit data relating Q to drainage area as volume/time/area (e.g., $m^3/s/km^2$)

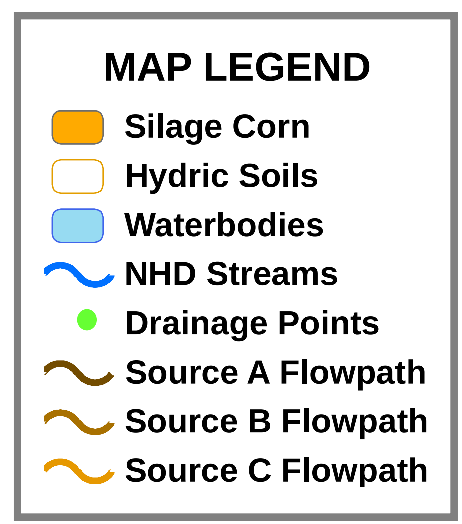
Source: Kellogg et al. 2010

Example: Flow path crosses hydric riparian zone



Width of hydric soils in riparian zone = 12 m

N removal in hydric soils in riparian zone = 40% of N entering riparian zone



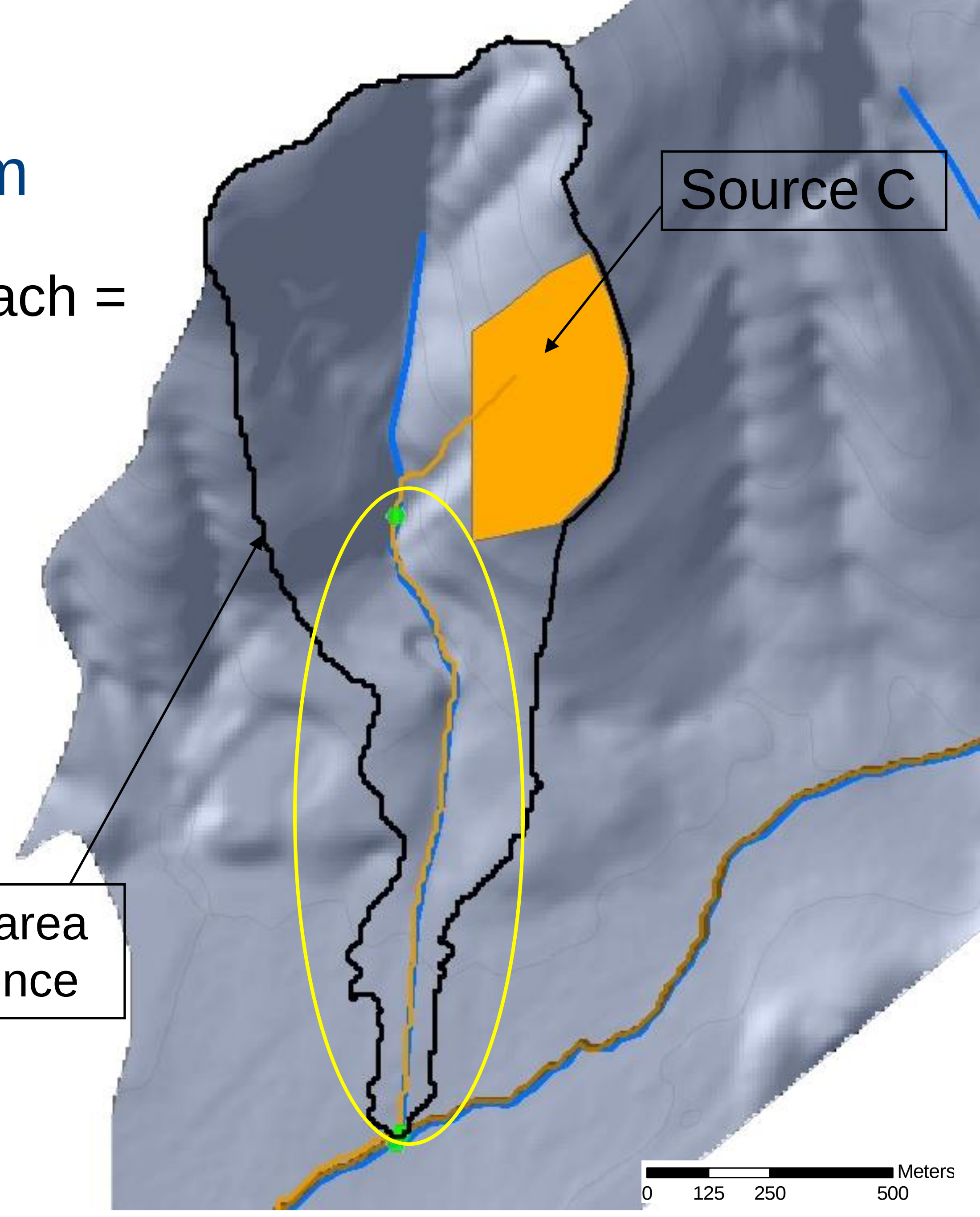
Source: Kellogg et al. 2010

Example: Flow path along first order stream

Time of travel in stream reach = 3.3 hrs (0.14 days)

Depth: 0.1 m

N removed in stream reach = 17% of N entering at top of reach



Drainage area to confluence

MAP LEGEND

- Silage Corn
- Hydric Soils
- Waterbodies
- NHD Streams
- Drainage Points
- Source A Flowpath
- Source B Flowpath
- Source C Flowpath

Source: Kellogg et al. 2010

Lower Order Stream Reaches as N Sinks

From Alexander et al. (2007),

N Removal (%) = $1 - \exp(-\theta_{S1} * D^{\theta_{S2}} * T))*100$

where,

$\theta_{S1} = 0.0513\ [m^{-1}\ d^{-1}]$

$\theta_{S2} = -1.319$

D = stream depth (m)

T = time of travel (d) = retention time in reach

Estimating stream depth, D, using available GIS data:

1. Local field reconnaissance of 100+ lower order streams in RI (Rosenblatt, 2000), the following relationship was derived:

$D\ [m] = 0.076 * \mathrm{Ln}\ (\text{Drainage Area}\ [m^2] * 0.093) - 1.132$

2. Alexander et al. (2000): D = f (Q_{MA});

Predicts slightly lower depths than our field data

Source: Kellogg et al. 2010

Summary of N removal by sinks

Source	Edge of Field Loss kg N/year	Sink Removal			Total Removal
		Riparian Zones %	Ponded Areas %	Stream Reaches %	%
A	839	-	68	3	71
B	476	40	-	5	45
C	862	-	-	17	17

- Indicates sink not present

Source: Kellogg et al. 2010

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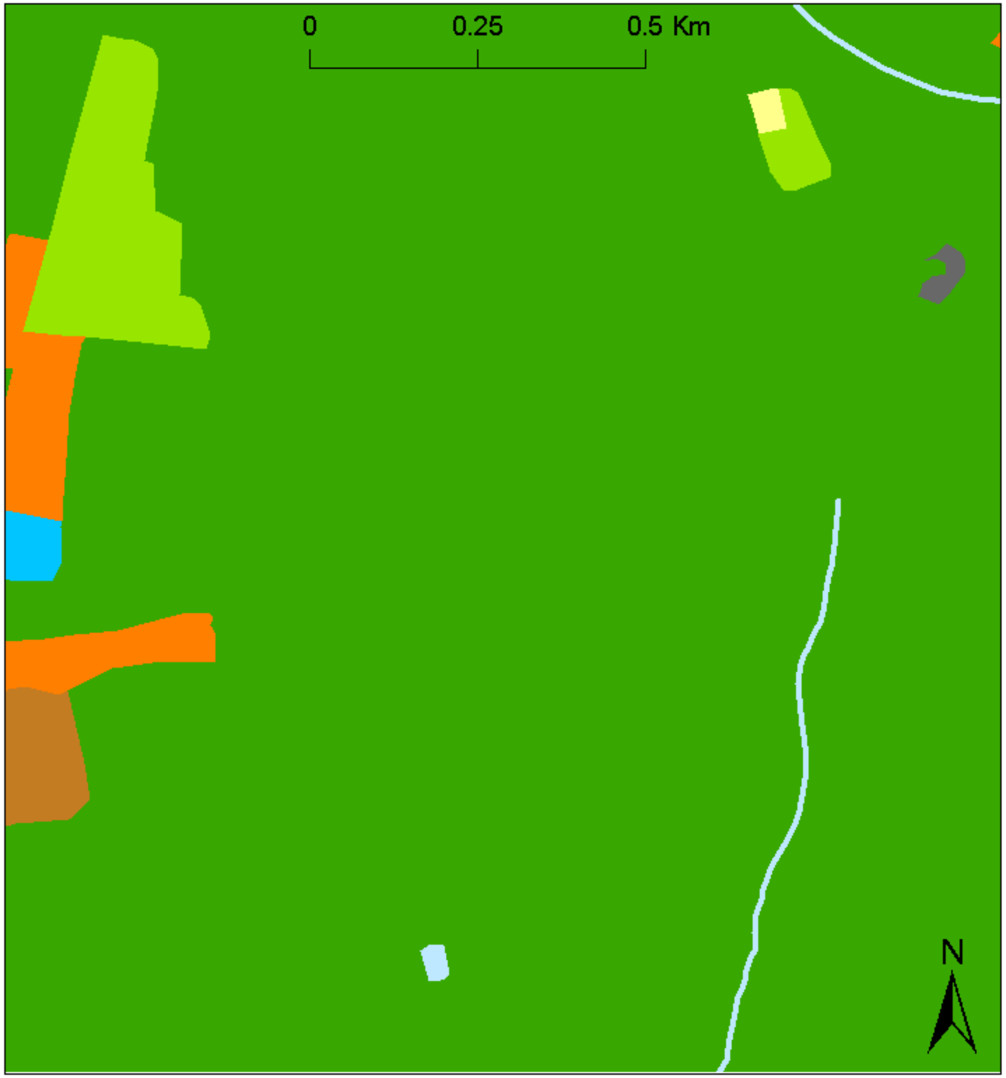
- Emerging issues. What are the effects of sources on multiple ecosystem services in the sink ecosystem.

- Monitoring. How to see the effects of landscape intervations at the watershed scale.

Scale/type of spatial data can <u>mask or display</u> 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)

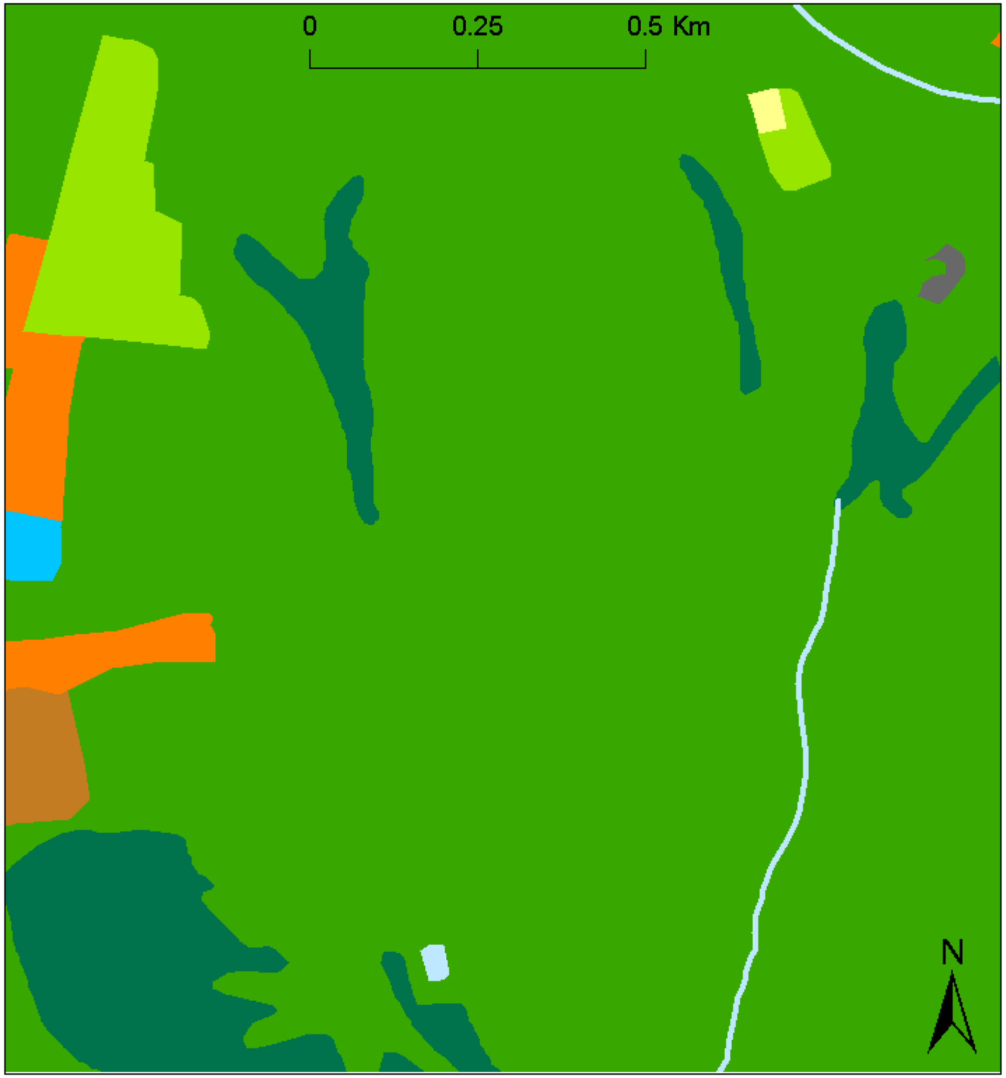
Res. (med high density)

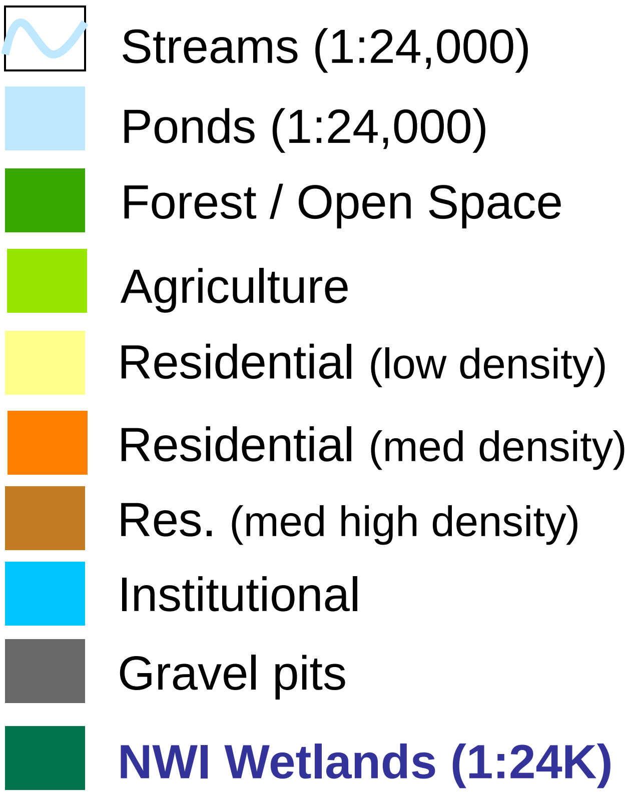
Institutional

Gravel pits

Source: Art Gold et al.

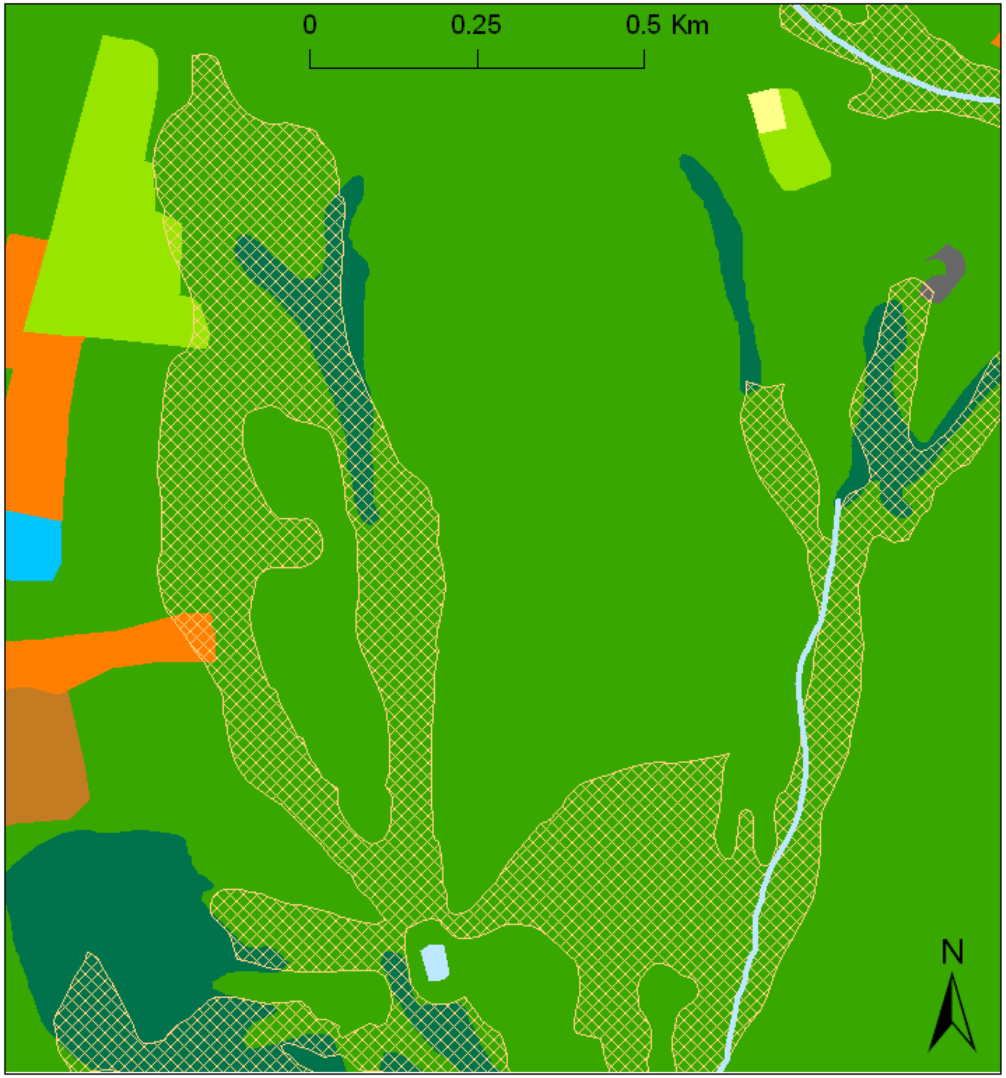
National Wetland Inventory (1:24,000) displays potential sinks





Source: Art Gold et al.

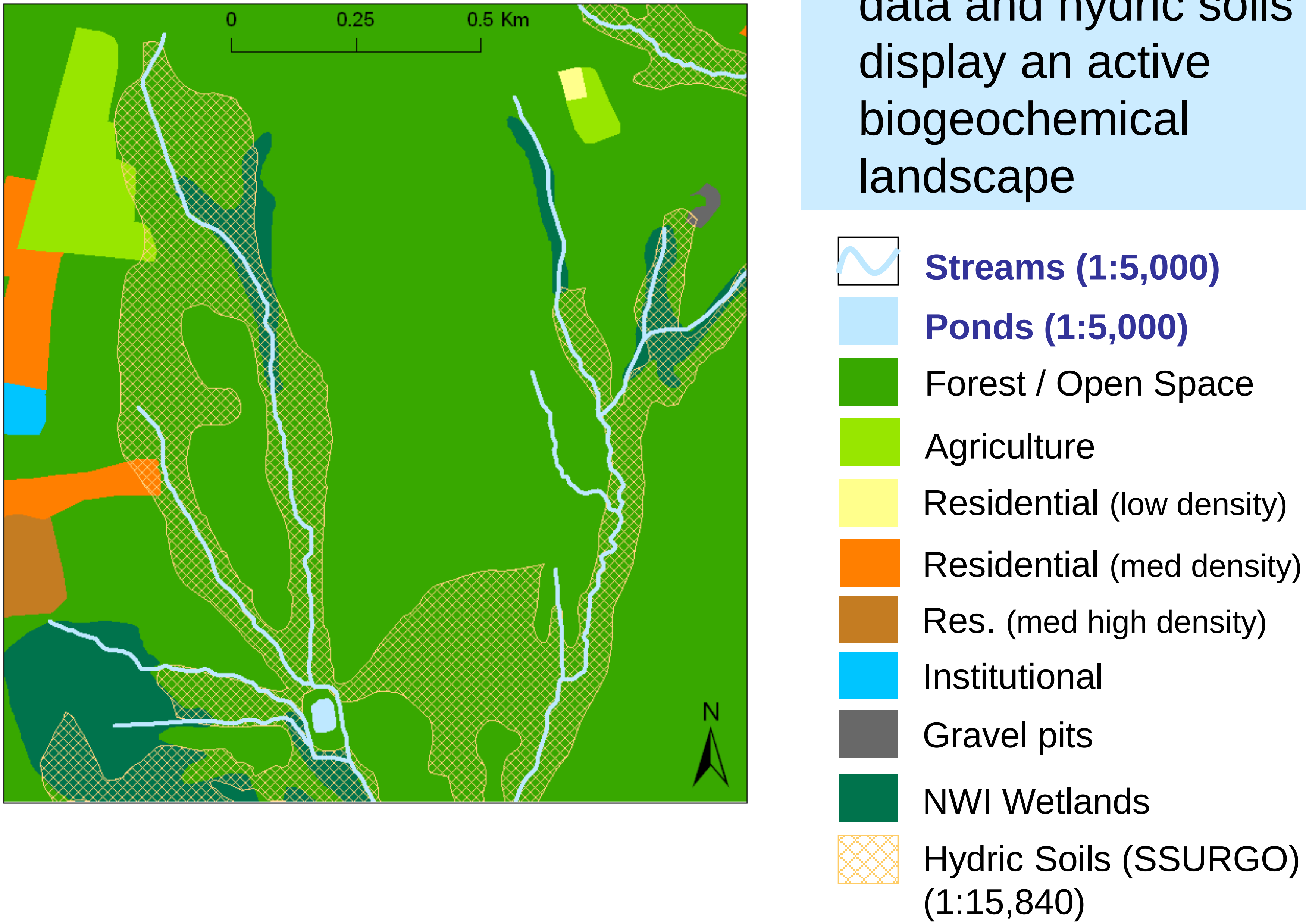
SSURGO Hydric Soils suggest wetlands and zero order streams connect source to stream



- 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: Art Gold et al.

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



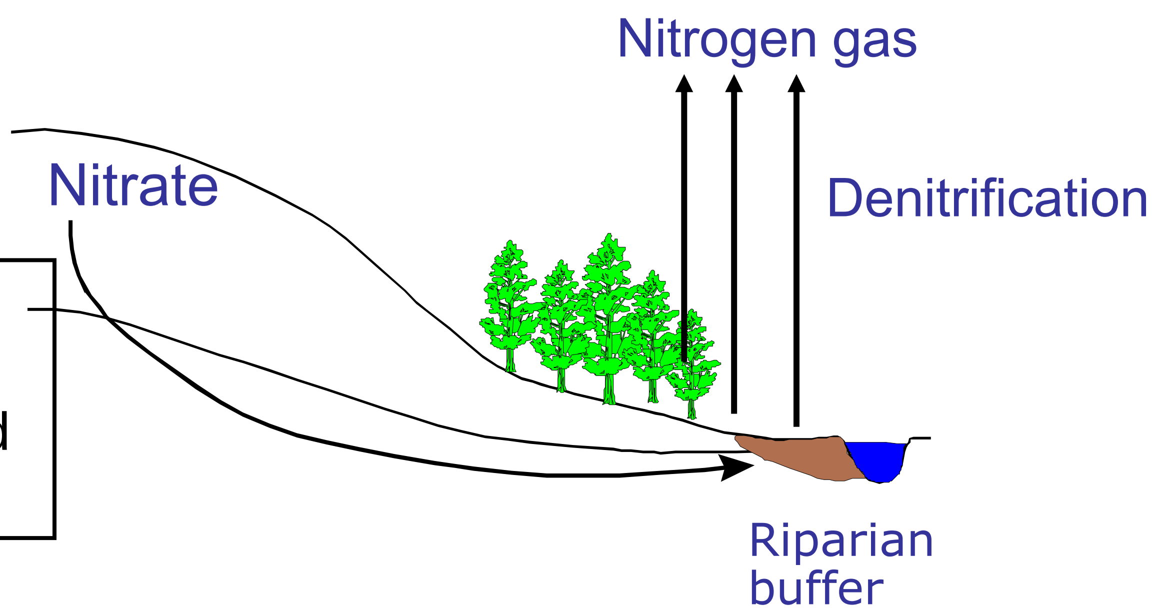
Source: Art Gold et al.

Need to be able to accurately depict flowpaths between source and sink:

Flowpath Uncertainties

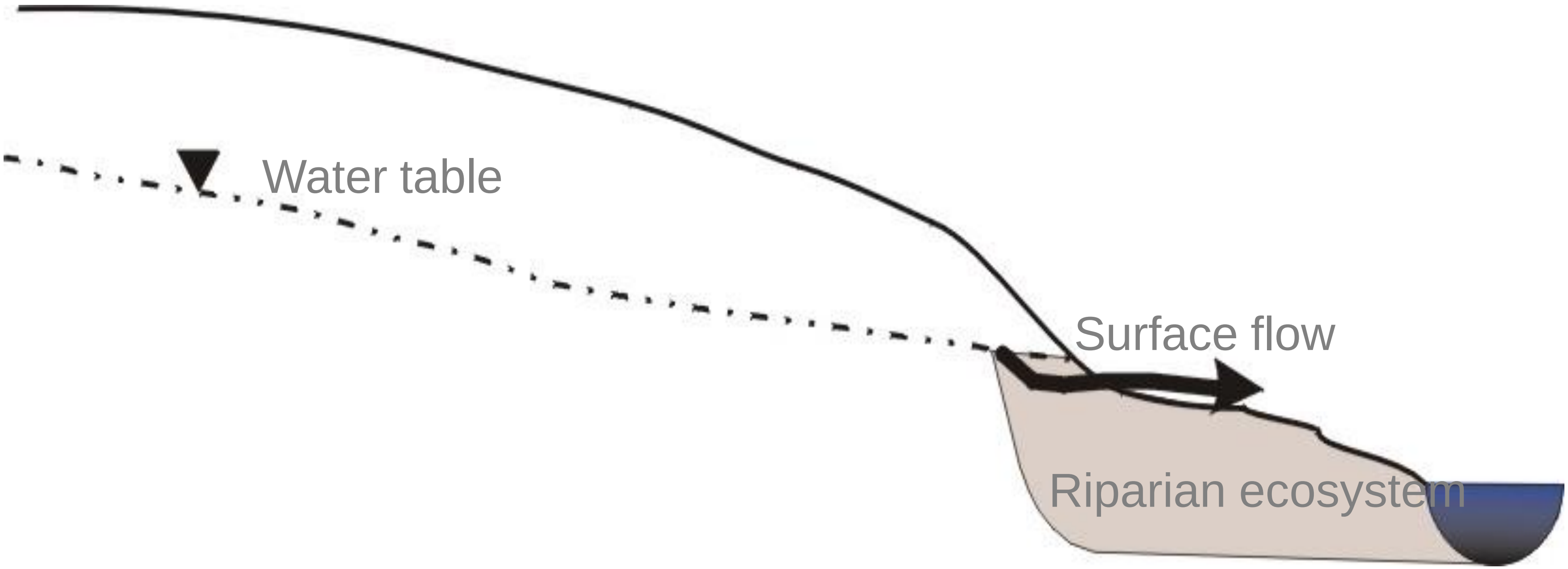
- Aquifer depth
- Distance from source area to riparian zone
- Extensiveness of riparian buffer along stream reach

Ideal:
Shallow groundwater moves through vegetated anaerobic, organic soils



Source: Louis Schipper

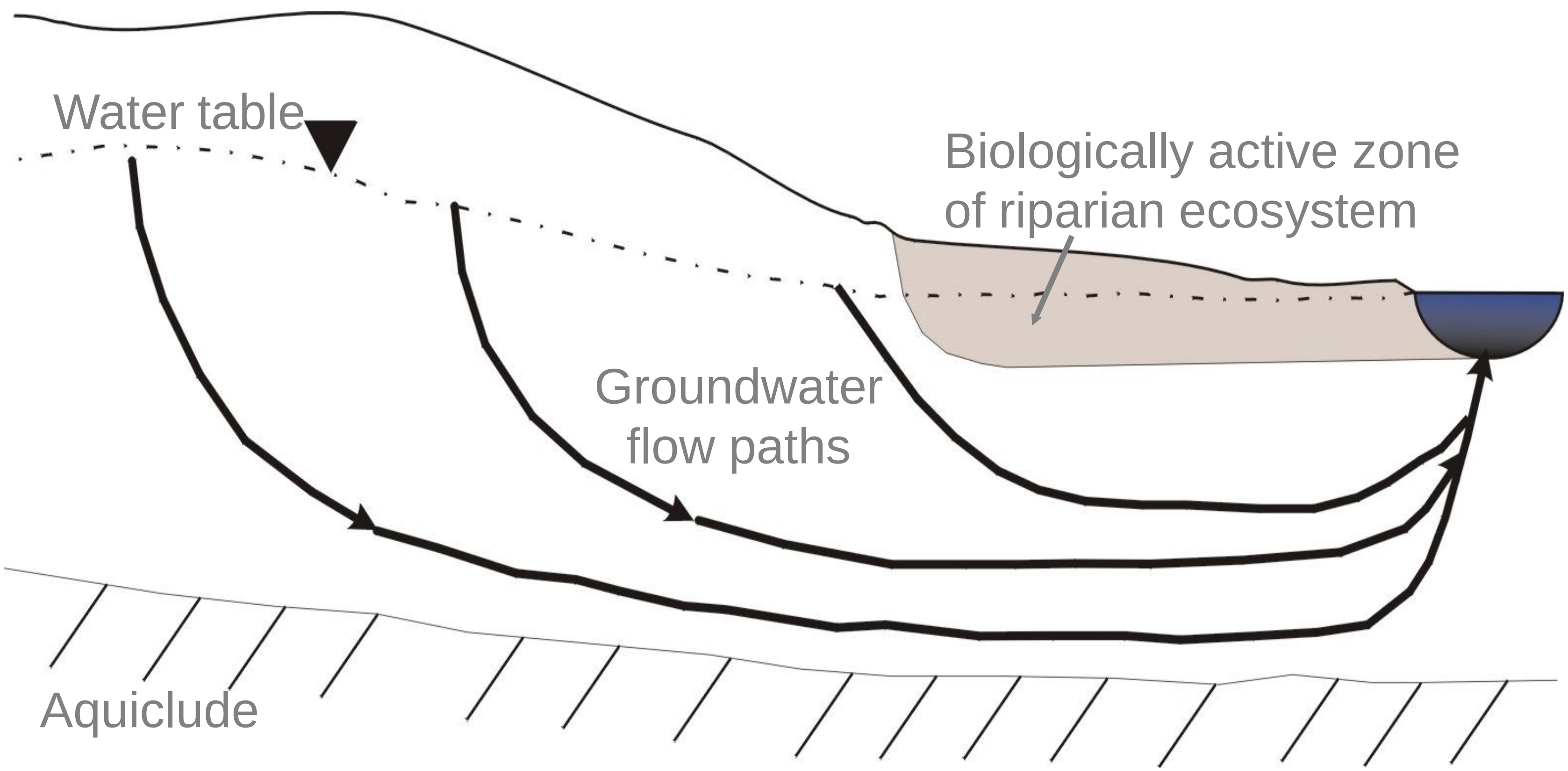
Flow path nightmare #1: seeps



- Groundwater moves as surface flow across riparian ecosystem
- Lower groundwater N removal

Gold et al. 2001

Flow path nightmare #2: Deep bypass flow:



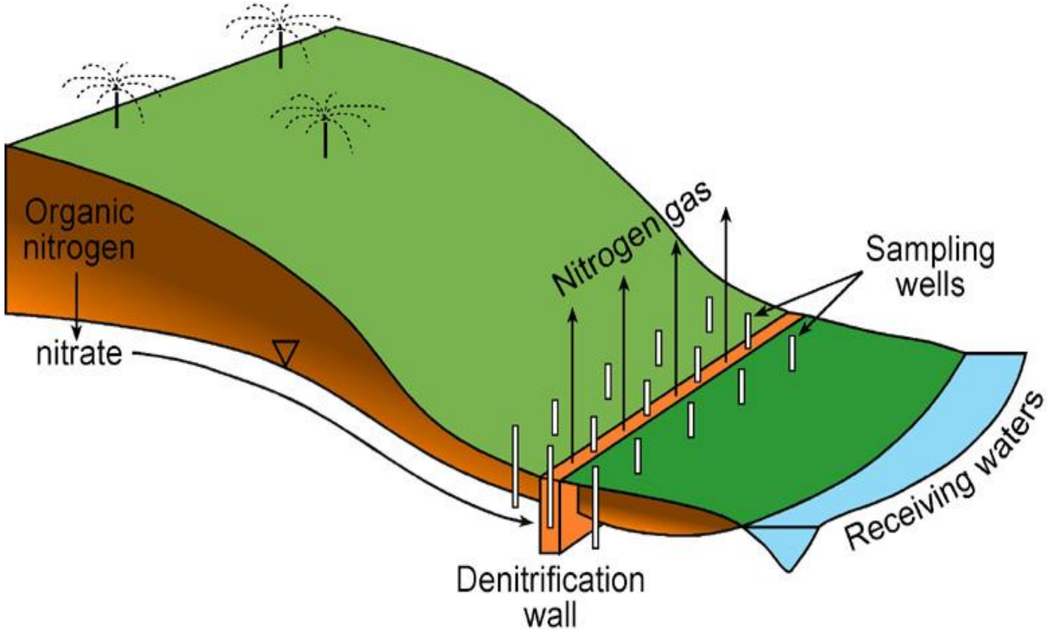
- Groundwater moves under riparian ecosystem
- Low groundwater N removal

Source: Gold et al. 2001

Intercepting and Treating N laden Waters: Woodchip Bioreactors

Filling trench box with wood chips

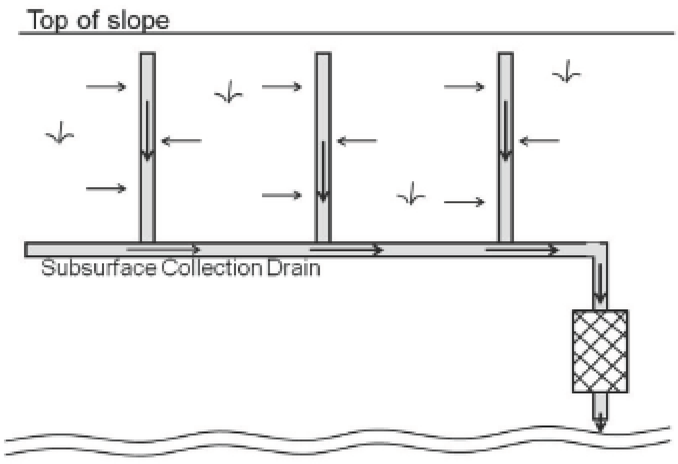
Photo courtesy of Betty Buckley, URI Graduate School of Oceanography

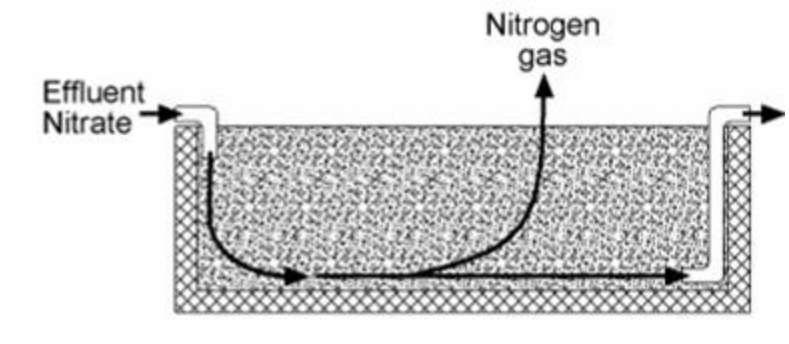


© THE UNIVERSITY OF WAIKATO • TE WHARE WANANGA O WAIKATO, Schipper et al.

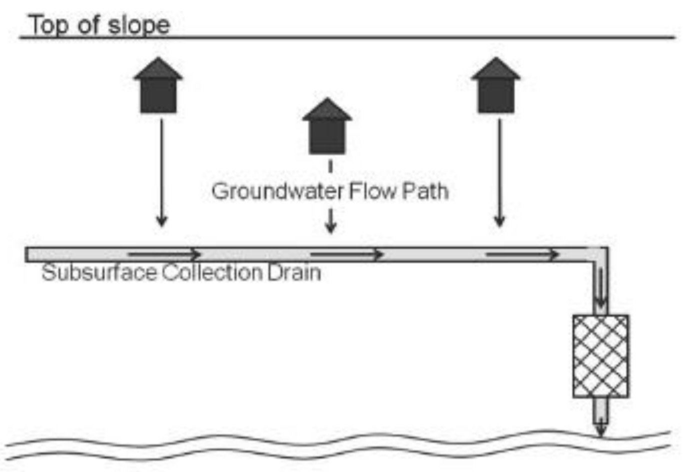
Source: Louis Schipper

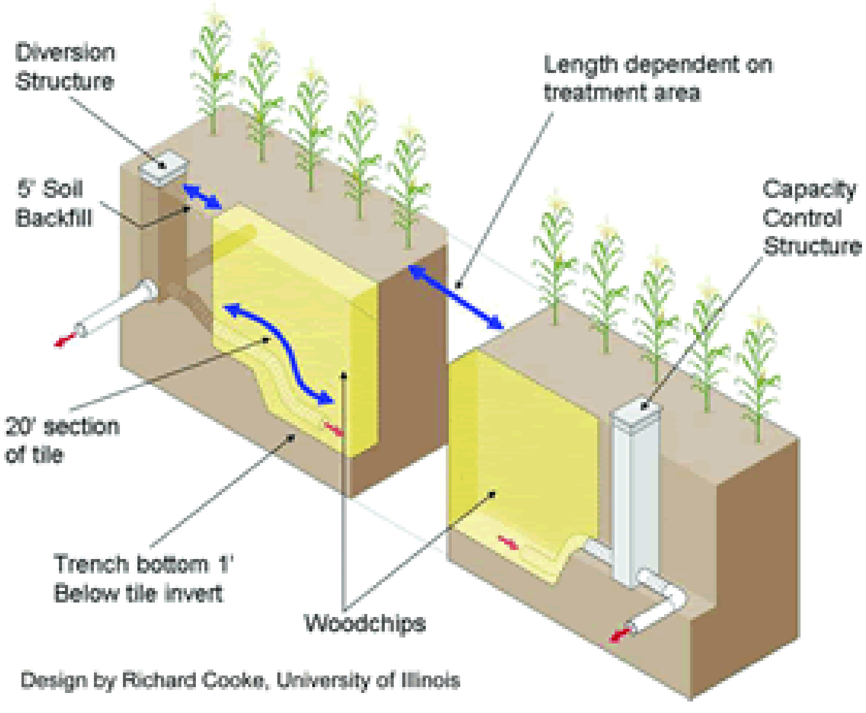
Carbon (wood chip) bioreactors:
Intercept and treat N enriched pipe flow





Schipper, Robertson, Gold, Jaynes, Cameron. 2010. Eco. Engin.





Source: Louis Schipper NRCS: Bioreactors Eligible for EQIP Assistance

Emerging issues, e.g. wetlands as buffers or buffers for wetlands?

- If we establish sink areas in watersheds, e.g., wetlands, riparian buffers, will wildlife be attracted to them?
- Will this attraction increase wildlife exposure to contaminants, e.g., amphibian exposure to atrazine?
- Should we revisit the multi-zone buffer specification?

Source: Richard Lowrance

Monitoring: How to see the effects of landscape interventions at the watershed scale:

- Long-term:
  - – Time lags
- Simple:
  - – Sustainable
- Multi-parameter:
  - – Ecosystem services:
    - Water quality
    - Air quality
    - Biodiversity

Conclusions: From "connecting the dots" to "threading the needle."

- We have made great conceptual progress and real practical improvements in our ability to manage agricultural watersheds and lanscapes.
- Challenges remain; mapping, flowpaths, monitoring, emerging issues, a changing world.
- Great prospects for continued progress; strong science in multiple disciplines, powerful outreach tools, new ideas about institutions and policies.