The influence of the two-stage ditch on water quality in an agricultural landscape

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ENVIRONMENTAL CHANGE INITIATIVE

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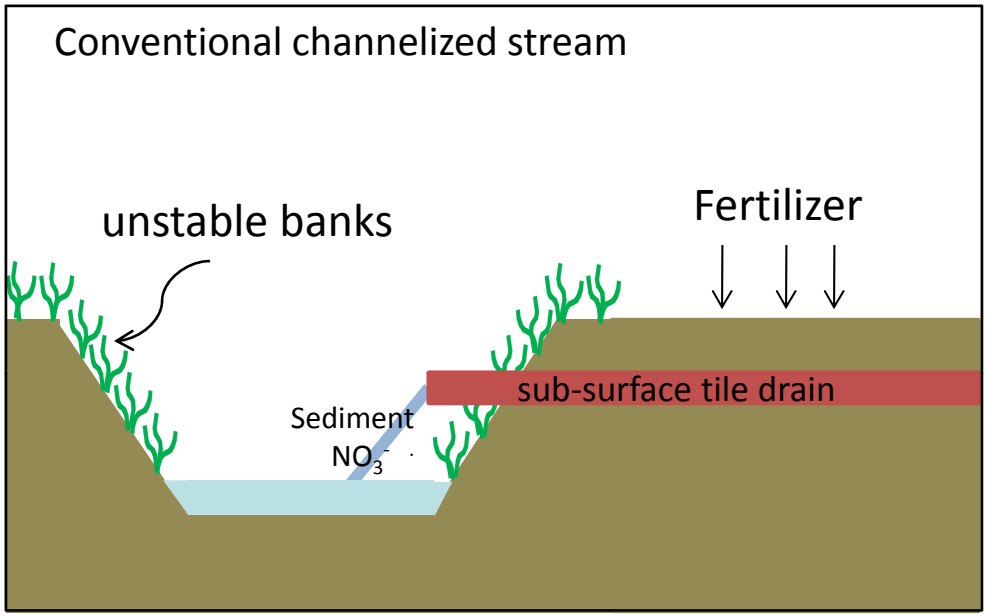
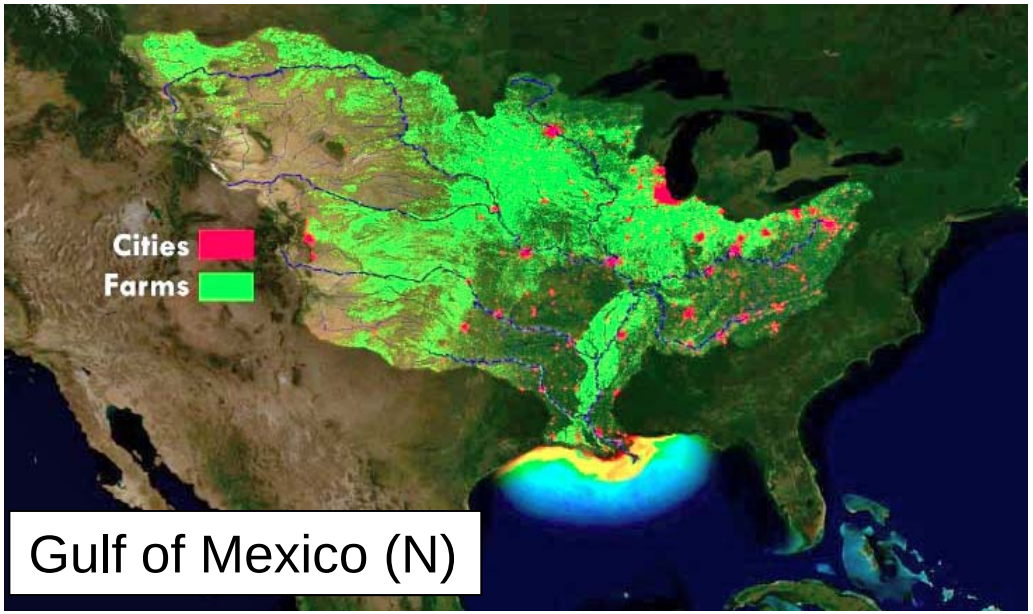
Streams draining row crop agriculture export excess nutrients and sediments



- In Indiana, >90% of the over 50,000 km of stream/ditches are located within 500 m of a row-crop field.
- Fertilizer addition, channelization, and tile drainage improve crop yields, but these practices also reduce nutrient retention and channel stability.

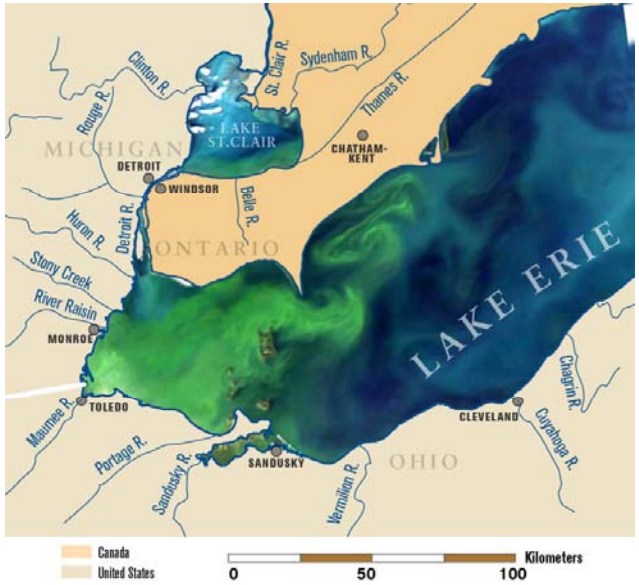
Net Result: drainage modification results in increased export of excess nutrients and sediments to downstream water bodies.

Agricultural activity and the export of excess nutrients result in algal blooms followed by hypoxia



Gulf of Mexico (N)

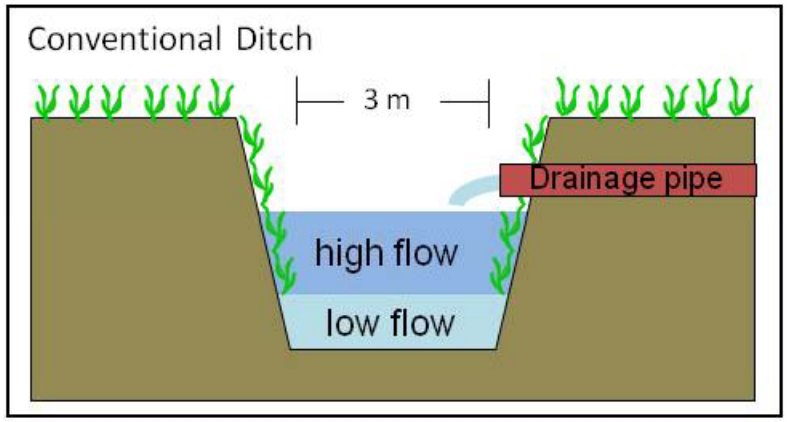
Excess Nutrients
↓
Algal Blooms
↓
Algal Death & Decomposition
↓
Water Column Hypoxia

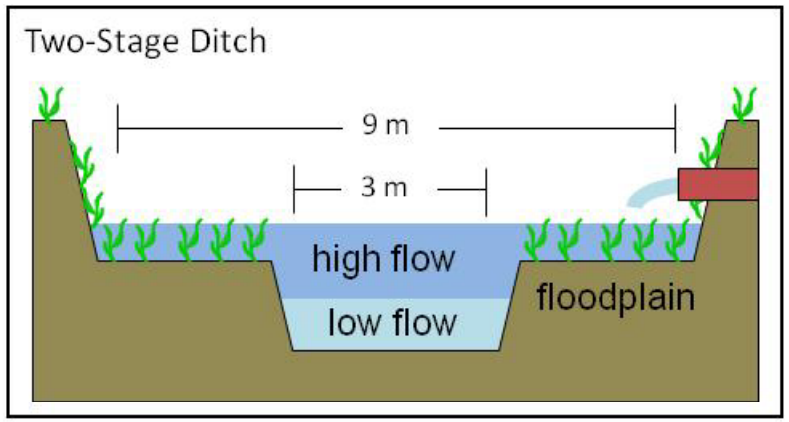


Lake Erie (P)

- Peak run-off often occurs during spring snowmelt and storms.

New in-stream management tool: two-stage ditch



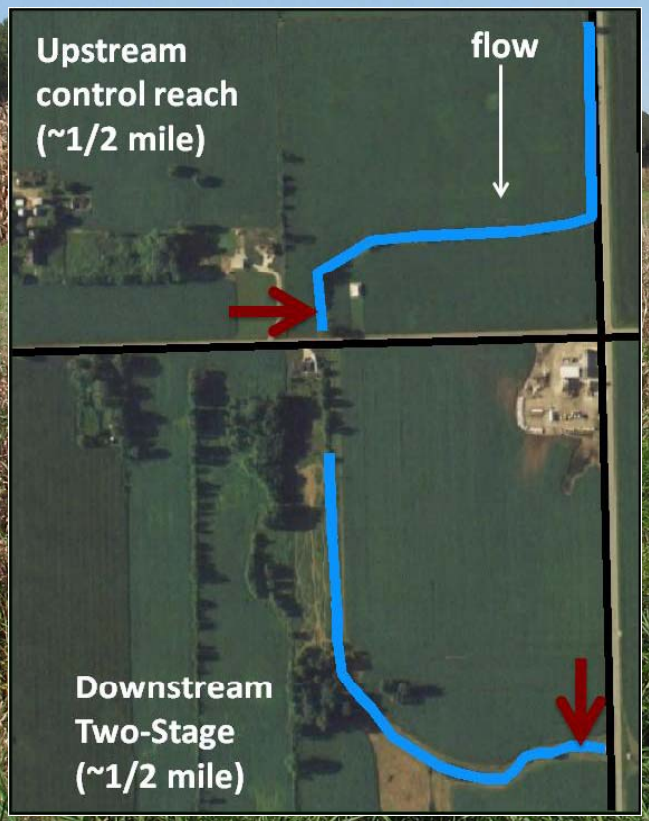


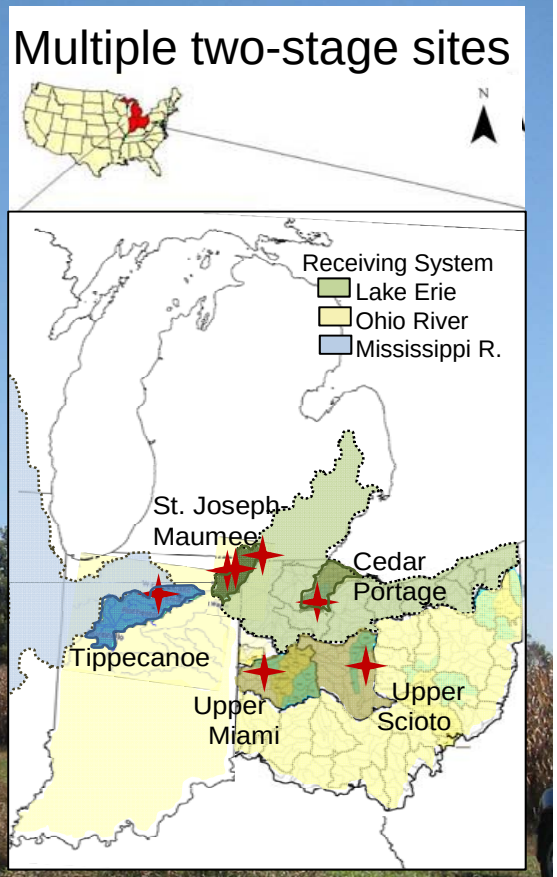
- Increase channel stability
- increased sedimentation → particles settle out on floodplains
- We predict increased nutrient retention→ more time/space for removal

Mature floodplain benches (6 yrs post)

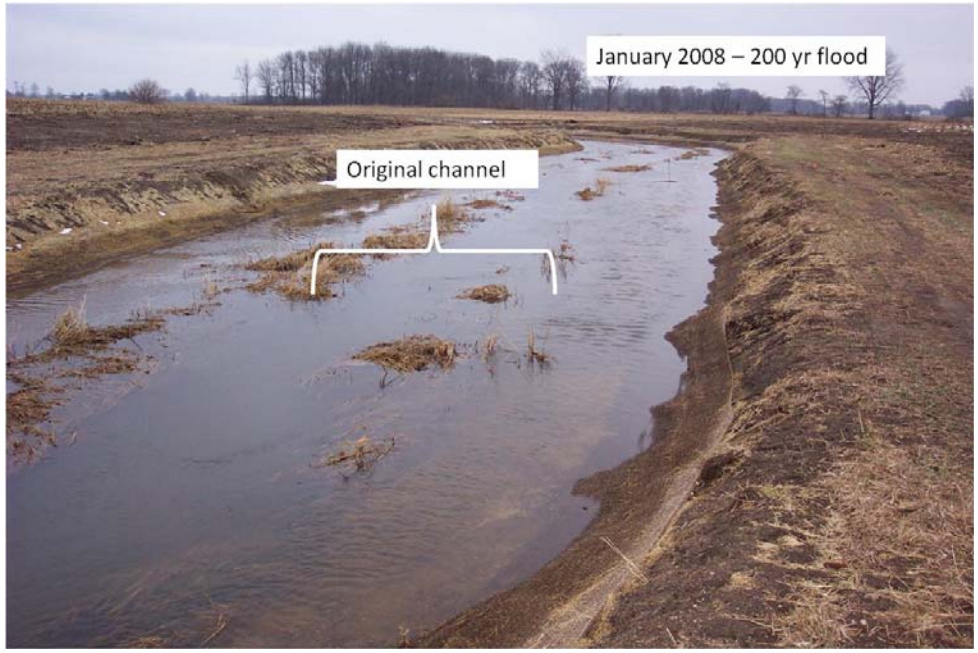
Two-Stage Ditch Monitoring

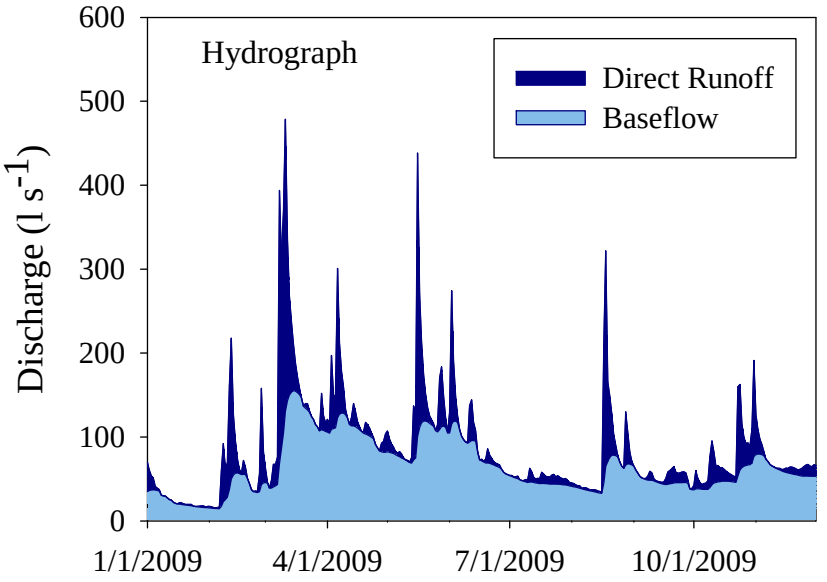
1. Can we reduce sediment and phosphorus export?
2. Can we increase nitrate-N removal?



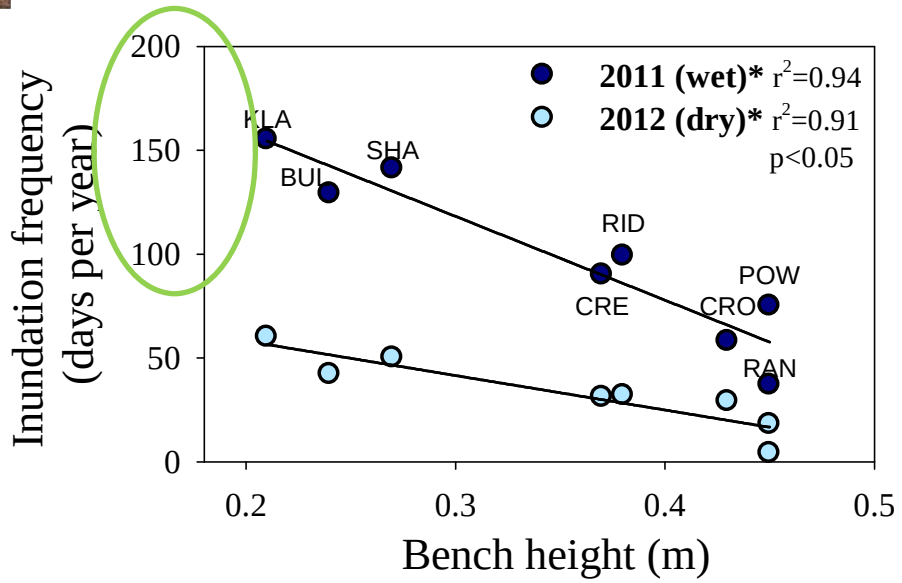


Two-stage floodplains slow water velocities during storms





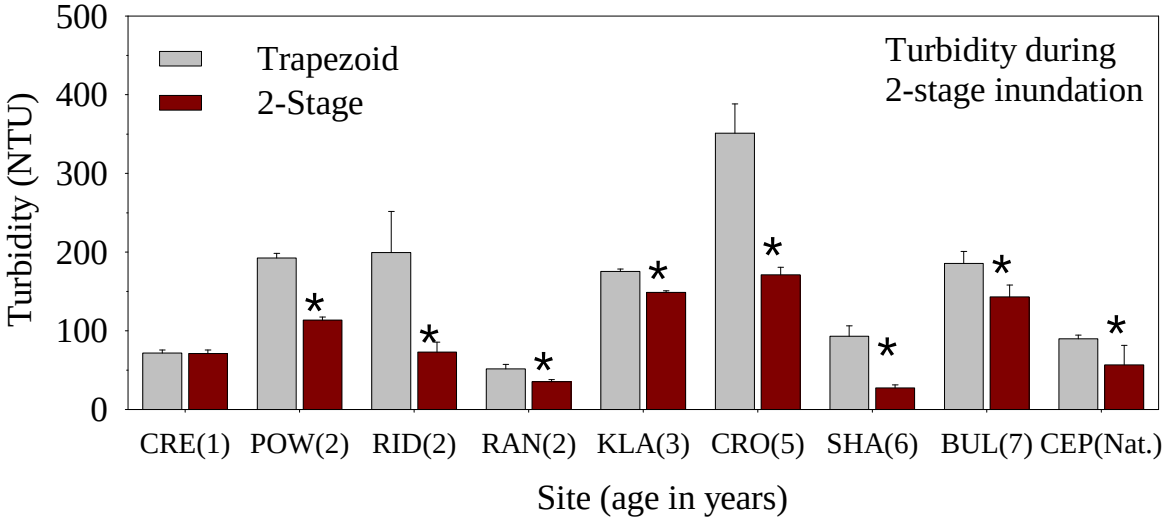
- Agricultural streams have flashy discharge, especially during winter/spring
- Storm flows inundate two-stage floodplains, but duration varies in wet and dry years.
- Net effect: decrease in water velocities, and increased sedimentation.

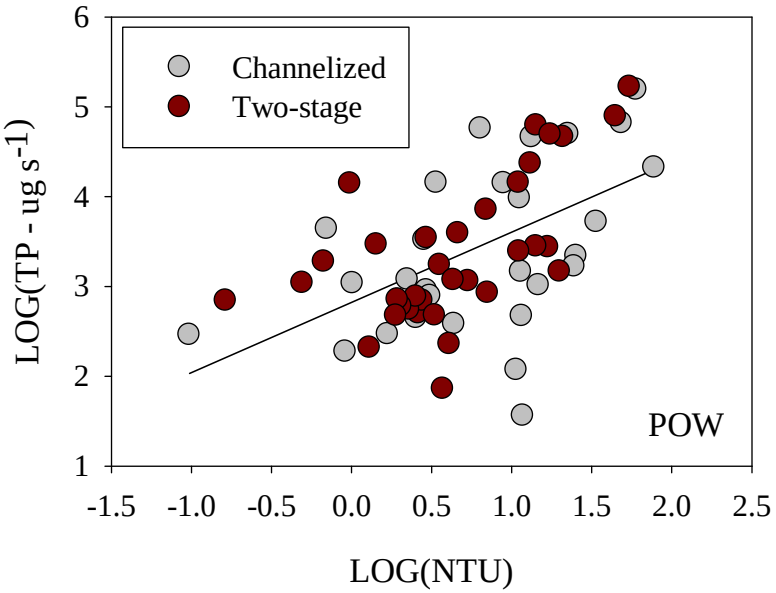


Tank, Mahl et al. unpublished data

Does the two stage influence sediment export?

- Two-stage reduced water column turbidity, even as the two stage ages.
- Turbidity correlates with total phosphorus (TP), so reducing sediment load may reduce particle-associated P export.





Tank, Davis et al. unpublished data

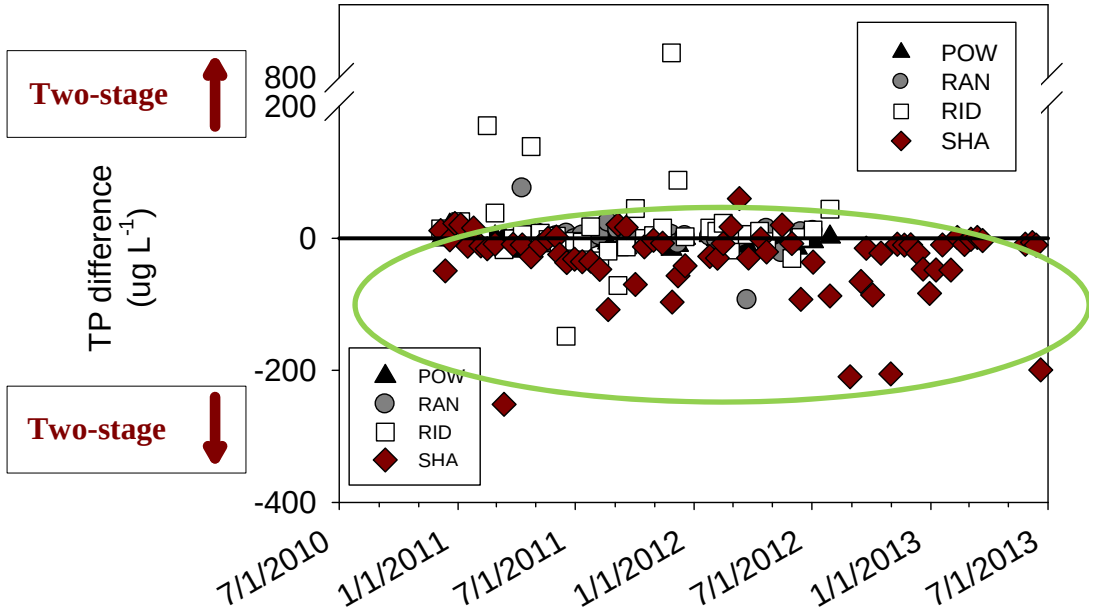
Take home: During inundation, the two-stage ditch slows water velocities, allowing sediments to deposit onto floodplains.

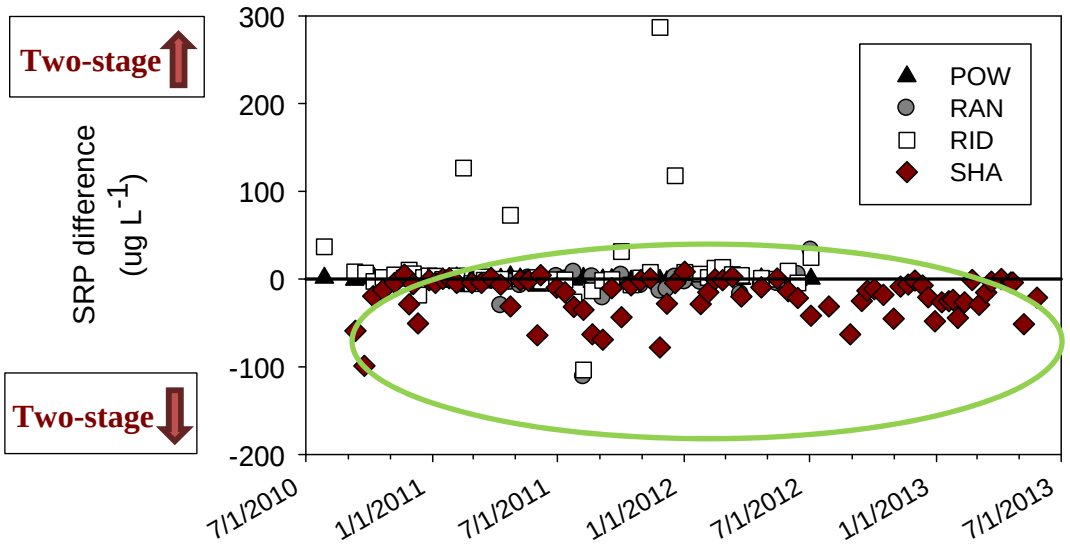
Q: Does this have benefits for phosphorus export?

Does the two stage reduce particulate and dissolved P?

- We are monitoring water chemistry using paired sampling approach comparing two-stage with upstream channelized reach.
- TP was variable; at Shatto TP was generally lower in two-stage reach.
- Similar results for dissolved P; two-stage also reduced concentrations but reduction depended on site (e.g., manure).

Take-home: The two-stage can reduce TP and SRP export, but stream-specific landscape practices matter, and can mediate efficacy.





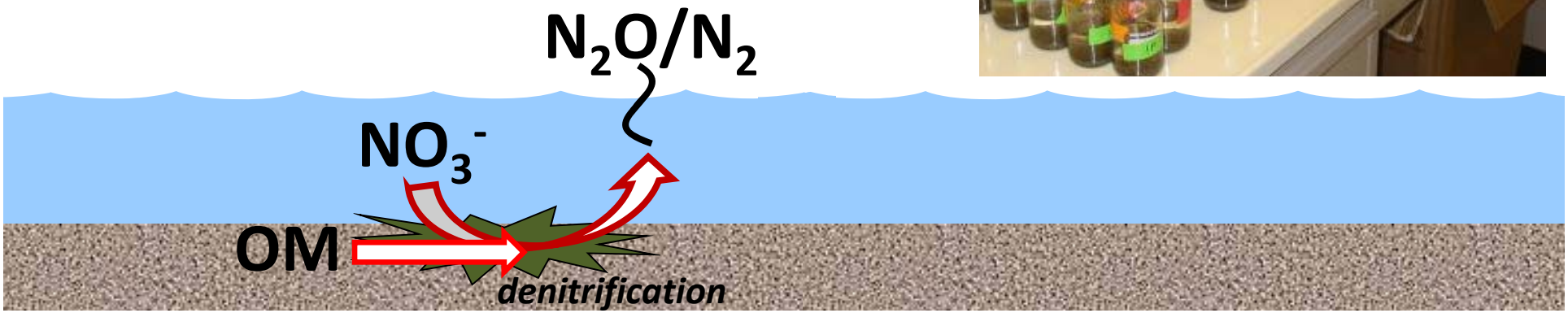
Tank, Davis et al. unpublished data

Quantifying N removal via denitrification

- Permanent Removal: **denitrification**
  - Microbial conversion of dissolved N to gaseous N
  - Occurs in the presence of organic matter & anoxia

- Denitrification measurement
  - Transects: stream sediments & floodplain soils
  - **Lab assays: (acetylene reduction)**


Lab assay bottles

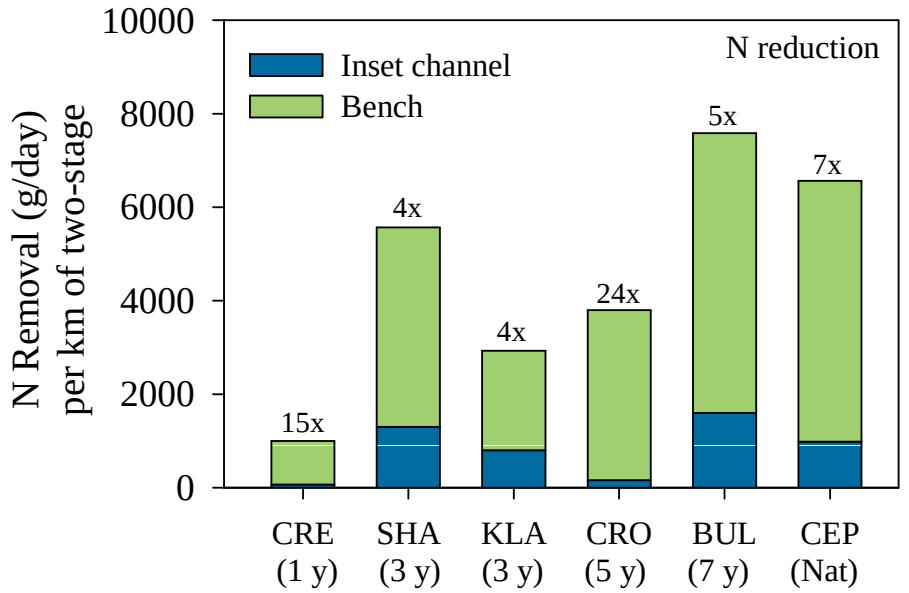


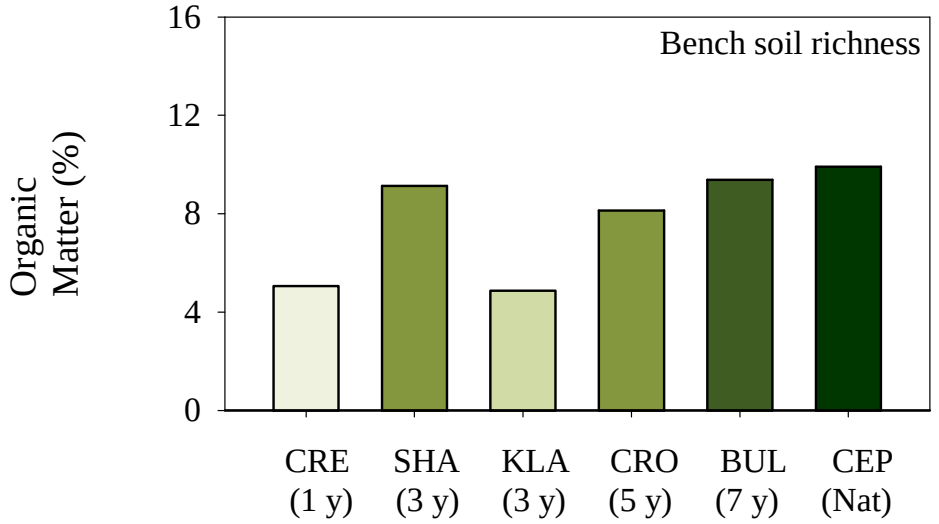
Do two-stage floodplains increase denitrification N removal?

- During flooding, the two-stage significantly increased bioreactive surface area and thus reach-scale denitrification; rates were 4-24x higher than for channelized ditch alone.

- Denitrification N removal tended to increase as floodplains get older, and we found that older two-stages have richer floodplain soils, which provides C for denitrifying microbes.

Take home: Two-stage floodplains "mature" through time, and denitrification nitrate-N removal improves without additional stream management





Tank, Mahl et al. unpublished data

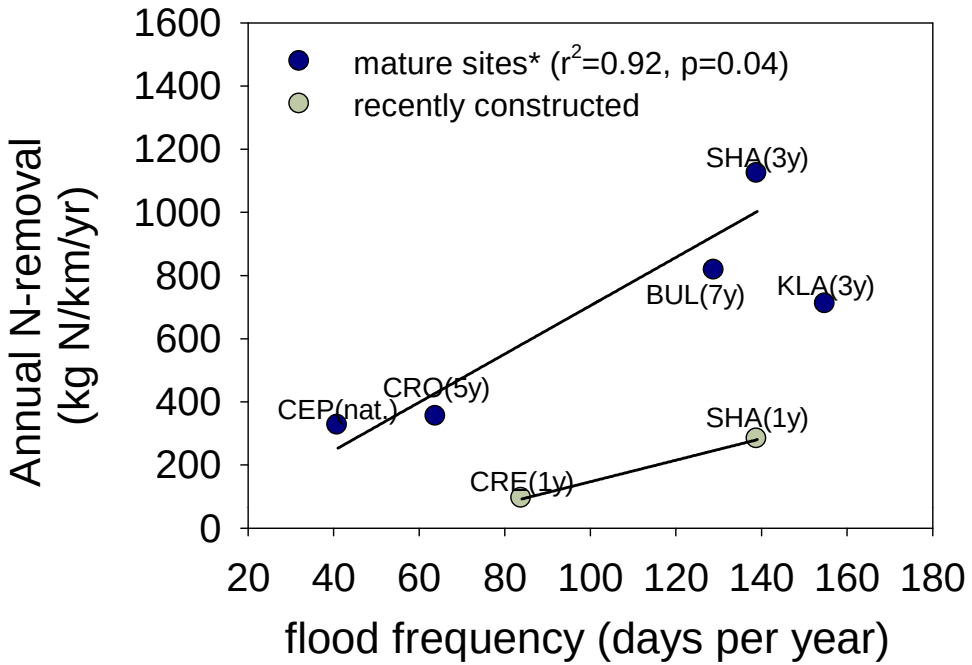
Can improved denitrification N removal reduce nitrate export?

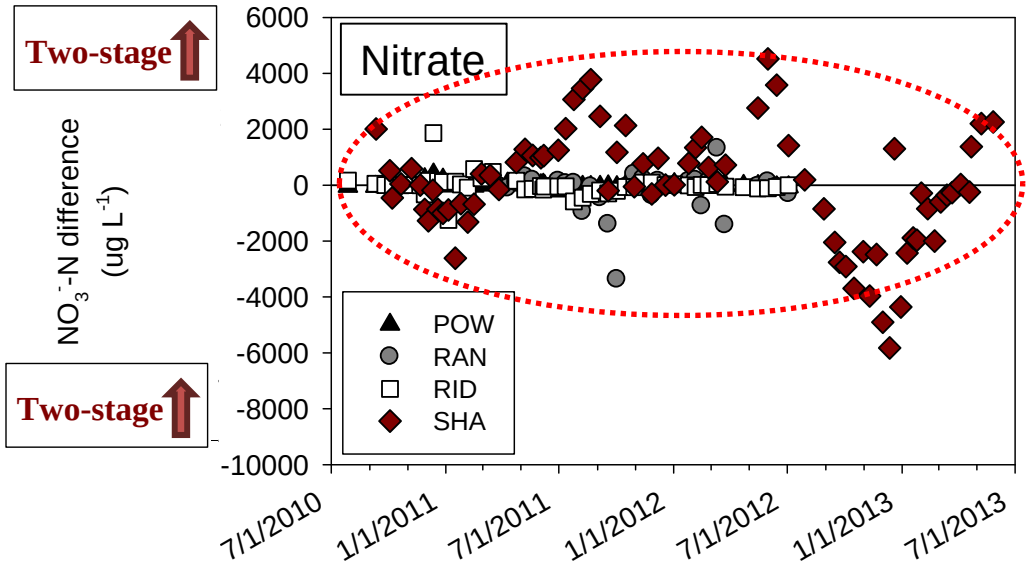
- Combining inundation data with denitrification N removal, we can estimate annual N removal by floodplains.

- Mature two-stage: 300-1100 kg N/km/yr, while younger two-stages remove less.

- No consistent declines in NO_3^- due to high concentrations (>5mg/L); currently too high to be significantly reduced by 600-800m of two-stage.

Take-home: Efficacy could be improved if two-stages were longer or practice combined with other land management to reduce nutrient inputs.



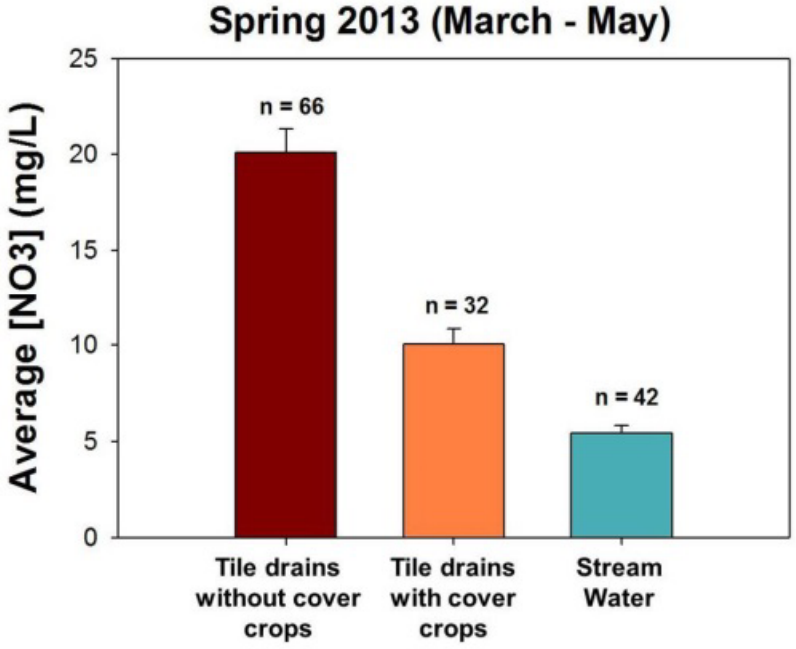


Tank, Mahl, Davis unpublished data

Reducing nutrient inputs into adjacent waterways

- Most NO_3 enters streams through tile drains during winter and spring when fields are bare.
- Cover crops, like ryegrass, can be planted after cash crop harvest; growth coincides with critical period for NO_3 export (March-May).
- Preliminary data suggest that cover crops have potential to significantly reduce NO_3 export from tile drains.

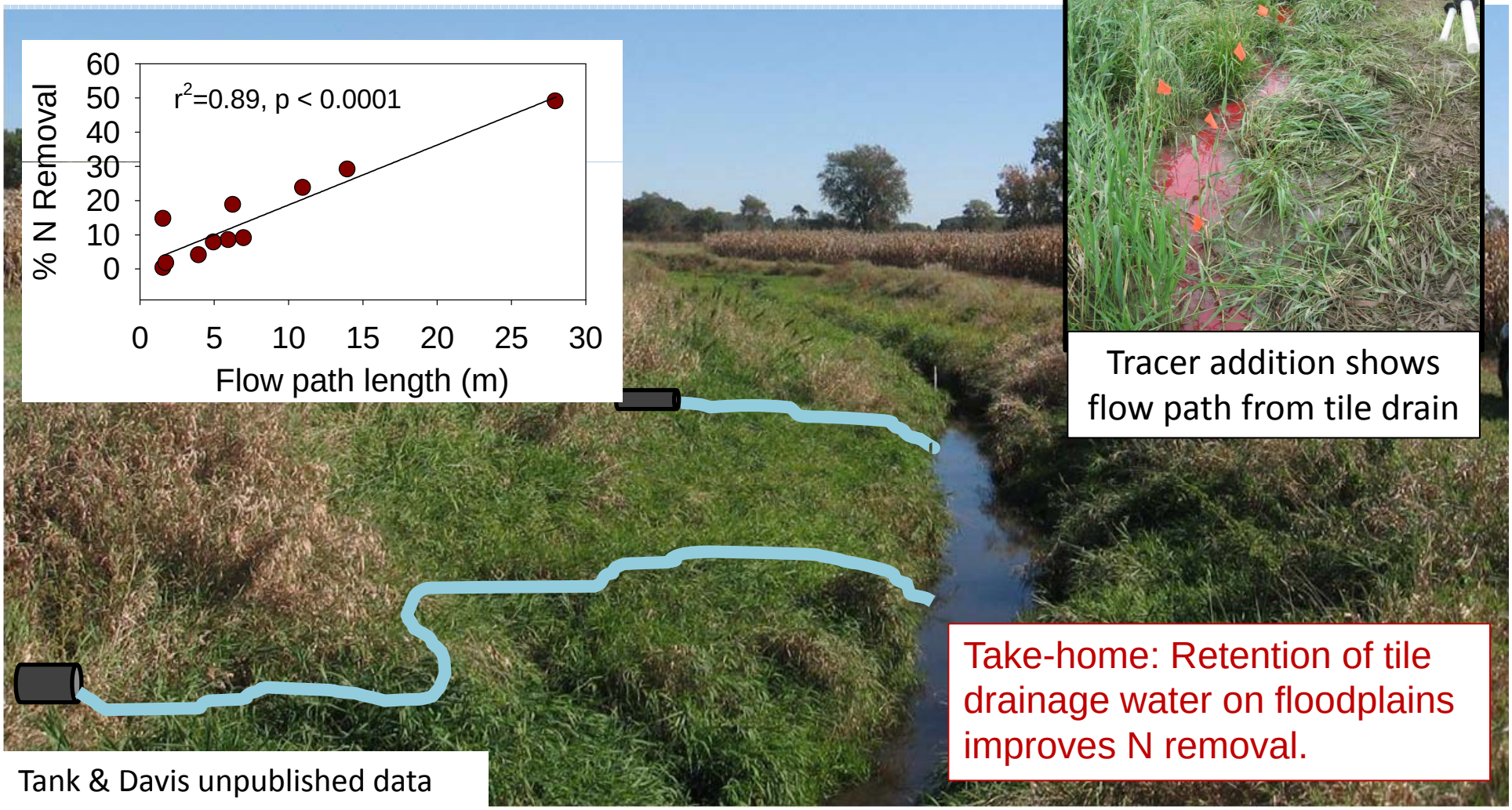
Take-home: Stacking management practices like cover crops with in-stream practices like the two-stage could further improve water quality.



Tank & Hanrahan unpublished data

Can two-stage floodplains reduce nitrate during baseflow?

- With two-stage, tile drains empty onto floodplain benches.
- During base-flow, two-stage can reduce NO_3^- nitrate from tiles depending upon length of flow path.



Tracer addition shows flow path from tile drain

Take-home: Retention of tile drainage water on floodplains improves N removal.

Tank & Davis unpublished data

Summary: effects of two-stage ditch on water quality

- During storms, the two-stage can reduce sediments and increase nutrient removal via floodplain inundation, which can be extensive depending on water year and height of floodplain construction.
- With no additional maintenance ,the two-stage practice “ages” well and function improves, making it a self-sustaining practice.
- During baseflow, two-stage floodplains can also reduce NO_3^- in tile water as the flowpath moves across vegetated floodplains.
- Stacking the two-stage with other landscape practices (e.g., cover crops) may be even more effective in managing nutrient export in a high-nutrient landscape.

Roley, S. S., J.L. Tank, M.L. Stephen, L.T. Johnson, J.J. Beaulieu and J.D, Witter. 2012. Floodplain restoration enhances denitrification and reach-scale nitrogen removal in an agricultural stream. Ecological Applications. 22: 281–297.

Roley, S. S., J.L. Tank, and M.A. Williams. 2012. Hydrologic connectivity increases denitrification in the hyporheic zone and restored floodplains of an agricultural stream. J. Geophys. Res- Biogeosciences. doi:10.1029/2012JG001950

Implementation best practices – the two-stage ditch works best when:

- Floodplain benches are inundated regularly.
  → best when > 12 inundation events per year.
- Tile water flows across floodplains for as long as possible.
  → Construct tile outlets so not rip-rapped.
- Floodplain benches "age" better when vegetated.
  → Species identity secondary, does not alter N removal.

Take-home: The two-stage is a potential tool in the nutrient management toolbox that can be implemented to improve water quality while coexisting with productive agriculture.

Two-stage Information:

Nutrient and sediment benefits (Univ. of Notre Dame)

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Site Evaluation and channel stability (The Ohio State Univ.)

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The Nature Conservancy
Protecting nature. Preserving life.™

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