Combating nutrient transport in drainage water using various conservation practices

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Friday, March 3, 2017

Latitude: 45°N

Latitude: 43.7°N

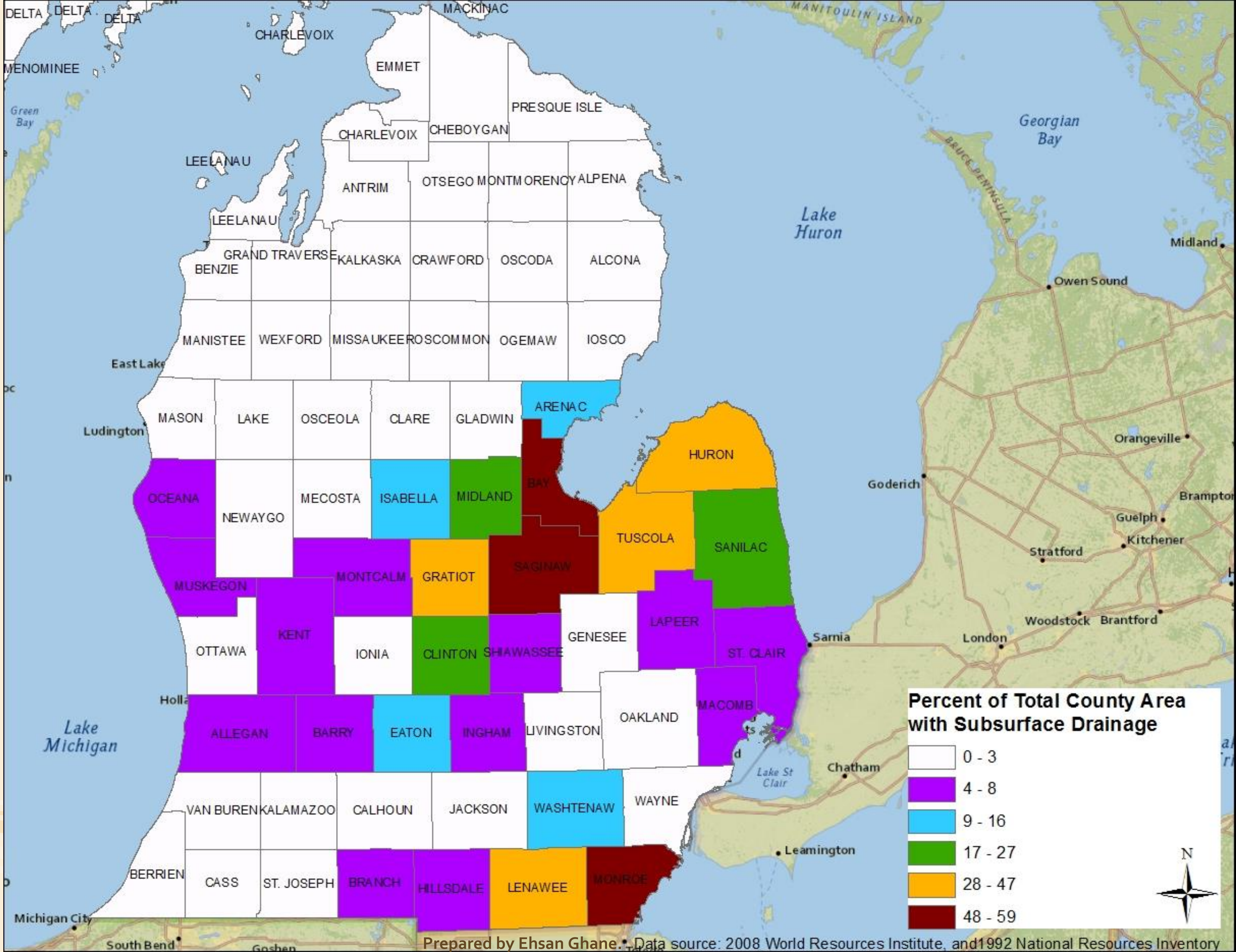
Latitude: 40°N

Tile: Michigan

- 2.3 million acres Agricultural subsurface drainage

- 29% total cropland is tiled

1992 data



Why subsurface (tile) drainage?

Near Willmar, MN: Photo taken on June 15, 2016

Photo taken on September 2, 2016

Great Lakes Algal Bloom Status?

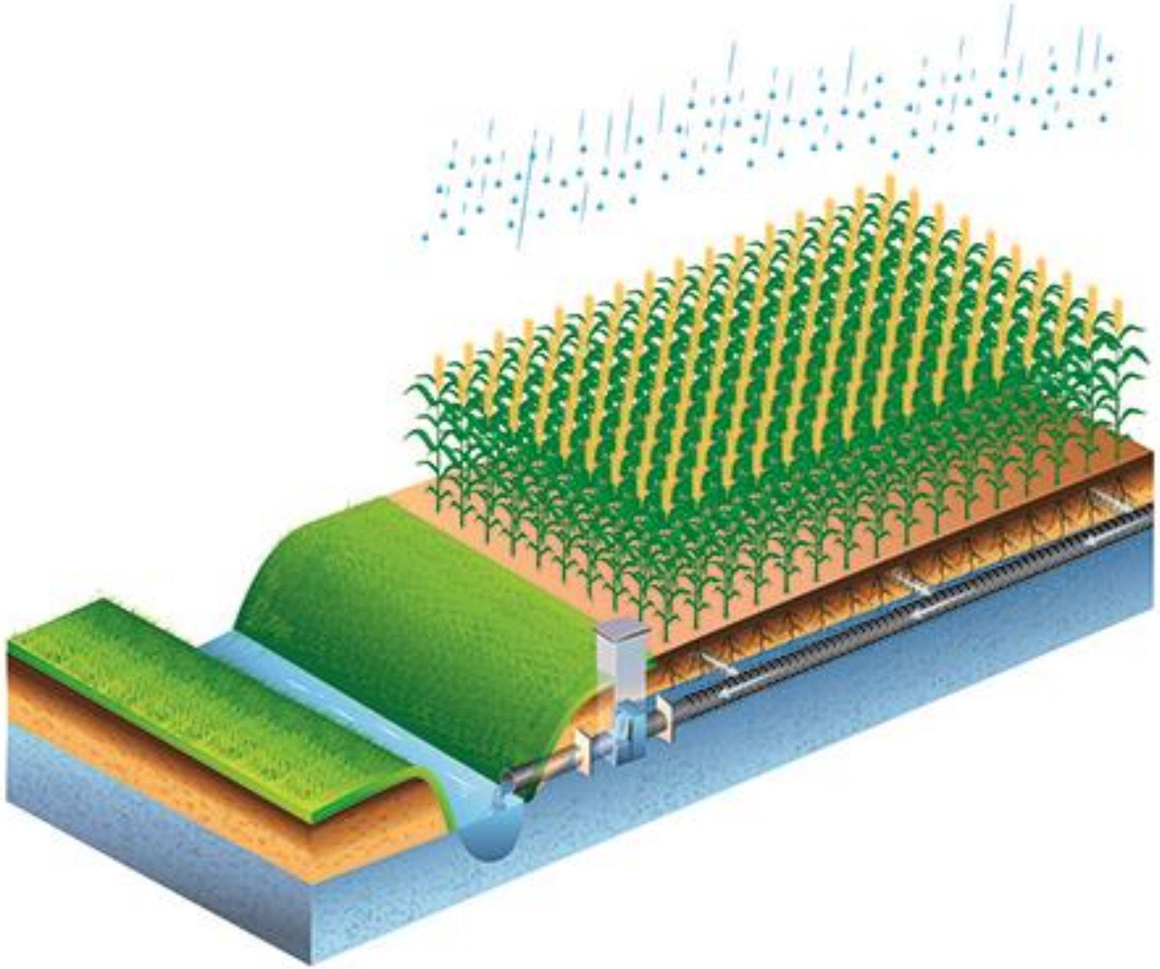
- NASA Worldview

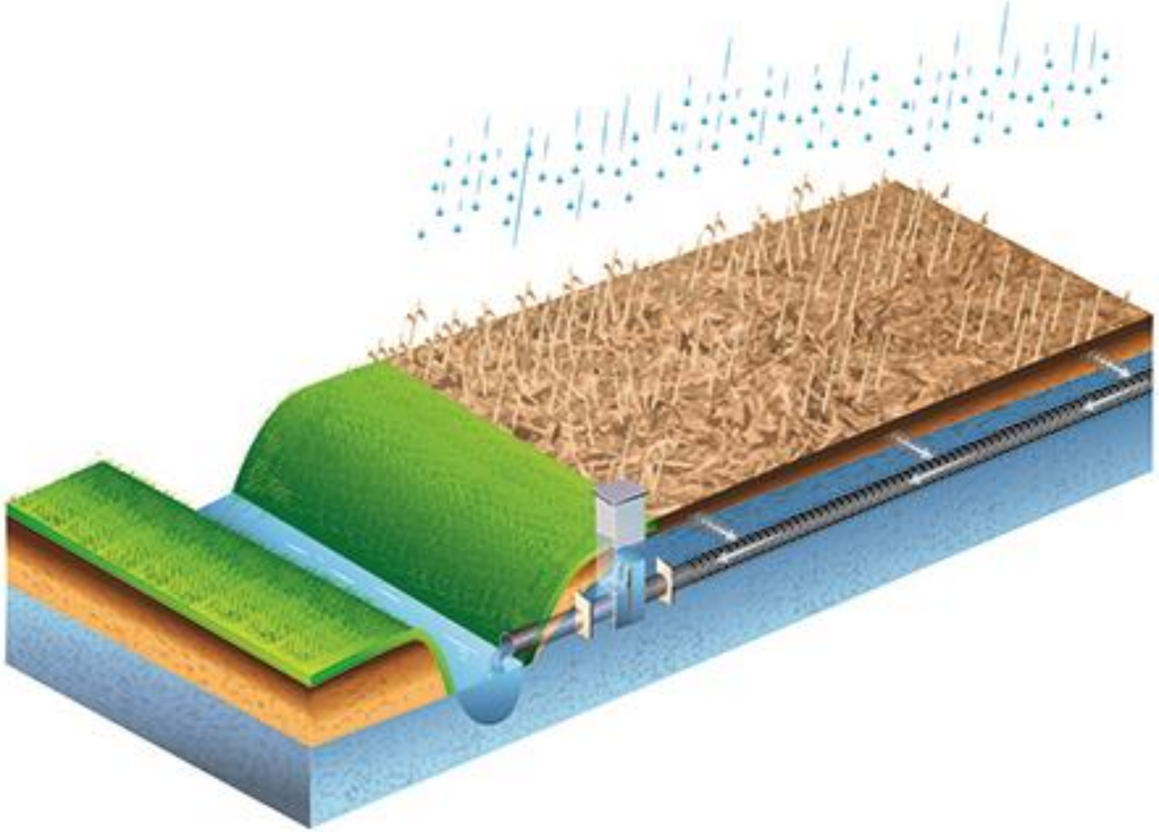
What can we do?

- Wetland
- Two-stage ditch
- Cover crop
- 4R approach (fertilizer: right place, right time, right rate, right form)
- Drainage Water Recycling
- Saturated buffer
- Drainage water management (Controlled drainage)
- Denitrification Bed (Woodchip bioreactor)

Drainage Water Management

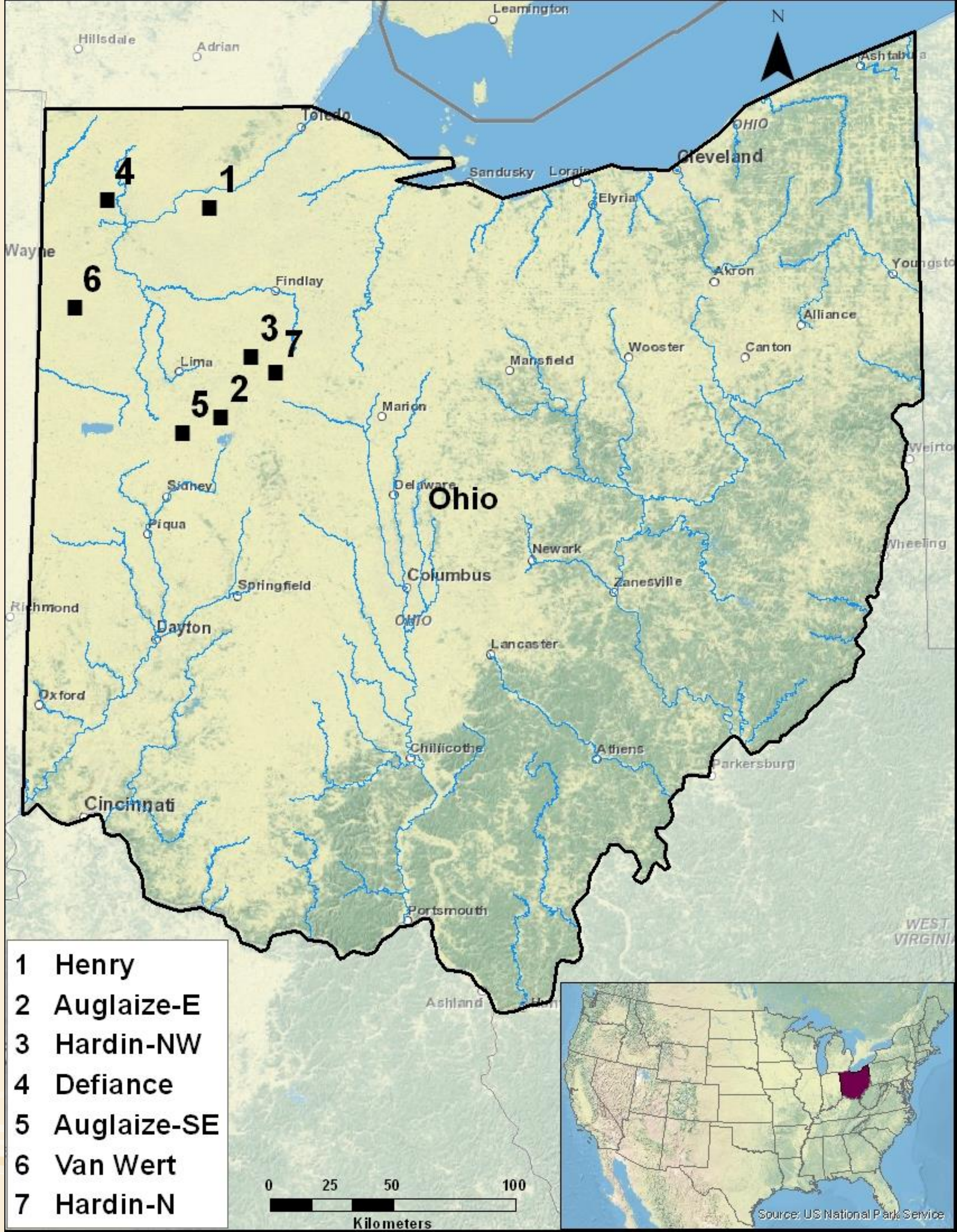
- Main purpose is to reduce nutrient delivery to surface water





Research

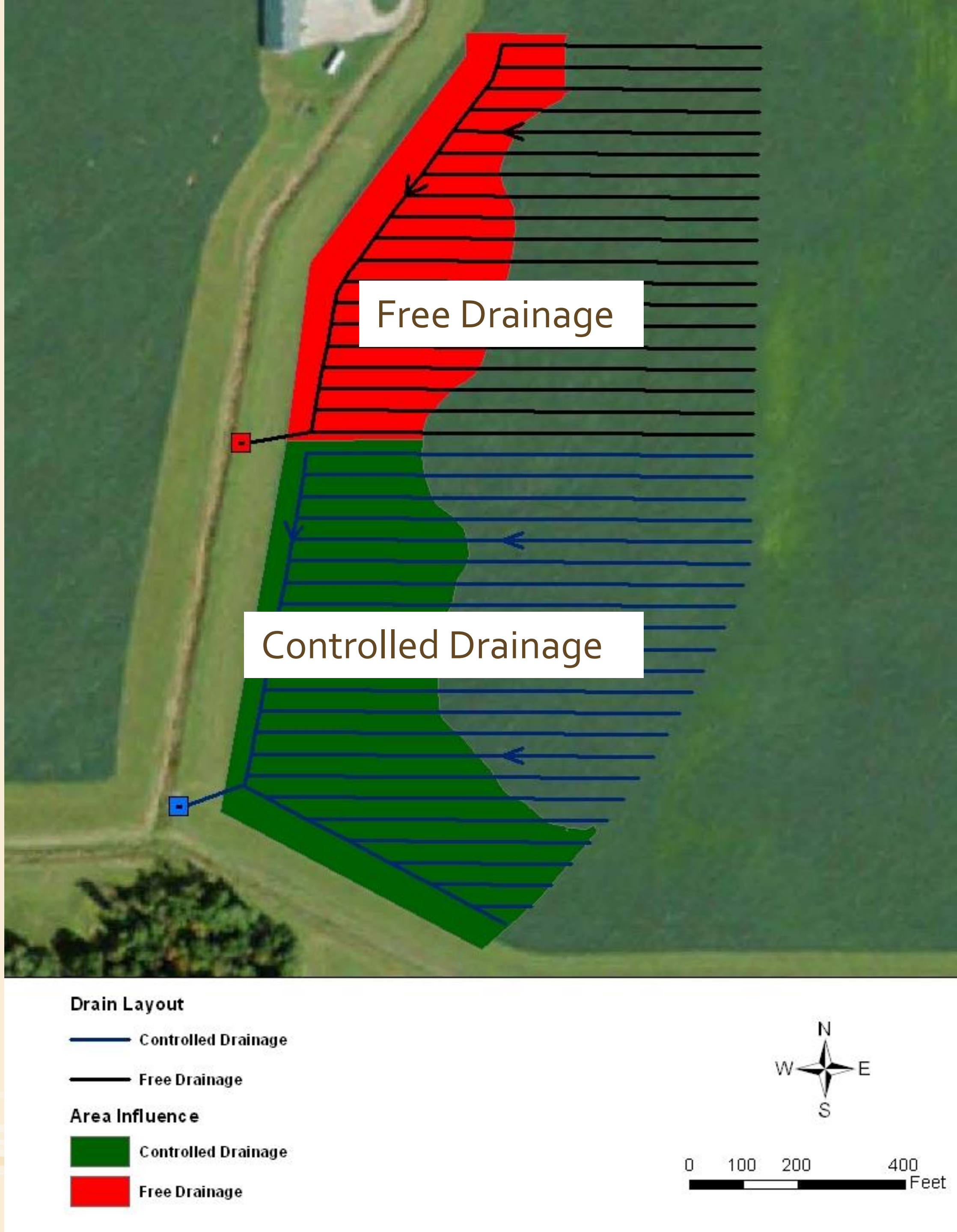
- Initiated in 2007
- Four-year applied project
  - Seven sites
  - (2008-2011)



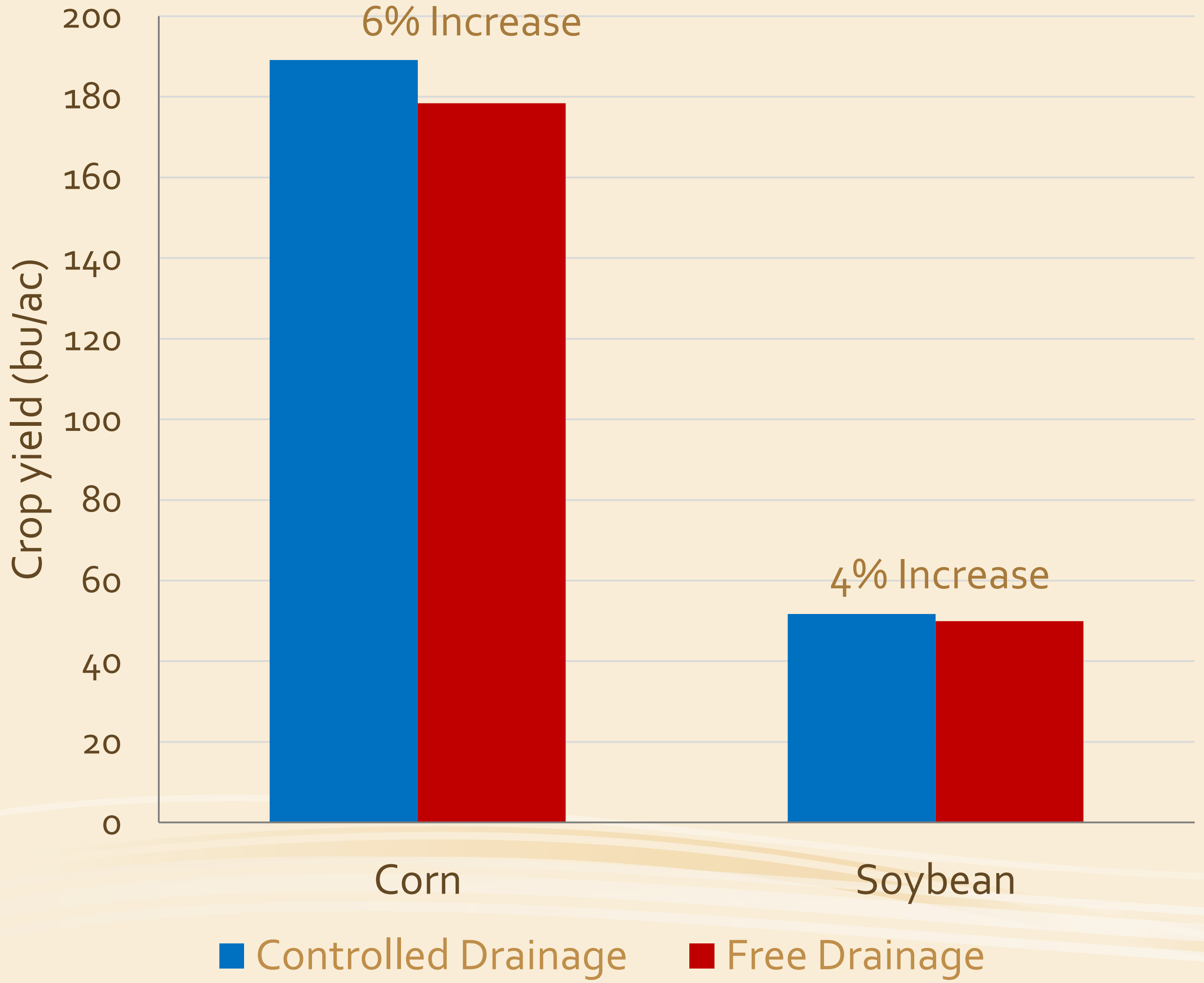


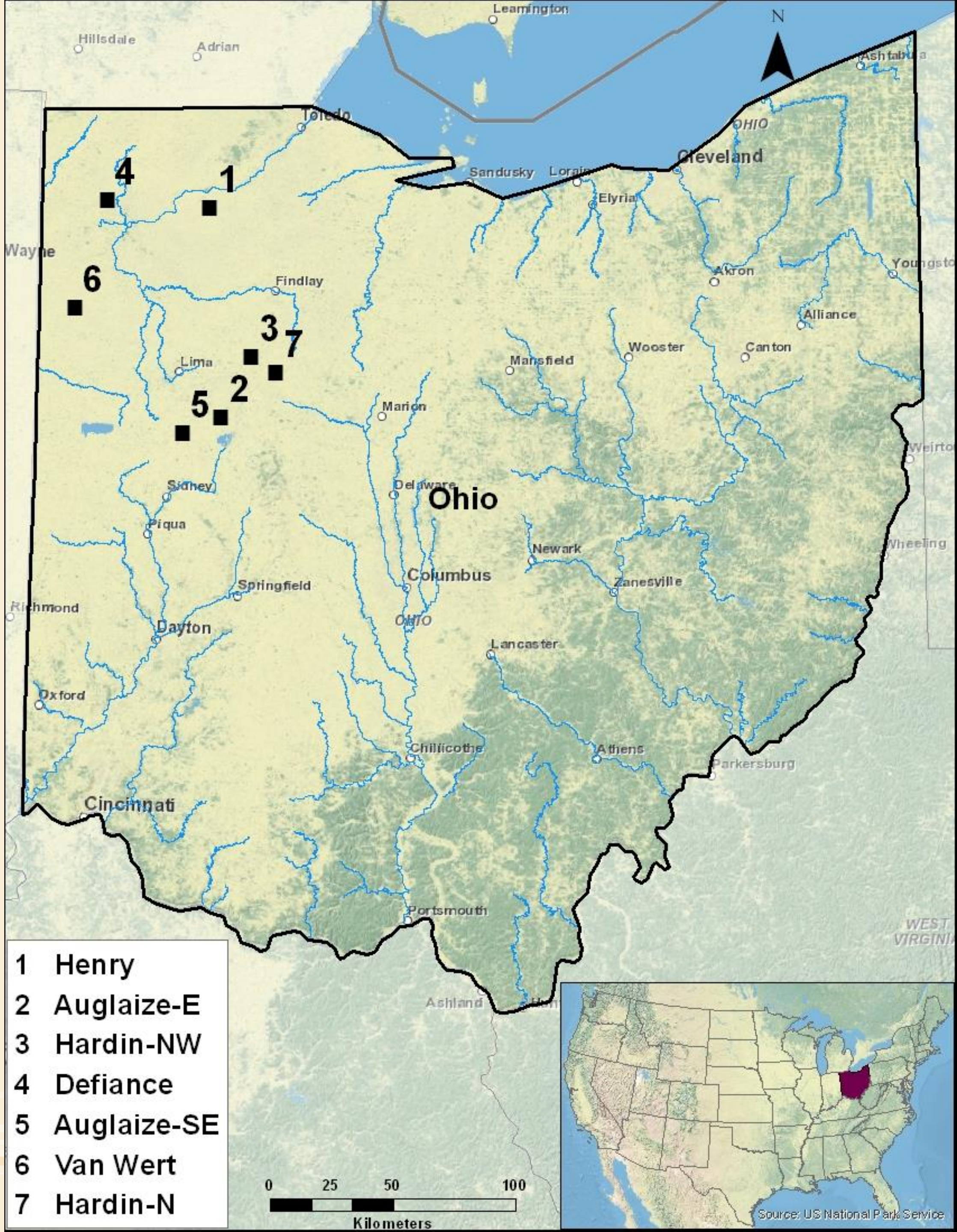
Water Management Zone

- Hardin-NW site (Ohio)



Percent Yield Increase
Water management Zone

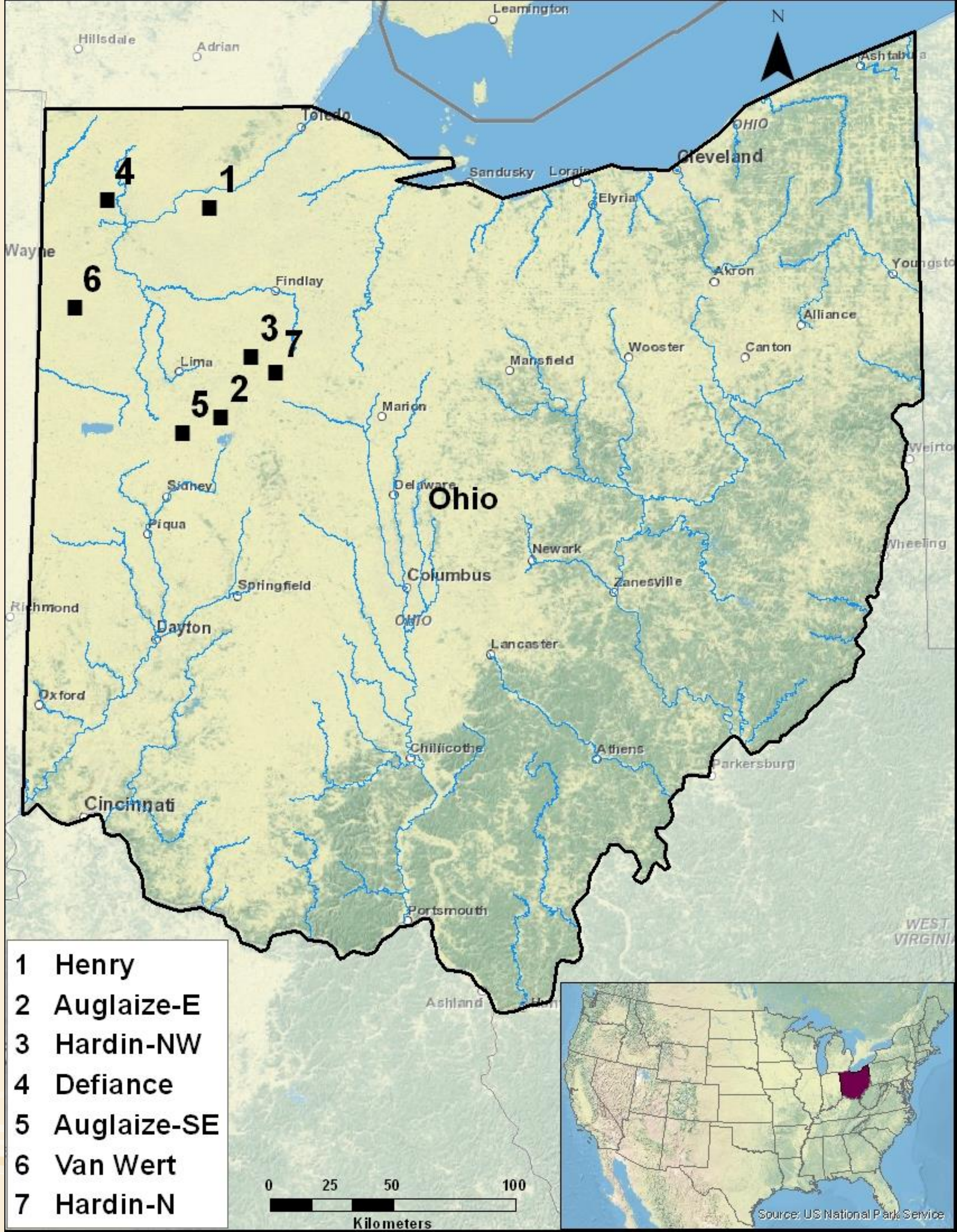




Ghane et al. 2012; J of Soil and Water Conservation

Controlled Drainage

- Found **reduced flow (40% to 100%)**
  - Reduce nutrient loss



Why would DWM be of interest?

- No land is taken out of production
- Low maintenance and requires management
- Reduces nutrient runoff (nitrate load reduction 15% to 75%)
- Improves crop yield with proper management and timely rainfall

Any Questions So Far?

- Drainage Water Management

Denitrifying Bioreactors

1. Denitrification Wall
2. Streambed Bioreactor
3. Denitrification Bed (woodchip bioreactor)

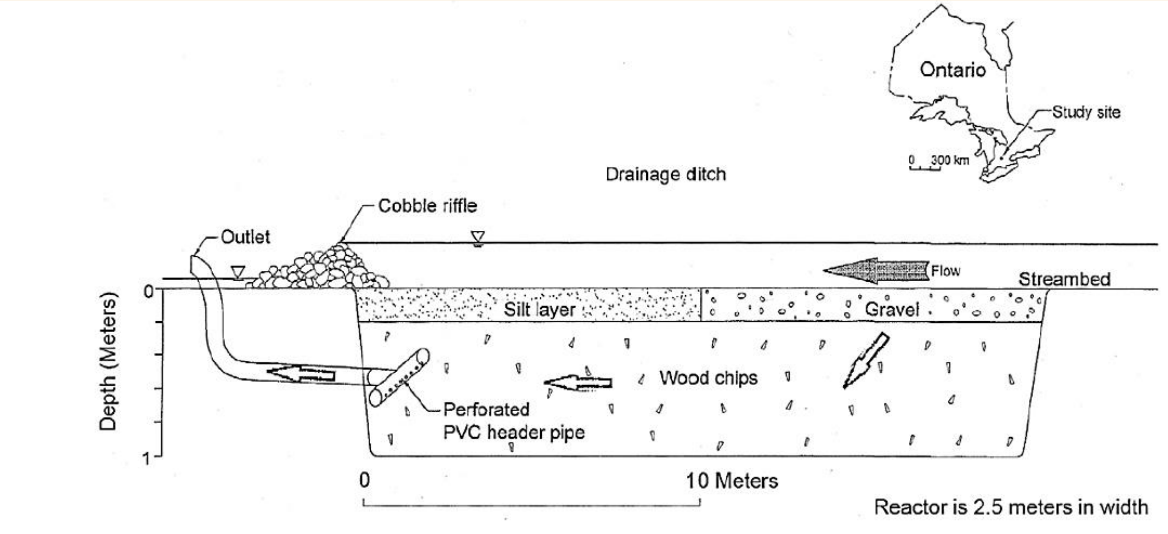
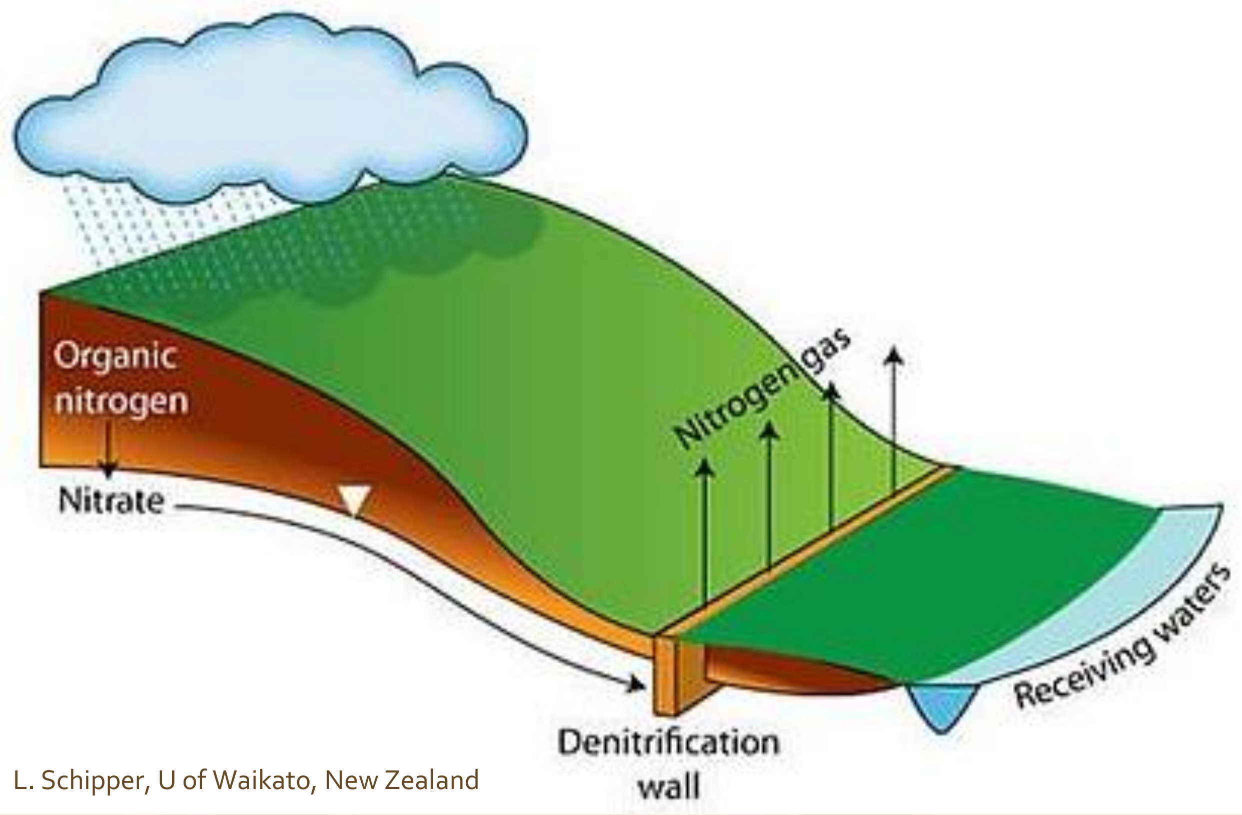
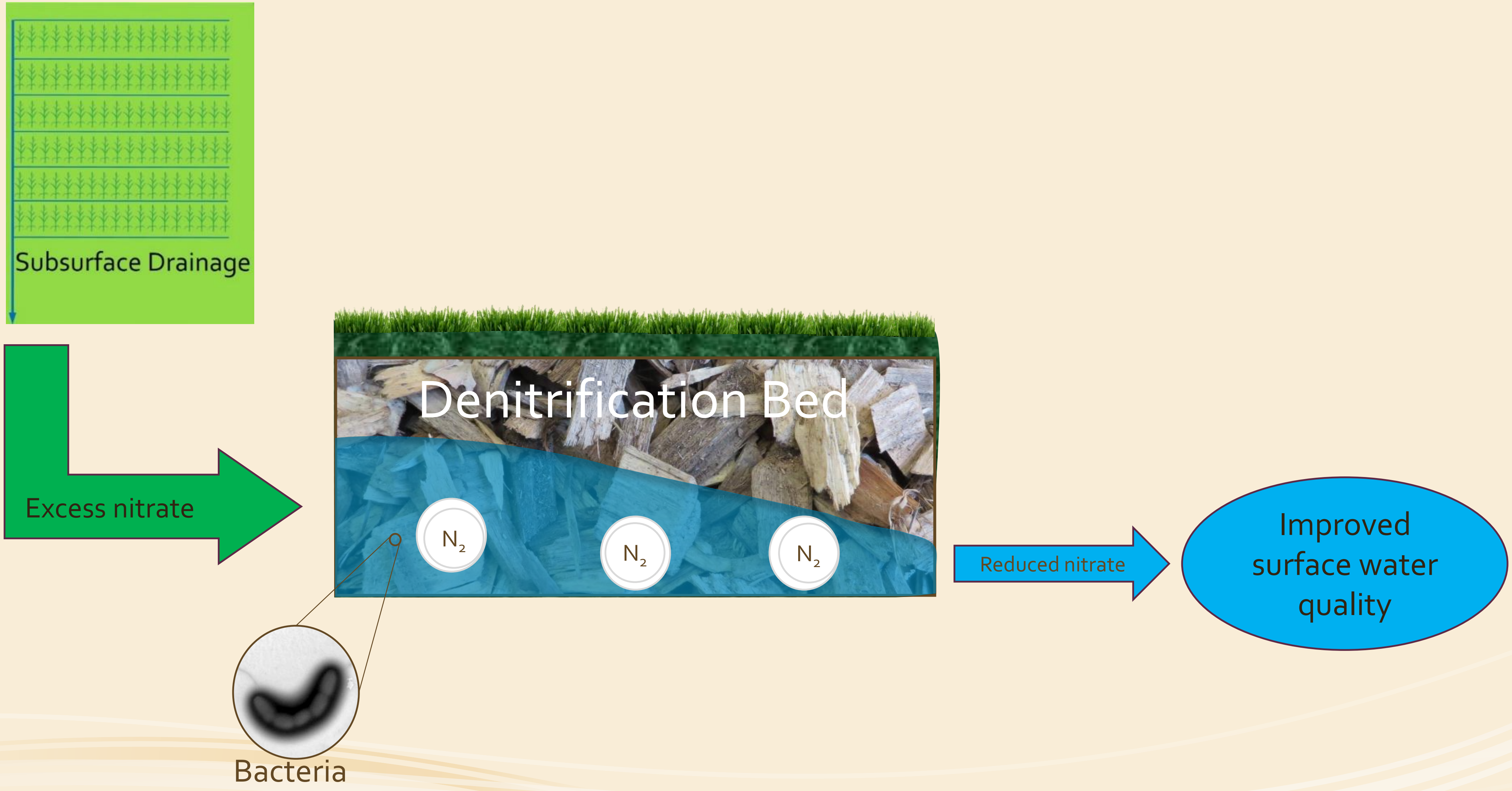


Fig. 1. Design sketch of Avon streambed bioreactor (adapted from Robertson and Merkley, 2009).

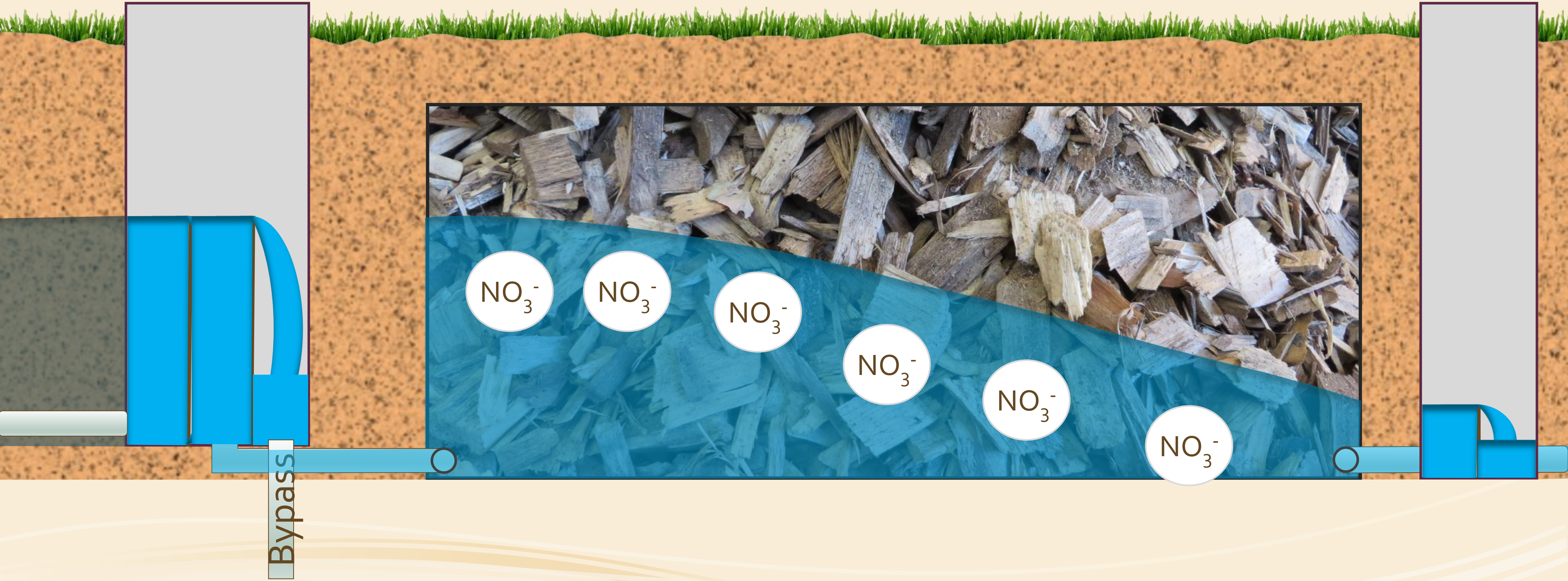


L. Schipper, U of Waikato, New Zealand

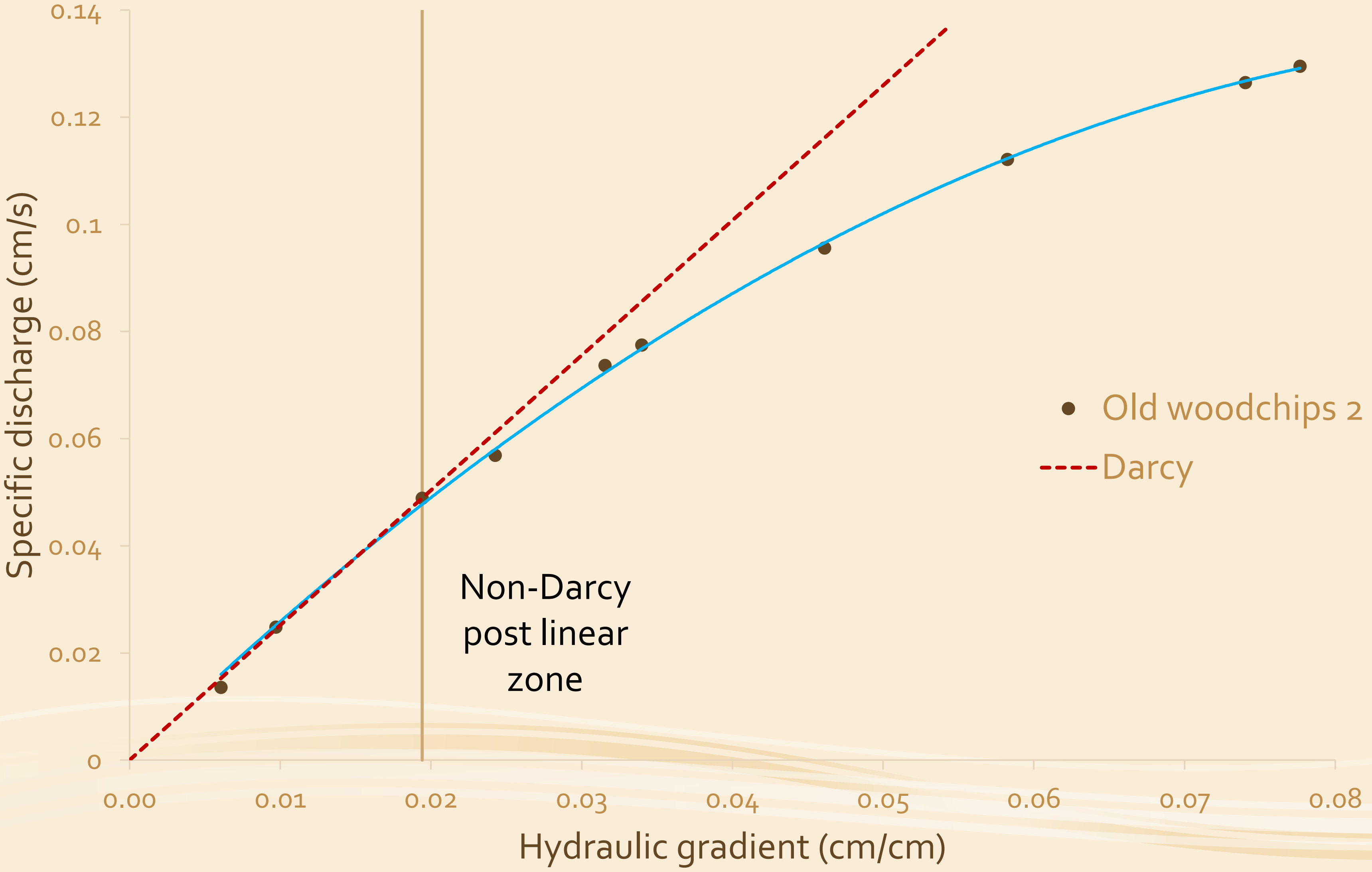
What’s a Denitrification Bed?



Side View: Woodchip Bioreactor

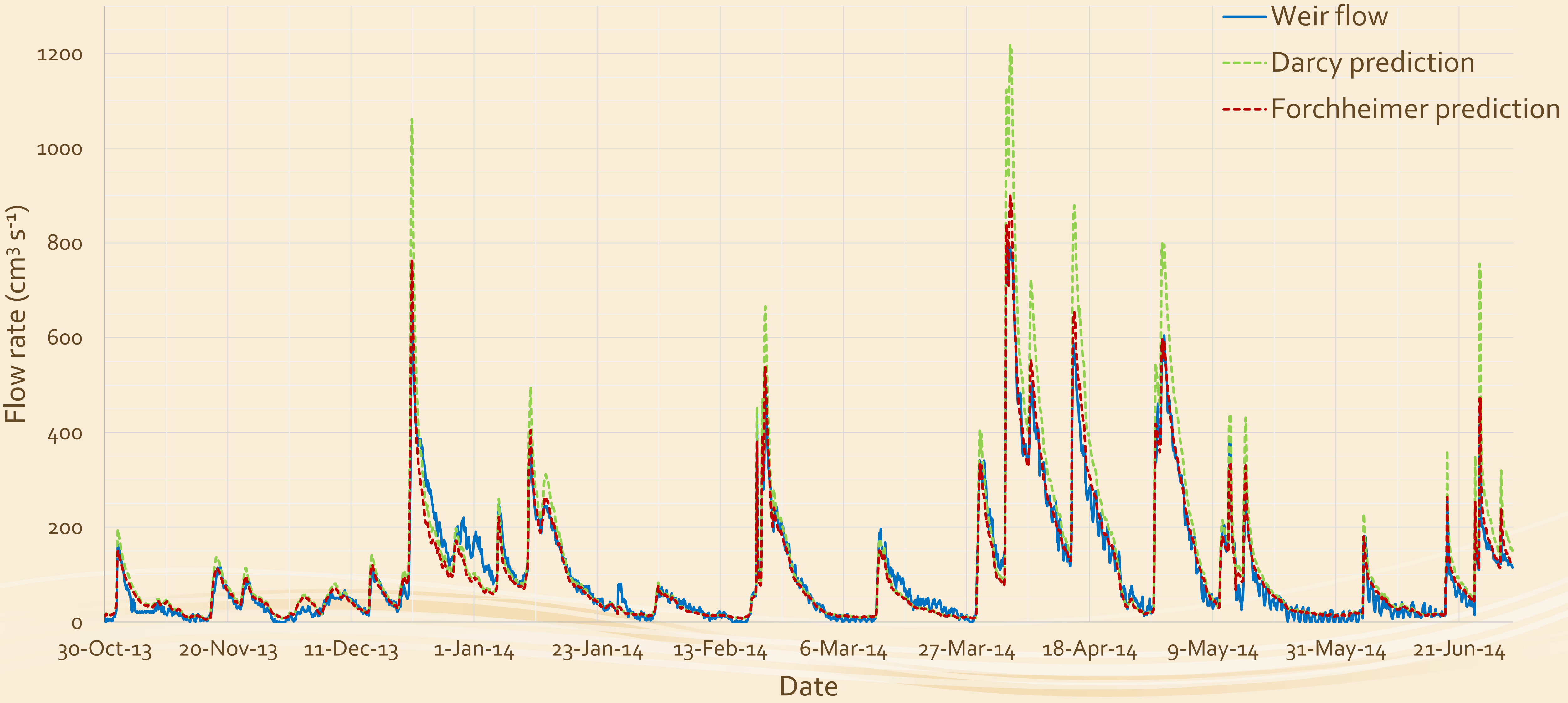


Non-Darcy flow through woodchips



Ghane et al. (2014) data:

Darcy's Law Flow Overestimation



Galaxy of woodchip bioreactors

Darcy

Forchheimer

Denitrification Bed Model v2.0 Beta - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW — Ehsan Ghane

X67

Denitrification Bed (Woodchip Bioreactor) Model v.2.0 Beta

Ehsan Ghane, Ph.D., The Ohio State U, and U of Minnesta

Not for distribution

Woodchip Media Properties	Input
Intrinsic permeability, k_{in} (cm^2)	0.0000568
ω constant (s^2/cm^2)	0.88
Effective porosity or drainable porosity, n_e	0.45

Nitrate Removal (Michaelis-Menten and Arrhenius Equations)	Input
Maximum nitrate removal rate, V_{max} (mg-N/L·h)	7.1
Michaelis-Menten constant, K_M (mg-N/L)	7.2
Temperature coefficient, θ	1.109

Denitrification Bed Properties	Input
Denitrification bed depth (ft)	4
Denitrification bed length, L (ft)	60
Denitrification bed width, w (ft)	15
Denitrification bed bottom slope, S (ft/ft)	0.001

Denitrification Bed Summary	Output
Inflow height of water in the bed, h_i (ft)	3.53
Outflow height of water in the bed, h_o (ft)	0.63
Hydraulic gradient, i (ft/ft)	0.049
Bed outflow temperature, T (°F)	58
Outflow dynamic visosity, μ (g/cm·s)	0.0116
Hydraulic conductivity at outflow temperature, k (ft/s)	0.16
Analytical solution to Forchheimer's Equation=0	0.0
Bed flow rate that makes Forchheimer's Equation equal to zero	0.153
Denitrification bed flow rate, Q (cfs)	0.153
Actual hydraulic retention time, AHRT (h)	1.6

Overall Summary	Output
Outflow nitrate concentration, C (mg N/L)	12.1

Field Properties	Input
Drainage area (ac)	67.6
Drainage coefficient, DC (in/d)	0.5

Flow Conditions	Input
Control structure size (in)	10
Inlet height of stoplogs (ft)	Three (7"+5")= 3 ft
Outlet height of stoplogs (ft)	7" (bottom stoplog only)
Inflow nitrate concentration, C_i (mg N/L)	15
Bed inflow (tile water) temperature, (°F)	55

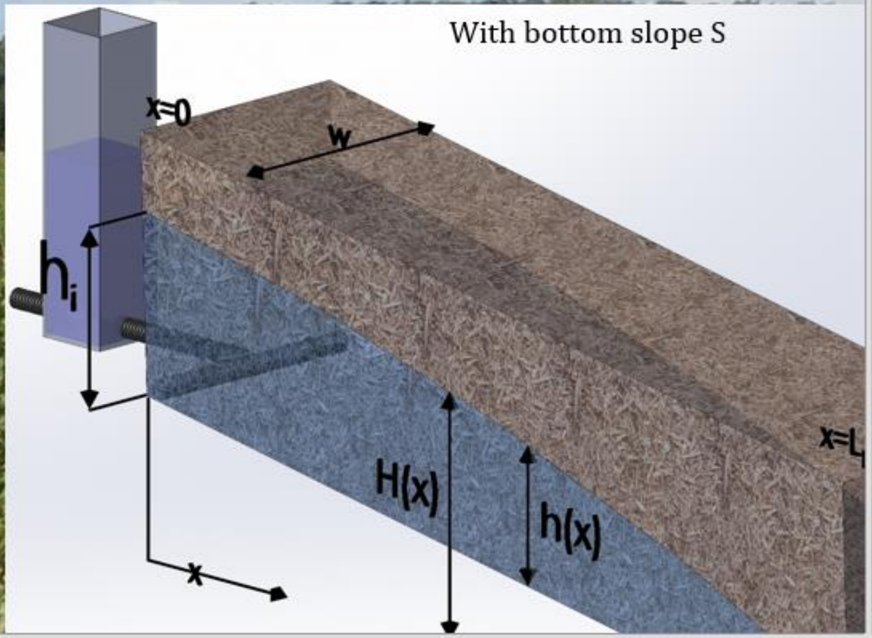
Weep Hole Properties (Optional)	Input
Weep hole on bottom stoplog?	Yes
Weep hole diameter (in)	0.5
Weep hole distance from bottom (in)	5.875

Control Structure Summary	Output
Drainage system capacity (cfs)	1.420
Bypass flow from the inlet structure (cfs)	1.267
Flow depth above inlet stoplog crest (ft)	0.61
Flow depth above outlet stoplog crest (ft)	0.13

Weep Hole Summary	Output
Weep hole flow rate (cfs)	0.003
Portion of bed flow through weep hole (%)	2.1

Instructions: This worksheet can be used to optimize the design parameters (i.e., length, width, and slope).
First, type all input values and then adjust the length and width. Try to obtain outflow nitrate concentration between 5 to 10 mg N/L, total nitrate load reduction (bed+bypass flow) of at least 5%, and treatment of at least 15% drainage system capacity. These targets are expected to achieve the minimum target of 45% annual load reduction suggested in the Gulf Hypoxia Action Plan 2008.
It is suggested that the design parameters be determined for mid-spring when the outlet elevation of the tile is raised after planting, crop establishment and spring field operations.

Note 1: If you get a "Compile error: Can't find project or library", load the Solver add-in. Then, re-open the Excel Worksheet.
Note 2: Clicking on the description in some boxes will give further



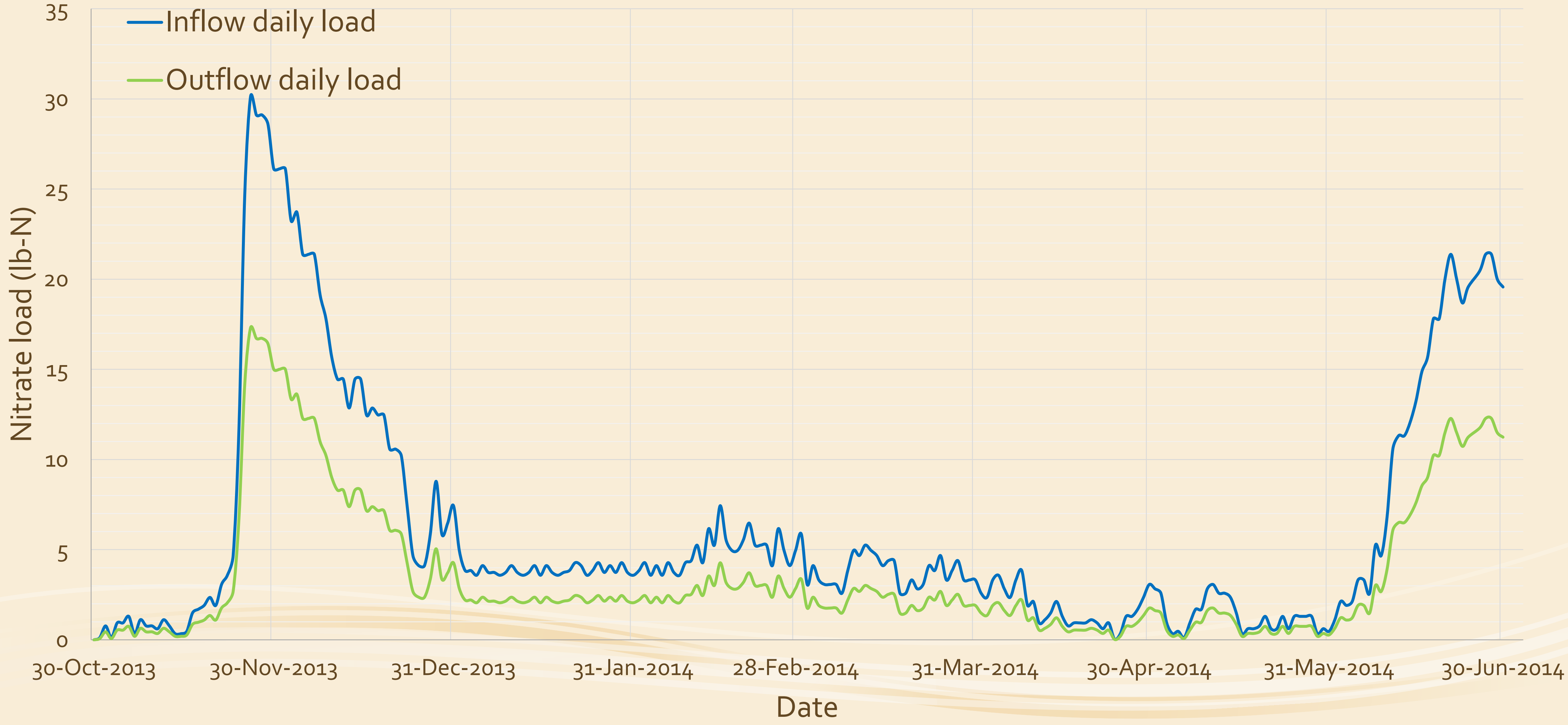
Model (English Units)

READY 100%

Ask me anything — Denitrification Bed ... — ENG 18:58 8/13/2016

Results

Woodchip Bioreactor: Waterman site in Ohio



Why would a Woodchip Bioreactor be of interest?

- Little or no land is taken out of production
- Low maintenance
- Long life (15-20 years)
- Compatible with controlled drainage
- Remove nitrate
  - herbicide (atrazine), pesticides, and pathogens?

PhosphoReduc
Environmental Solutions

PhosphoReduc filter

N_2

P

Woodchip Bioreactor

NO_3^-

P

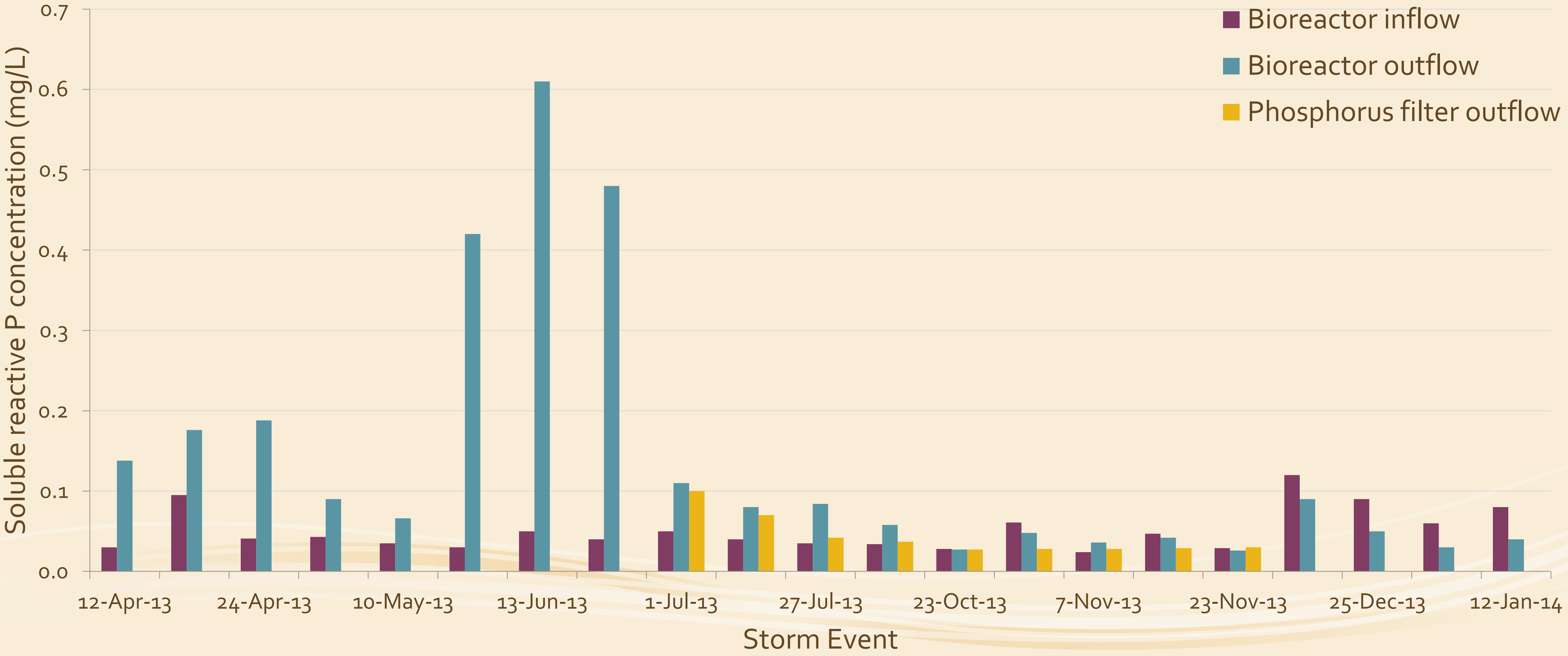
Subsurface Drainage Nutrient Transport


Bobcat
SUNBELT
PhosphoReduc™
Media


437973

Results

Phosphorus Removal with the P-filter



Take Homes

- Long-term crop yield benefit and nutrient reduction from controlled drainage
- Denitrification bed (woodchip bioreactor) is effective in nitrate removal
- Each should be used in combination with other conservation practices

Thank you

More Questions?

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MICHIGAN STATE UNIVERSITY