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Restoring wetlands on cranberry farmland to reduce downstream nitrogen loads in Marstons Mills (Barnstable, MA)

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Acknowledgments

Local farmers and other landowners

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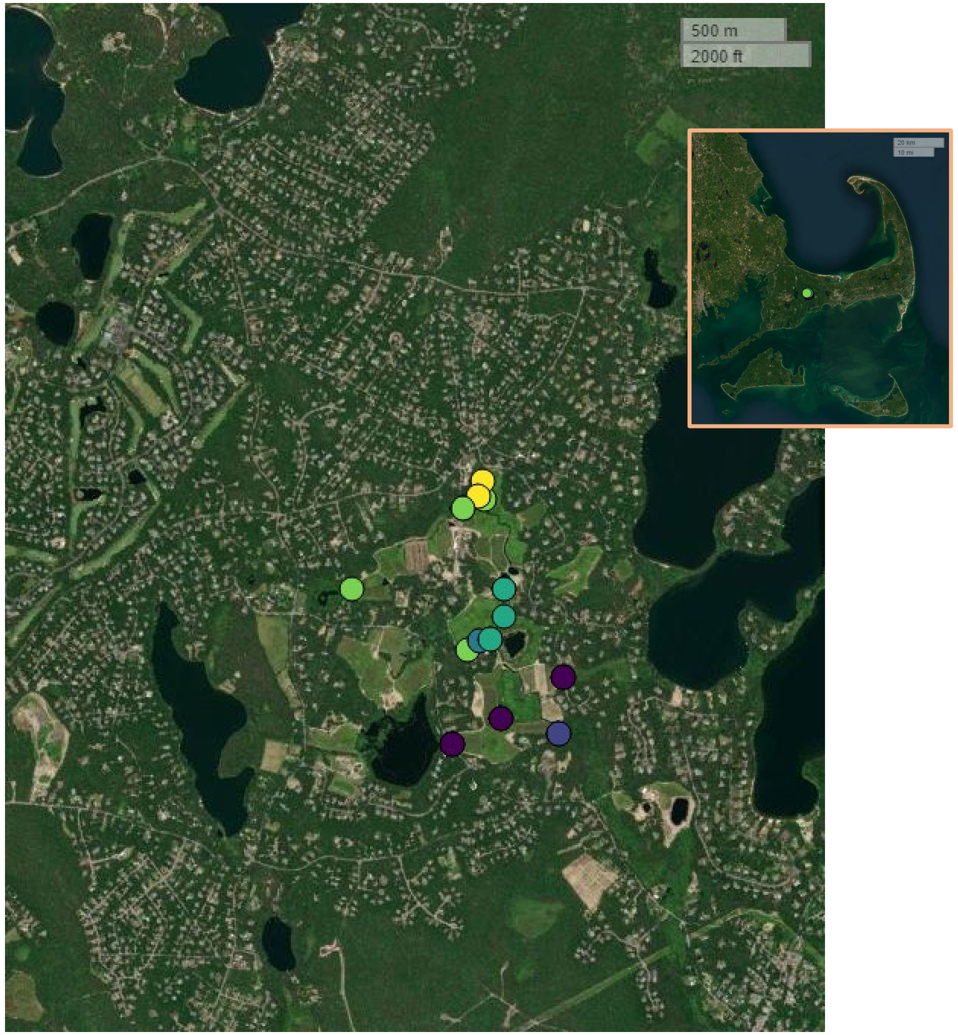
Marstons Mills cranberry bogs
Barnstable, MA

- region is densely settled and unsewered
- site has active farming and water controls
- inflows from ponds and regional aquifer
- outflow to Marstons Mills River (MMR)
- MMR flows to Three Bays estuary
- estuary has a Total Maximum Daily Load (TMDL) for nitrogen (N)

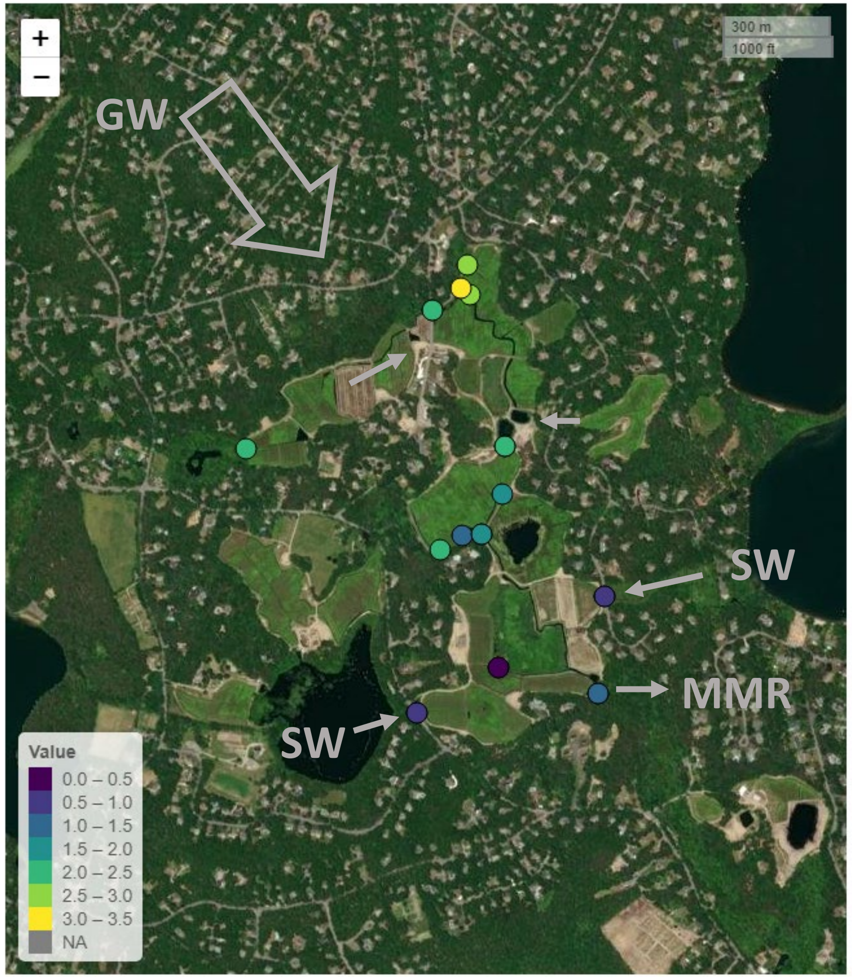


Marstons Mills cranberry bogs
Barnstable, MA

- high total nitrogen (TN) in upper bogs, mostly as nitrate (NO_3^-)
- lower TN in downstream inflows, mostly organic
- dilution and attenuation in existing system
- channelized internal flow

GW = regional groundwater flow
SW = surface water inflows
MMR = Marstons Mills River outflow

TN (mg/L) on 2020-03-05 at sampled stations



Data source: SMAST Tech Memo, 2022

Hydrologic point of view

the agricultural drainage system is superimposed on a complex of wetlands and streams that drains the regional aquifer

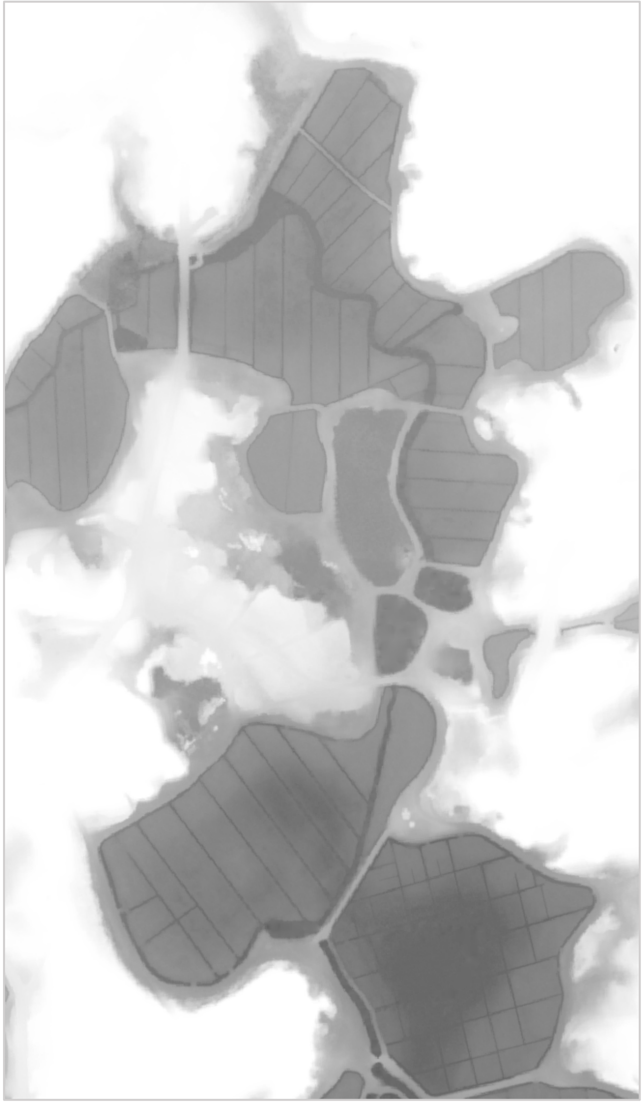
Outflow, Marstons Mills cranberry bogs. Photo: L. Erban

Reducing downstream nitrogen loads

Assertions (microscale):

- denitrification is the most important process
- mediated by microbial communities
- goal is to offgas NO_3^- as N_2
- enhance contact of NO_3^- rich water with wetlands soils

Images: L. Erban



LiDAR elevation data for site, from MassGIS

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Reducing downstream nitrogen loads

Assertions (macroscale):

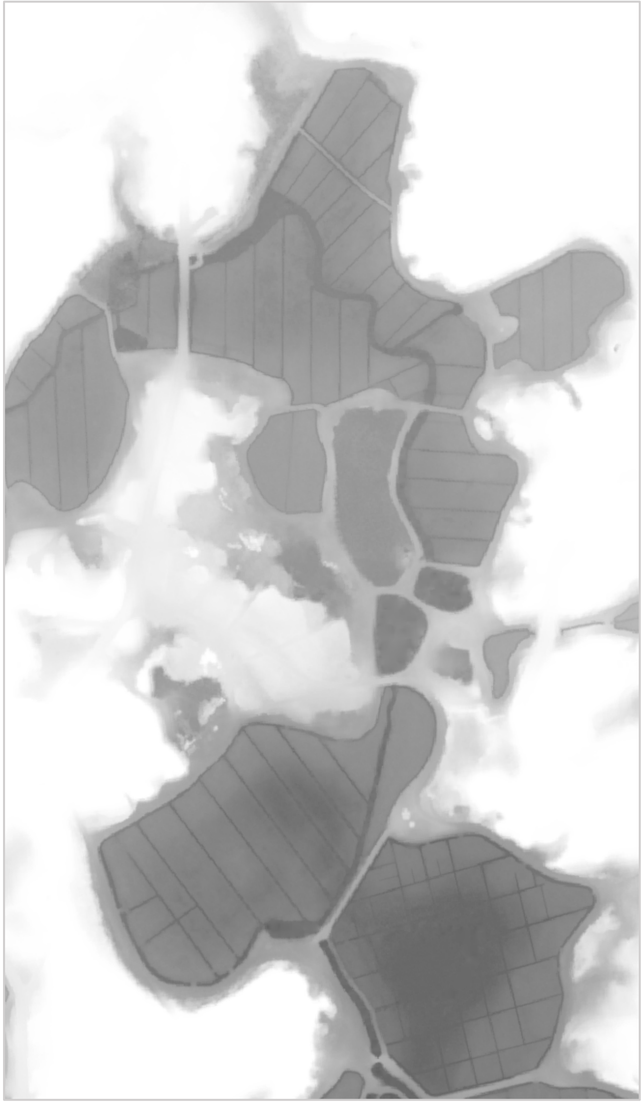
- areal process most dependent** on nitrate concentration and hydraulic loading rate (HLR):

  HLR = Q/A
  where Q = flow, A = area

  (depth of water per time)

** Among other things. Assertions based on prior research in Kadlec & Wallace, 2008; Kadlec, 2012; Crumpton et al., 2020


Images: L. Erban



LiDAR elevation data for site, from MassGIS

Reducing downstream nitrogen loads

1. Intercept NO_3^- rich groundwater

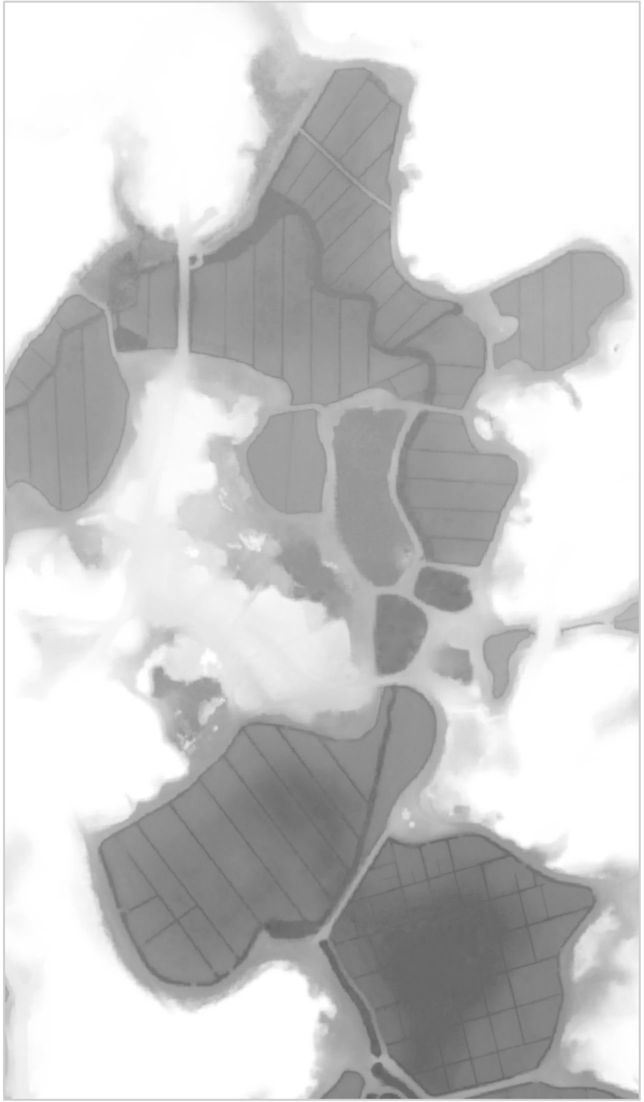
2. Slow and spread the flow onsite

   - plug ditches
   - narrow main channel
   - increase sinuosity and baffles
   - roughen surface

3. Increase inundation extent, residence time

   - currently ~15% of the site is regularly under water

Images: L. Erban



LiDAR elevation data for site, from MassGIS

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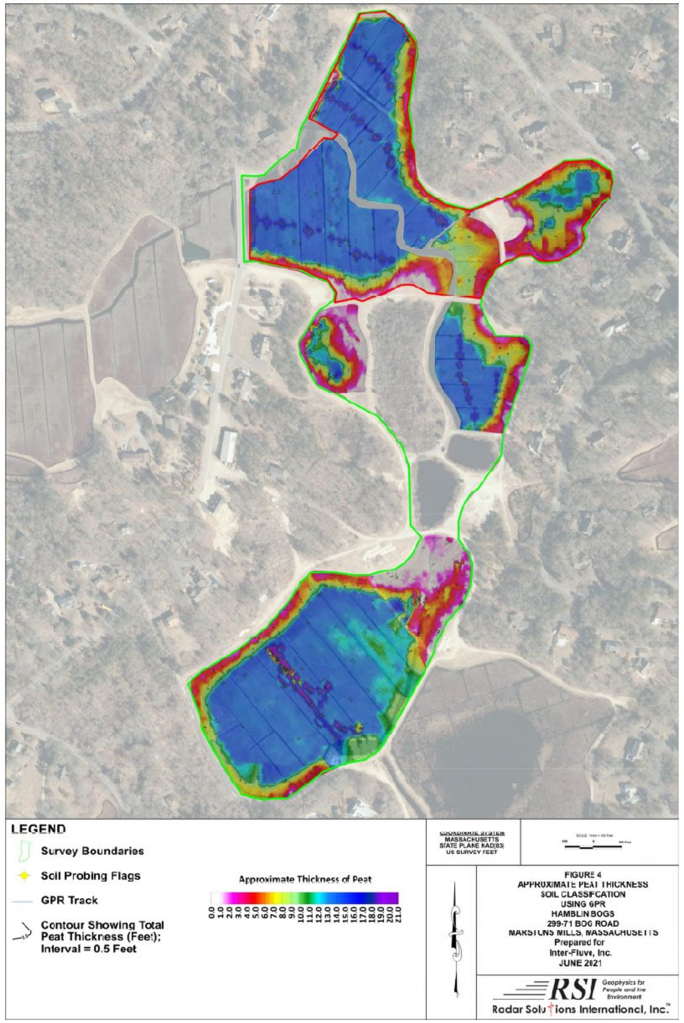
1. Intercept nitrate-enriched groundwater

- site is a string of bowls full of peat in a more transmissive regional aquifer

- seepage is more likely where peat is thin or curvature is high (Hare et al, 2017)

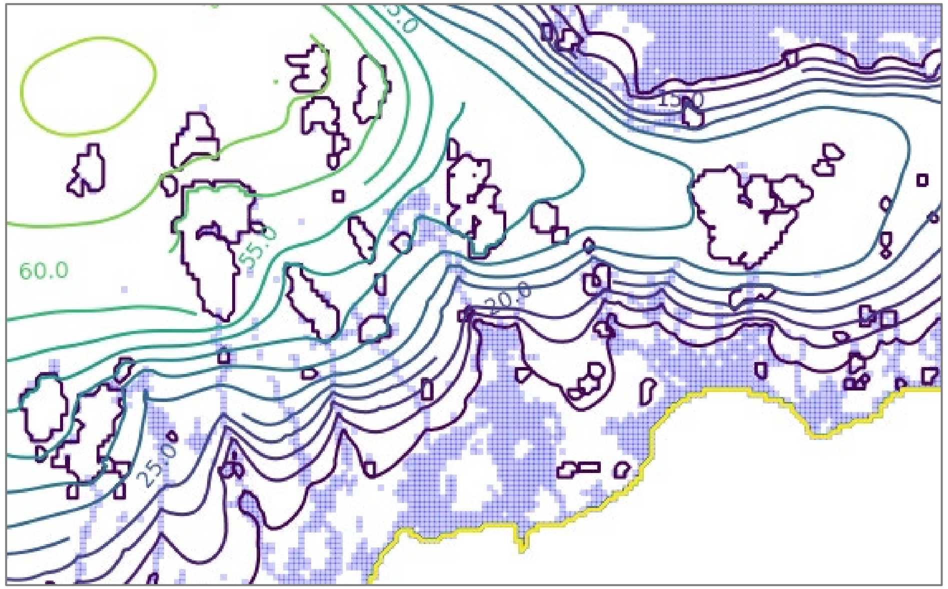
- deeper peat may be more compacted and resistive to flow (Hatch & Ito, 2022)

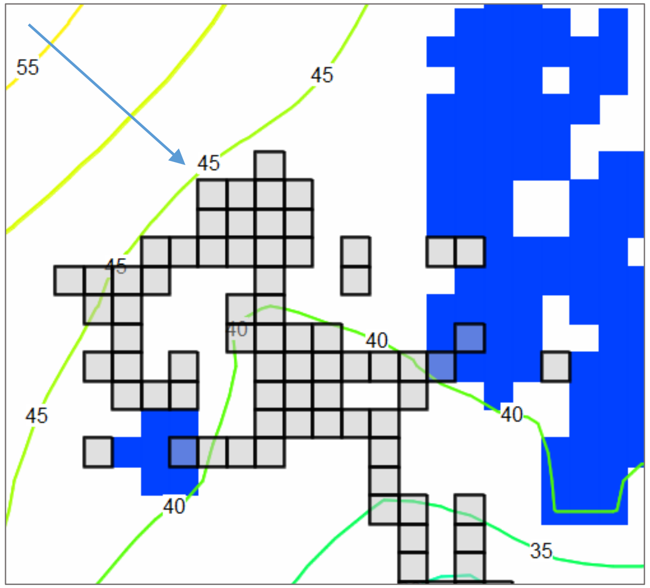
Ground-penetrating radar (GPR) indicates thin and thick peat



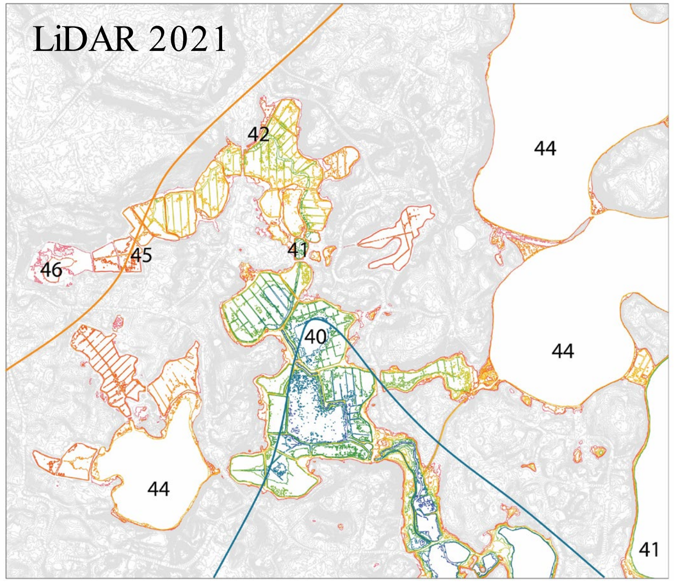
1. Intercept nitrate-enriched groundwater

- flow is a function of hydraulic gradients and conductivities
- reverse engineering (restoration) can impact both





Modeled contours of the regional water table elevation (ft)
Model by McCobb and Walter, 2019. Available at https://doi.org/10.5066/P9U5AKLC



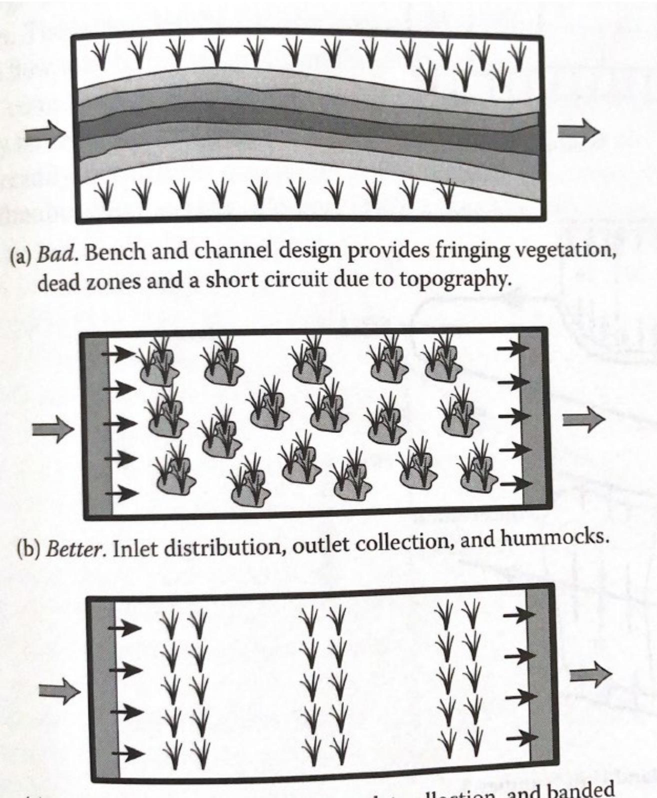
Hand contours of inferred water table, based on surface water elevations (ft)

2. Slow and spread the flow onsite

Key excerpts from Kadlec, R. H. (2012) Constructed Marshes for Nitrate Removal.

"it is necessary to remove antecedent ditches parallel to flow, or other topographic features that could lead to channelization and short-circuiting."

"Deeper water is little benefit after the anoxic sites in sediments and litter have been immersed."



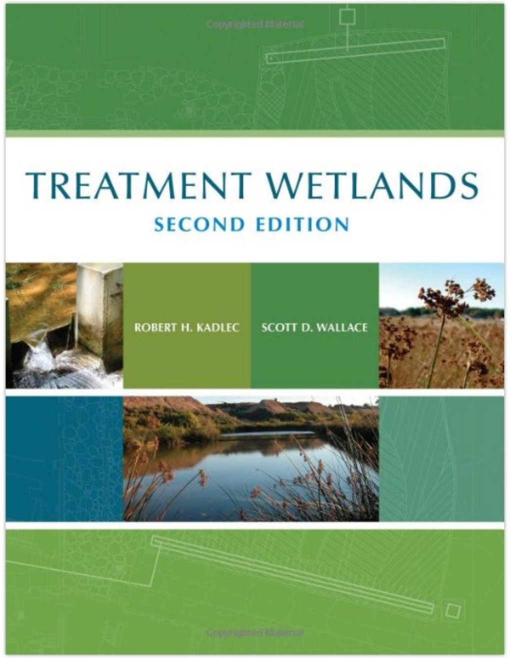
(a) *Bad*. Bench and channel design provides fringing vegetation, dead zones and a short circuit due to topography.

(b) *Better*. Inlet distribution, outlet collection, and hummocks.

(c) *Still Better*. Inlet distribution, outlet collection, and banded vegetation.

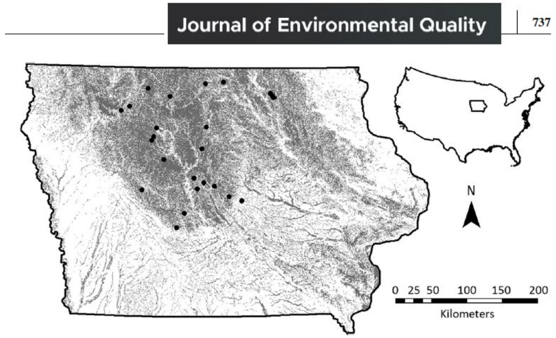
Source: Kadlec & Wallace, 2008

1046 pages! It's complicated!!



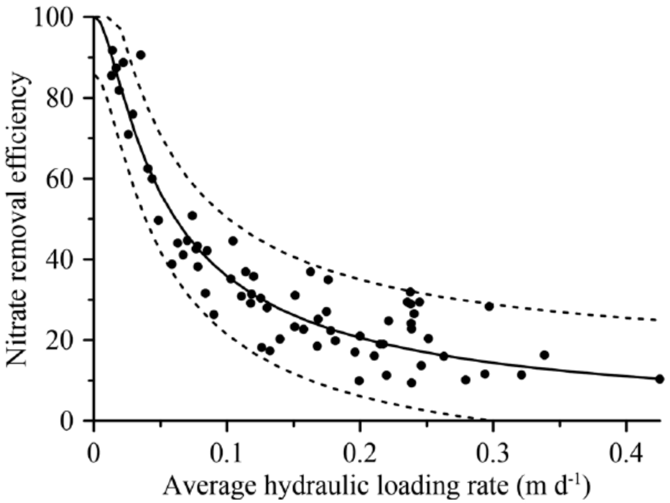
3. Increase inundation extent, residence time

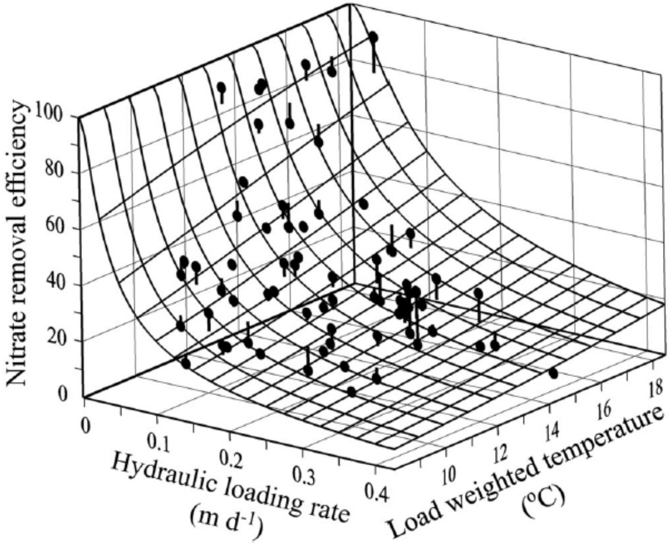
- Iowa Conservation Reserve Enhancement Program (CREP) develops wetlands to remove nitrate in tile-drained landscapes.



- hydric soils, limited earthwork:
  - low earthen dikes
  - submerged berms

- average annual performance well described by a model based on HLR and load-weighted temperature.





Data from 26 restored wetlands in Iowa; Crumpton et al., 2020

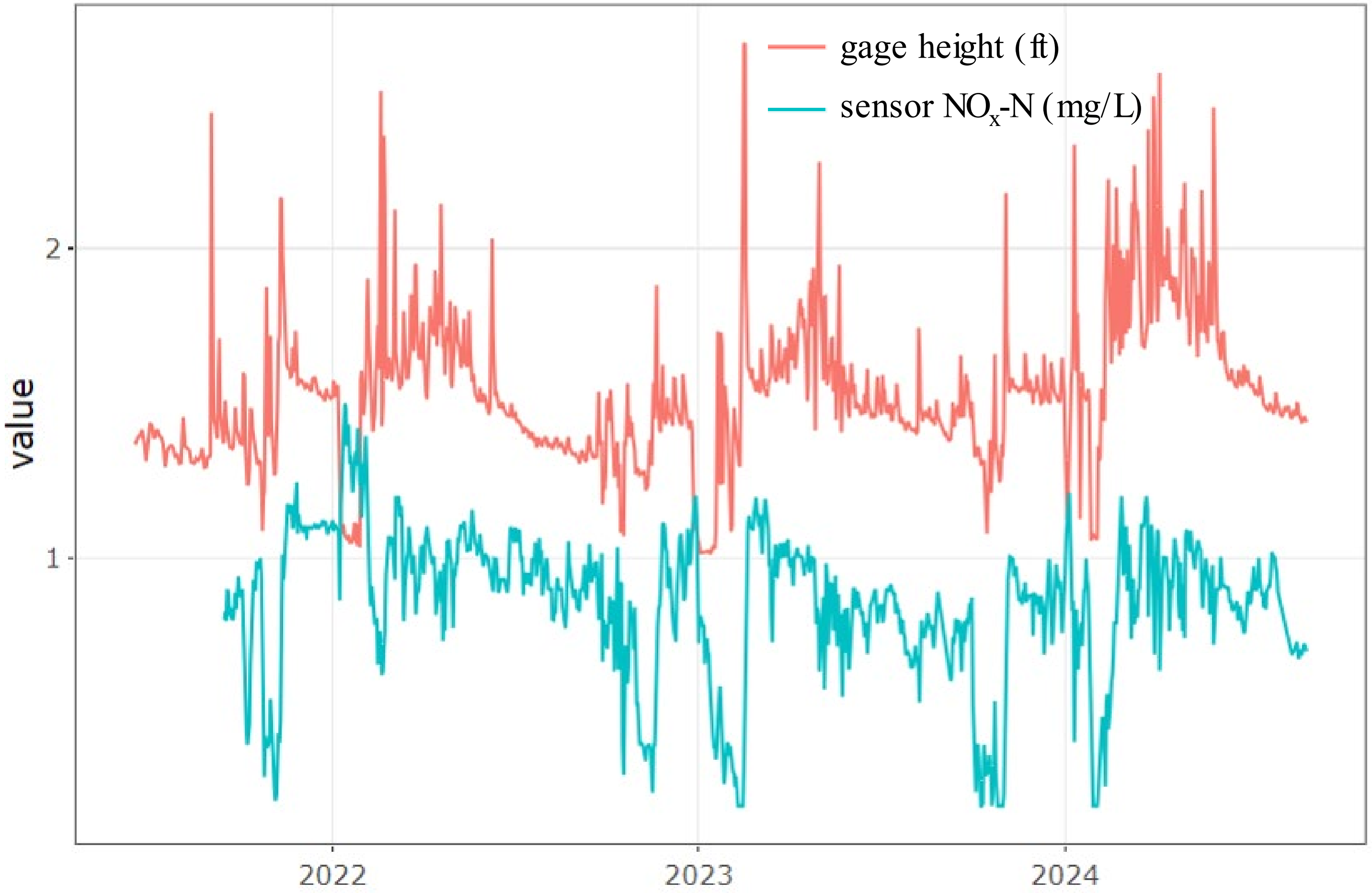
Monitoring loads at the outlet

- 3 yrs of USGS stream gage data
- continuous (15-min) record of stage, flow, and NO_2/NO_3 (NO_x-N) by optical sensor (OTT ecoN)


outflow, from inside bogs


outflow stream gage

USGS site # 0110588332 – mean daily values



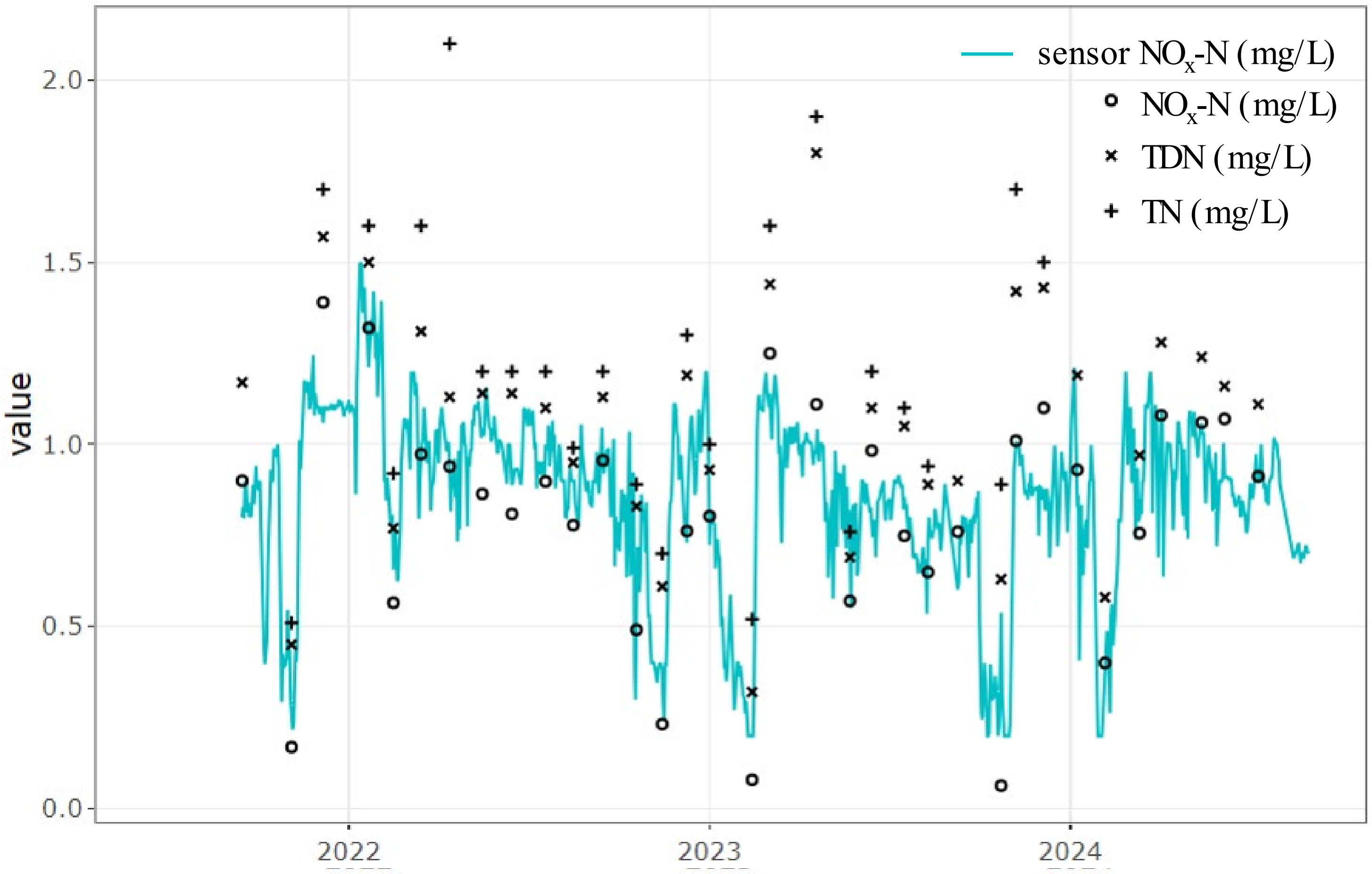
Preliminary Information-Subject to Revision. Not for citation.

Monitoring loads at the outlet

- monthly grab samples
- 18 total parameters (lab & field)
- ~80% of dissolved nitrogen in outflow is NO_x-N.

TDN = total disolved nitrogen
TN = TDN + particulate nitrogen

USGS site # 0110588332 – mean daily values



Preliminary Information-Subject to Revision. Not for citation.

Monitoring loads at the outlet

- late spring highs, late summer lows correspond with flows

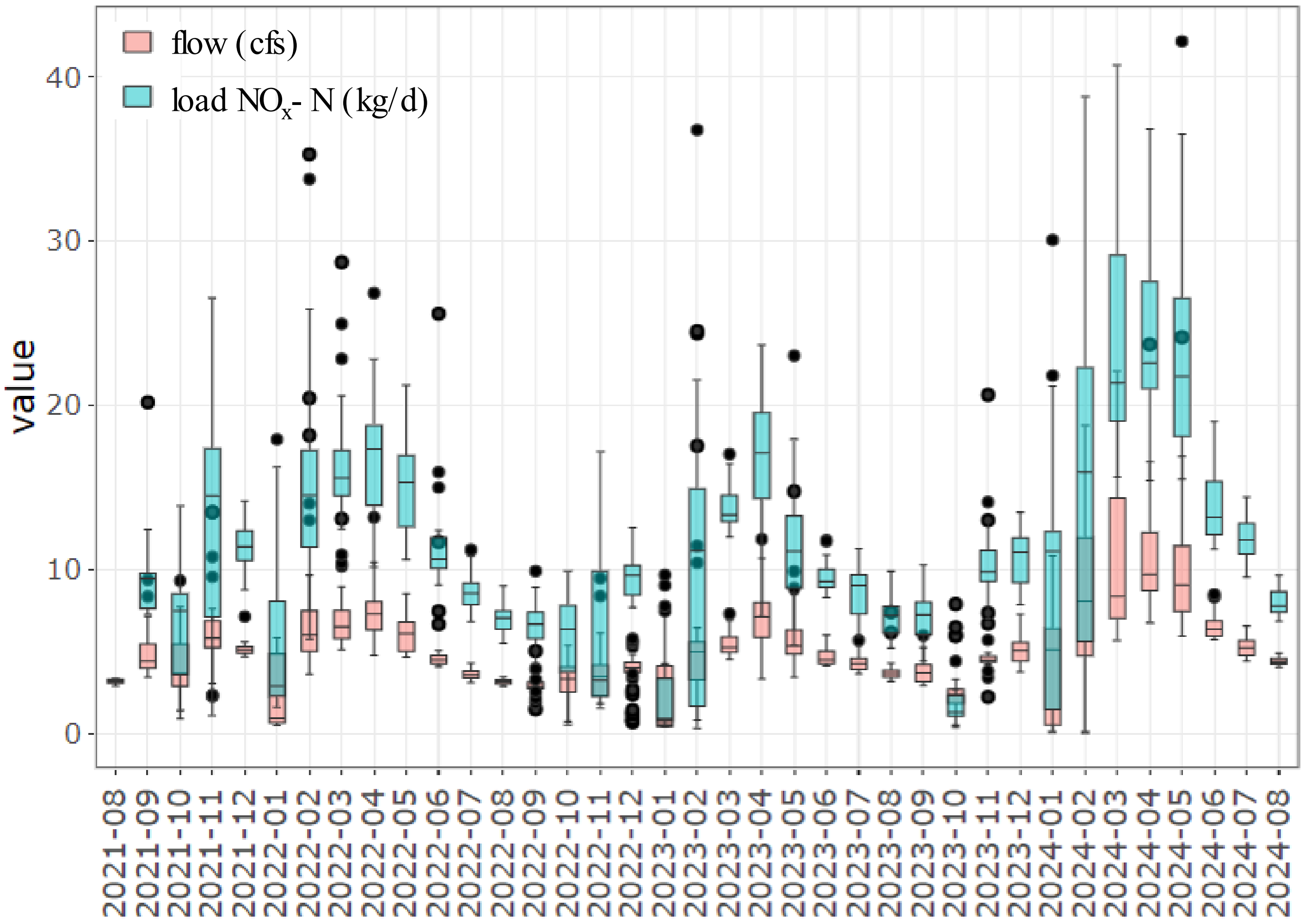
- disproportionate decrease in loads in Jan/Feb and Oct/Nov

- water year (Oct-Sept) means:

2022	11.0 kg/d
2023	8.8 kg/d
2024*	13.5 kg/d

- load-weighted temperature ~12 ºC

USGS site # 0110588332



Preliminary Information-Subject to Revision. Not for citation.

* incomplete water year (as of 2024-08-28)

More questions

Partners review design drawings onsite. Photo: L. Erban

What about other pollutants?

What about changes in loading?

- new development
- existing land use

What about other objectives?

- recreation and cultural uses
- habitat and fish passage
- climate change hazard mitigation

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Questions?

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