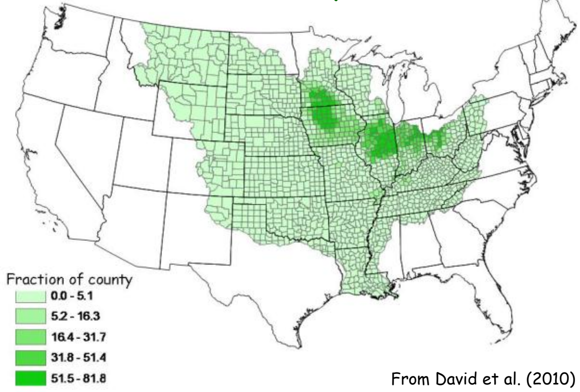
Managing Denitrification in Constructed Wetlands

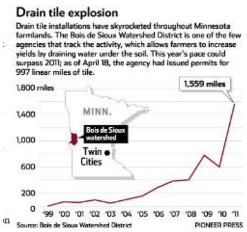
Mark B. David, Lowell E. Gentry, Tyler A. Groh, Richard A. Cooke, David A. Kovacic, and George F. Czapar
University of Illinois at Urbana-Champaign

Fraction of county tile drained

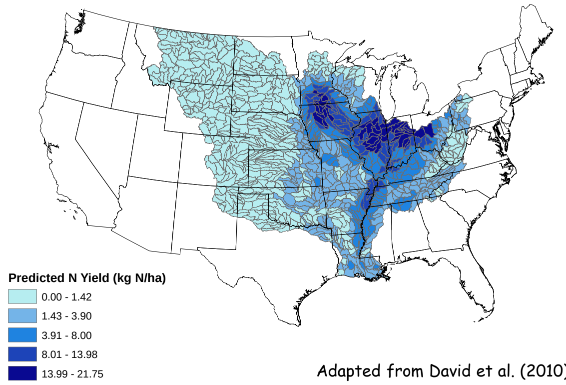


From David et al. (2010)

More tile drainage every year



January to June Nitrate-N Yield



Adapted from David et al. (2010)

What are constructed wetlands?

- intercept tile line or water flow path with small constructed wetland (0.5 to several ha)
  - bulldoze berm
- water is retained for hours to days
- allows for nitrate removal by denitrification
- usually along side of ditch or stream
- extensive literature and experience with sewage treatment
  - less for agricultural drainage waters
  - Kadlec, R.H. 2012. Constructed marshes for nitrate removal. Critical Reviews in Environmental Science and Technology 42:934-1005.

Tile wetland

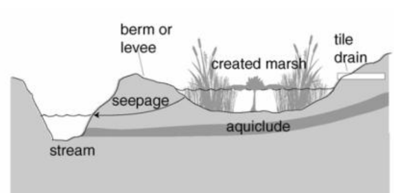


Fig. 5. Conceptual diagram of farm runoff wetland.

From Mitsch and Day (2006)

Riparian wetland

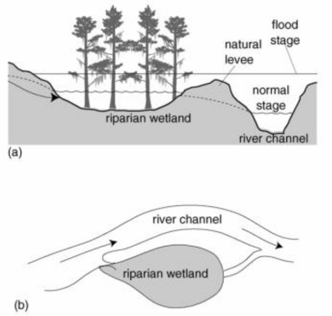


Fig.6. Conceptual diagram of river diversion wetland: (a) plan view, (b) aerial view.

From Mitsch and Day (2006)

Inputs of water and N

- most tile flow in upper Midwest winter to spring
- Kovacic et al. (2000) water and N inputs
  - 30% winter
  - 65% spring
  - 5% summer & fall

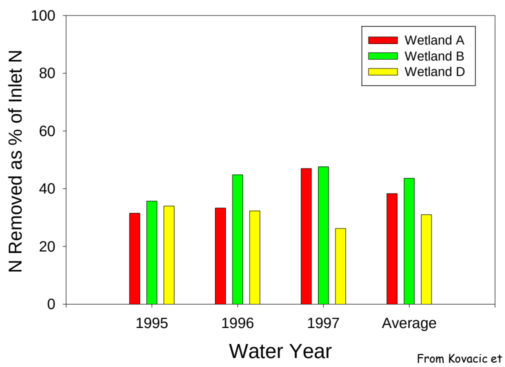
From Kovacic et al. (2000)

Illinois seasonal N removal (%)

Season	A	B	D	Overall
Fall	83	83	83-97	83-97
Winter	39-48	34-54	8-34	8-54
Spring	30-53	26-52	34-44	26-53
Summer	93-100	100	88-100	88-100

From Kovacic et al. (2000)

Illinois total N removal



From Kovacic et al. (2000)

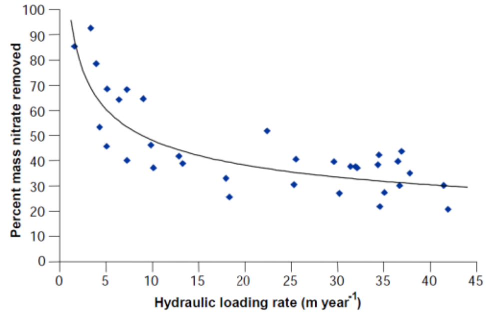





What determines effectiveness?

- hydraulic loading
  - amount of water and nitrate
  - retention time
- nitrate concentration
- carbon
- temperature
- soils and vegetation
- microbial populations

Loading controls % removal



From Crumpton et al. (2008)

Retention time and temperature

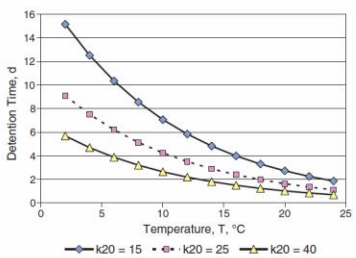
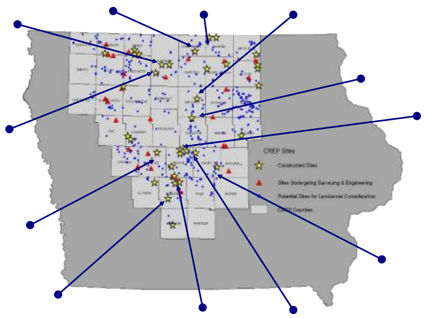


FIGURE 5. The effect of water temperature on the hydraulic loading, and corresponding detention time, required to accomplish 30% nitrate reduction. First-order NTIS areal model, with depth = 30 cm, N = 4 TIS, q = 1.1, and various k_{20} (m/year) (Color figure available online).

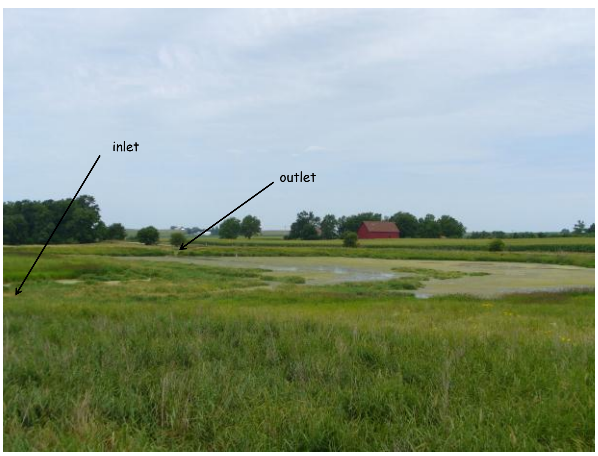
From Kadlec (2012)

Iowa Wetlands

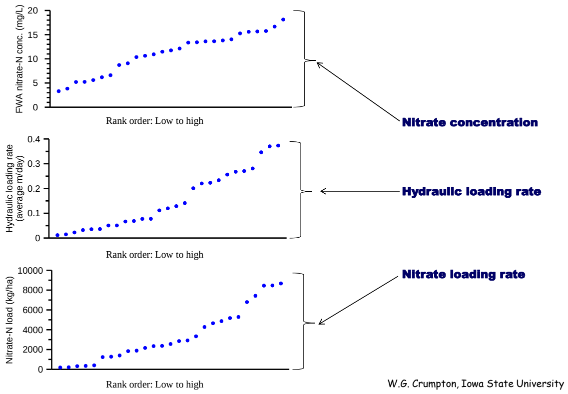
- 1.5 to 7.3 ha (3.8 ha avg)
- depth 0.34 to 0.78 m
- 1 to 13 yrs old
- ratio of 0.34 to 5.3%
- tile inlets, plus surface runoff
- 44 to 93% rowcrop
- surrounded by buffers



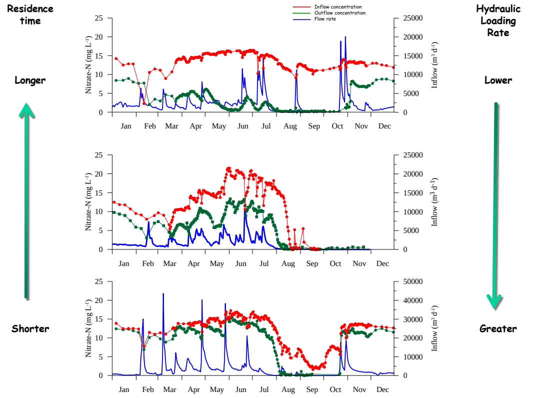
W.G. Crumpton, Iowa State University



Wide range of wetlands

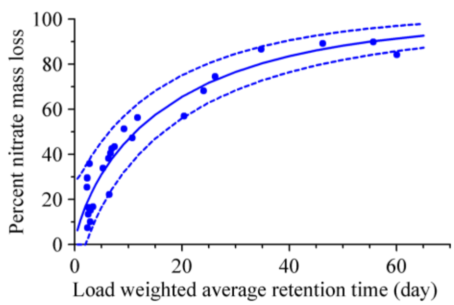


W.G. Crumpton, Iowa State University



W.G. Crumpton, Iowa State University

Retention time critical



W.G. Crumpton, Iowa State University

Denitrification rates

- only directly measured in a few studies
  - Fleischer et al. (1994), Xue et al. (1999), Poe et al. (2003)
- both ^{15}N and acetylene inhibition have given similar results
  - 0.02 to 11.8 mg N m^{-2} h^{-1} (average ~2)
  - equates to 100's of kg N ha^{-1} yr^{-1}
  - temperature, nitrate, and C controlling factors

see O'Geen et al. (2010) for review

Major unknowns

- overall greenhouse gas emissions
- long-term performance
- optimum wetland to watershed area
- placement limitations
- large-scale acceptance
- costs

Limitations

- cost
  - bottom line
- landscapes and land
  - can't put them everywhere
- flows
  - high winter/spring tile flow
- social barriers
  - many

Conclusions

- wetlands are effective at the end of tile lines, or when placed to intercept flow path of high nitrate water
- removal rates of nitrate variable
  - 20 to 90%
  - mass amounts of nitrate removed can be high
  - most likely lost as N_2 through denitrification
- many landscape, financial and social barriers
- manage water, retention time; denitrification will do the rest