Assessment of Scenarios for the Boone River Watershed in North Central Iowa

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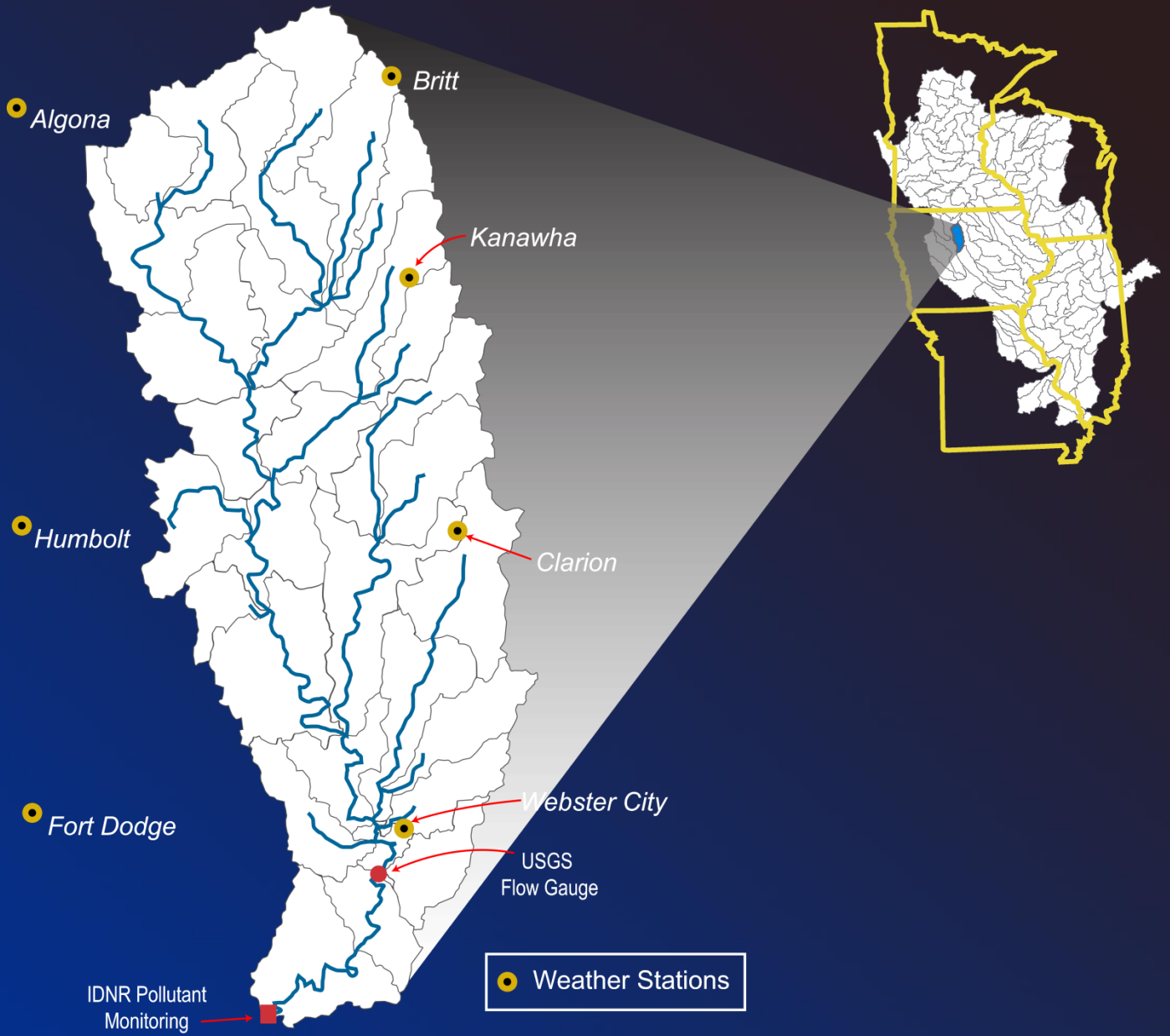
Overview of Presentation

- Background on Boone River Watershed and SWAT modeling structure
- Issues regarding nutrient load estimation
- Model testing results
- Results of some bioenergy scenarios
  - switchgrass, miscanthus, removal of corn stover (biomass)
- Conclusions/Next steps

Boone River Watershed

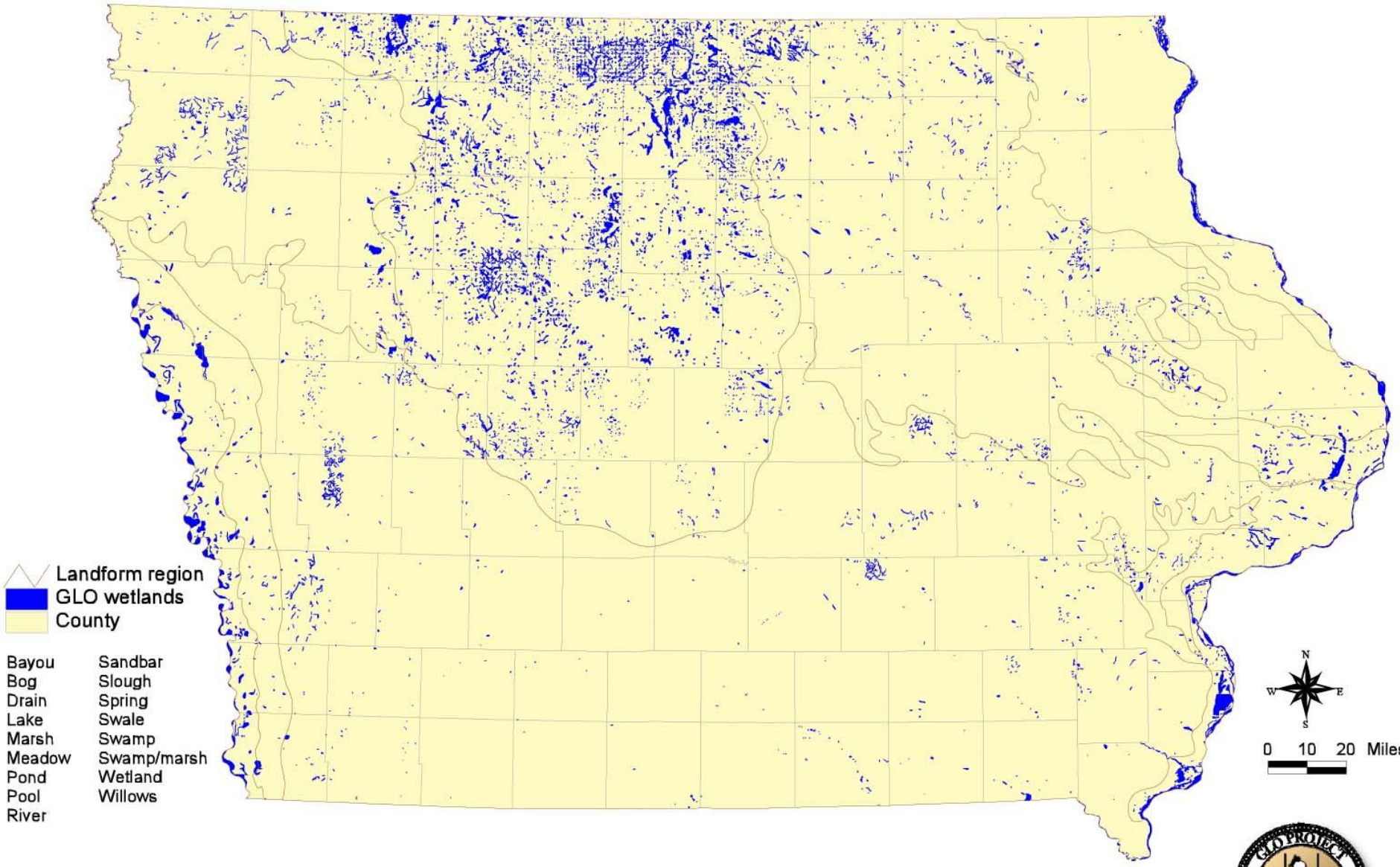
- ~237,000 ha in parts of six counties
- Des Moines Lobe; southern portion of North American Prairie Pothole region
- Generally level topography; heavily tile drained
  - tile drains typically installed at depth of 1200 mm
- Dominated by crop production

Boone River Watershed



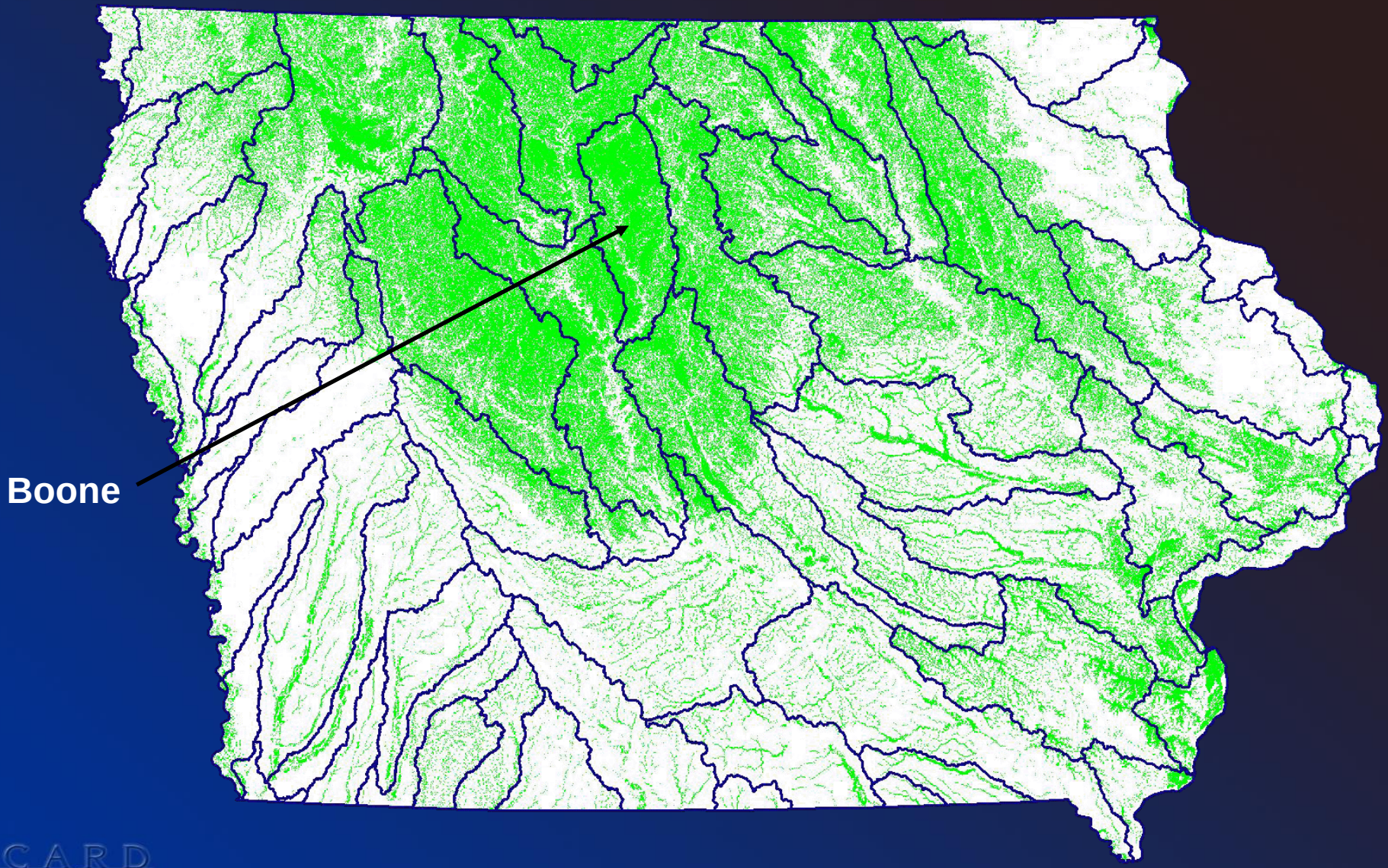
GLO Wetland Vegetation Types

General Land Office Survey of Iowa (1832 - 1859)



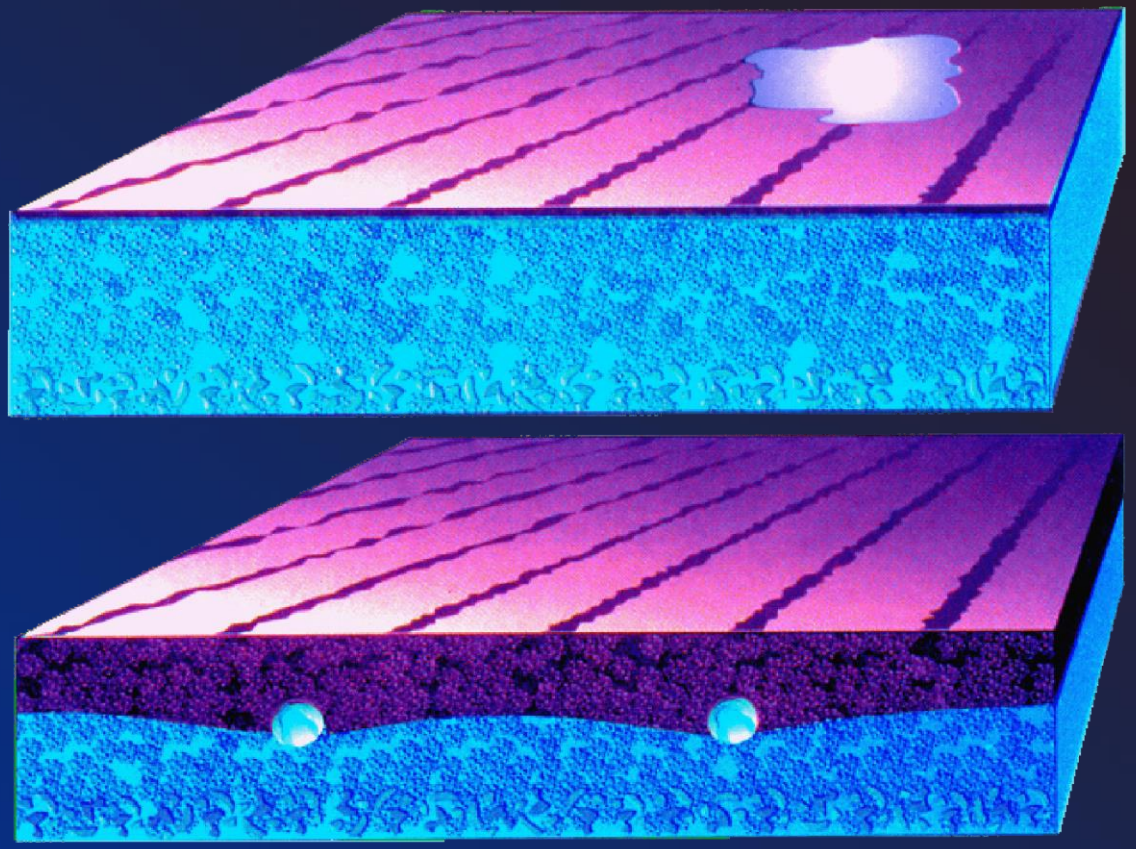
Anderson, P.F. 1996. GIS Research to Digitize Maps of Iowa 1832-1859 Vegetation from General Land Office Township Plat Maps. Iowa State University, Ames, Iowa.

Locations of Hydric (Wet) Soils in Iowa



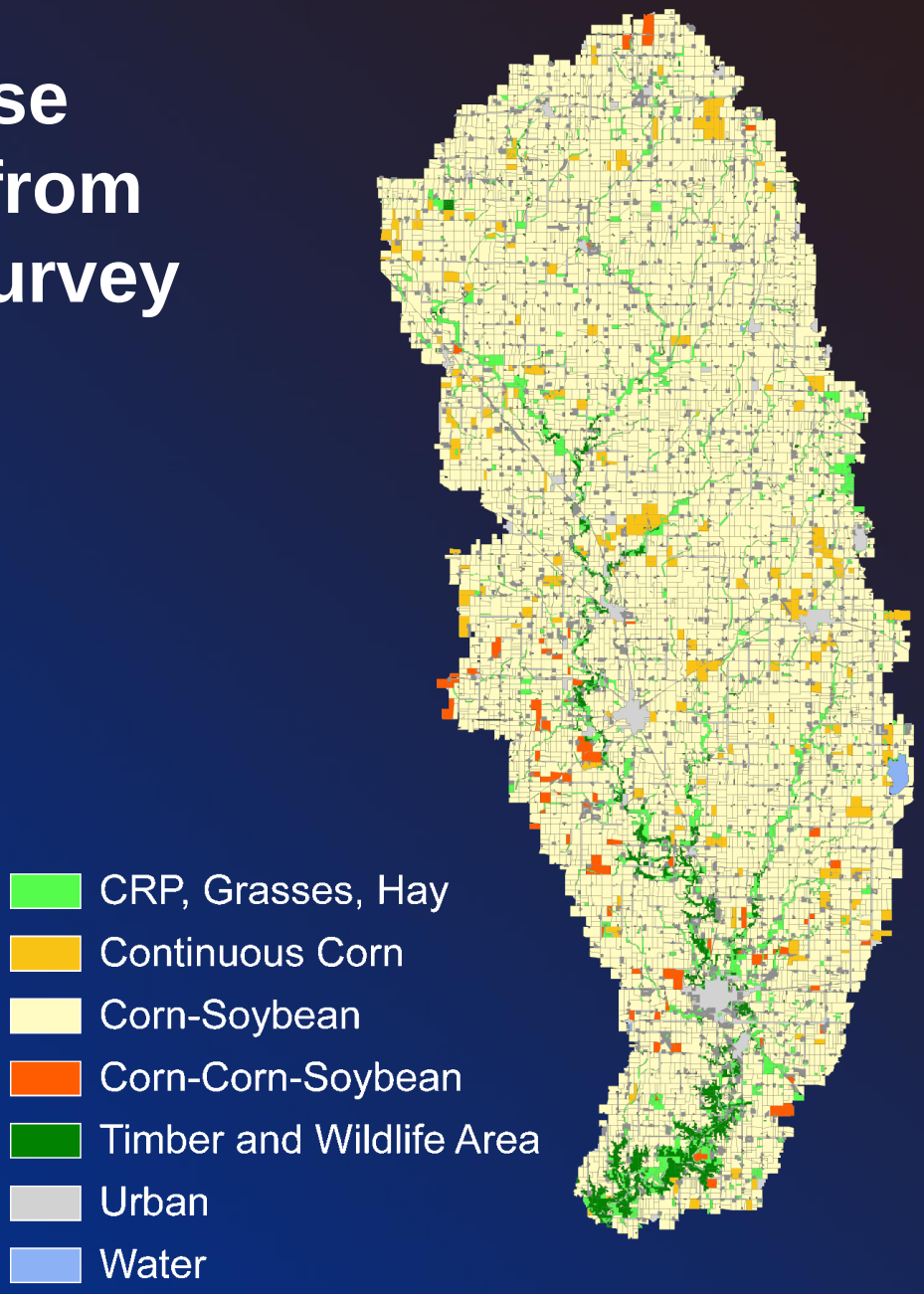
Data generated by C. Wolter, Iowa Deptartment of Natural Resources, Des Moines, IA

Effects of Tile Drainage on Soil Water



Adapted from: Zucker, L.A. and L.C. Brown (eds.). 1998. Agricultural Drainage: Water Quality Impacts and Subsurface Drainage Studies in the Midwest. Ohio State University Extension Bulletin 871. The Ohio State University.

2005 Land Use Determined from Field-level Survey



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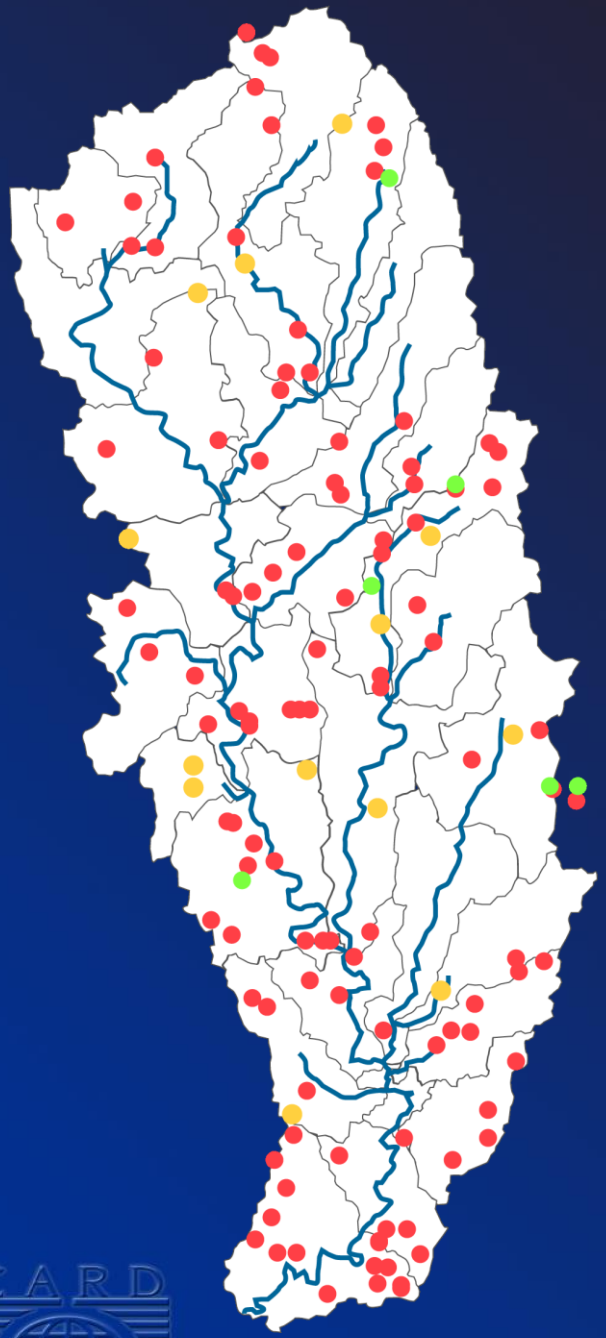
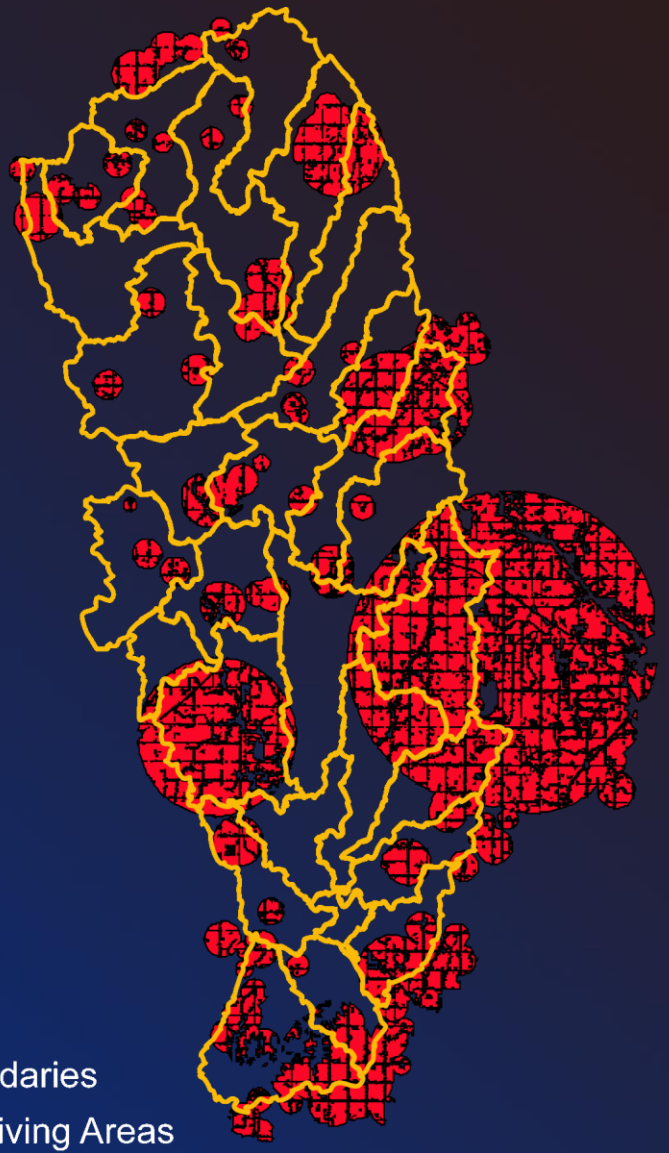


CAFOs

Type	Total operations	Total head
Swine	109	481,448
Cattle	13	4,265
Layers	6	6,962,112

Source: 2005 IDNR CAFO data

Estimated Manure Application Zones (112 kg/ha N rate)



Data generated by C. Wolter, Iowa Dept. of Natural Resources, Des Moines, IA; Software developed by D. James, USDA -ARS, Ames, IA

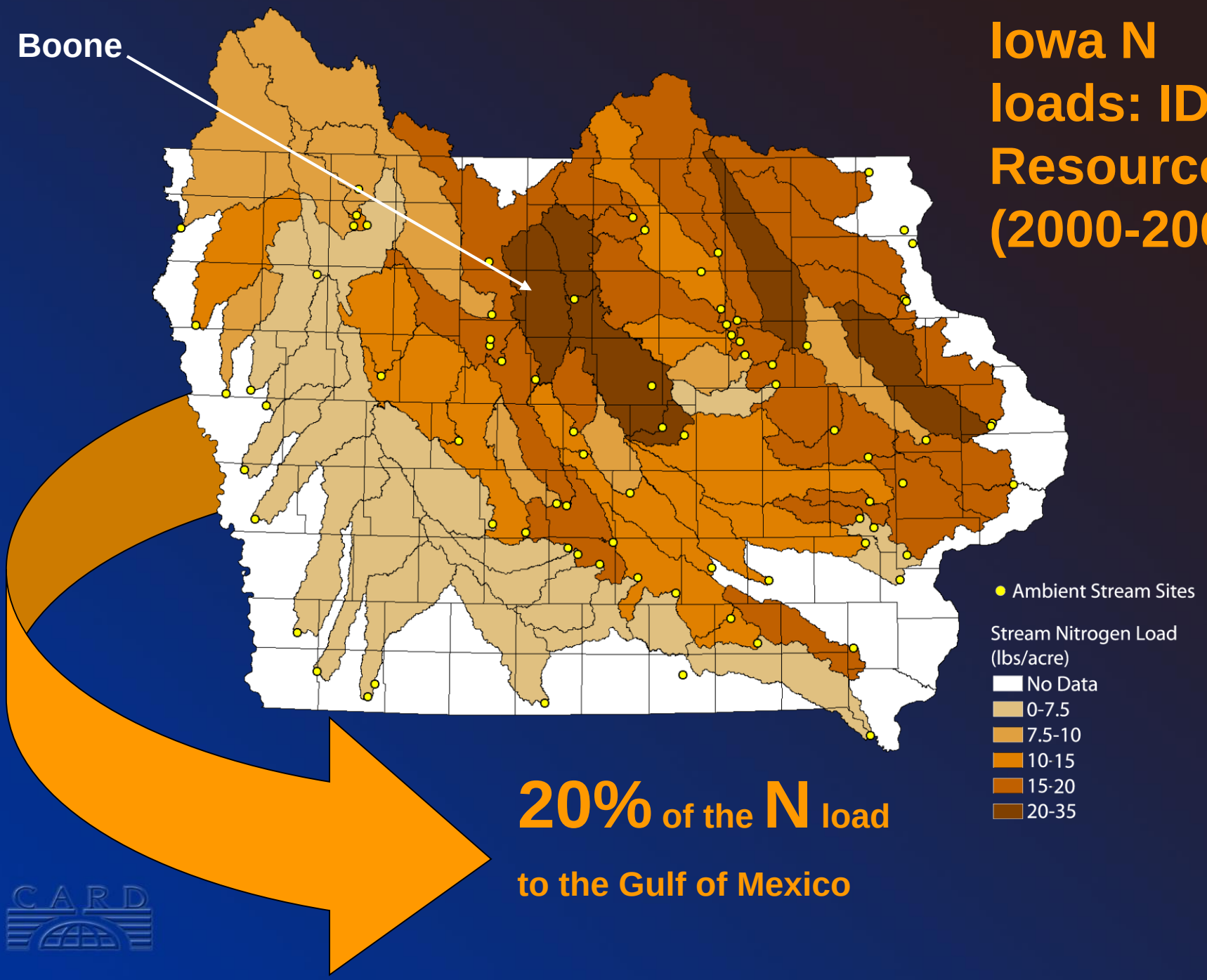
Nutrient Applications

- N fertilizer rates on corn not receiving livestock manure
  - corn after soybean:
    - spring: 172 kg/ha
    - fall: 183 kg/ha
  - corn after corn: 196 kg/ha

  - P_2O_5 fertilizer rate for corn: 49 kg/ha

- Manure assumptions less straightforward
  - 80% applied on corn & 20% on soybean
    - N rate: 190 kg/ha
    - P rate: 70 kg/ha
  - 50% of manured corn also fertilized

Iowa N loads: IDNR Resources (2000-2002)



20% of the N load

to the Gulf of Mexico

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SWAT Version & Simulation Approach

- SWAT version 2012, Release 615
- Contains modifications introduced by Cibin Raj for:
  - switchgrass & miscanthus growth/yields
  - removal of corn stover
- Used ET-based Runoff Curve Number Approach
  - ICN = 1; CNCOEF = 0.75
- Accounted for tile drainage (old method)

ET-based Runoff Curve Number Retention Parameter (S) Calculations

Standard

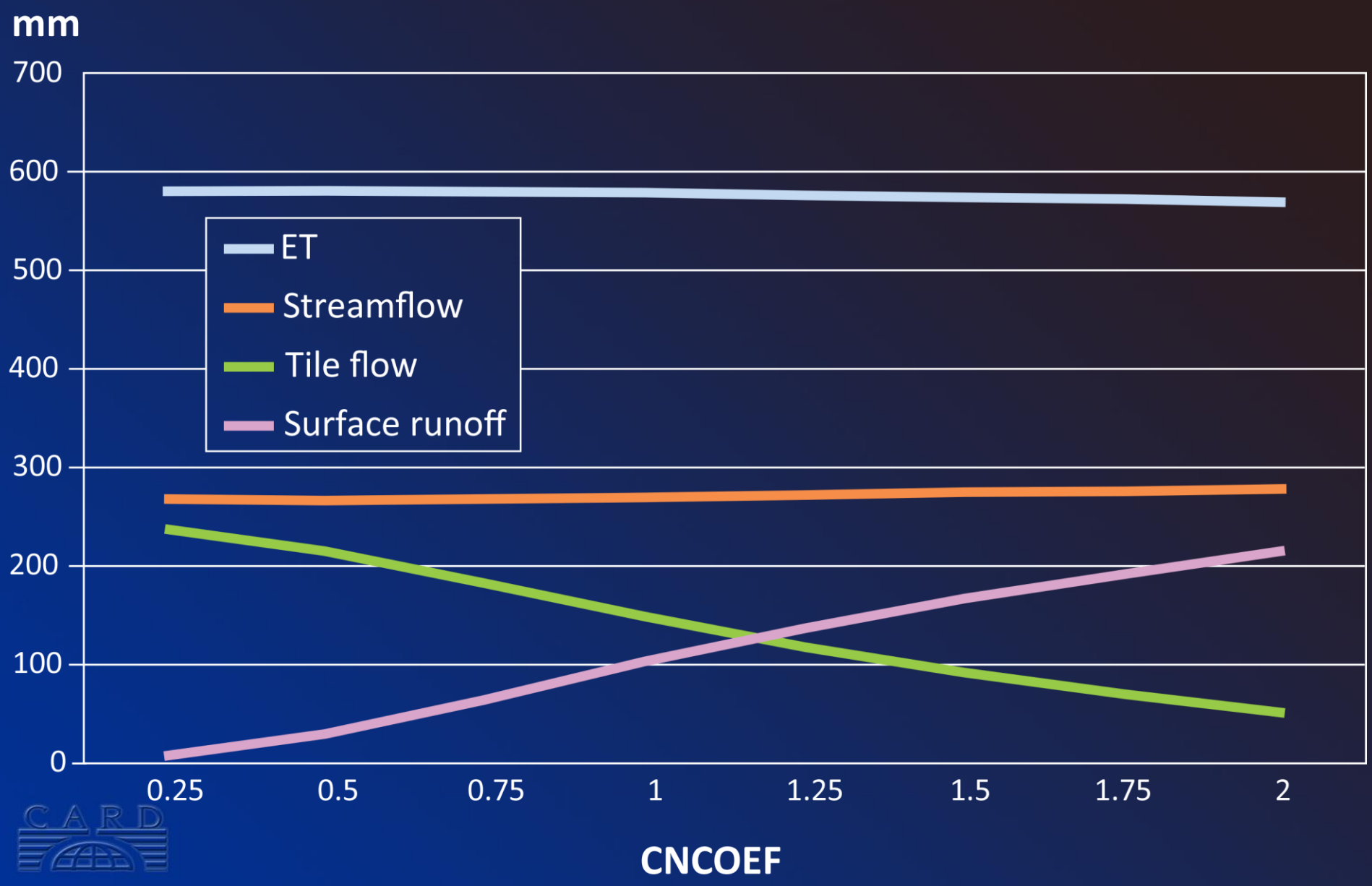
$$S = S_{\max} \cdot \left(1 - \frac{SW}{\left[SW + \exp\left(w_1 - w_2 \cdot SW \right) \right]} \right)$$

Alternative

$$S = S_{prev} + E_o * \exp\left(\frac{-CNCOEF - S_{prev}}{S_{\max}} \right) - R_{day} - Q_{surf}$$

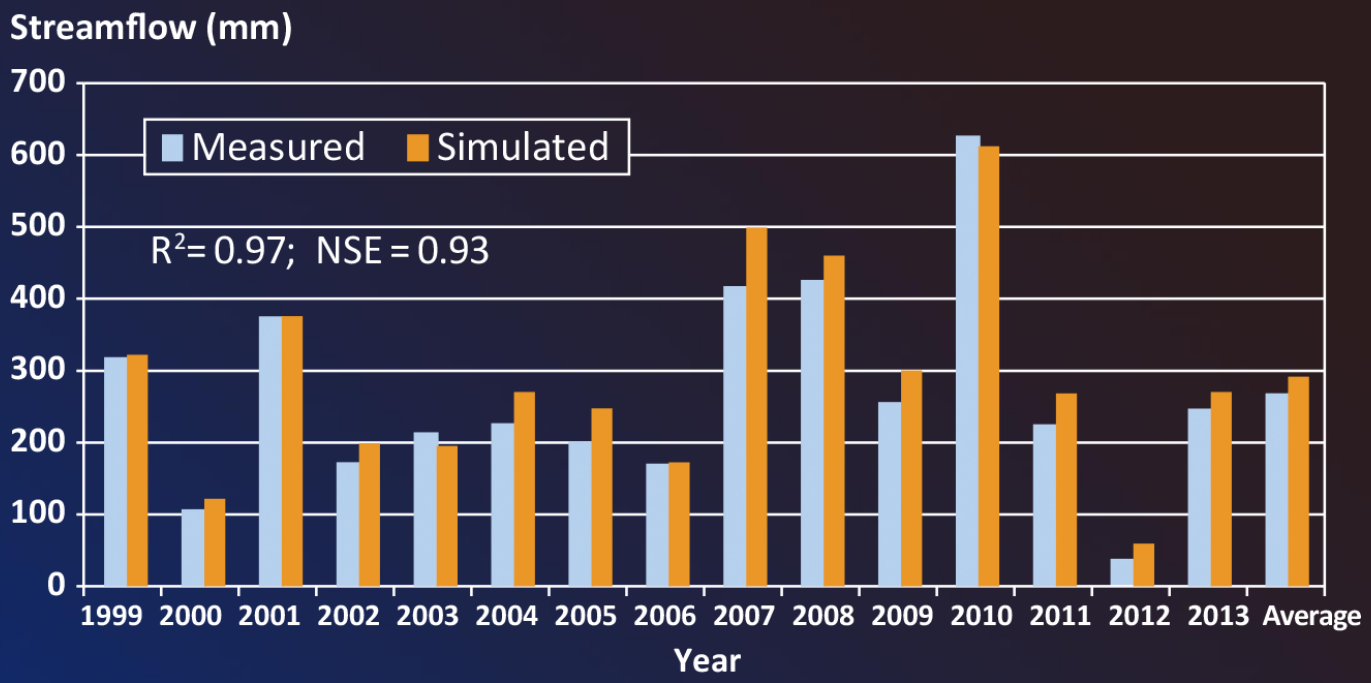
Kannan et al. 2008. Hydrol. Processes

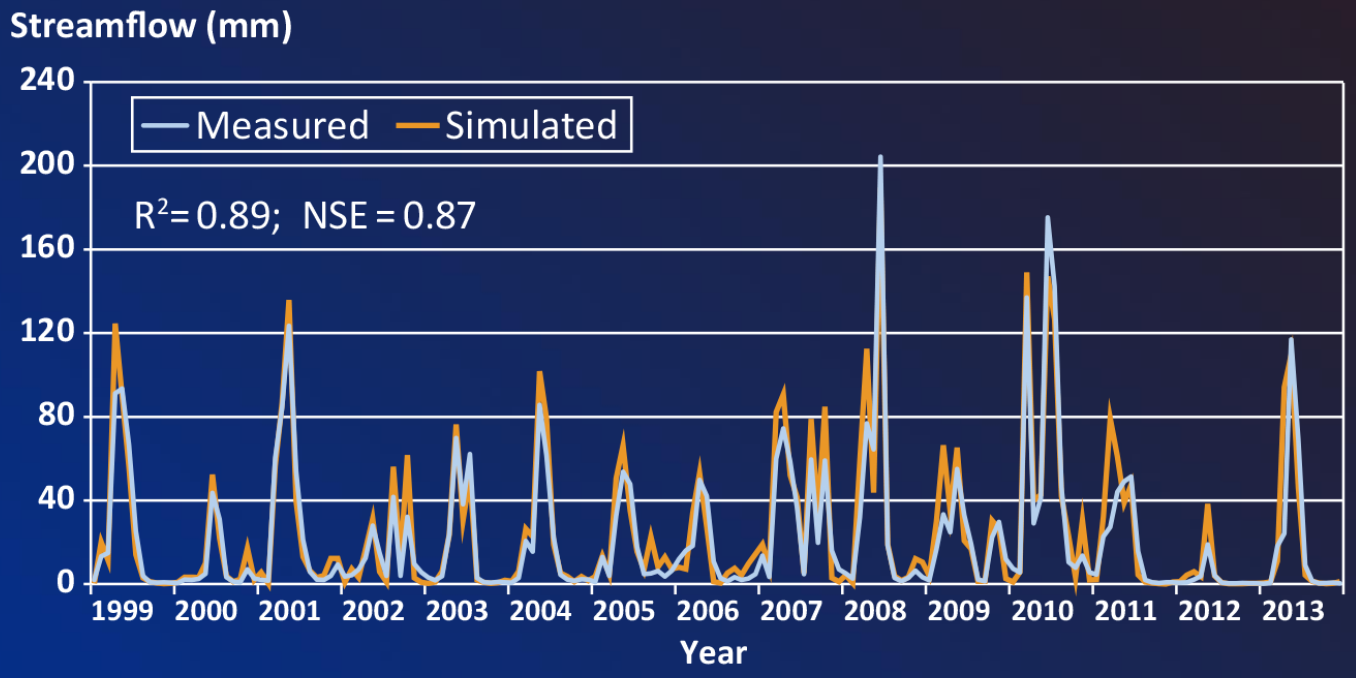
CNCOEF Sensitivity Analysis at Boone River Outlet



15 Year Calibration (1999-2013)

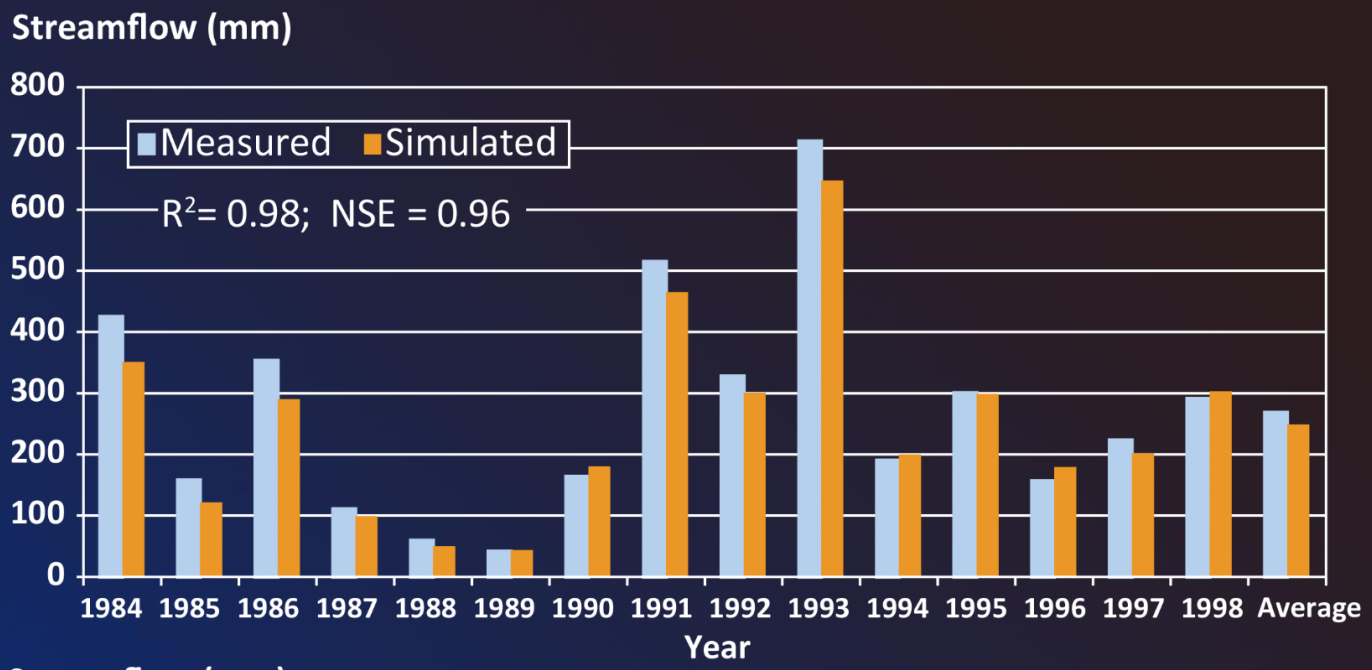
Warm-up years: 1997 & 1998

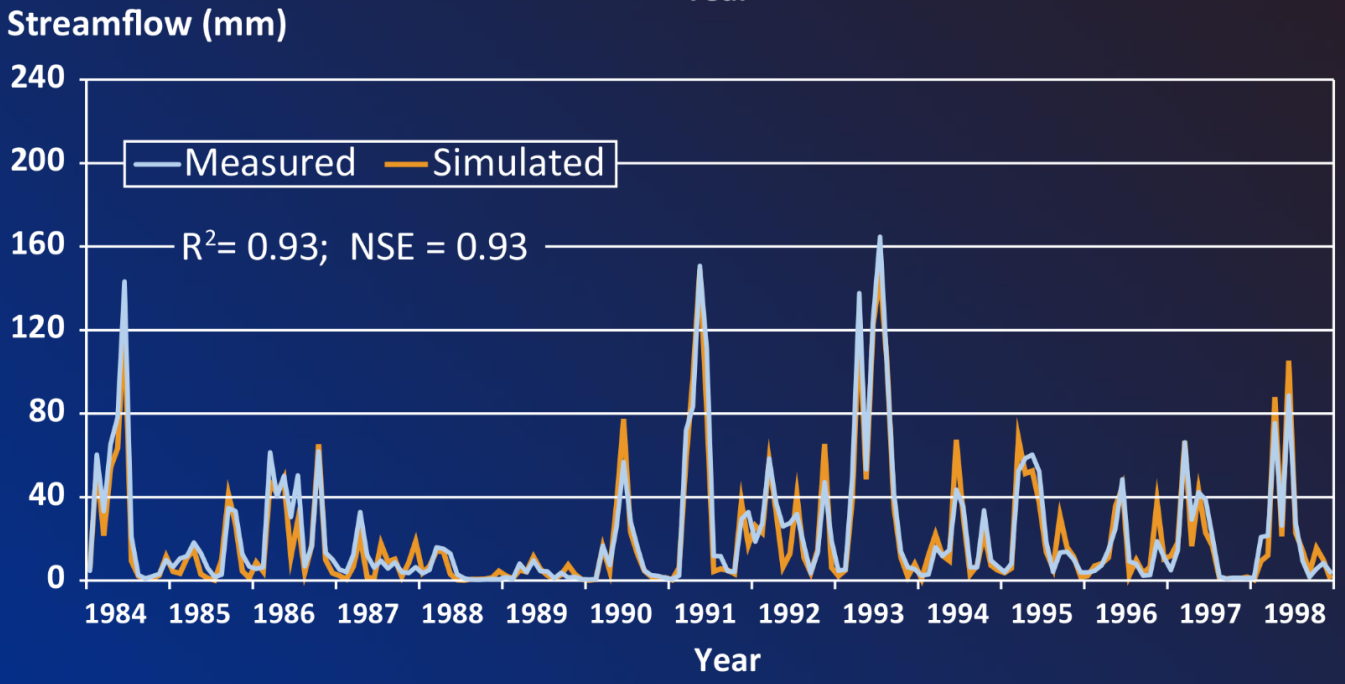




15 Year Validation (1984-1998)

Warm-up years: 1982 & 1983



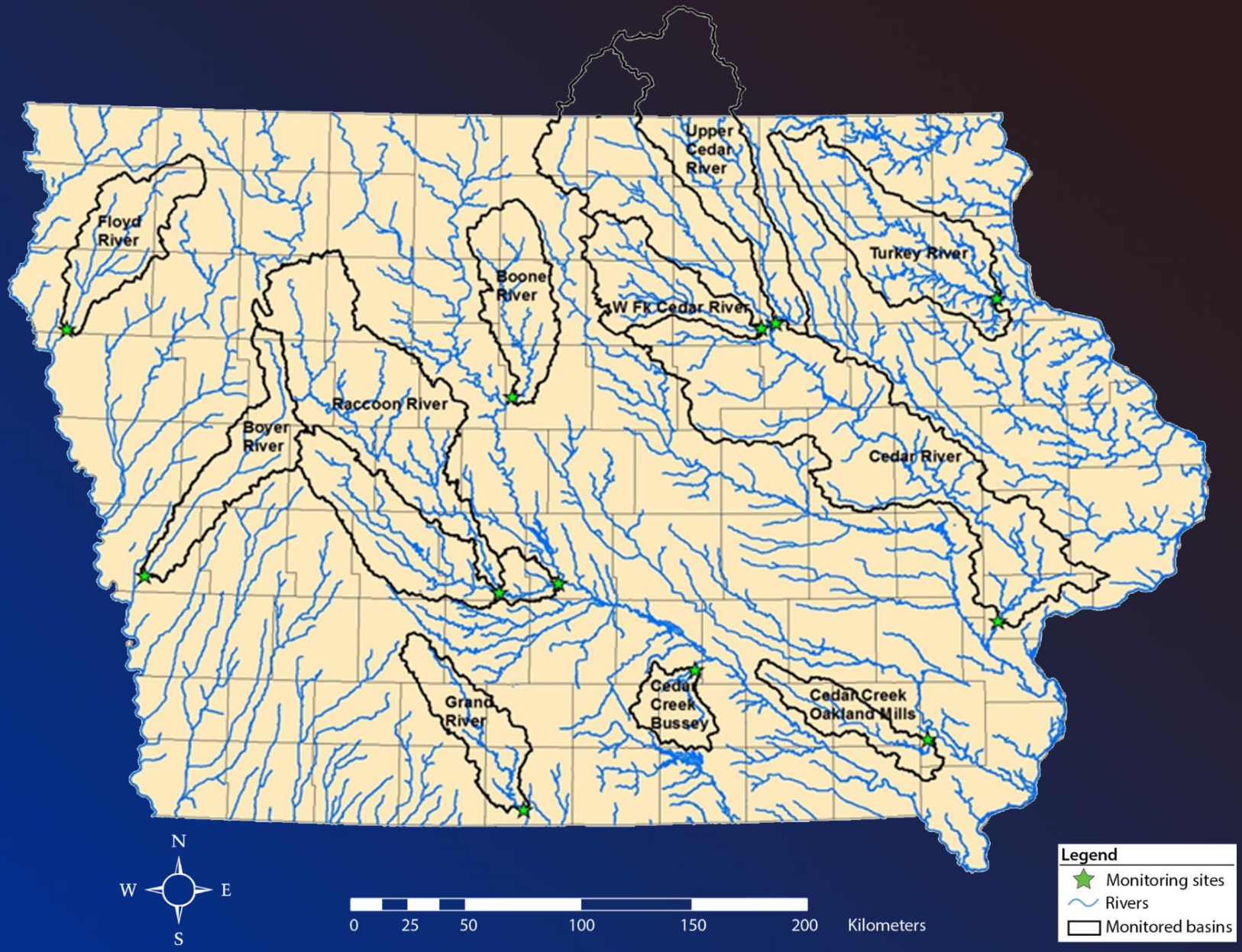


USGS LOADEST Problems

- **Stenback et al. 2011. Rating curve estimation of nutrient loads in Iowa rivers. Journal of Hydrology 396: 158- 169. DOI: 10.1016/j.jhydrol.2010.11.006.**

- http://water.usgs.gov/software/loadest/

IMPORTANT NOTE: LOADEST can produce biased load estimates when the selected model is a poor representation of the relationship between load and the explanatory variables. Problems with load bias may be identified through careful analyses of model residuals. LOADEST has therefore been modified since its initial release to include several features that facilitate residual analysis and bias identification. This updated version of the software was placed on the web site on March 27, 2013 …..



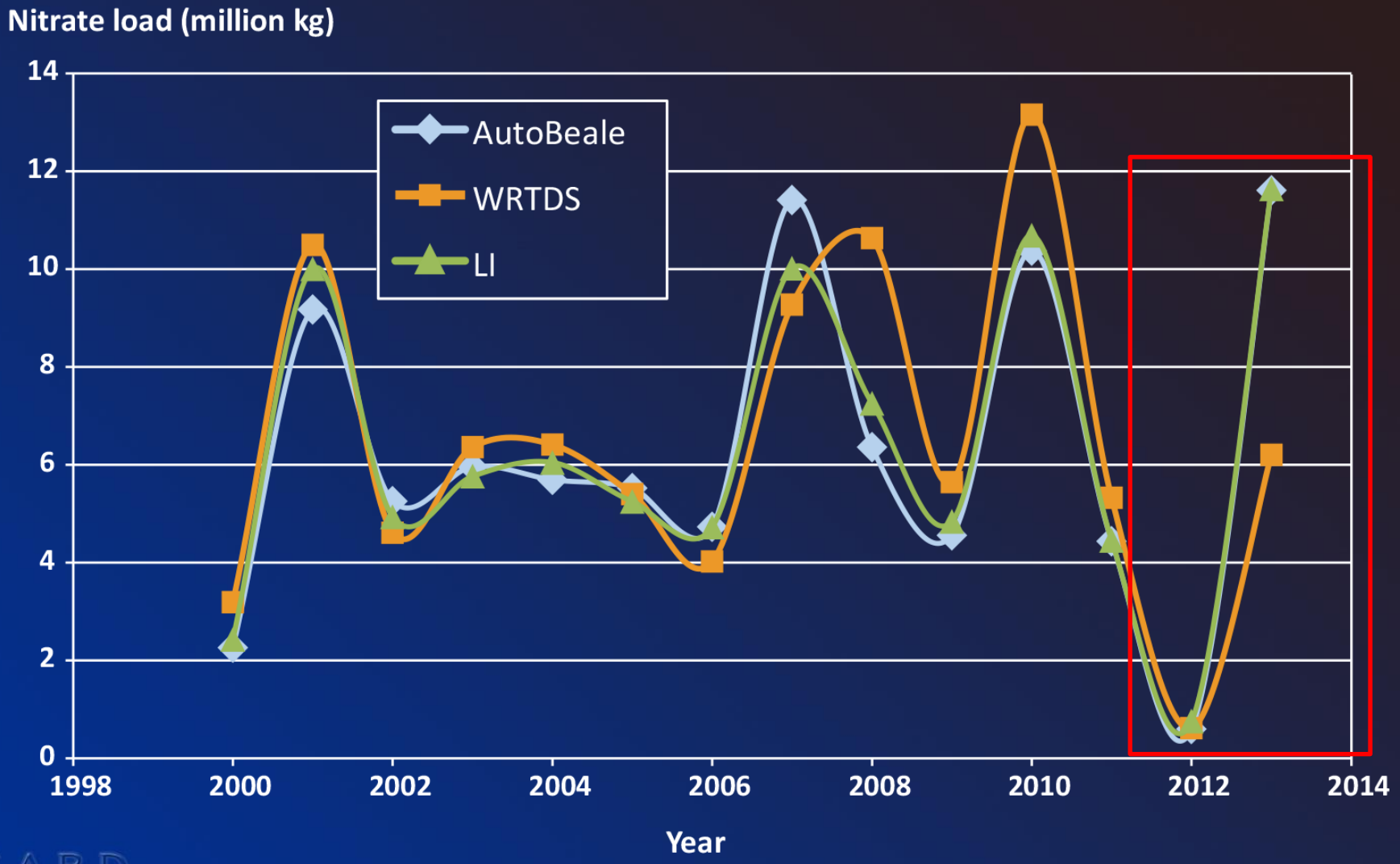
Source: Schilling et al. 2015. Assessment of Nitrate-N Load Estimation Methods to Quantify Load Reduction strategies. JAWRA (submitted).

Estimated Nitrate Loads at Boone Outlet

Load Estimation Method	Estimated Daily Average Nitrate Load (kg)
Linear interpolation	17,848
Average monthly values	13,626
AutoBeale method	16,517
Cokriging	24,652
LOADEST	40,009
WRTDS	17,376

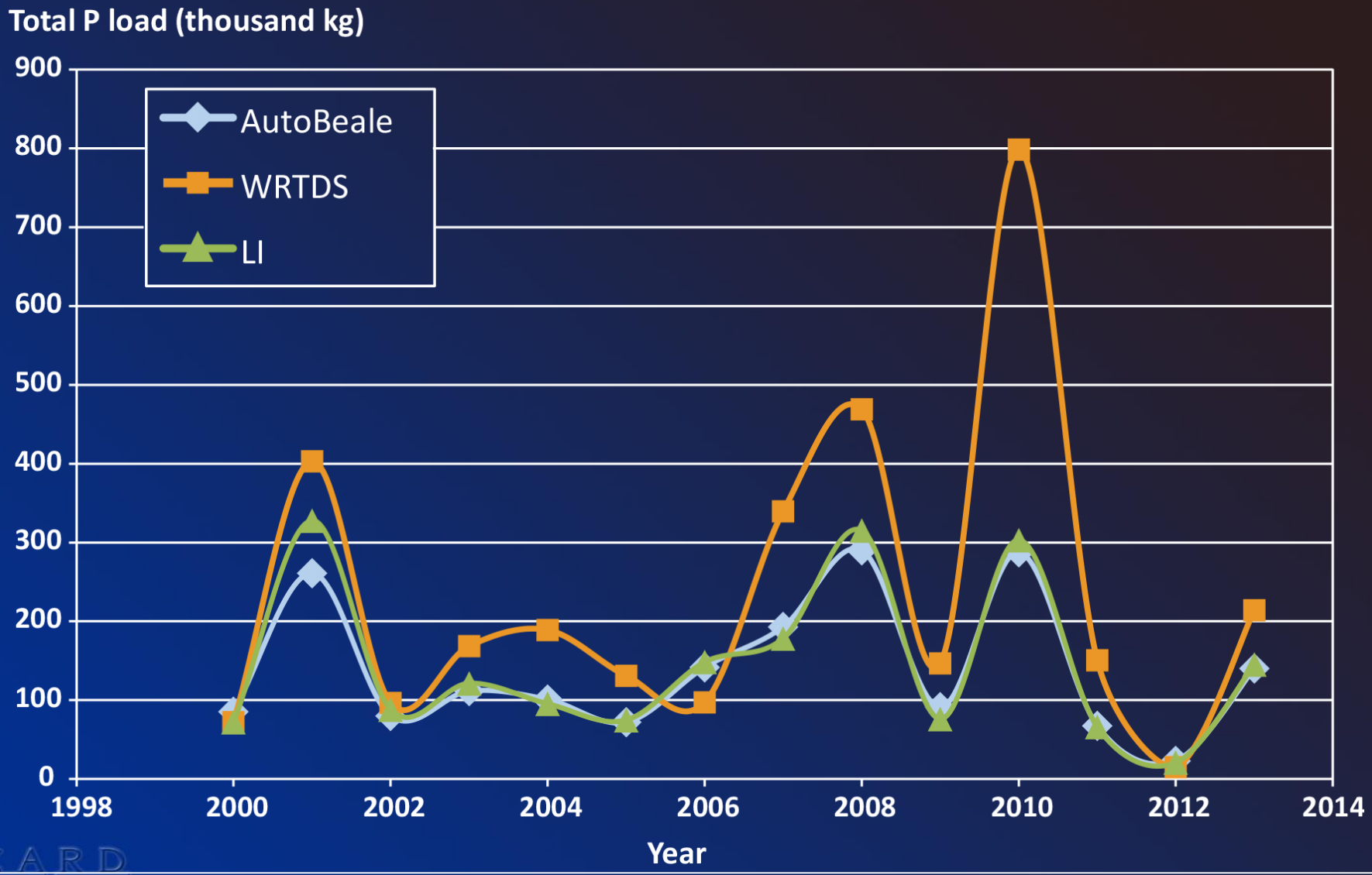
Source: Schilling et al. 2015. Assessment of Nitrate-N Load Estimation Methods to Quantify Load Reduction strategies. JAWRA (submitted).

Estimated Nitrate Loads at Boone Outlet



Data generated by C. Wolter, Iowa Deptartment of Natural Resources, Des Moines, IA

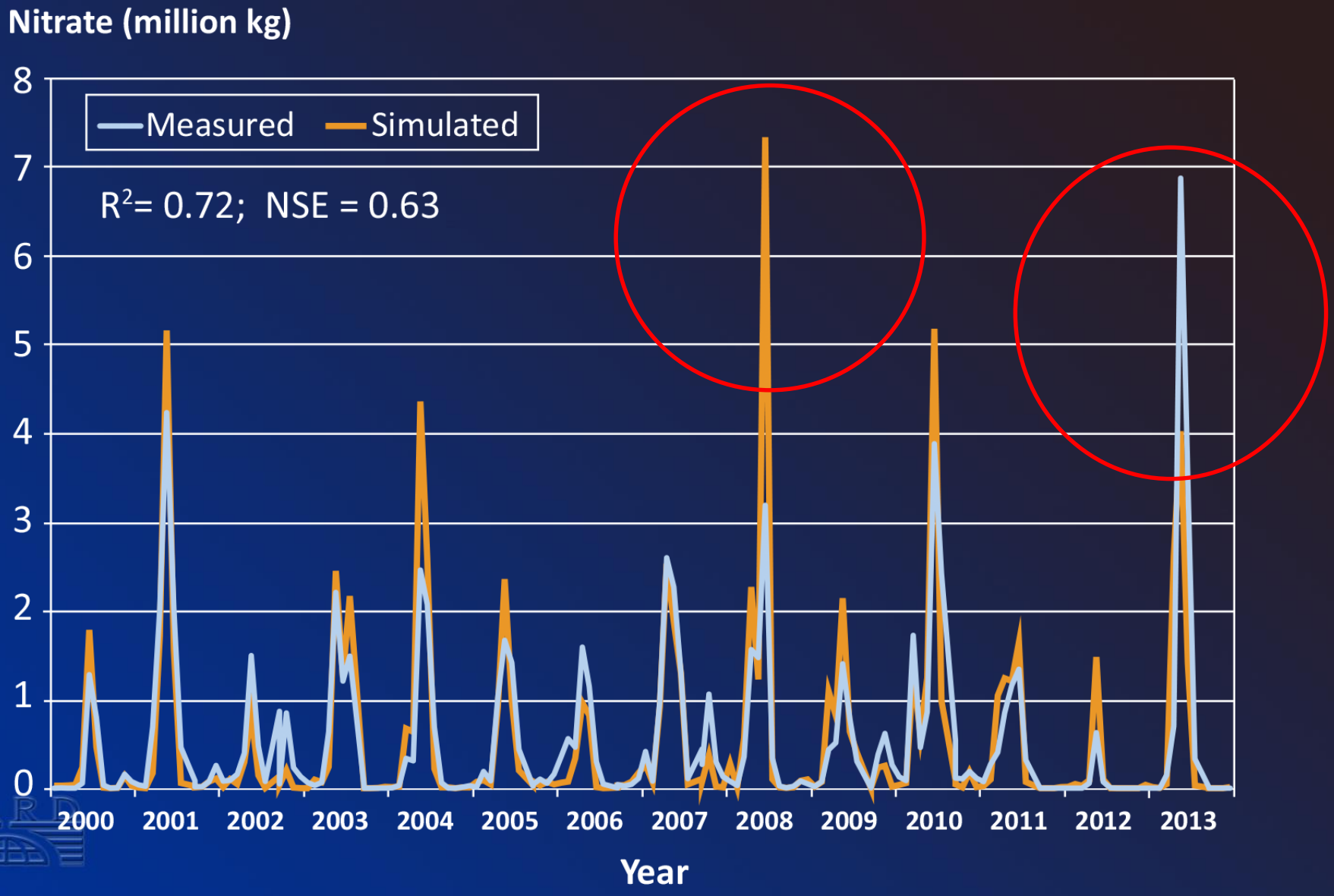
Estimated Total P Loads at Boone Outlet



Data generated by C. Wolter, Iowa Deptartment of Natural Resources, Des Moines, IA

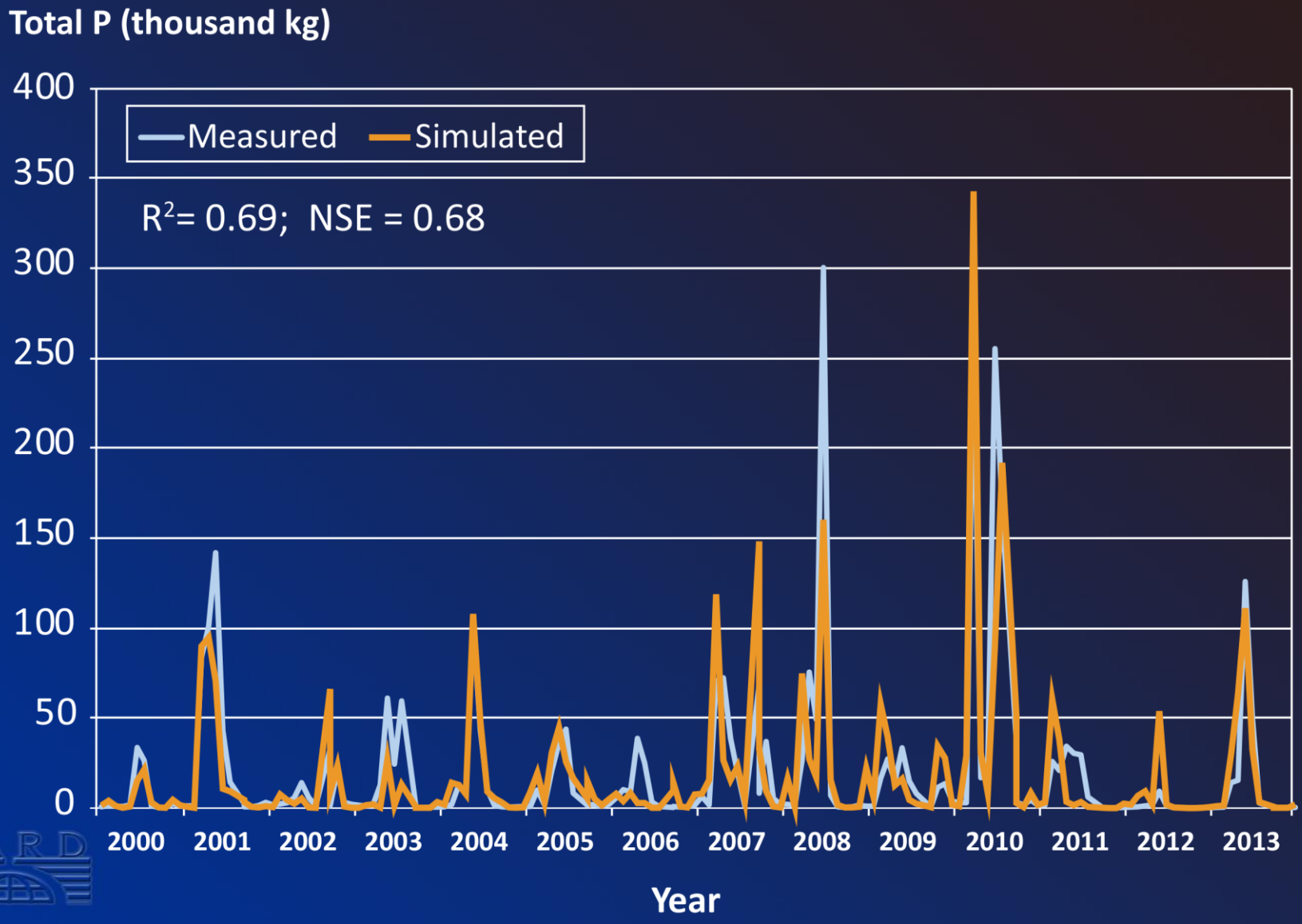
Simulated vs. "Measured" Nitrate Loads

(Measured Loads Based on LI Method)



Simulated vs. "Measured" Total P Loads

(Measured Loads Based on LI Method)



Bioenergy Scenarios

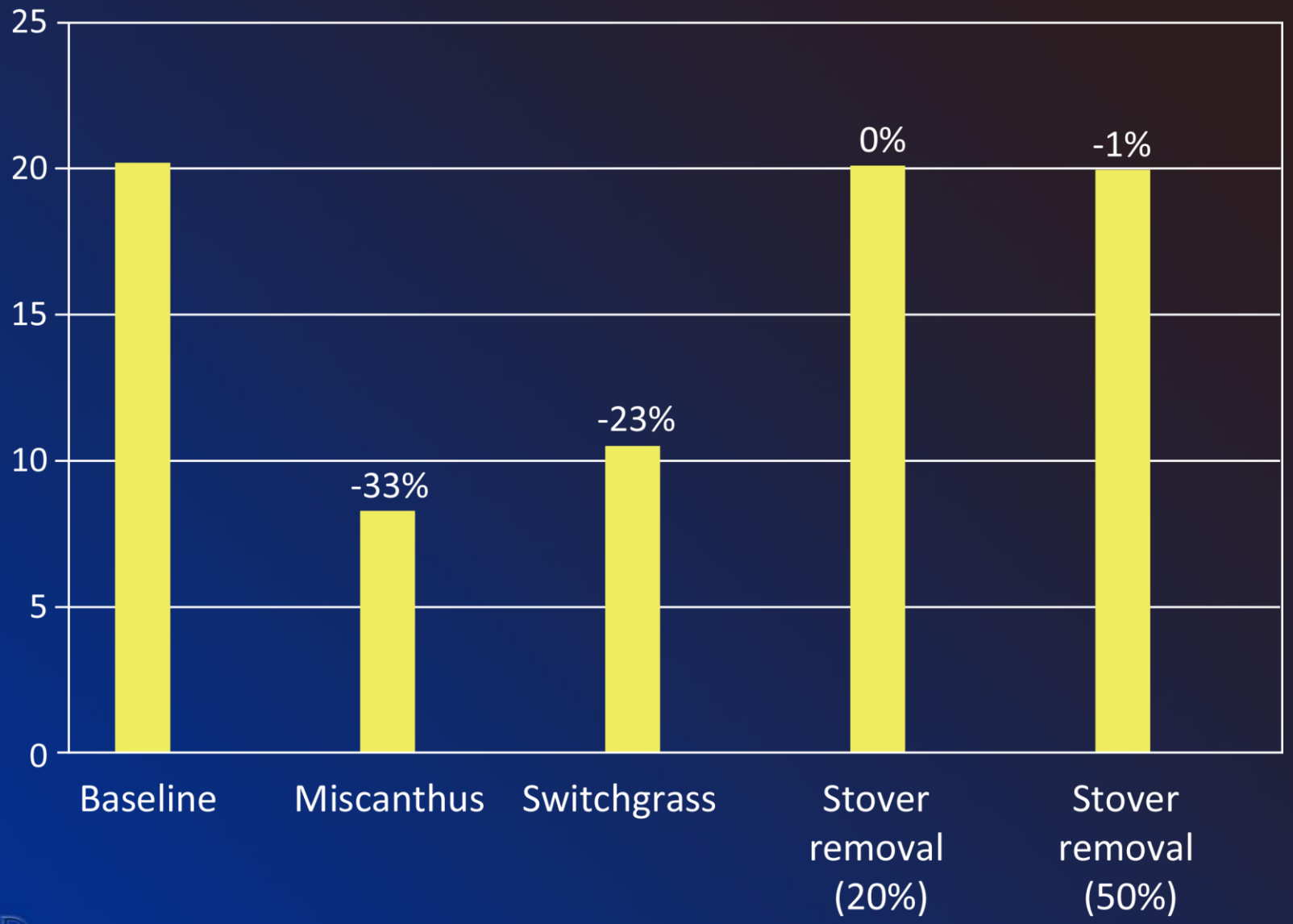
- Total conversion of cropland to either switchgrass or miscanthus
  - N application rate: 122 kg/ha surface applied as urea (46% nitrate)
  - manure nutrients also applied to some fields

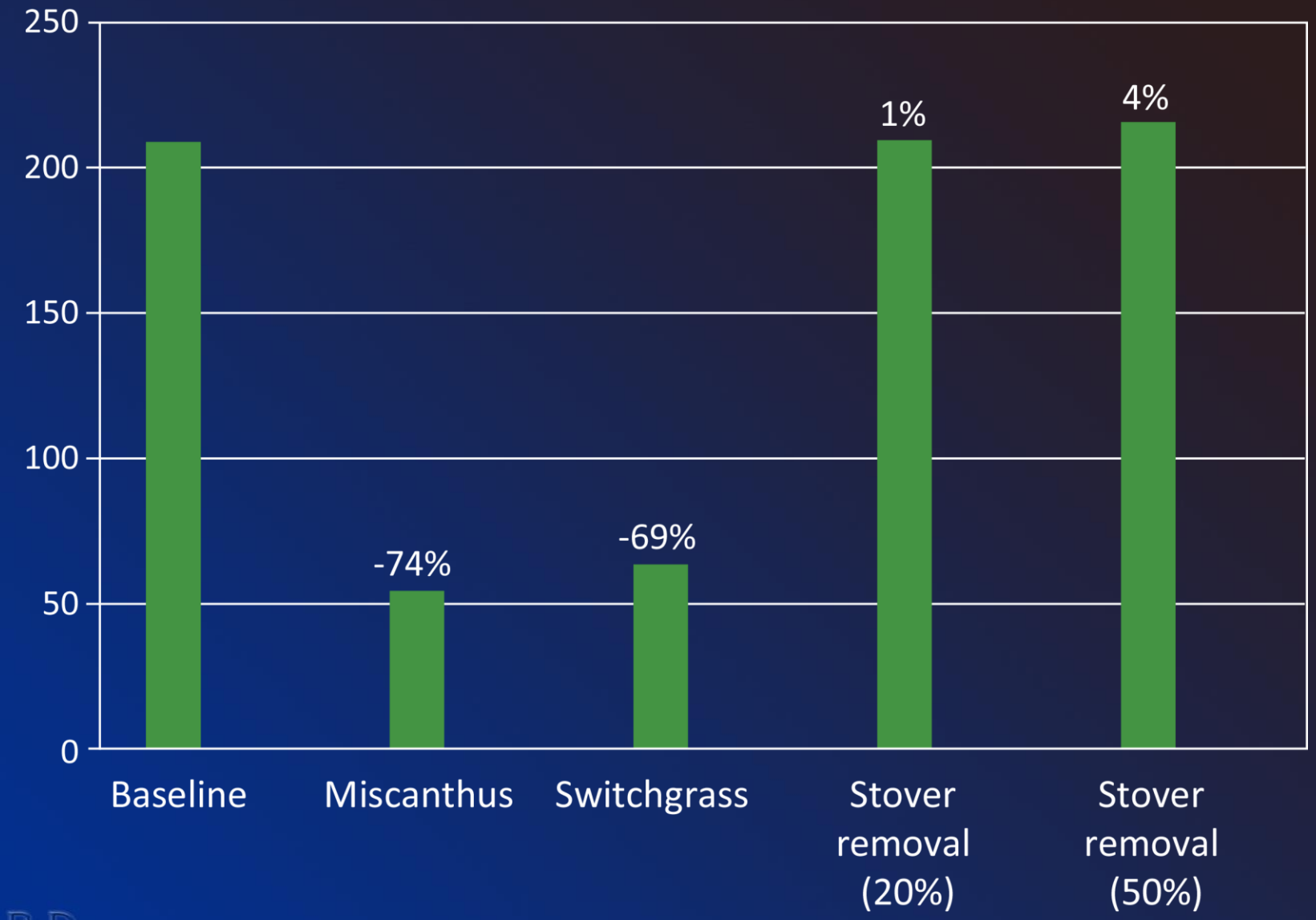
- 20% and 50% removal of corn stover
  - supplemental N & P fertilizer applied to corn to replace nutrients removed in stover

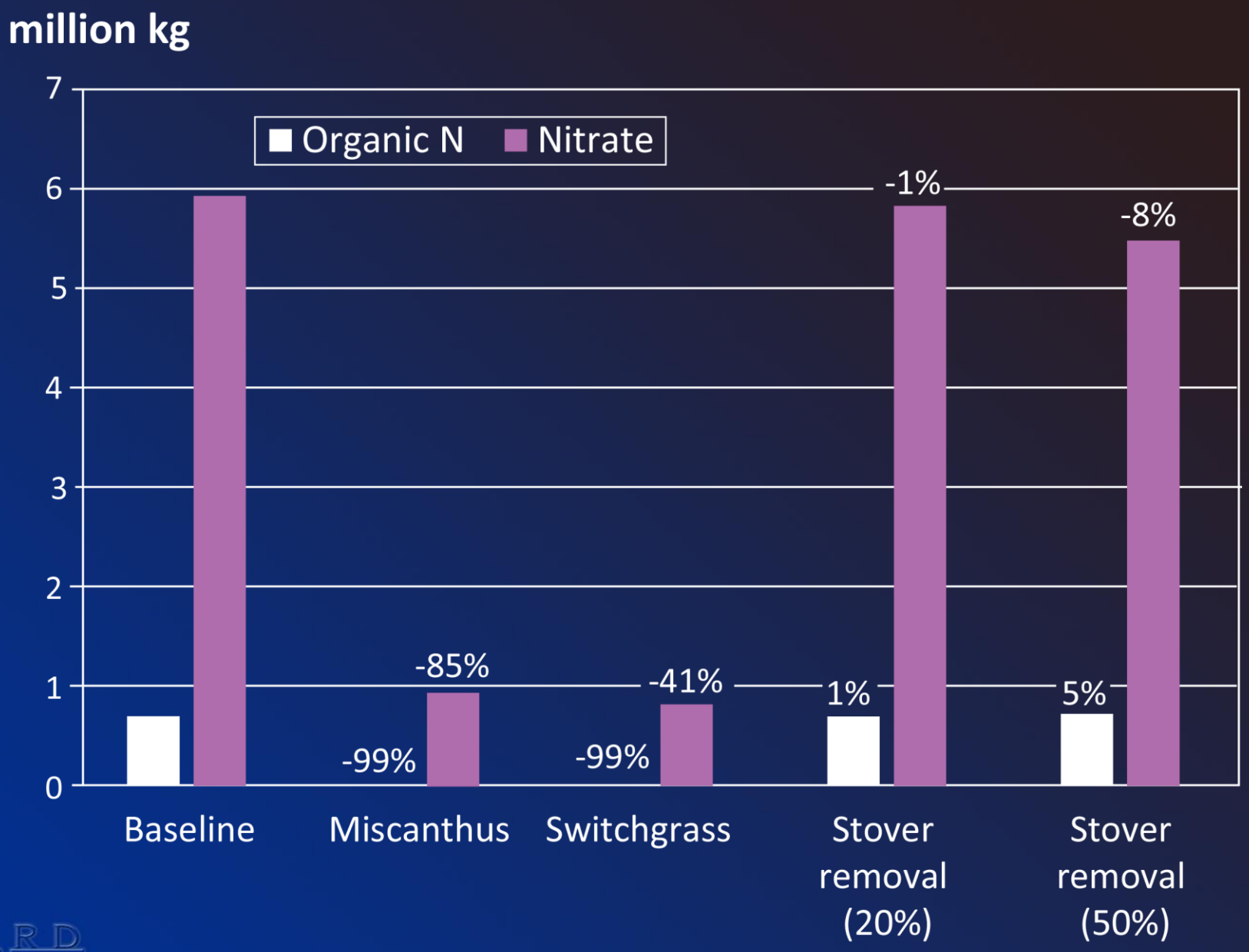
Bioenergy Scenarios

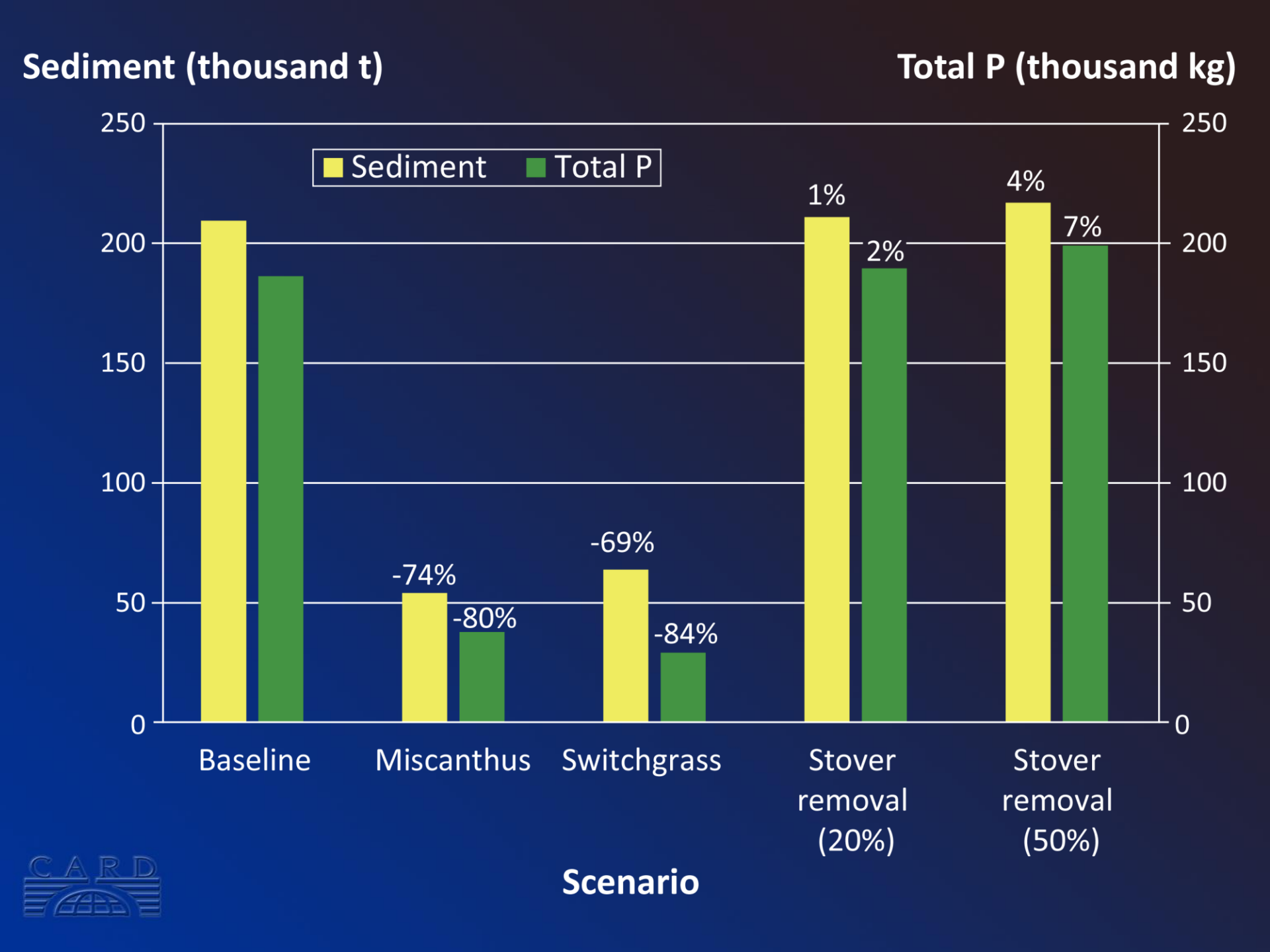
- Repeated miscanthus, switchgrass & 20%/50% stover removal scenarios for higher sloped cropland
- ≥ 2% slope; 17% of the cropland area (11% of the cropland = 2% slope)
- ≥ 7% slope; 1.4% of the cropland area

Streamflow (mm)

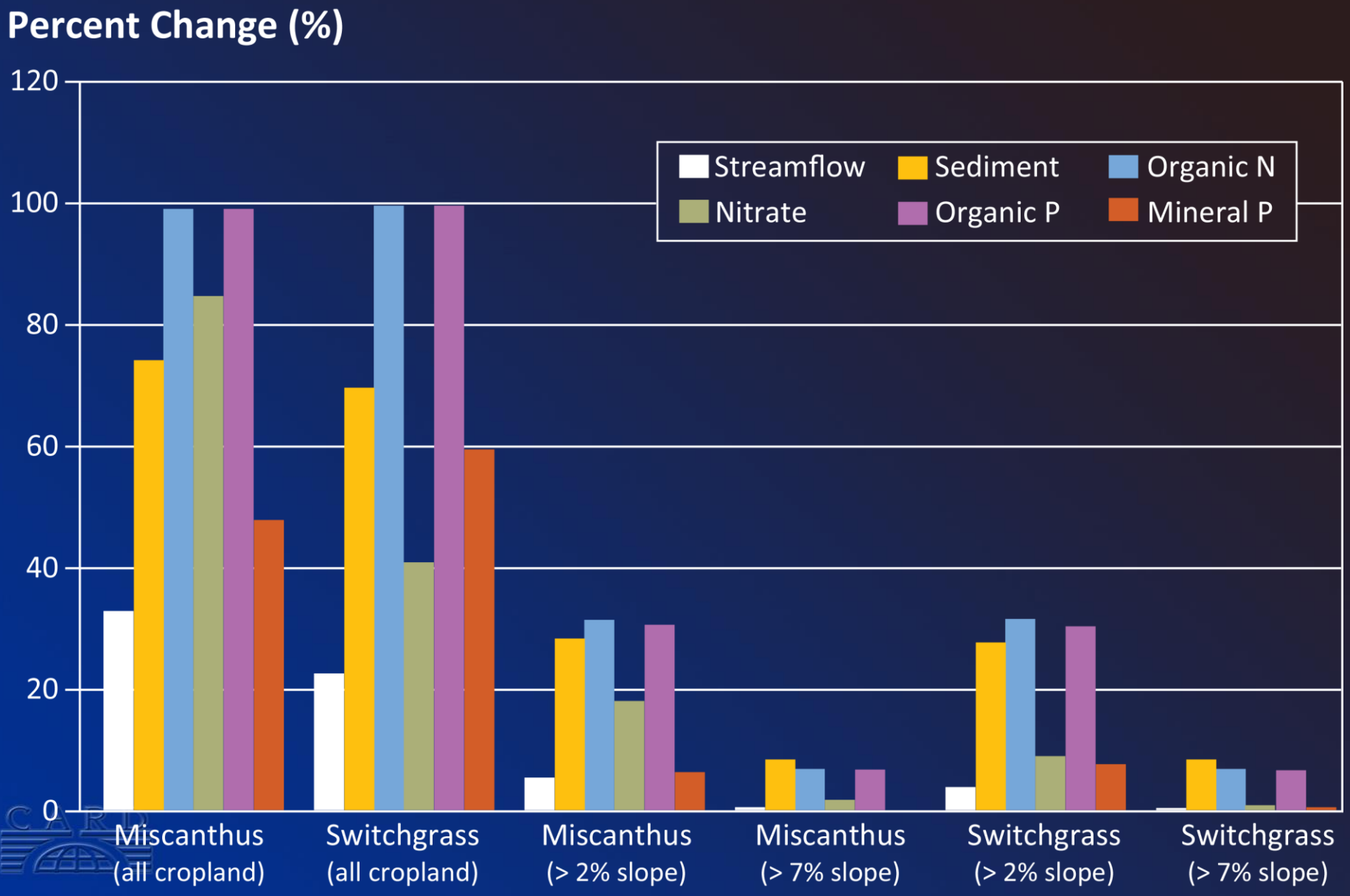



Sediment (thousand t)
250
200
150
100
50
0
-74%
-69%
1%
4%
Baseline
Miscanthus
Switchgrass
Stover removal (20%)
Stover removal (50%)
Scenario

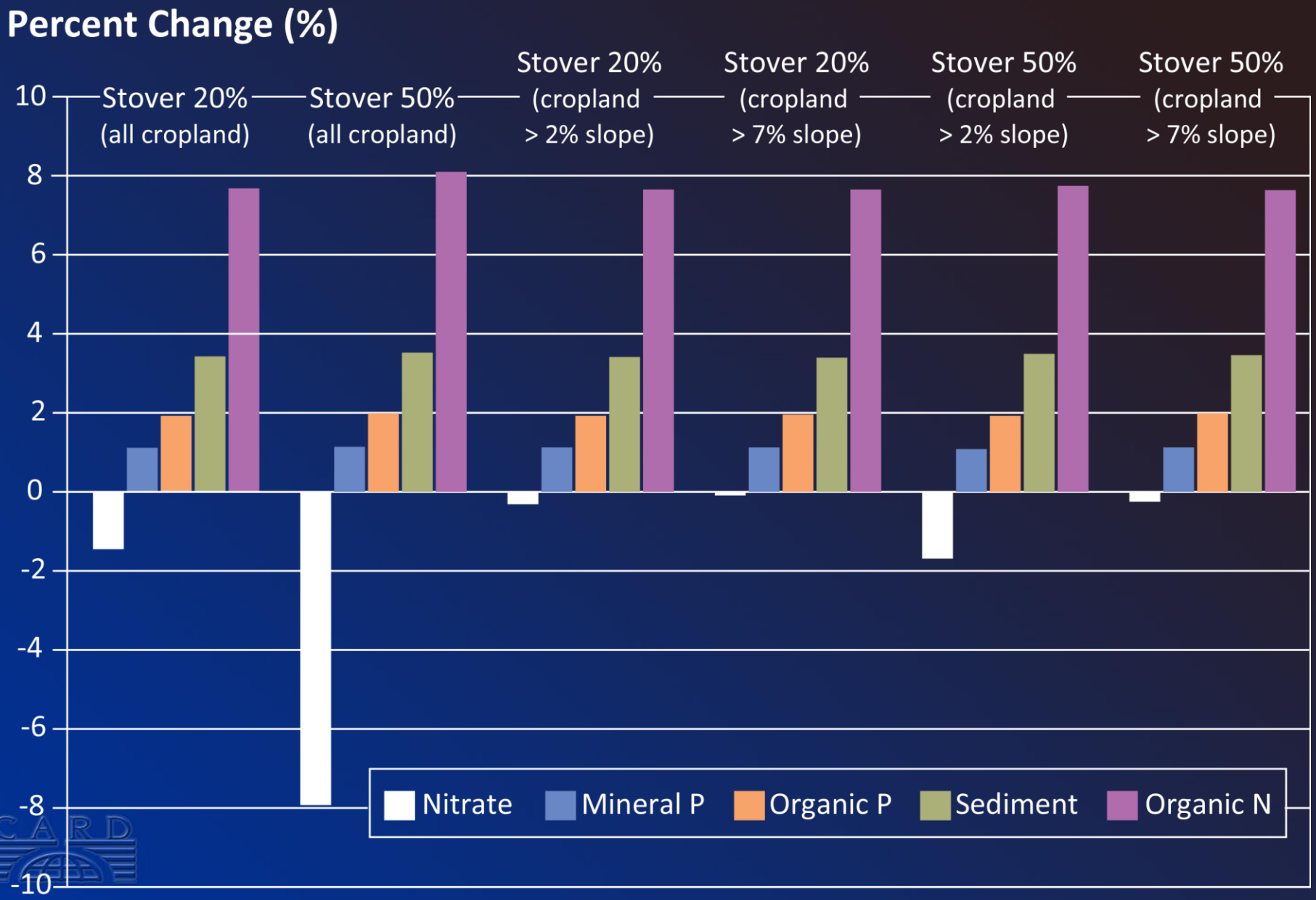

million kg
7
6
5
4
3
2
1
0
Organic N
Nitrate
-99%
-85%
-99%
-41%
1%
-1%
5%
-8%
Baseline
Miscanthus
Switchgrass
Stover removal (20%)
Stover removal (50%)


Sediment (thousand t)
Total P (thousand kg)
250
200
150
100
50
0
Sediment
Total P
-74%
-80%
-69%
-84%
1%
2%
4%
7%
Baseline
Miscanthus
Switchgrass
Stover removal (20%)
Stover removal (50%)
Scenario

Percent Reductions Due to Miscanthus and Switchgrass Scenarios



Effects of Stover Removal Scenarios



Conclusions / Next Steps

- Large scale adoption of switchgrass and miscanthus resulted in substantial reduction of pollutant loads
- Only minor pollutant impacts resulted for stover removal scenarios; nitrate predicted to decrease
- Future improvements: switch to new DRAINMOD-based tile drainage option / introduce potholes?
- Review nutrient input assumptions