Application of SWAT for the Boone River Watershed in North Central Iowa, U.S.: Implications of Different Nutrient Load Estimation Techniques for Model Testing

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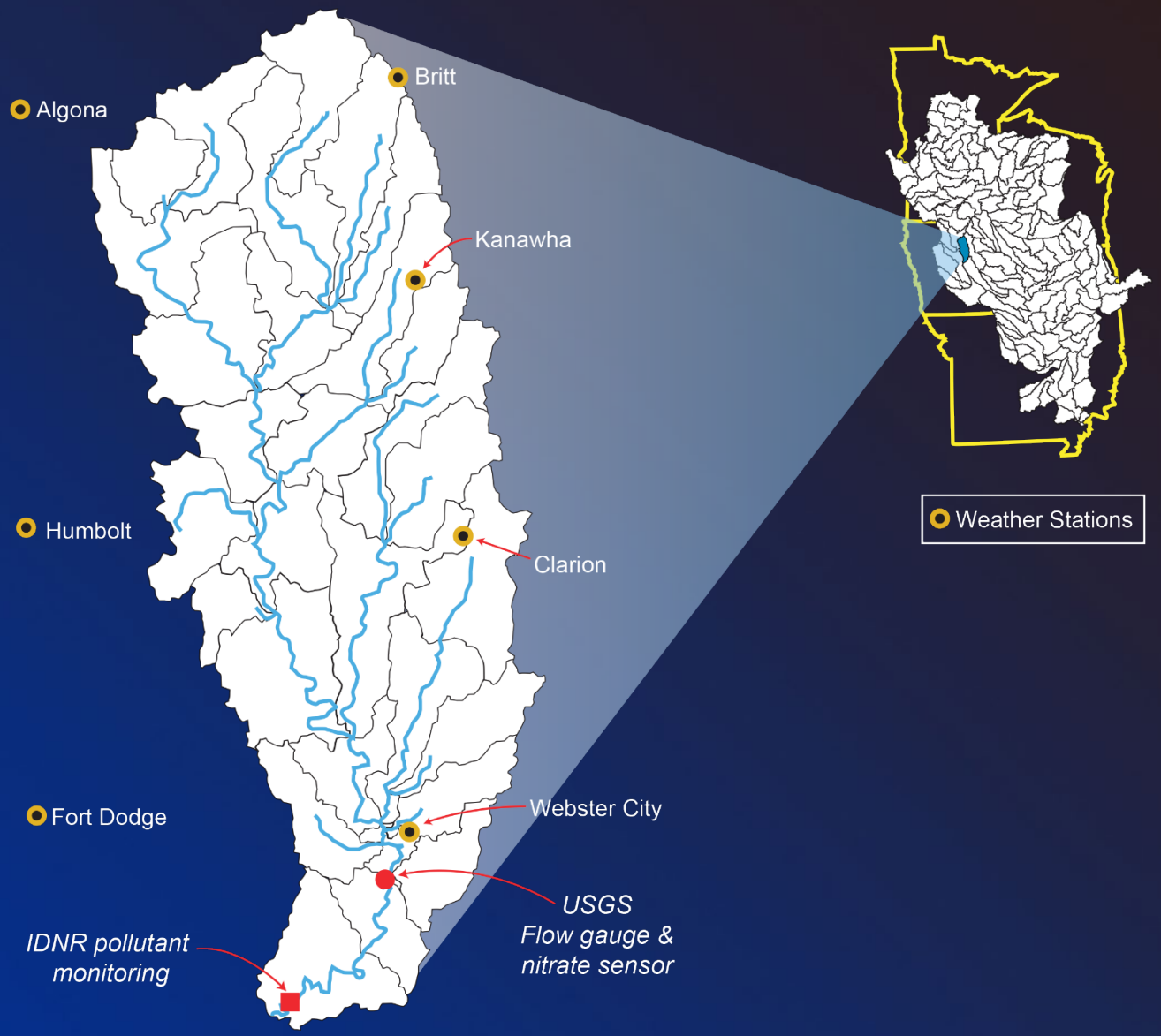
Overview of Presentation

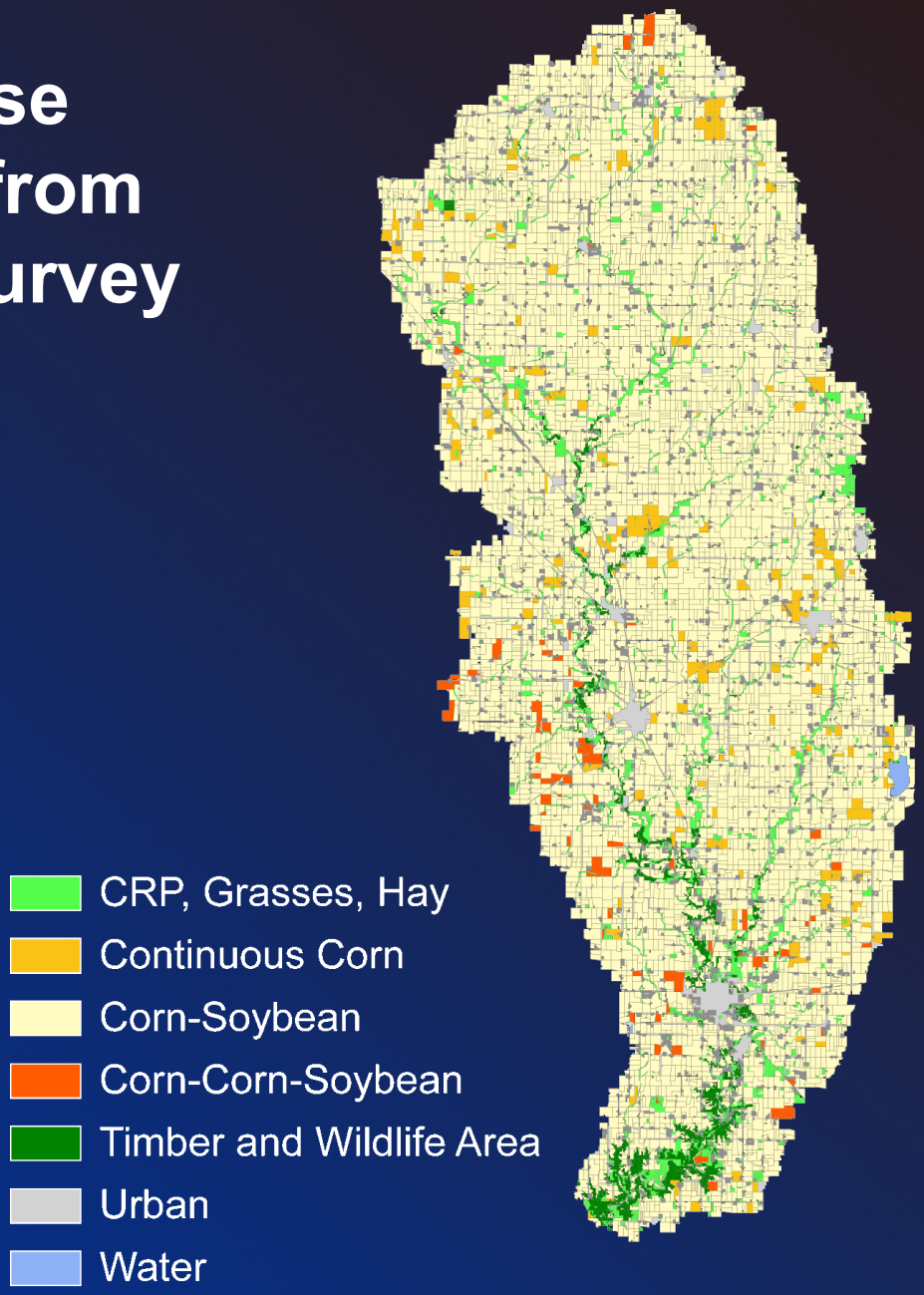
- Description of the Boone River Watershed (BRW) and Des Moines Lobe region
- Magnitude of nitrate loss problems in Iowa
- Pollutant load estimation issues
- BRW SWAT model testing
- Conclusions

Boone River Watershed

- 2,370 km^2 in parts of six counties in north central Iowa
- Des Moines Lobe landform region; southern most portion of North American Prairie Pothole region
- Generally level topography; heavily tile drained
- Dominated by crop production and also characterized by intensive livestock production


Britt
Algona
Kanawha
Humbolt
Clarion
Fort Dodge
Webster City
USGS
Flow gauge &
nitrate sensor
IDNR pollutant
monitoring
Weather Stations

2005 Land Use Determined from Field-level Survey



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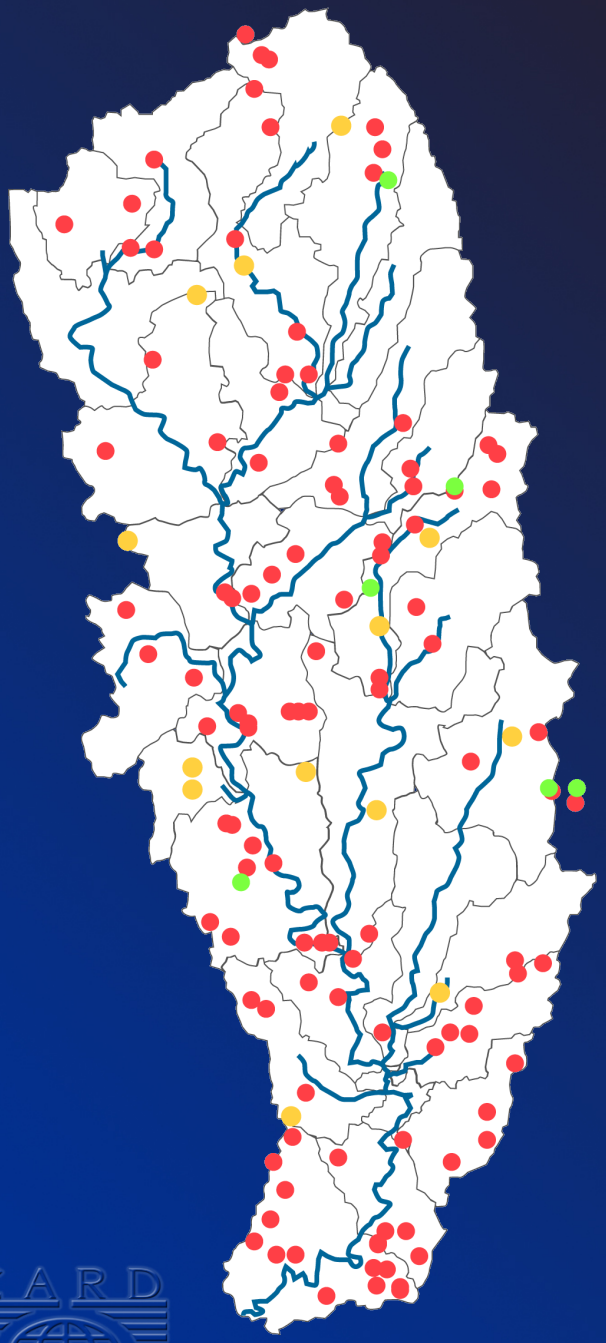

CAFOs

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

Source: 2005 IDNR CAFO data

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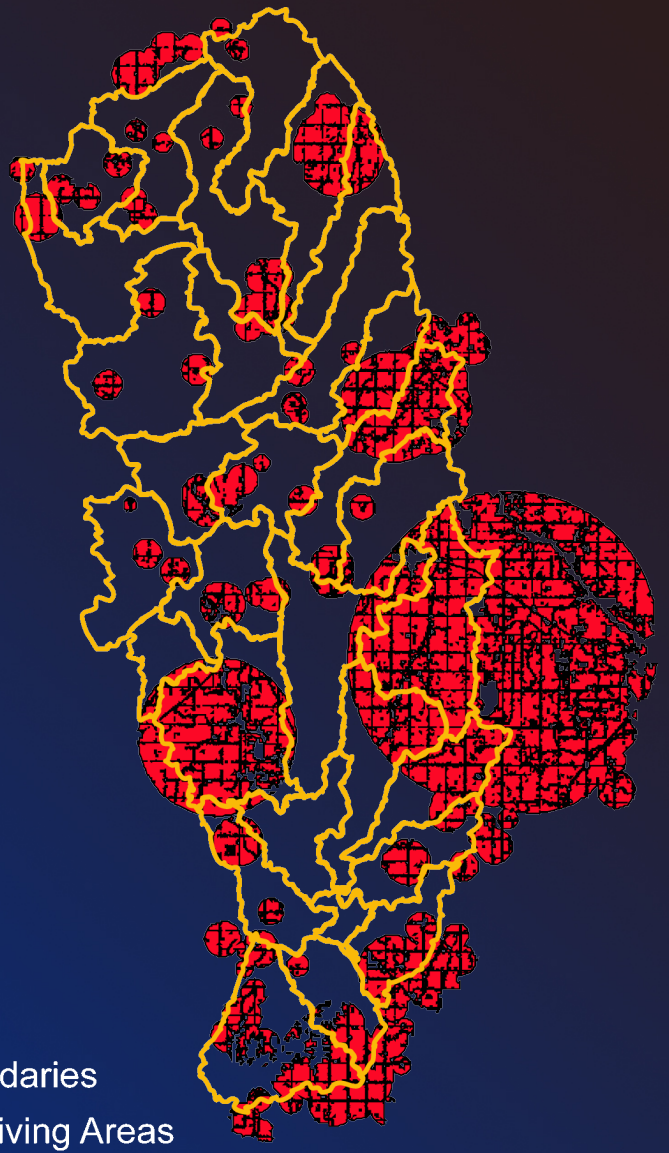
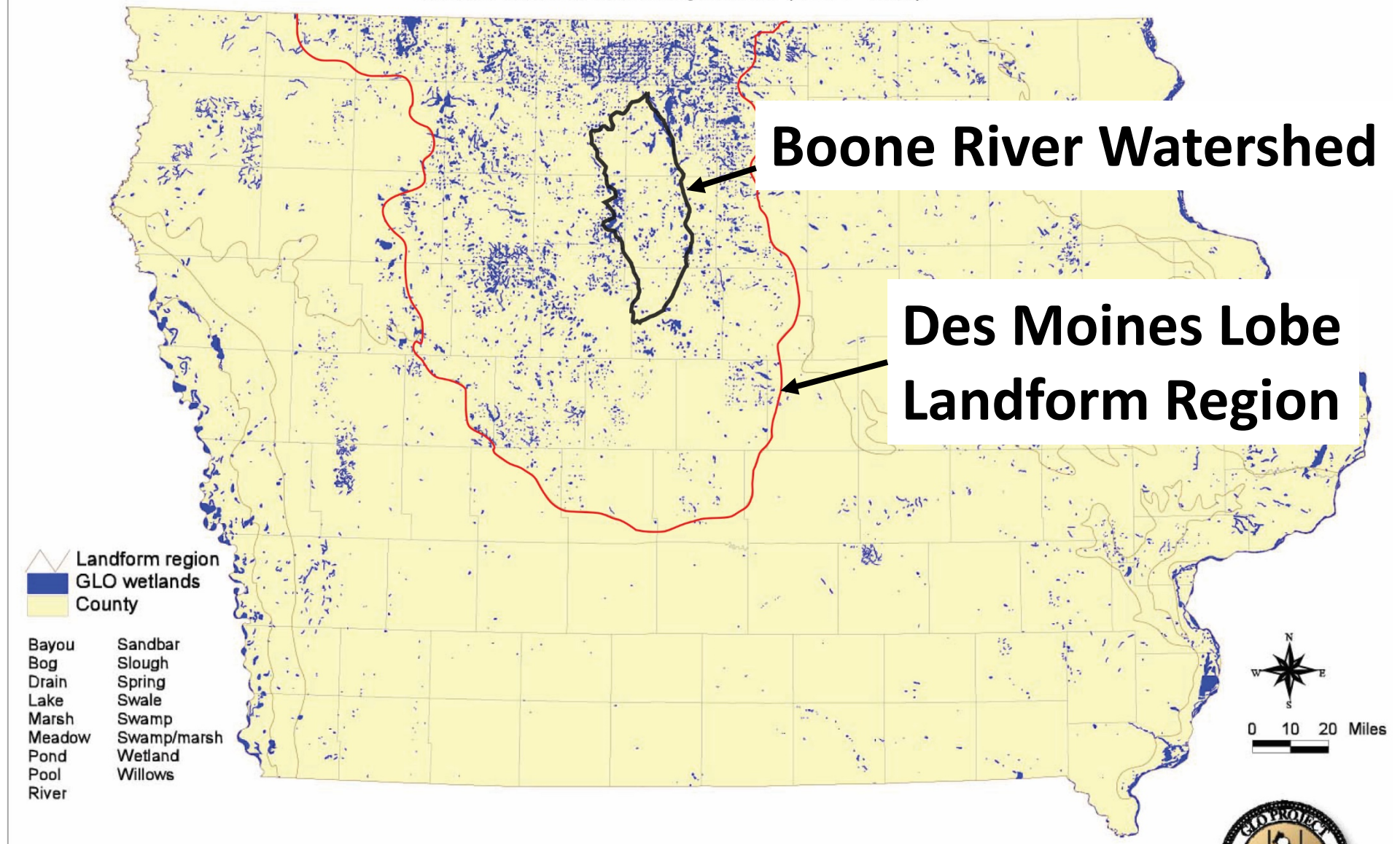
Estimated Manure Application Zones (112 kg/ha N rate)



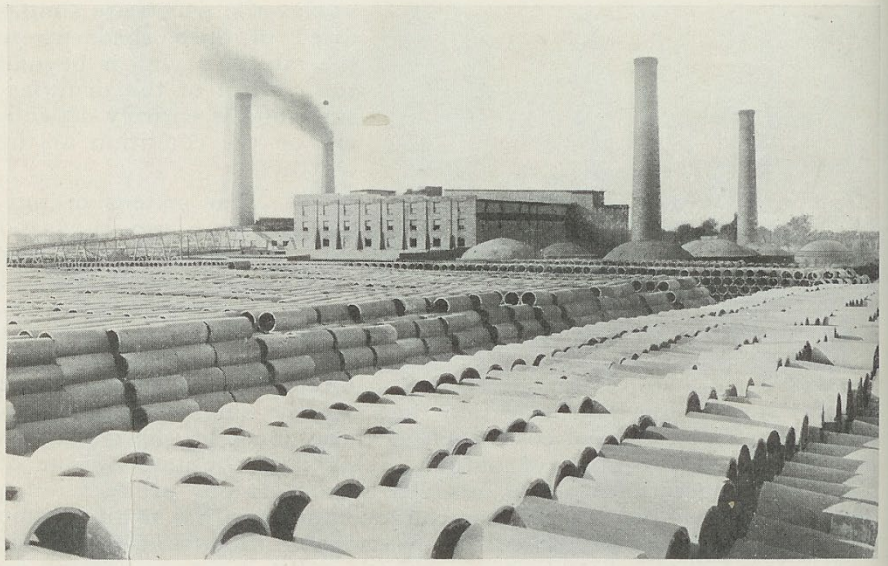
Data generated by C. Wolter, Iowa Dept. of Natural Resources, Des Moines, IA; Software developed by D. James, USDA -ARS, Ames, IA

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.



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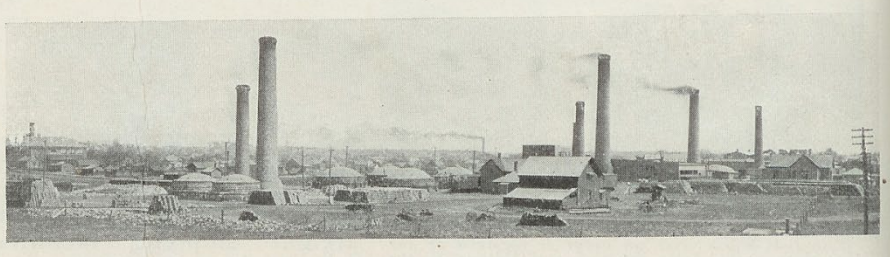
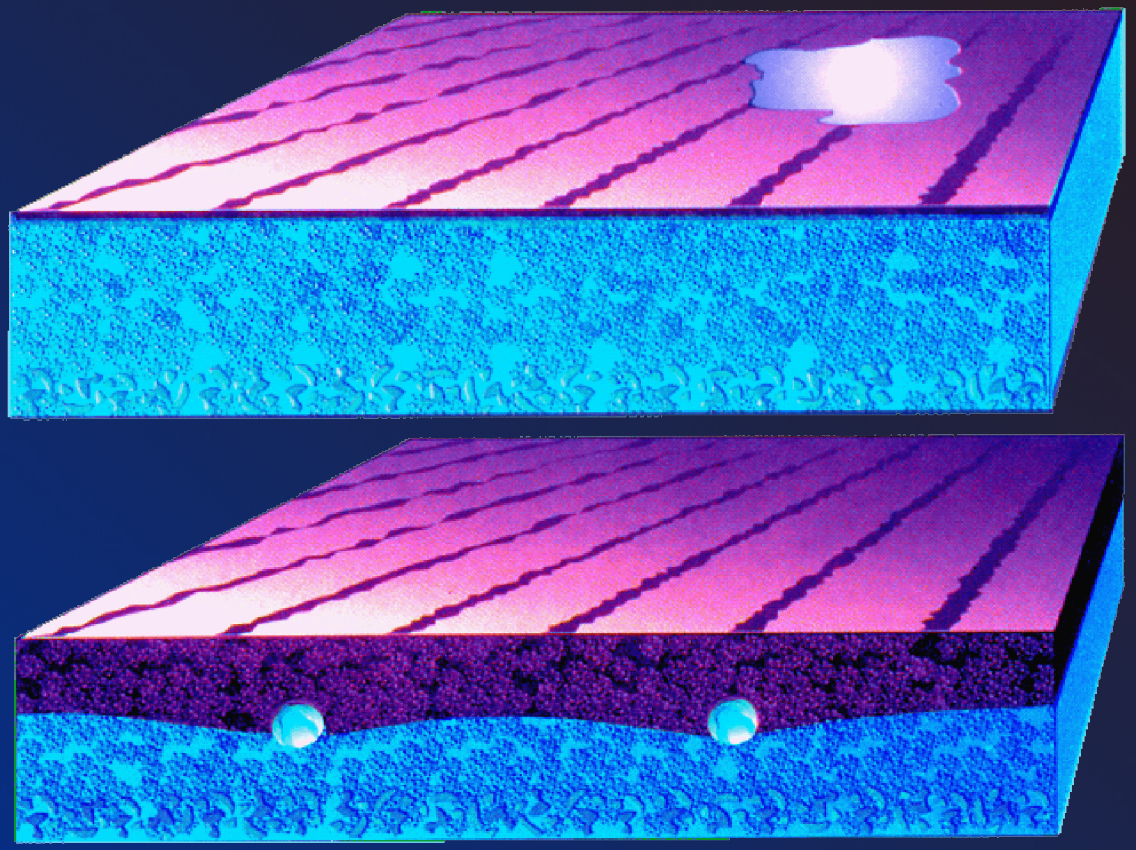


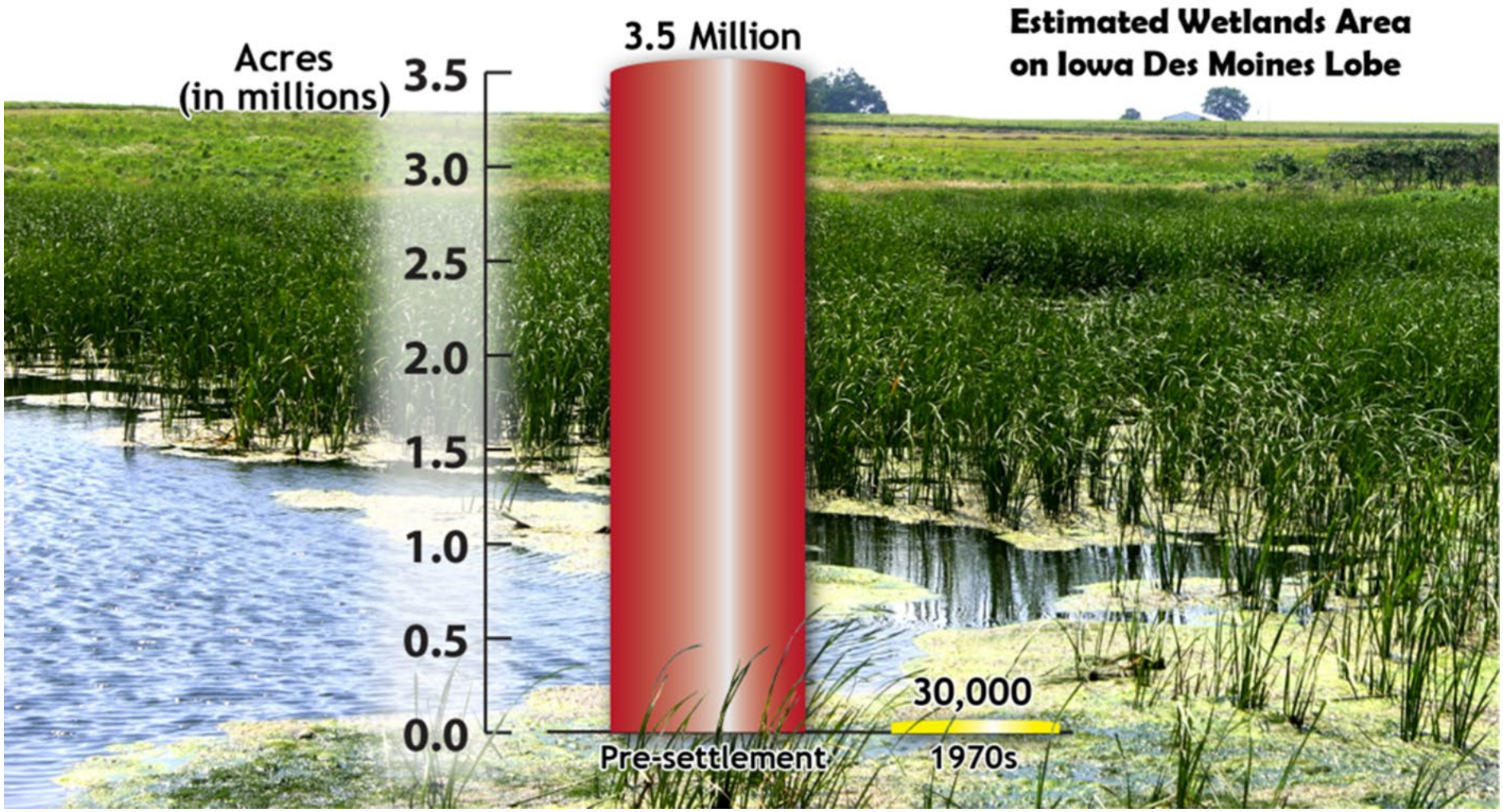
A bird's-eye view of one of our factories.

Effects of Tile Drainage on Soil Water



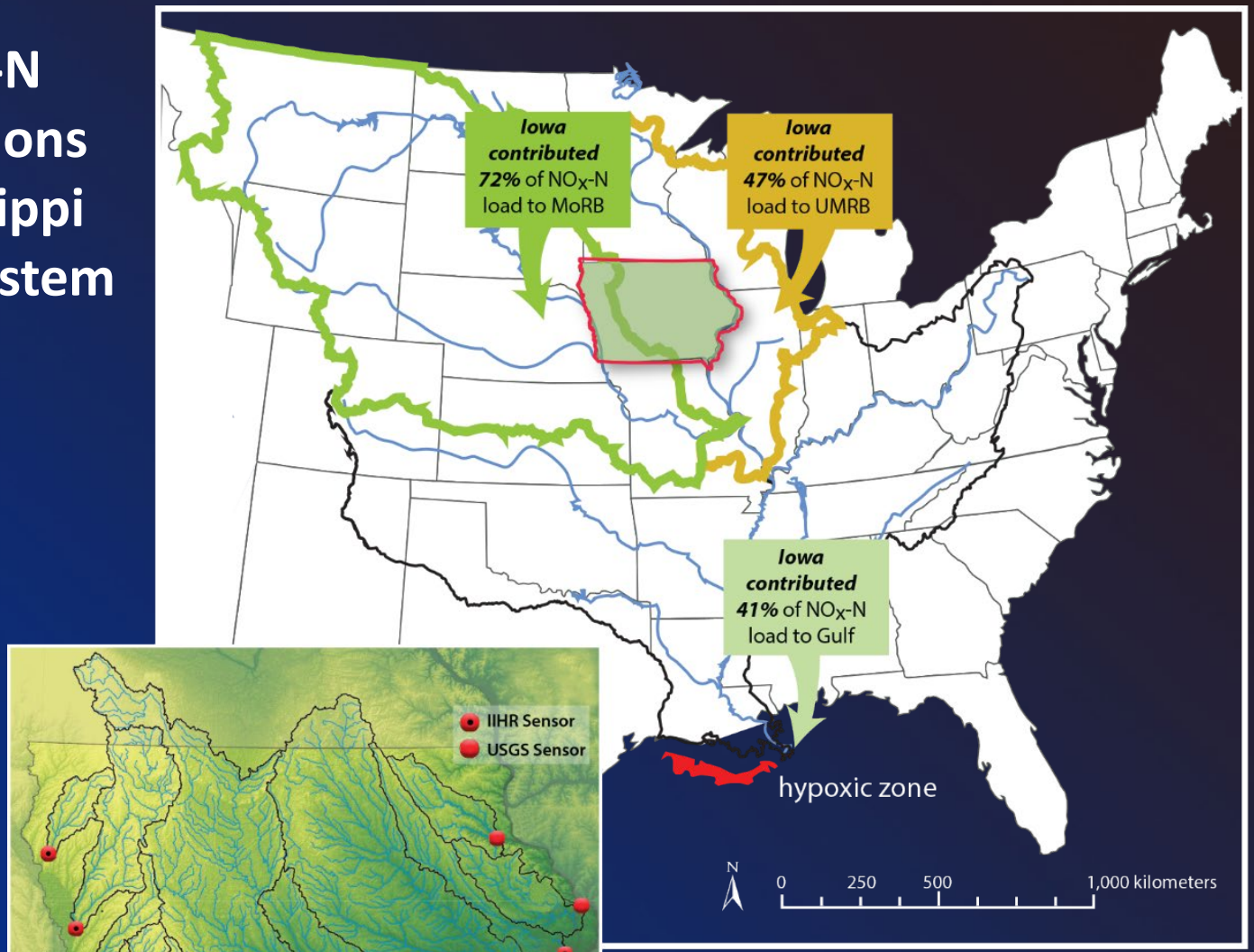
Adapted from: Zucker, L.A. and L.C. Brown (eds.). 1998. Agricultural Drainage: Water Quality Impacts and Subsurface Drainage Studies in the Midwest. Ohio State University Extension Bulletin 871. The Ohio State University.

Wetland Loss in the Des Moines Lobe Region: 99%



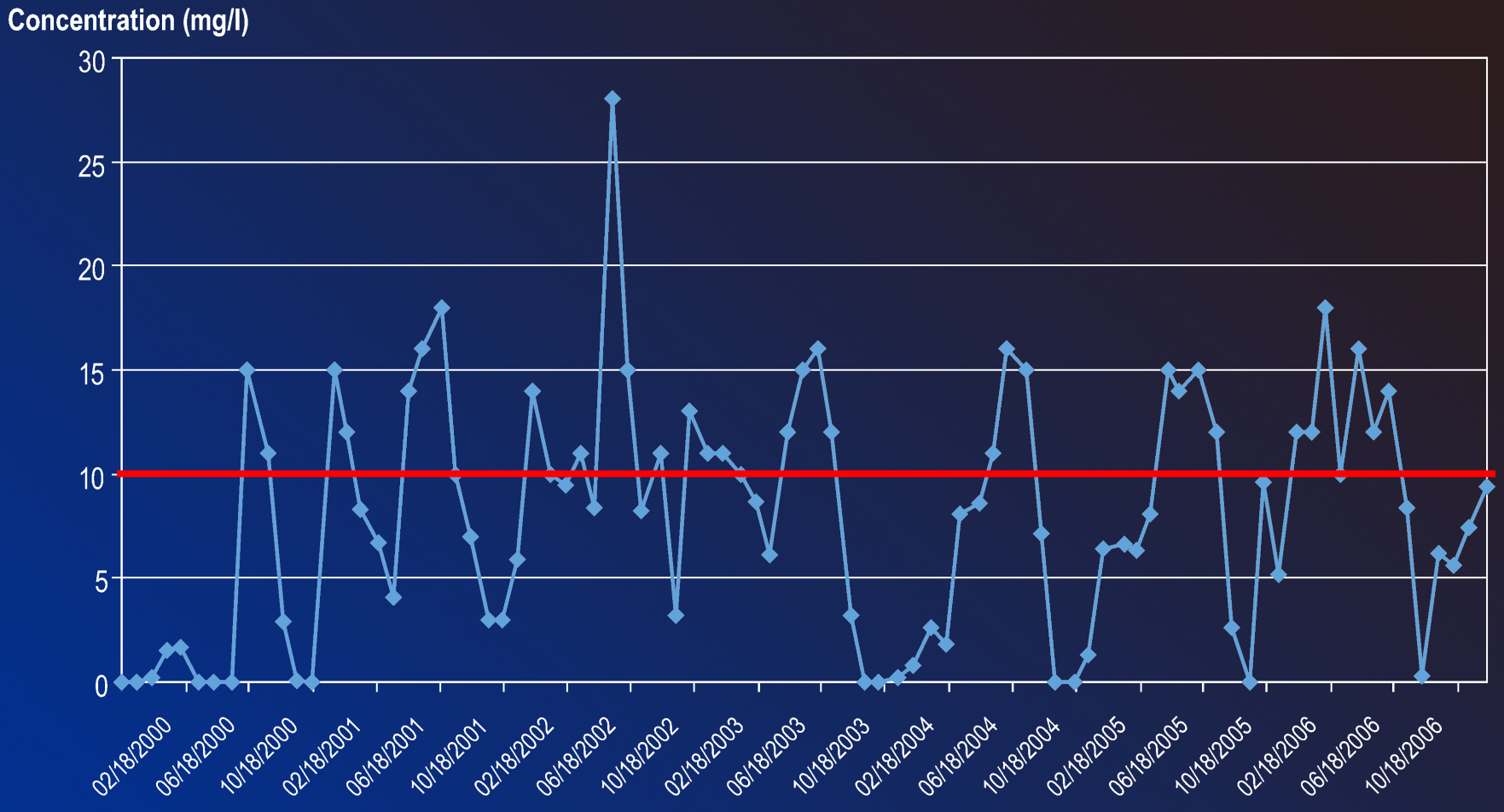
Source: Iowa Learning Farms. 2016. Wetlands: By the numbers. https://iowalearningfarms.wordpress.com/2016/05/17/wetlands-by-the-numbers/

Iowa NO_X-N Contributions to Mississippi Stream System in 2016



Source: Jones et al. 2018. Iowa Statewide Stream Nitrate Load Calculated Using In-Situ Sensor Network. JAWRA. 54(2): 471-486. Doi: 10.1111/1752-1688.12618

Jan. 2000 to Dec. 2006 Nitrate Concentrations at BRW Outlet

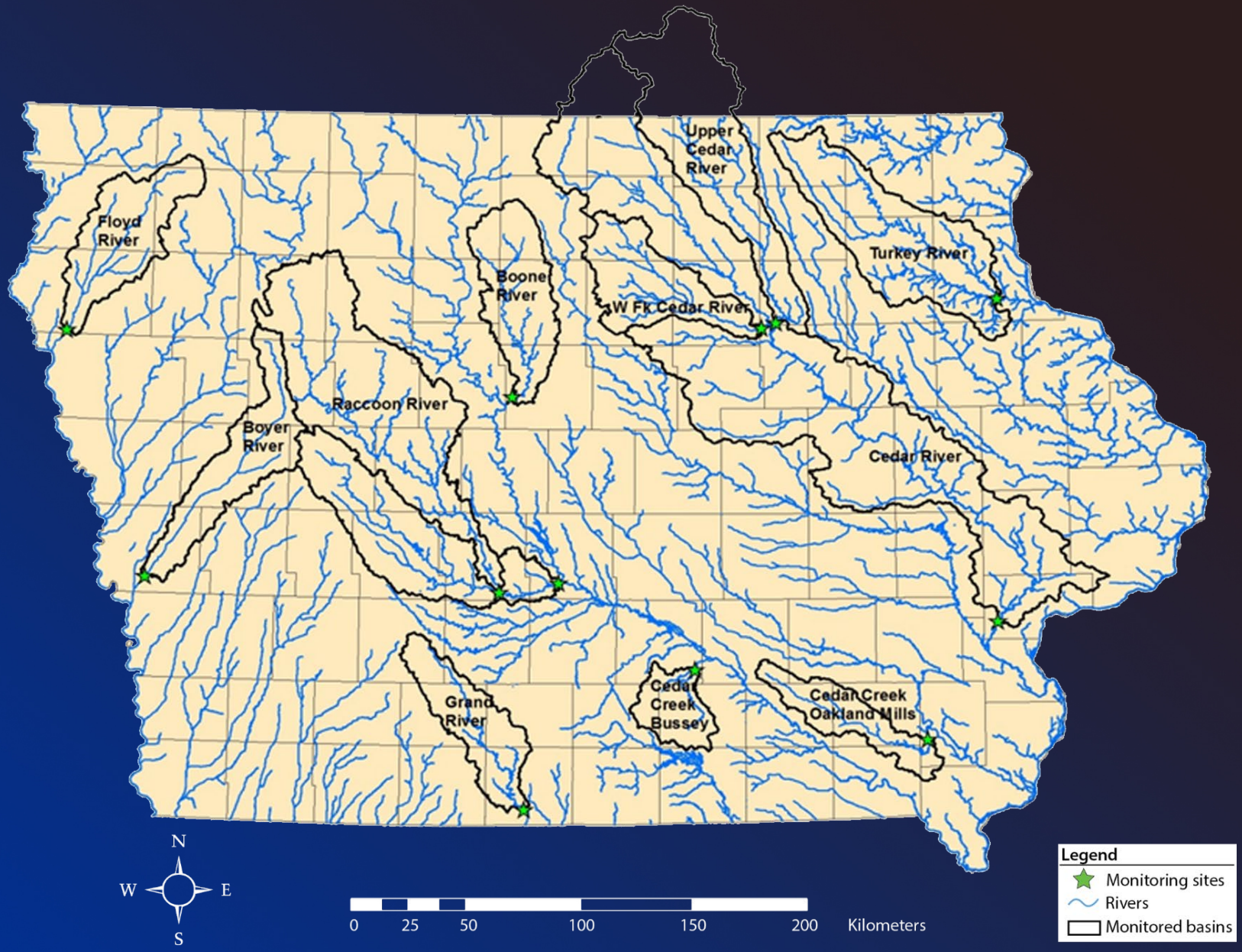


USGS LOADEST Problems

- **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. 2016. Assessment of Nitrate-N Load Estimation Methods to Quantify Load Reduction strategies. Journal of Soil Water Conservation (accepted).

Description of Nitrate Load Estimation Methods

Load Estimation Method	Description
Linear interpolation	Fill concentration gaps between measured values by a straight line; multiply by streamflow to obtain loads
Average monthly values	Average monthly streamflow multiplied by a monthly nitrate concentration
AutoBeale method	Annual load is computed as a function of concentrations and an adjusted flow ratio

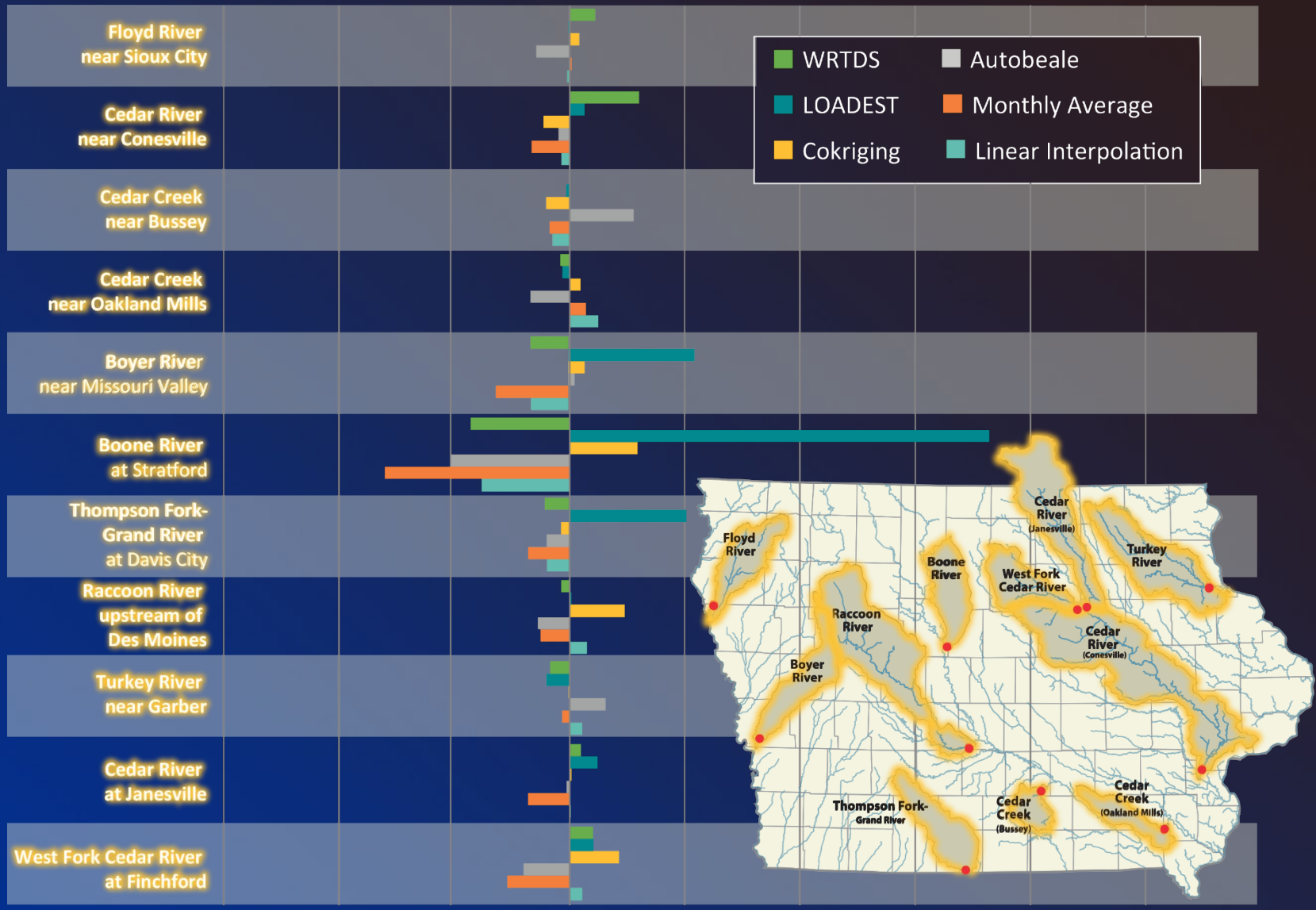
Source: Schilling et al. 2016. Assessment of Nitrate-N Load Estimation Methods to Quantify Load Reduction strategies. JSWC (accepted).

Description of Nitrate Load Estimation Methods

Load Estimation Method	Description
Cokriging	Correlation of measured NO3-N loads to daily discharge, to improve interpolation
LOADEST	Seven parameter regression model; uses continuous stream flow to estimate loads
WRTDS	Regression method that accounts for discharge, seasonality, long-term trends, and a random component

Source: Schilling et al. 2016. Assessment of Nitrate-N Load Estimation Methods to Quantify Load Reduction strategies. JSWC (accepted).

Variability of Nitrate Load Estimation Methods for 11 Iowa Watersheds



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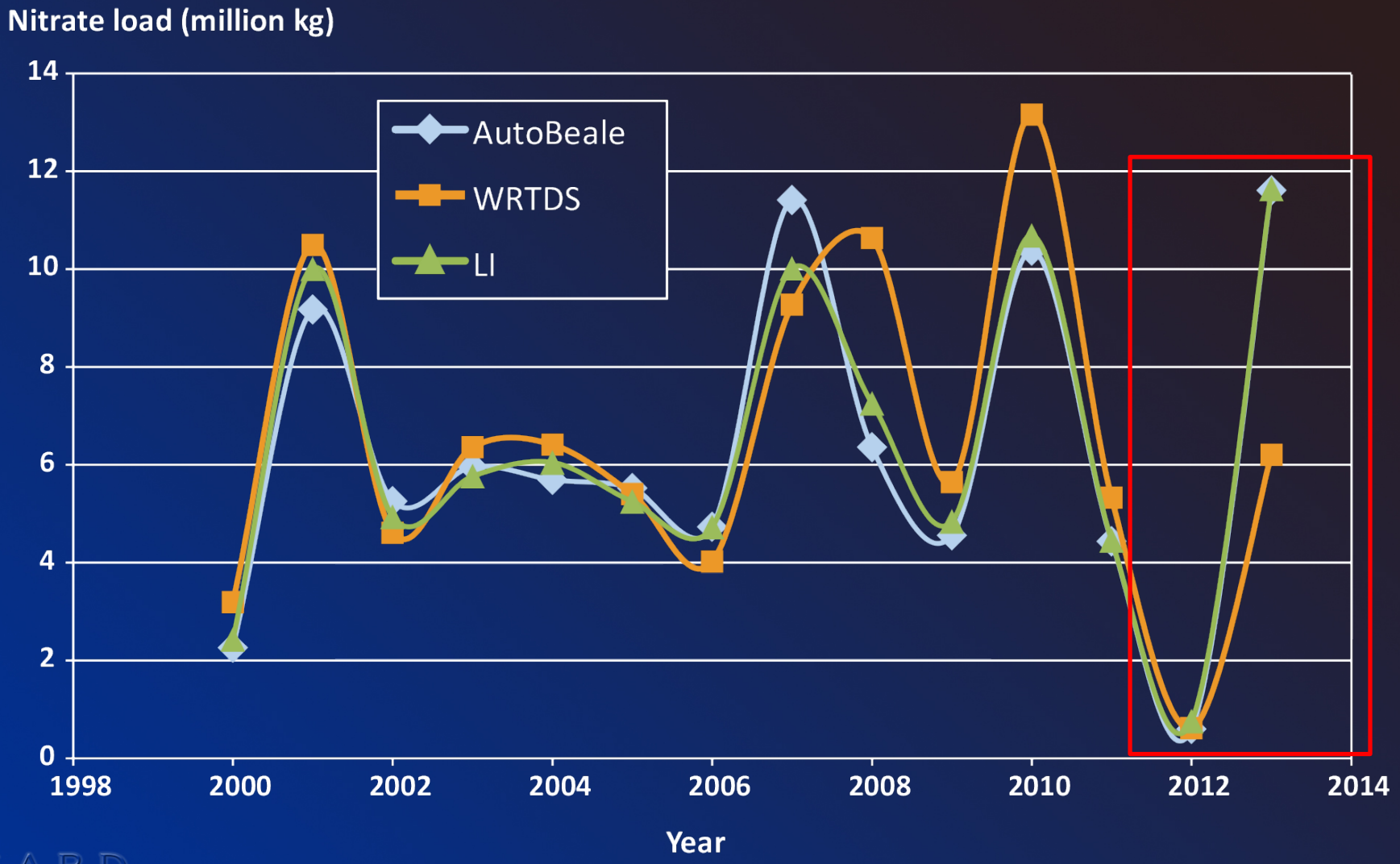
Source: Schilling et al. 2017. *Journal of Soil Water Cons.* 72(4): 317-325. DOI: 10.2489/jswc.72.4.317.

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

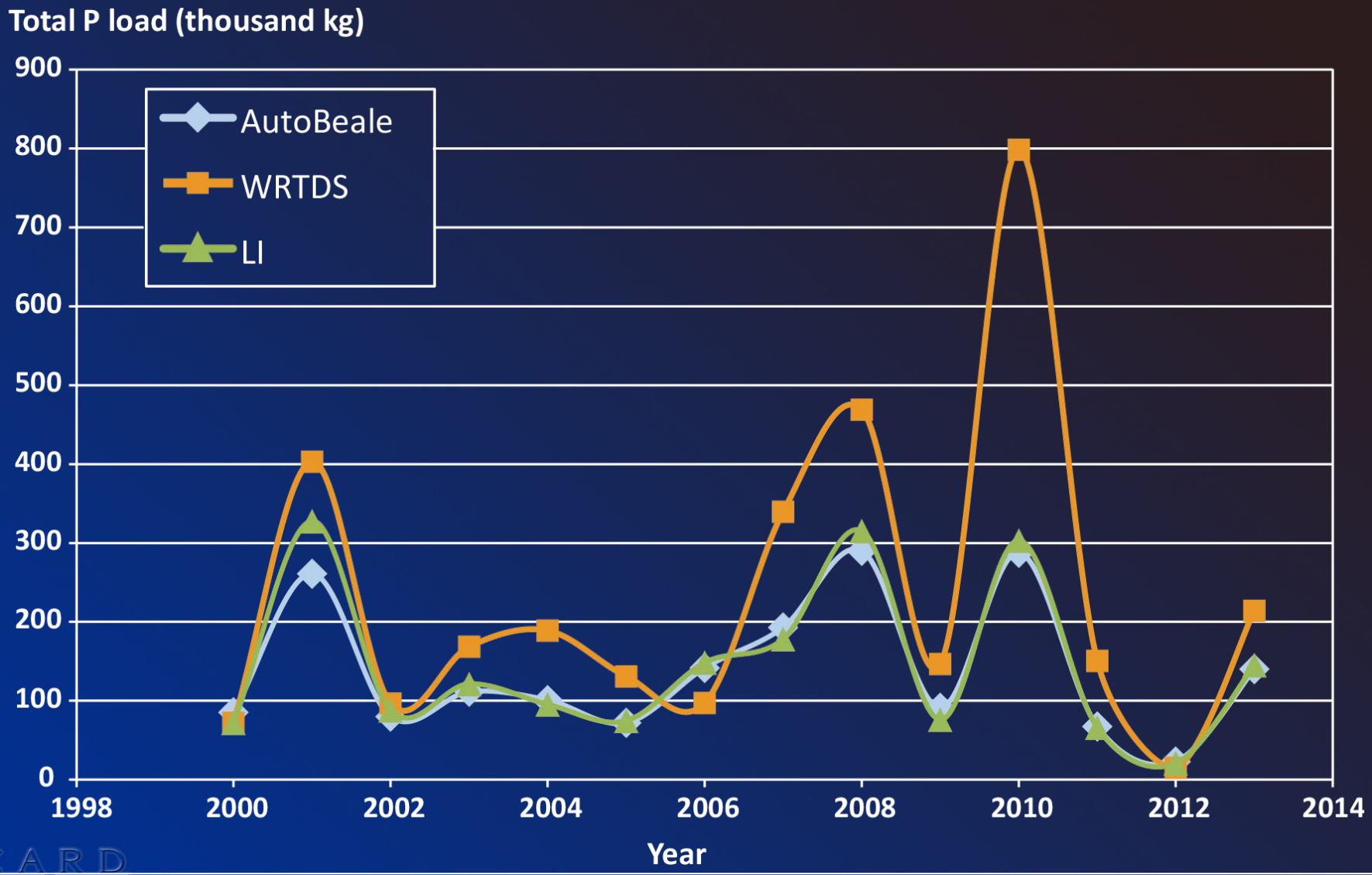
Source: Schilling et al. 2015. Assessment of Nitrate-N Load Estimation Methods to Quantify Load Reduction strategies. JSWC (in review).

Estimated Nitrate Loads at Boone Outlet



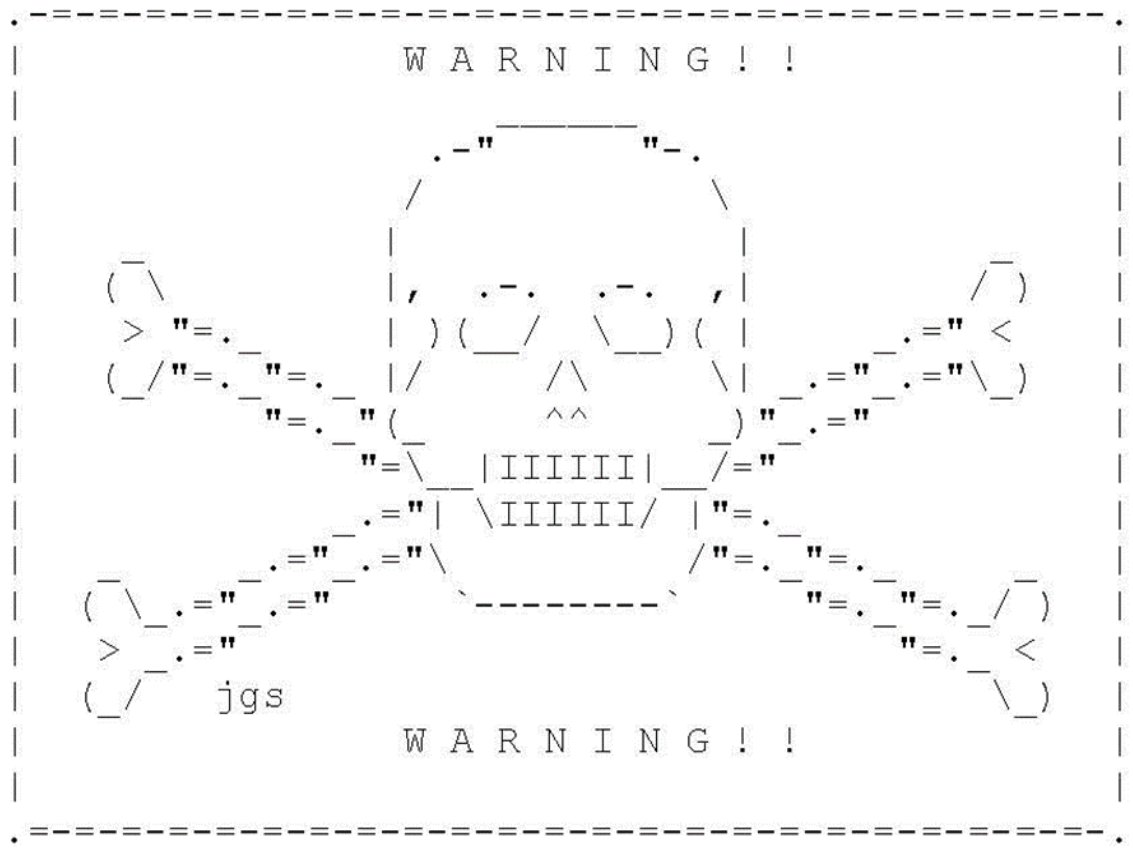
Data generated by C. Wolter, Iowa Department of Natural Resources, Des Moines, IA

Estimated Total P Loads at Boone Outlet



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

LOADEST Sediment Results were also Excessively Biased



IMPORTANT WARNING:

Load Bias (Bp) Exceeds + or - 25%
THE CALIBRATED MODEL SHOULD NOT BE USED FOR LOAD ESTIMATION

SWAT Version & Simulation Approach

- SWAT version 2012; Release 615
- Simulation period: 1984 to 2013
- Used ET-based Runoff Curve Number Approach
- Account for tile drainage (original method)
  - depth of 1200 mm (~4 ft)
- Tile drains simulated for cropland <2% slope
  - ~80% of the cropland
  - 2012 USDA-NASS Census: ~70% for six counties

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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

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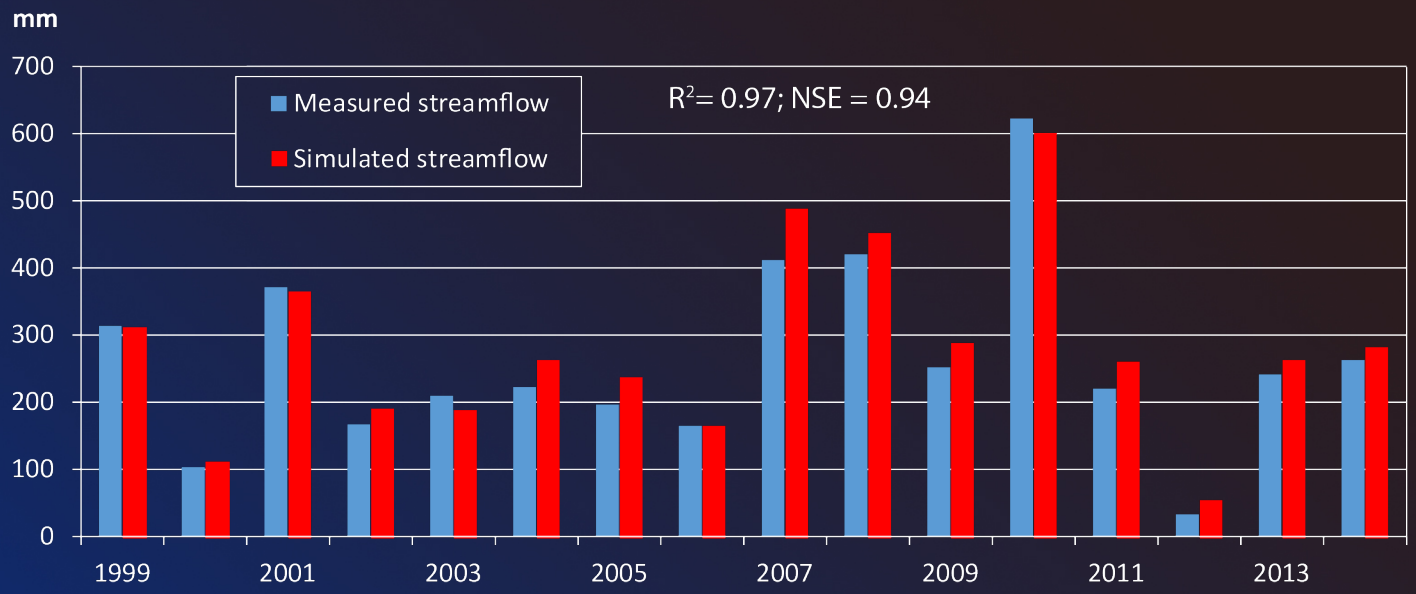
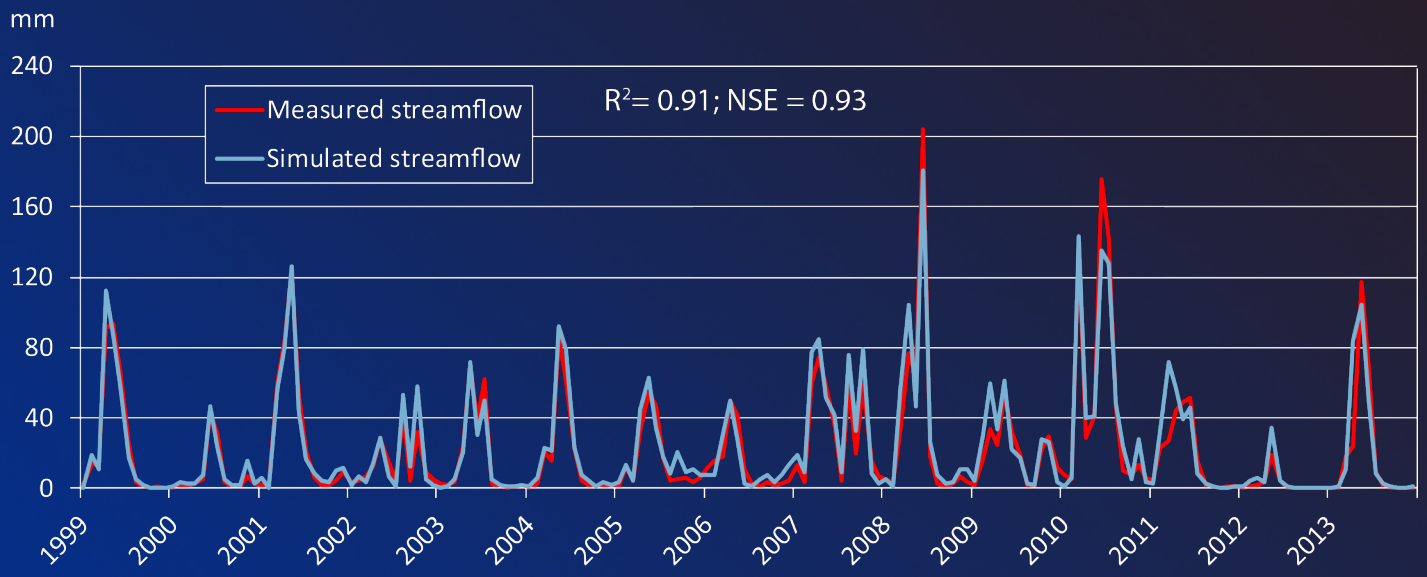
15-Year Streamflow Calibration (1999-2013)

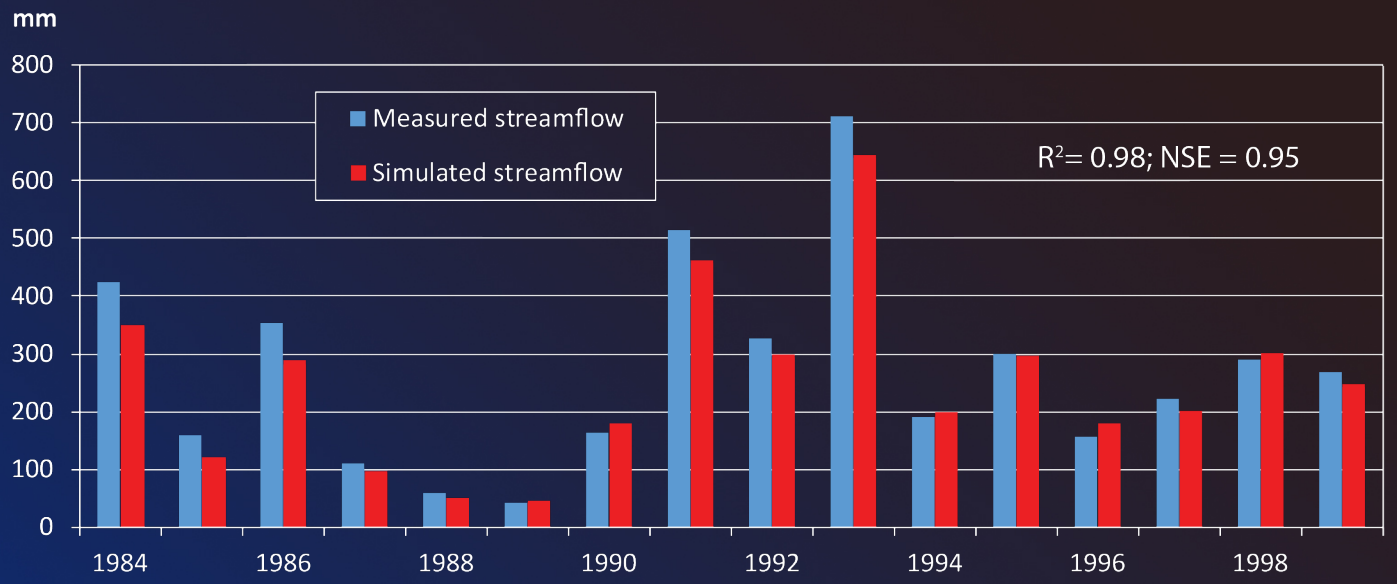
Initialization years: 1997 & 1998

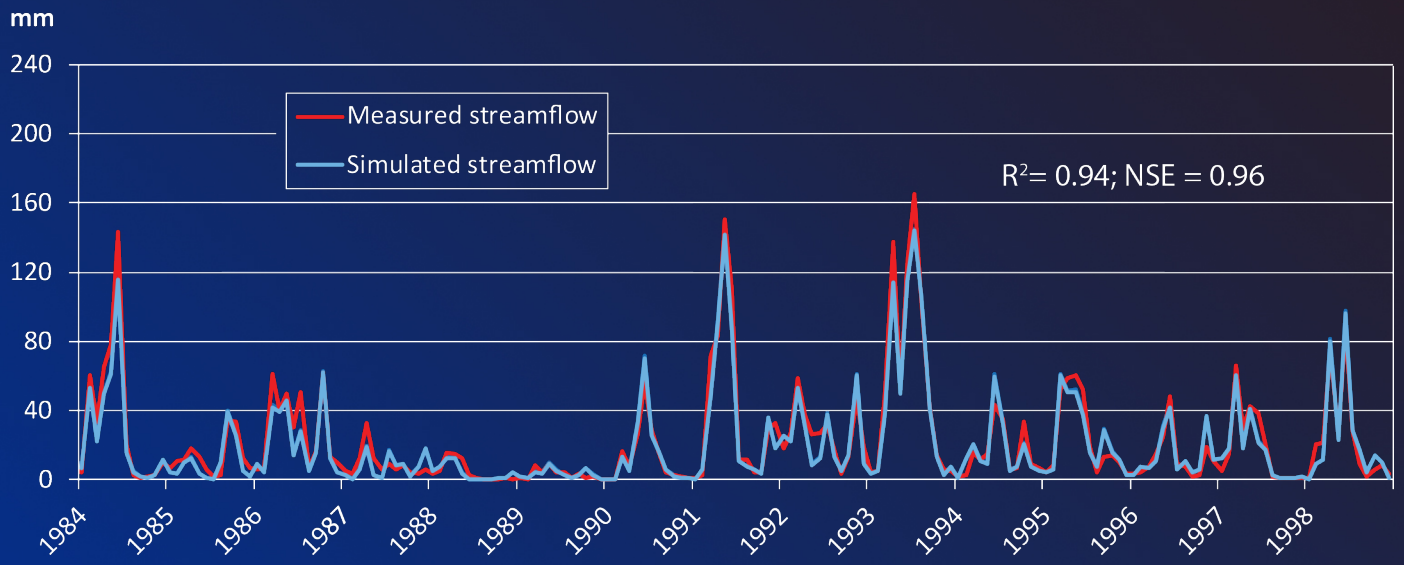




15-Year Streamflow Validation (1984-1998)

Initialization years: 1982 & 1983

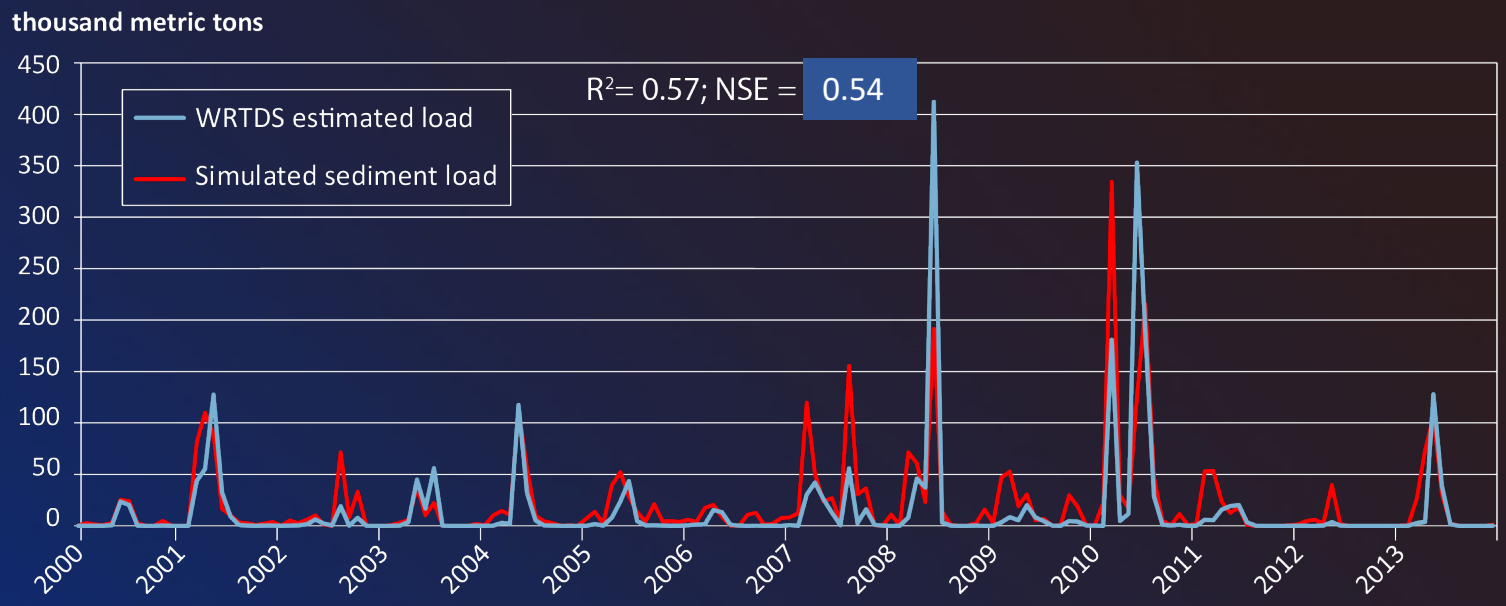




BRW Pollutant Monitoring Data

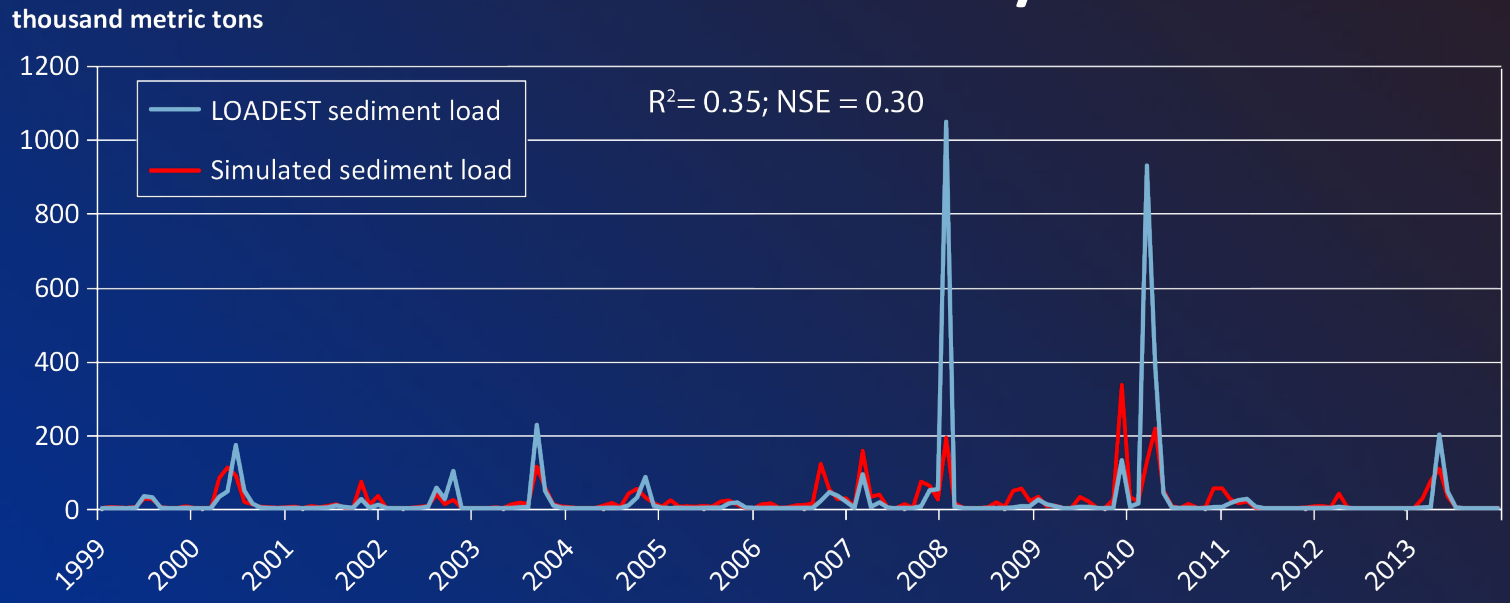
- Collected near watershed outlet (2000 to 2013)
- Monthly grab samples at best (sometimes periods of multiple months between samples)
- Just calibration was performed for pollutant loss/transport testing with these data

WRTDS-based SWAT Result

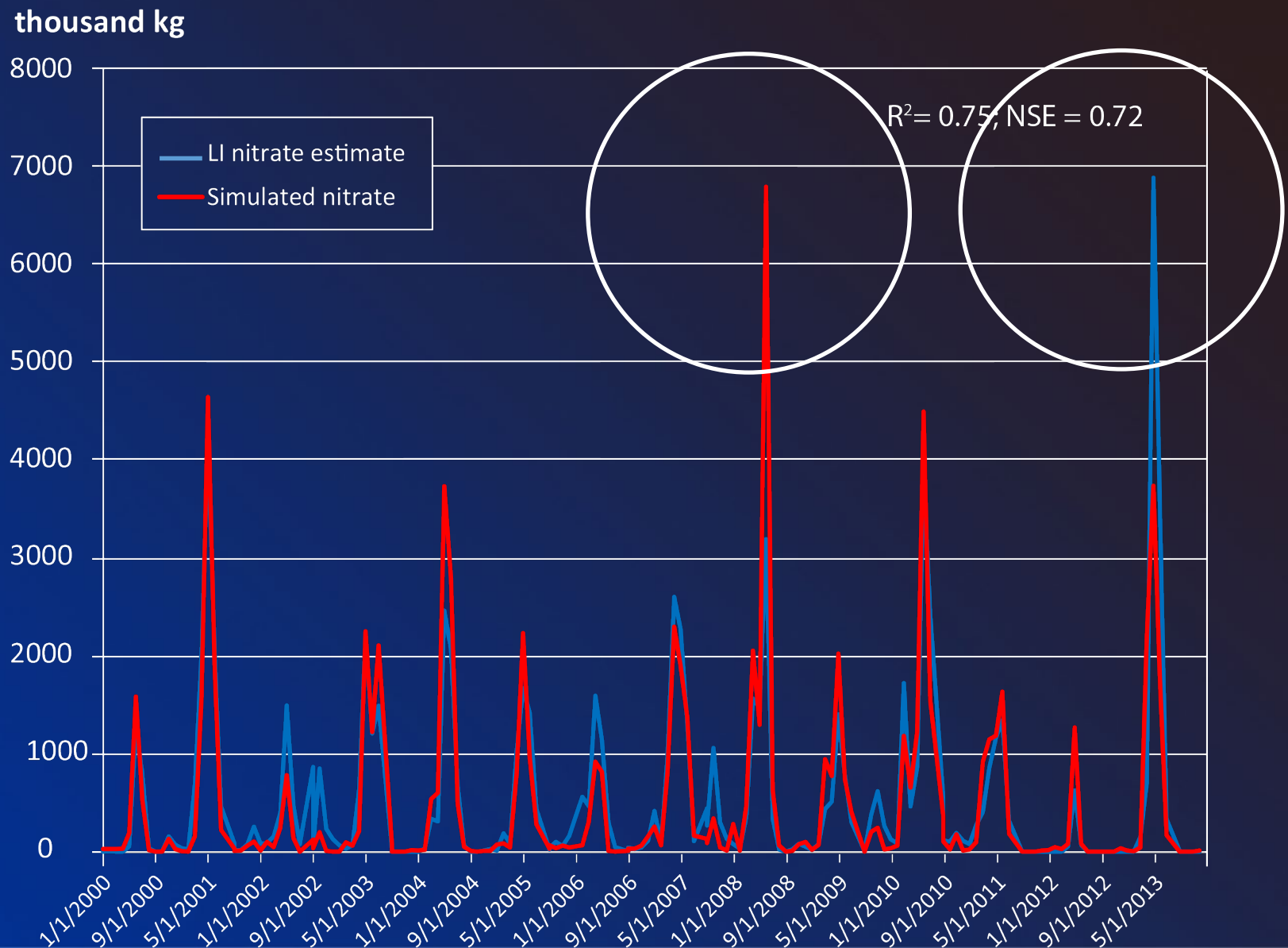


Baseline mean sediment load = 0.6 t/ha

LOADEST-based SWAT Result

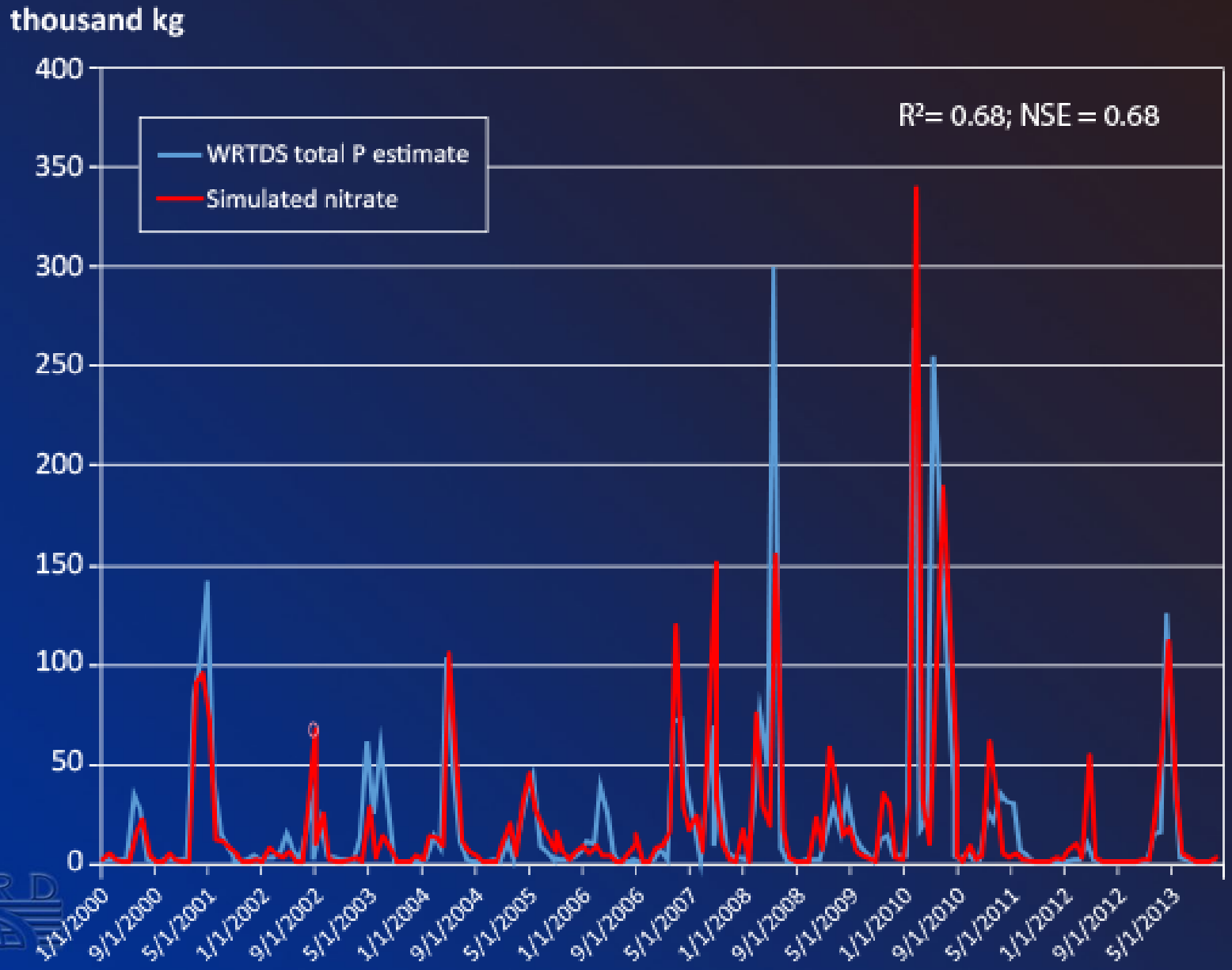


Simulated vs. "Measured" Nitrate Loads (Measured Loads Based on LI Method)

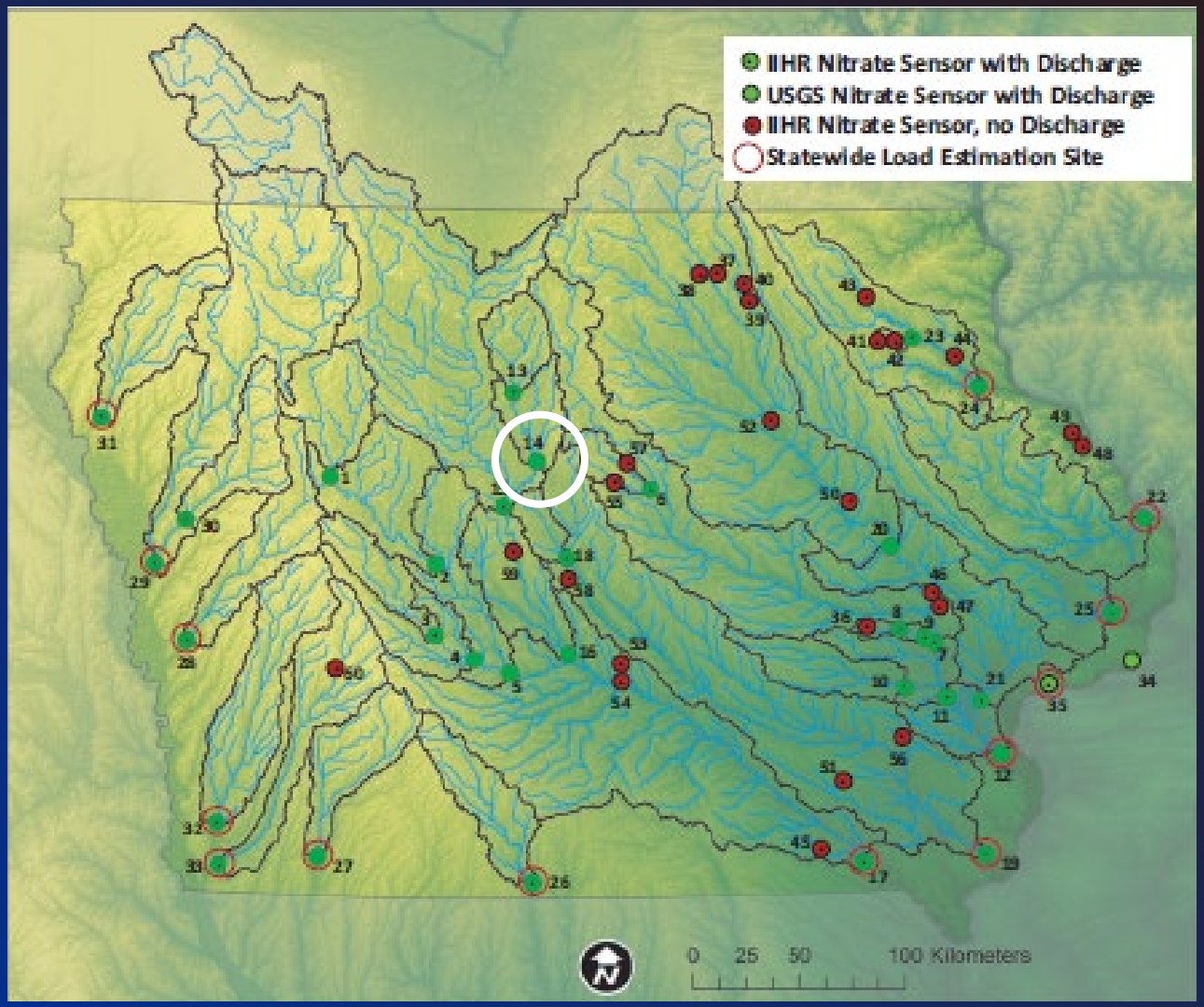


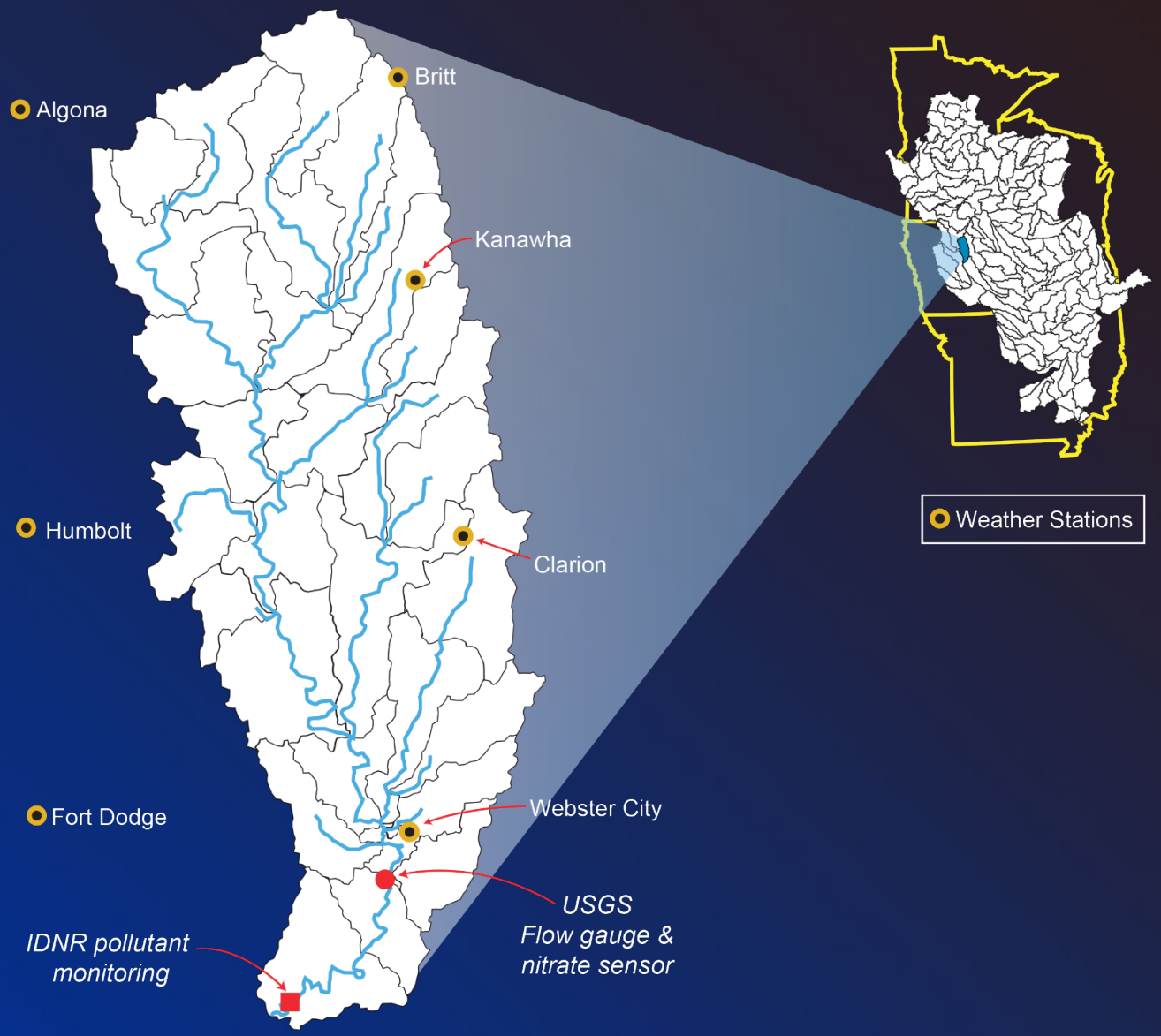
Simulated vs. "Measured" Total P Loads

(Measured Loads Based on WRTDS Method)



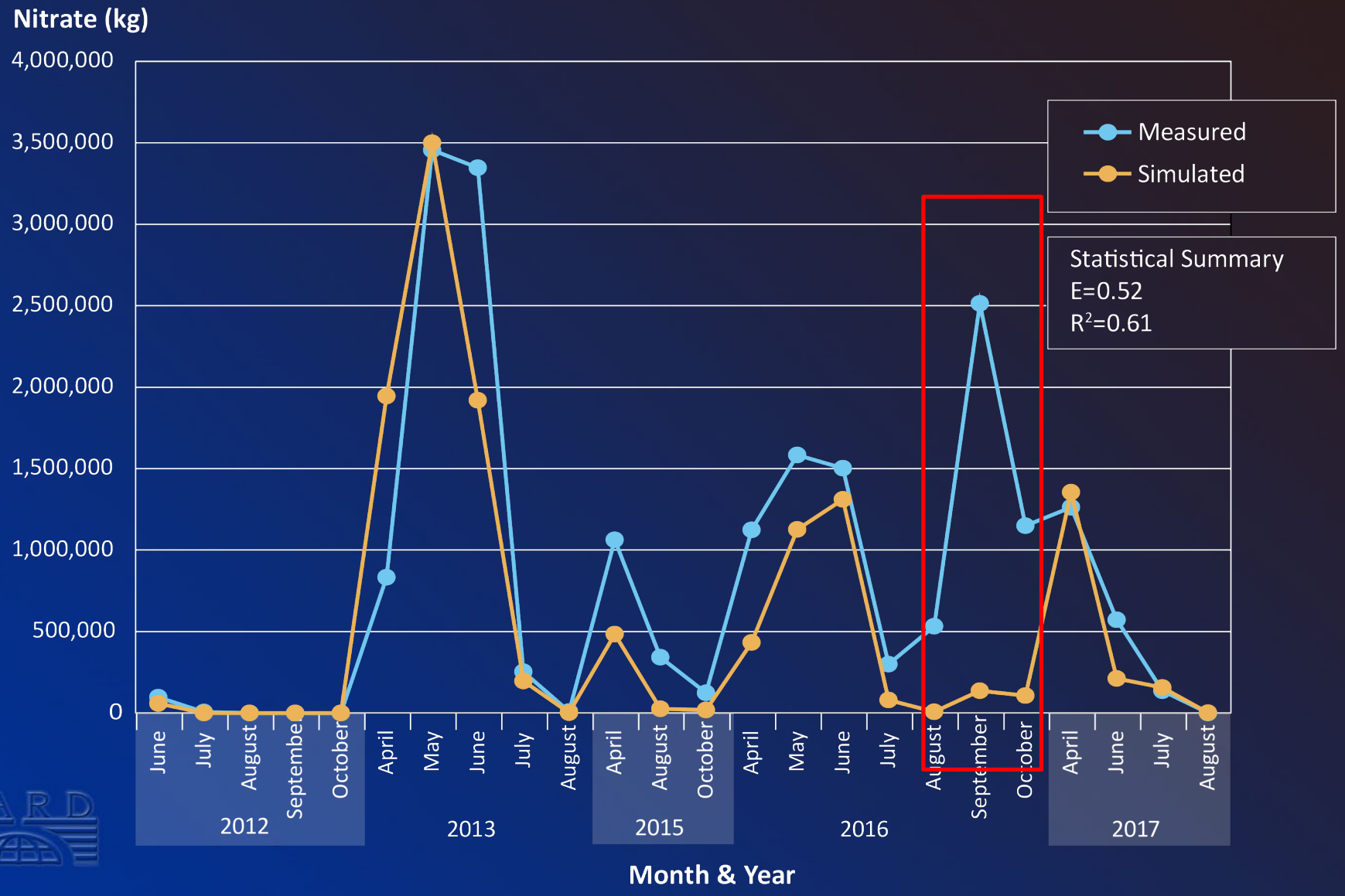
IIHR & USGS Iowa Nitrate Sensor Network




Britt
Algona
Kanawha
Humbolt
Clarion
Fort Dodge
Webster City
USGS
Flow gauge &
nitrate sensor
IDNR pollutant
monitoring
Weather Stations

Example Nitrate Sensor

Simulated vs. Measured Nitrate Loads at Nitrate Sensor Location south of Webster City



Conclusions

- LI and WRTDS provided most accurate nitrate and total P load estimates, respectively
- -LOADEST overestimated nitrate loads for BRW

- BRW sediment load estimates have bias problems -but sediment loads are low (mean = .6 t/ha)

- The results reveal that different load estimation methods may be needed for different constituents

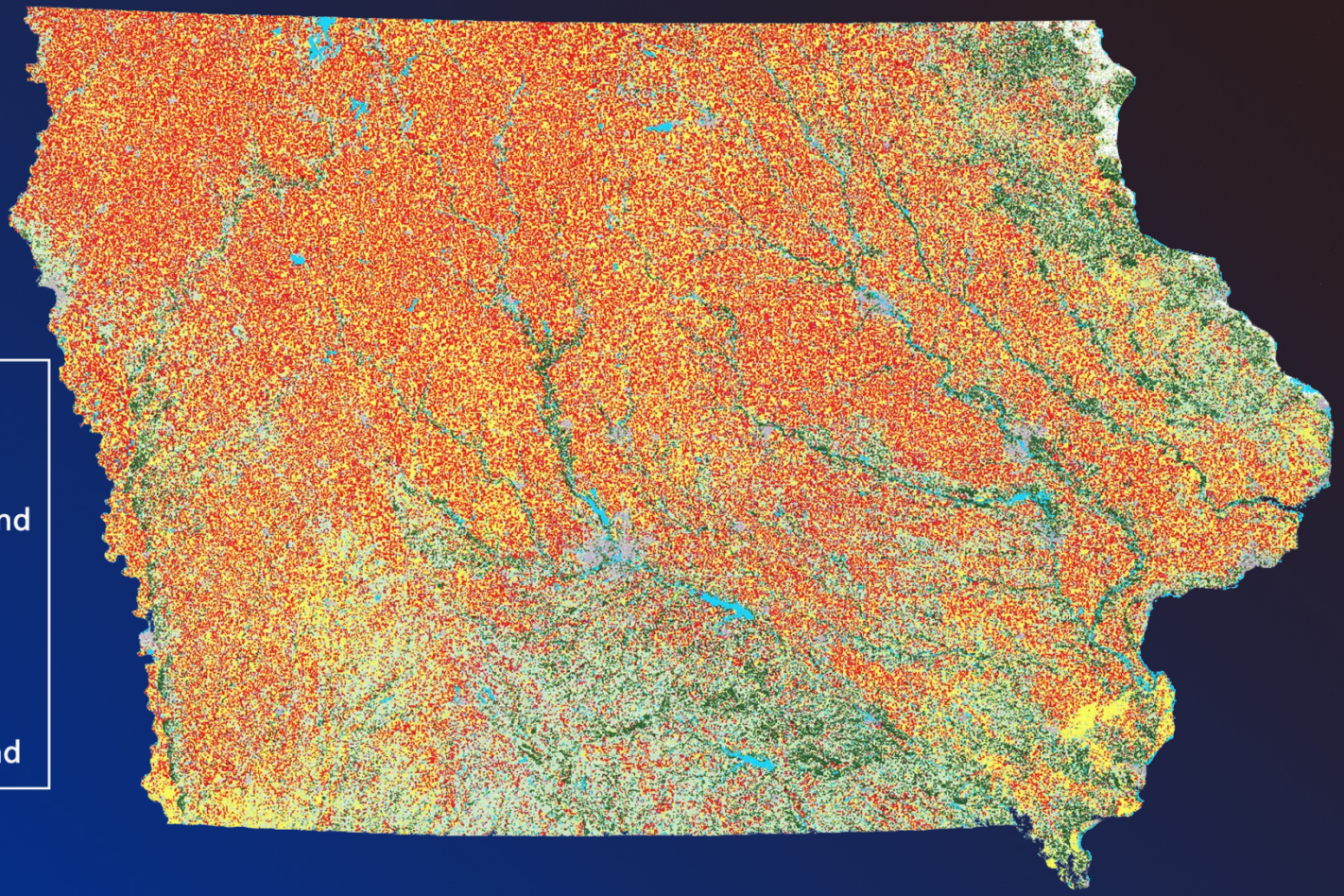
- Load estimates ≠ measured loads

Conclusions

- SWAT model calibration can be considered successful based on statistical results

- Initial nitrate validation results meet criteria suggested by Moriasi et al. (2015)
- -but some clear problems that show the need for further evaluation

2002 Iowa Landuse Map



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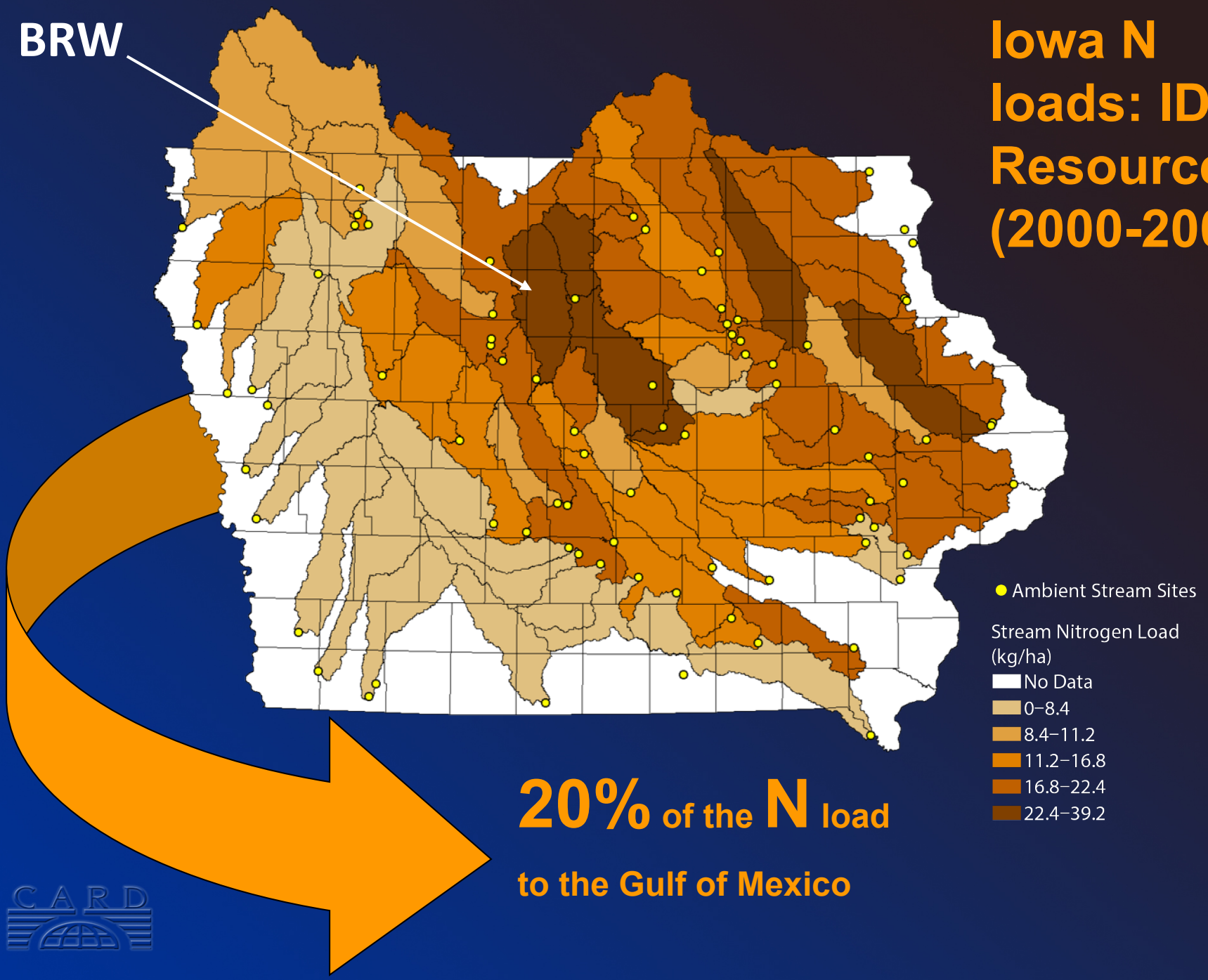
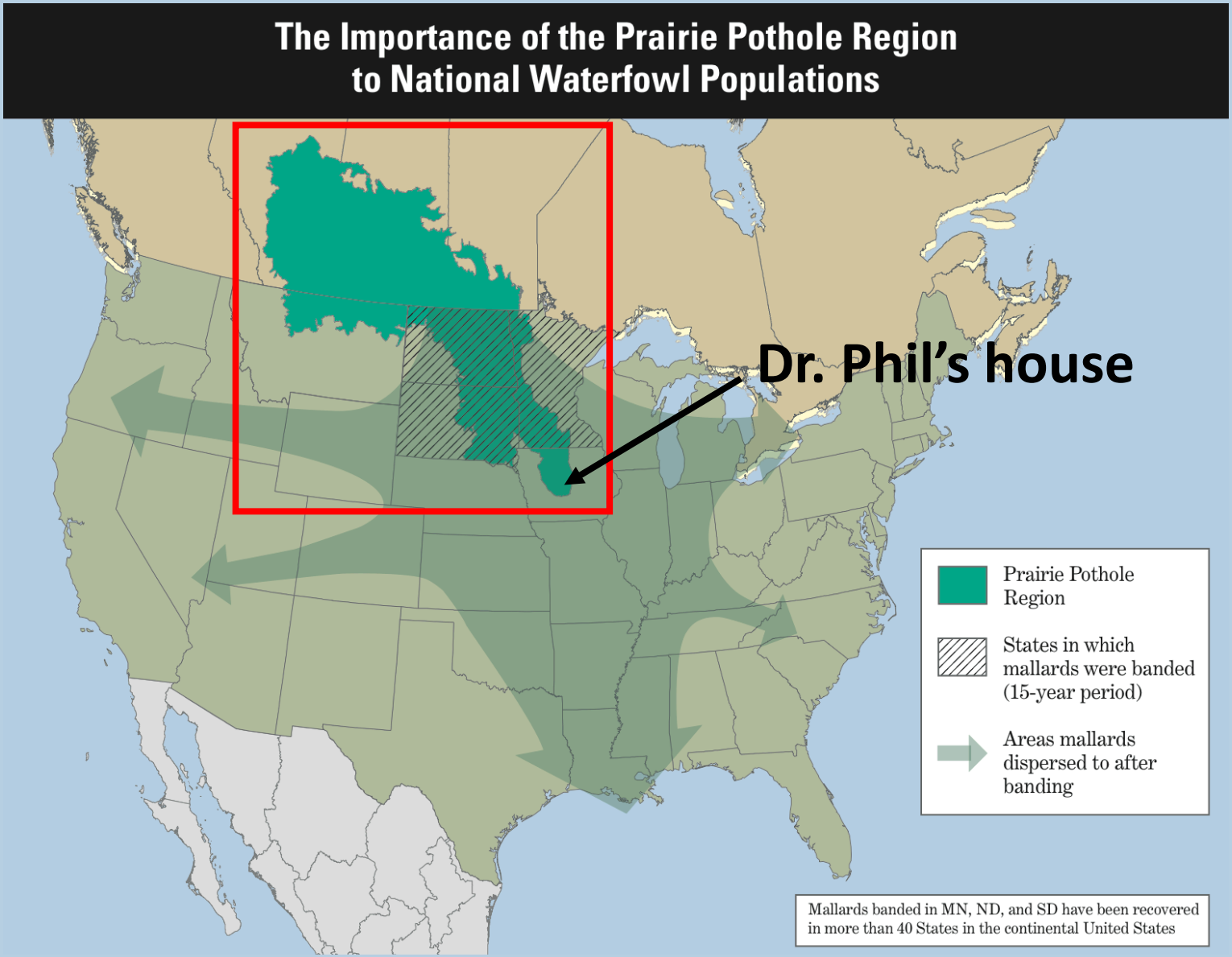
Iowa N loads: IDNR Resources (2000-2002)





Source: Prairie Pothole Joint Venture. 2014. Available at: http://ppjv.org/resources/maps