Applications of the SPARROW Model in California

by

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USGS, California Water Science Center

Outline

- What is SPARROW?
- SPARROW modeling uses
- Conceptual model
- SPARROW data Requirements
- Application of SPARROW in CA (MRB8).
- MRB8 Data
- Current SPARROW Activities
- Future of SPARROW application in CA

What is SPARROW?

Acronym for: SPAtially-Referenced Regression On Watershed attributes

Developed by USGS, 1997 to

- Help understand factors affecting water quality
- Examine statistics of sources and transport
- Provide a means to estimate loads in unmonitored locations

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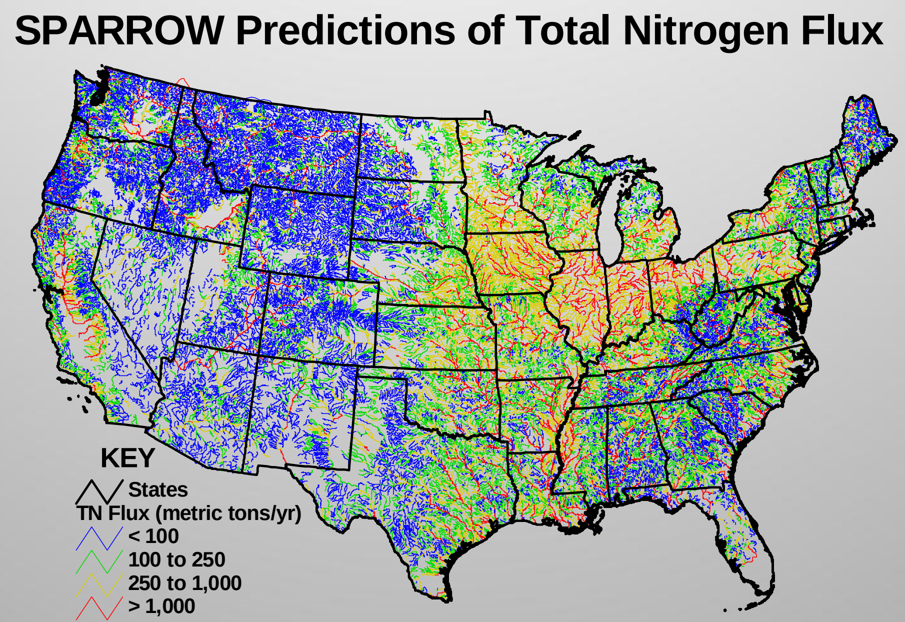
What is SPARROW?

SPARROW Models Can be Built to Various Scales, National to Watershed

Constituents successfully modeled: Nitrogen, Phosphorus, Suspended Sediment, Organic Carbon

USGS SPARROW Modeling

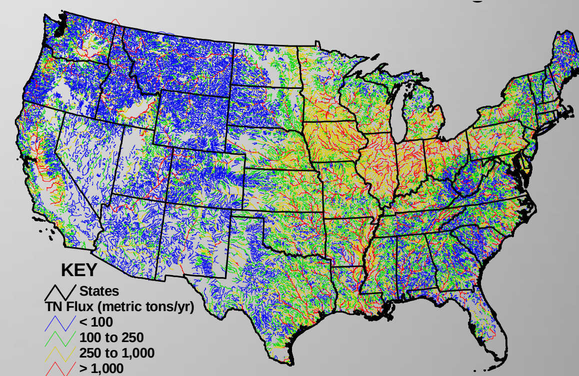


National Water Quality Assessment Program

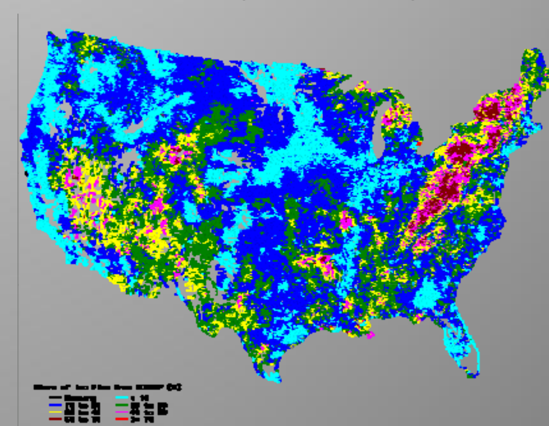
SPARROW Modeling Uses

- Predict mean-annual flux and yield (total, incremental, delivered), and concentration for unmonitored stream reaches and watersheds (and uncertainties)
- Assess effects of hydrological and biogeochemical processes on transport and fate in watersheds
- Apportion stream loads to major nutrient sources and upstream watersheds
- Simulate water-quality response to climate and land-use change (historical, future)
- Inform policy and management decisions (point and diffuse sources in TMDLs; targeting of “hot spots”, USDA; nutrient criteria development, EPA)

SPARROW Predictions of Stream Nitrogen Flux

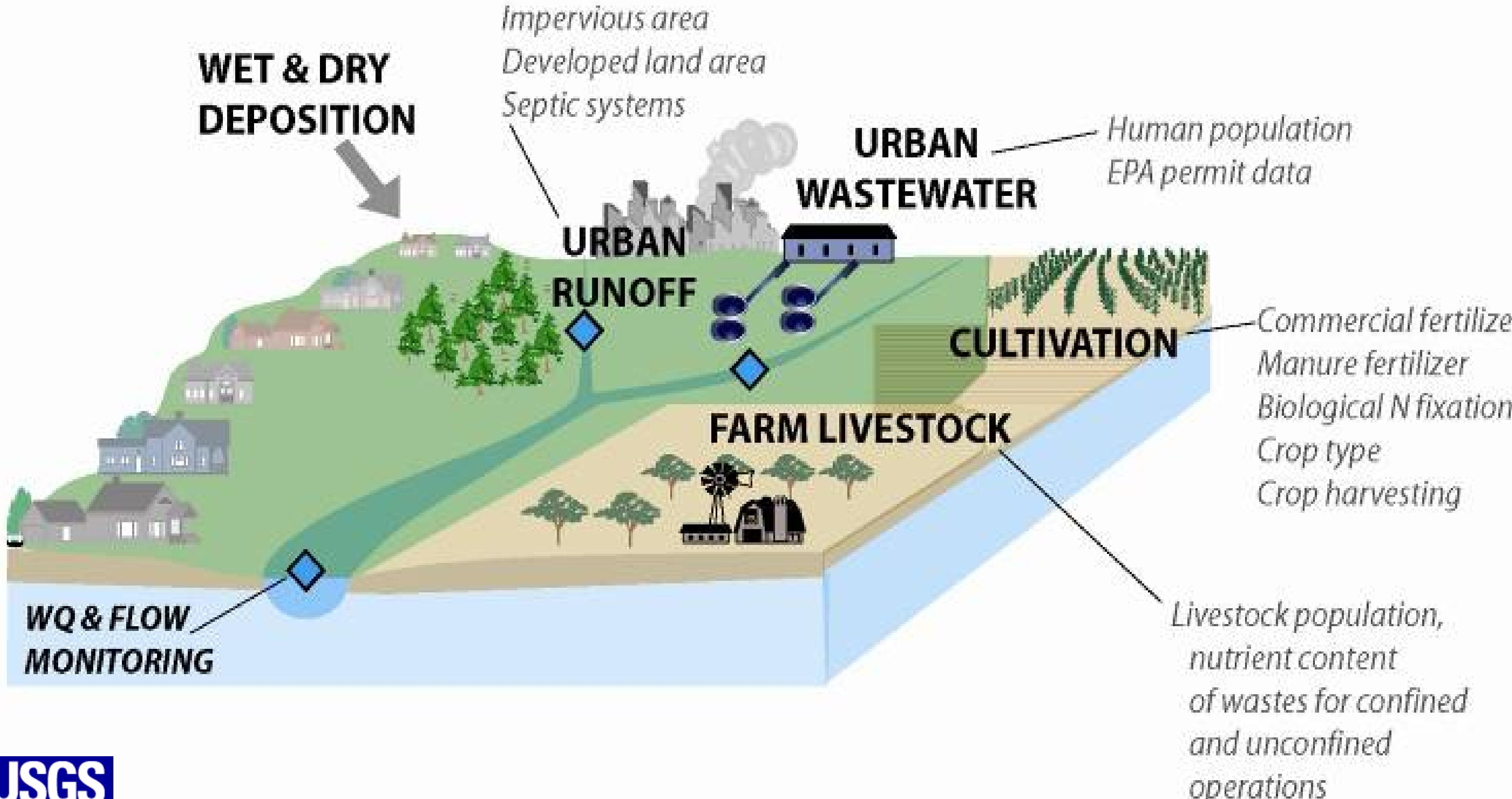


Share of Stream Nitrogen Flux from Atmospheric Deposition



SPARROW: A Spatially-Explicit Mass-Balance Watershed Model

Quantifies nutrient sources and sinks for annual time periods



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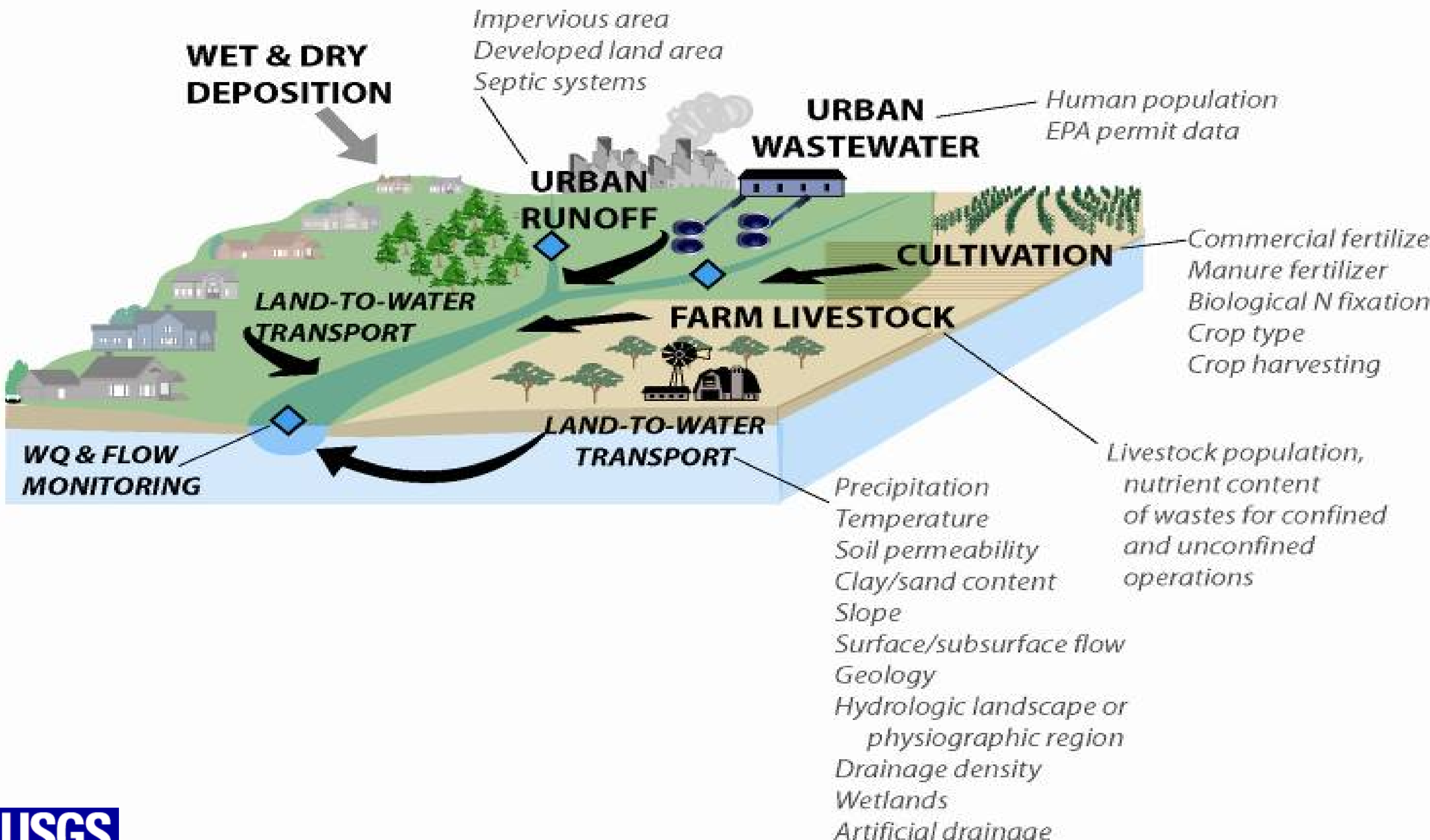

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SPARROW: A Spatially-Explicit Mass-Balance Watershed Model

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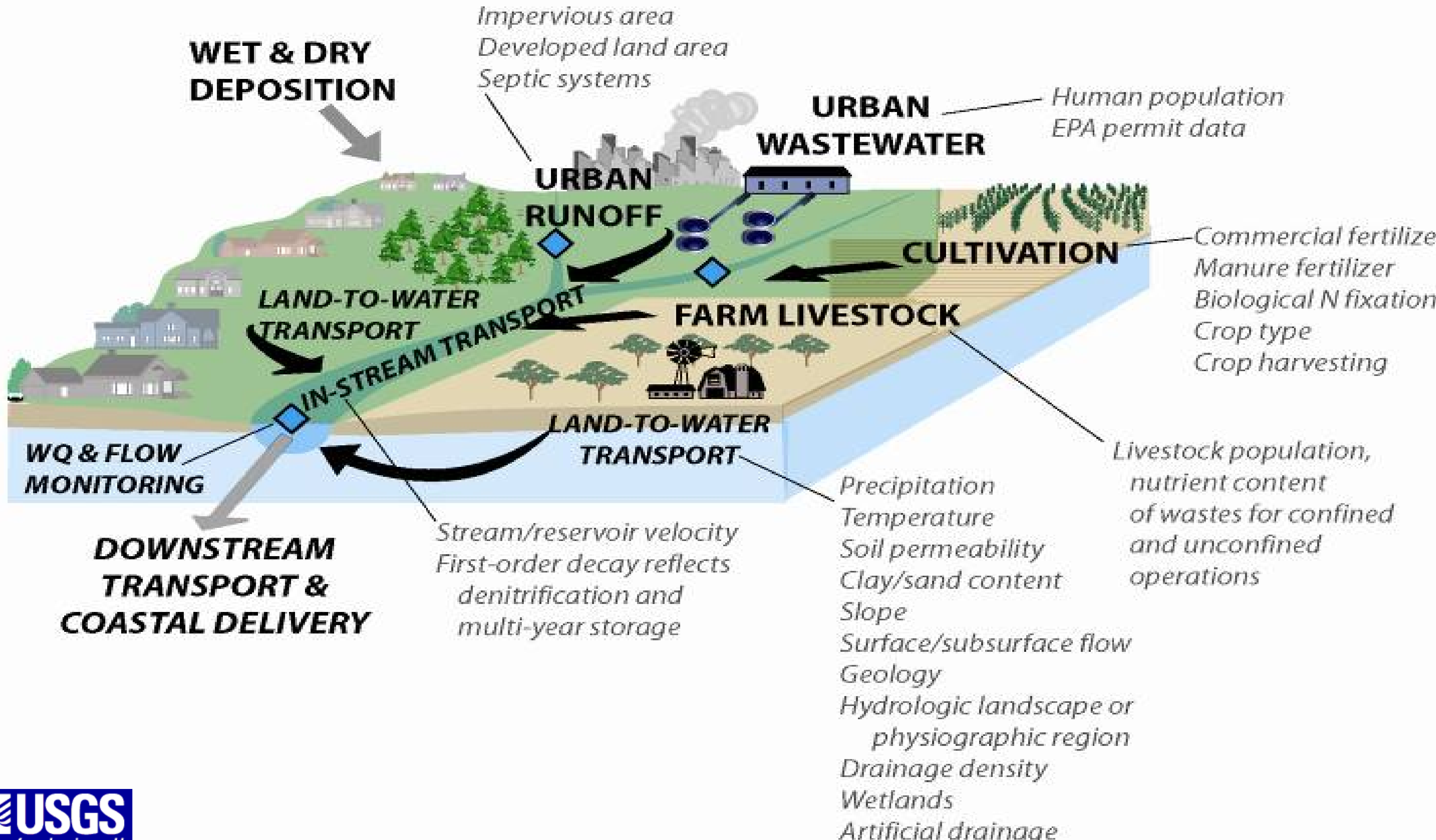

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SPARROW Model Mathematical Form

$$F_i^* = \left\{ \left[\sum_{j \in J(i)} F_j' \right] A\left(Z_i^S, Z_i^R : \theta_S, \theta_R\right) + \left[\sum_{n=1}^{N_S} S_{n,i}\, \alpha_n D_n \left(Z_i^D : \theta_D\right) \right] A'\left(Z_i^S, Z_i^R : \theta_S, \theta_R\right) \right\} \varepsilon_i$$

Flux from upstream reaches

Flux sources introduced to the stream network

Land-to-water delivery

Aquatic transport

Error

- The optimal set of rate coefficients are estimated, balancing the pollutant mass of the source inputs, stream loads, and storage loss on land and in water.
- All parameters are simultaneously determined to best fit the data.

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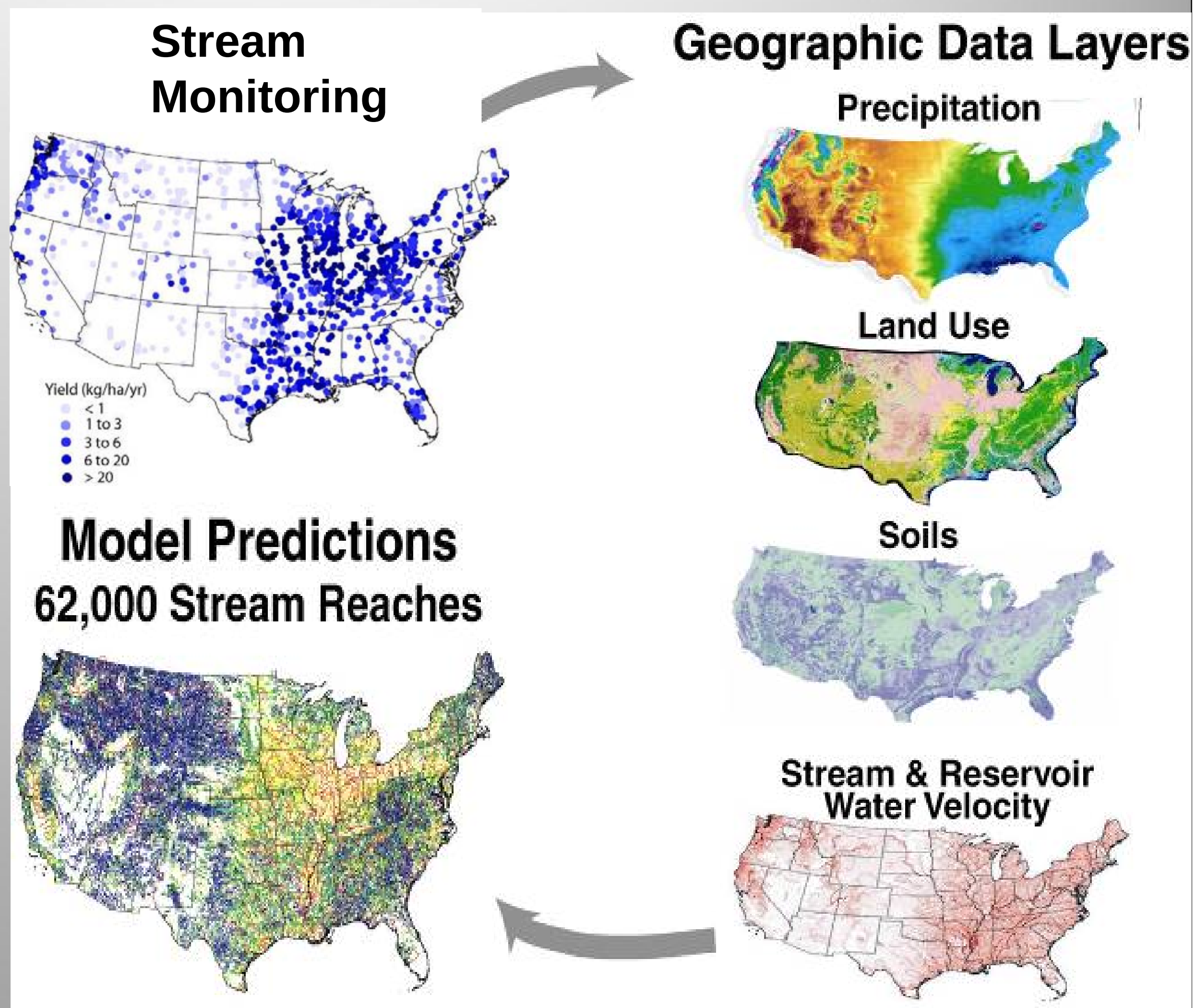
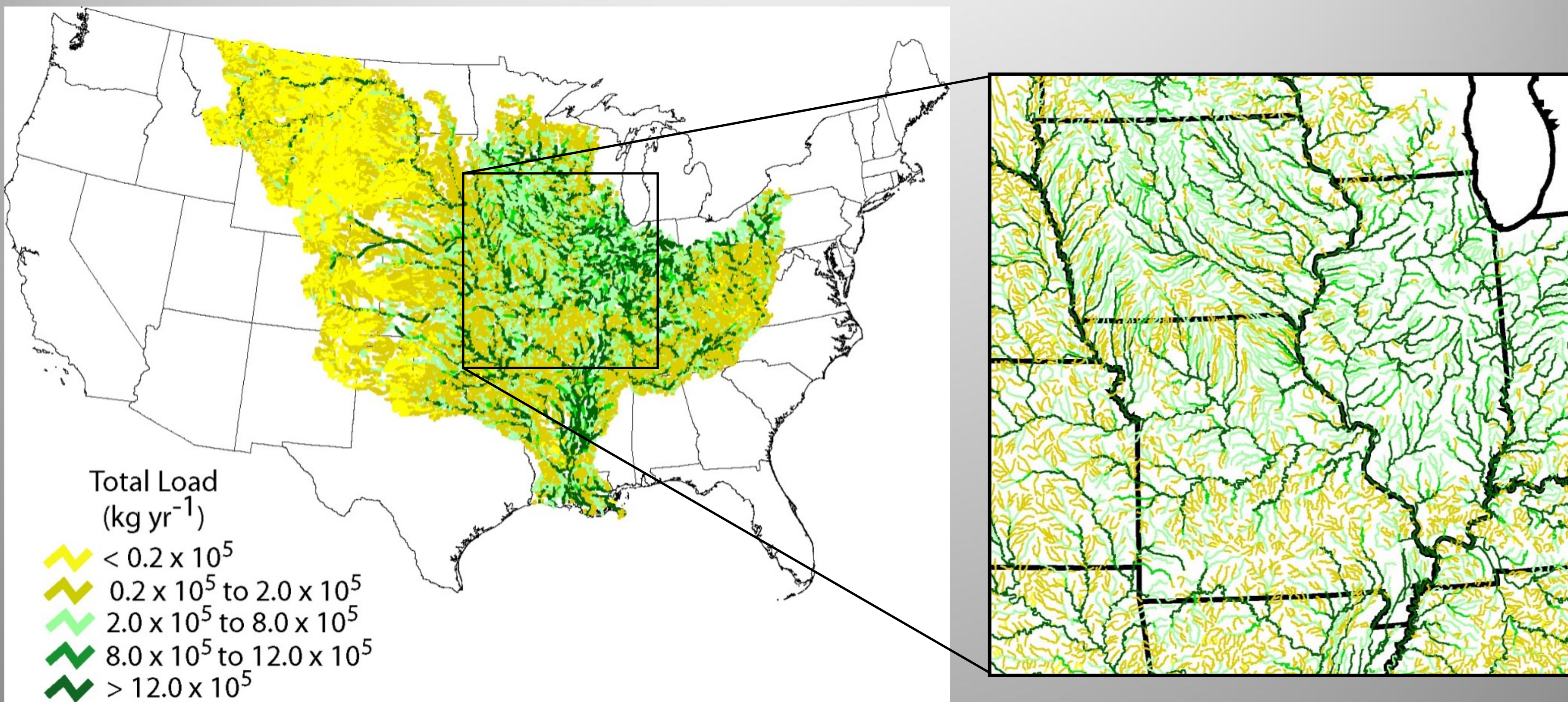
SPARROW Data Requirements

- Streamflow
- Monitoring data collected near a base year
- Contaminant source data for the base year
- Fertilizer use
- Point source discharges
- Atmospheric Deposition
- Soils
- Climate, etc.



SPARROW Predictions of Nitrogen Load in Streams

National Reach Network (~3,200 reaches in Upper Miss.)



Based on model predictions from Alexander et al., 2008, *Environ. Sci. Technol.*, v 42

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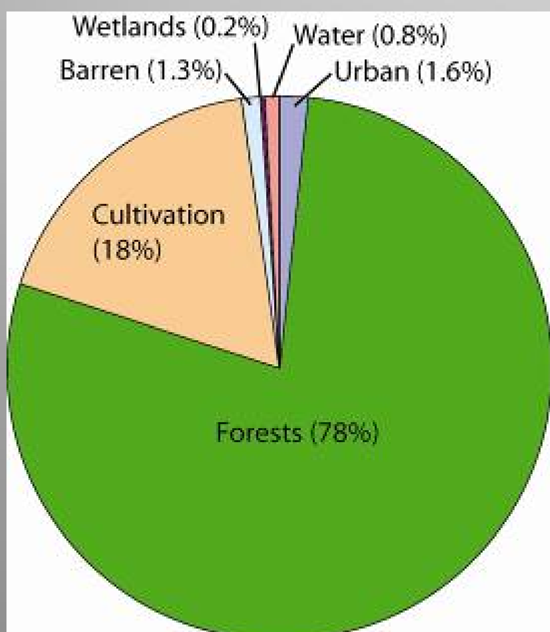
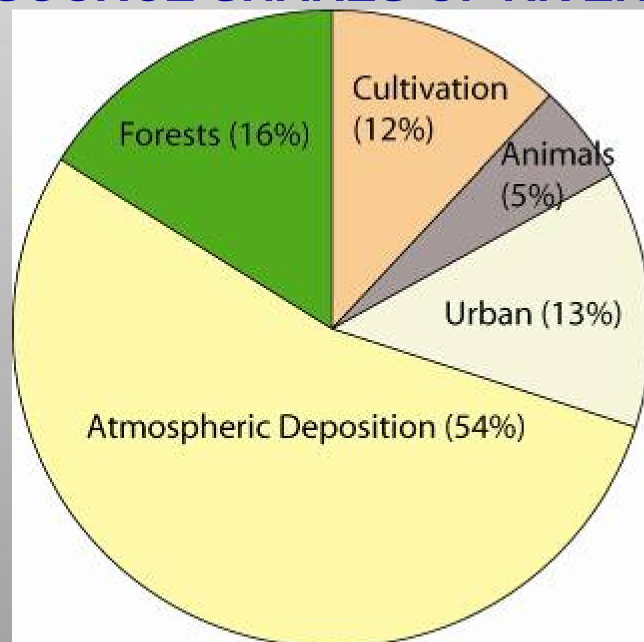
Watershed Total Nitrogen (TN) Sources Monongahela River above Cheat River Confluence (below Morgantown, WV)

Drainage area (km2): 7,093
Population (1990): 271,680
TN yield (kg/km2/yr): 817
Flow-weighted mean annual conc. (mg/L): 1.4
Delivered TN fraction to Gulf of Mexico: 79%

LAND USE
(1992 NLCD)

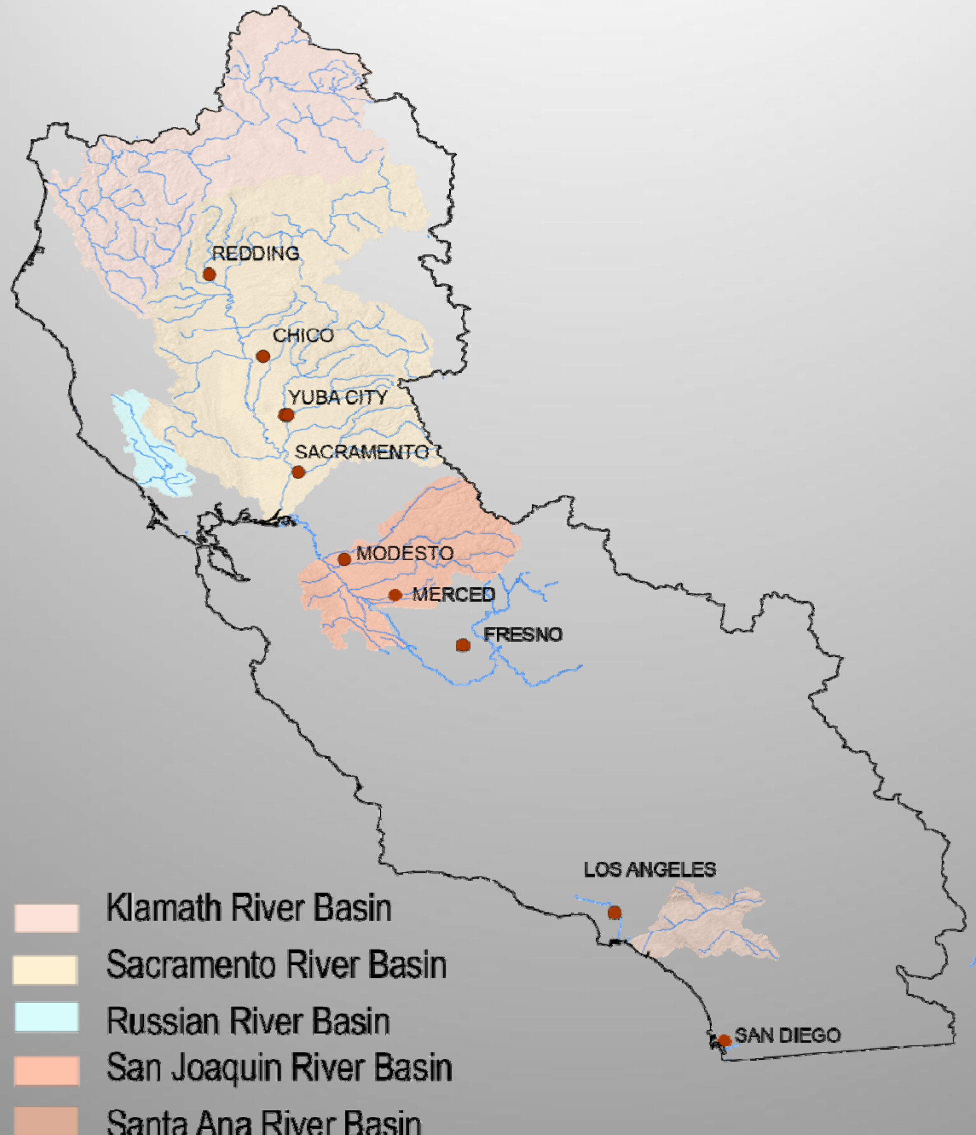


SOURCE SHARES OF RIVER TN



Based on model predictions from Alexander et al., 2008

MRB8; (California ,Oregon, and Nevada)



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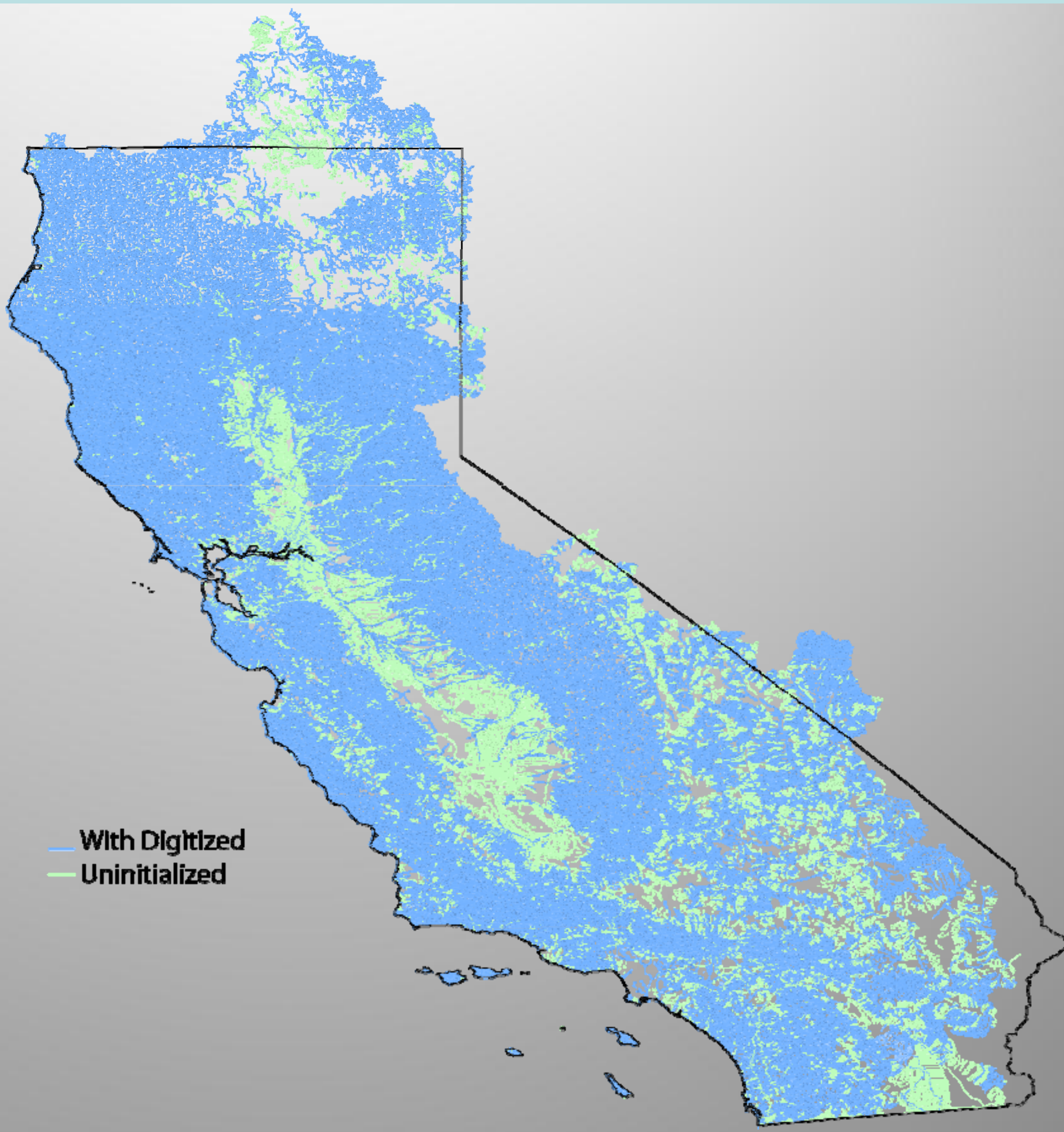
NHDplus 18V01_01

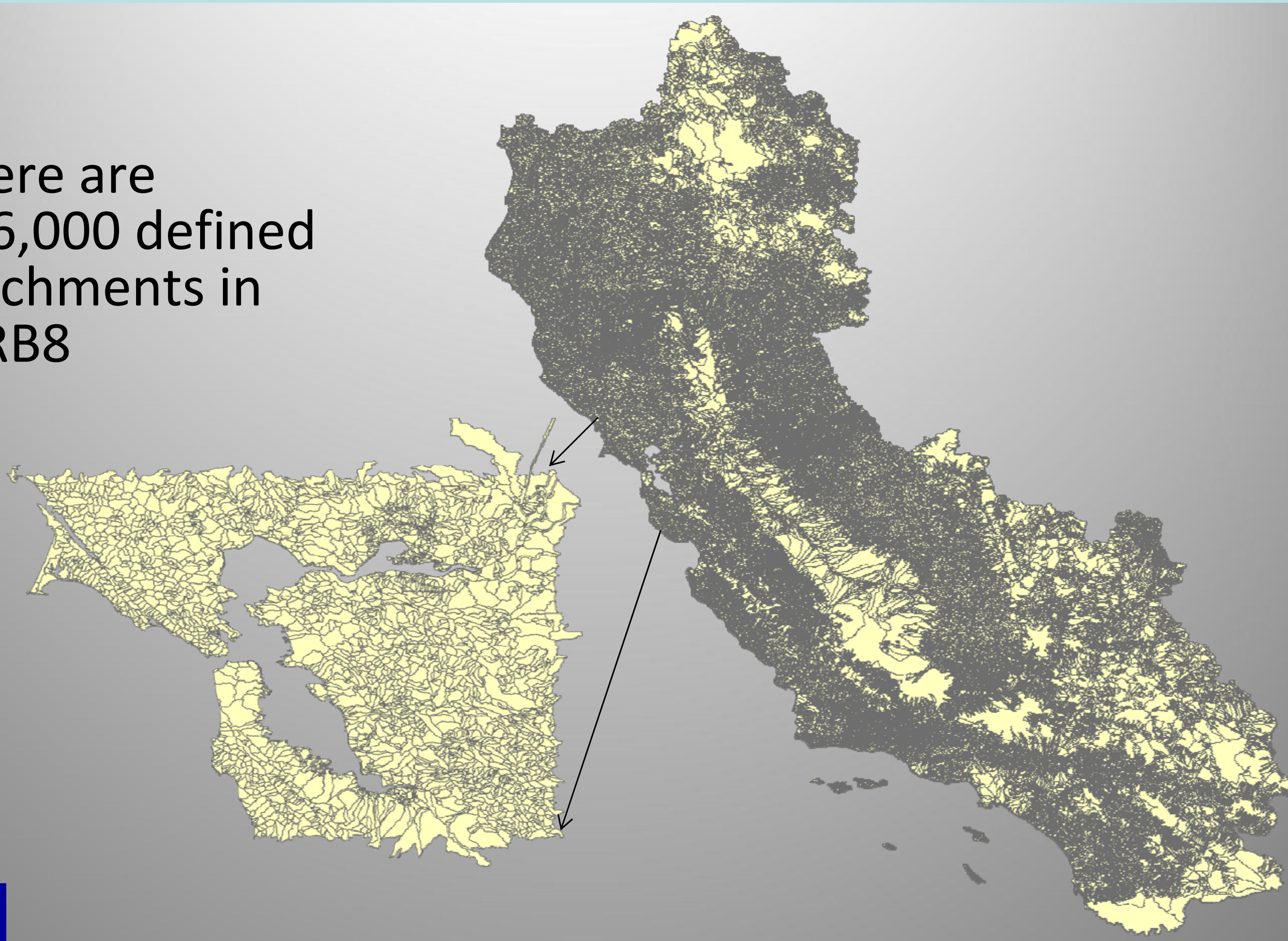
- Scale is 1:100k
- From 30 meter DEM
- Blue lines are streams with defined watersheds
- Green lines are areas with no defined watersheds (channels, aqueducts, ditches, and other areas that are flagged as uninitialized in the NHDplus data set)



d3

MRB8 Catchments

- There are 136,000 defined catchments in MRB8



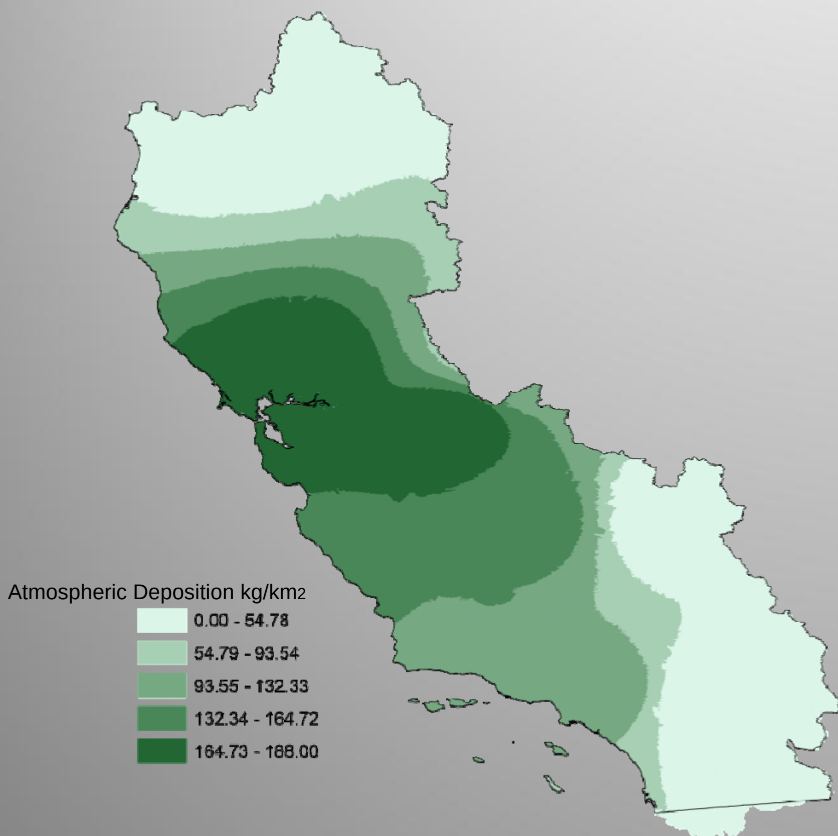
Slide 16

d3 Add catchment map with zoom in with scale

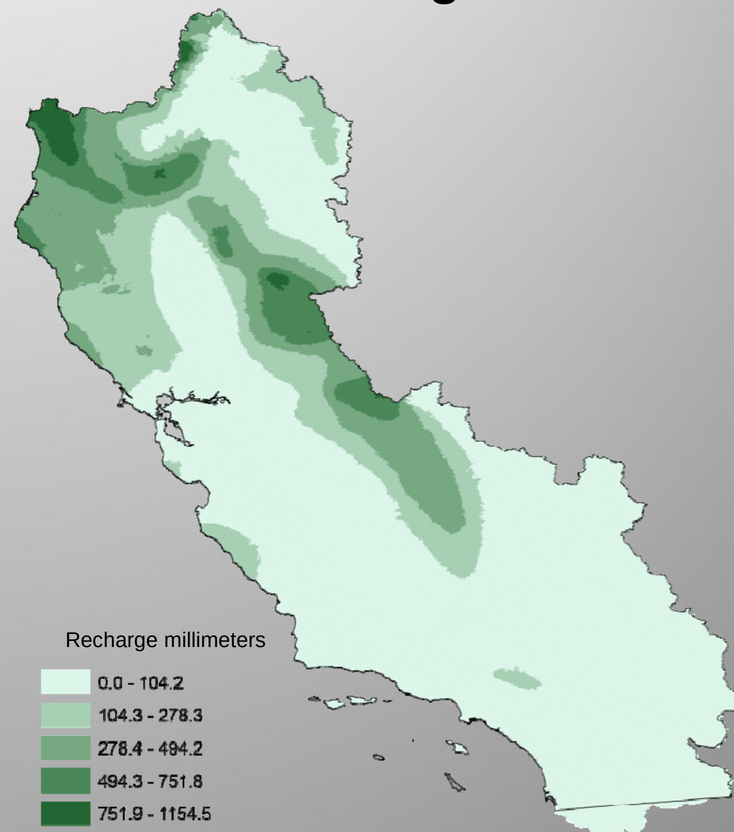
dsaleh, 5/11/2011

Example SPARROW Data Layers

Atmospheric Deposition

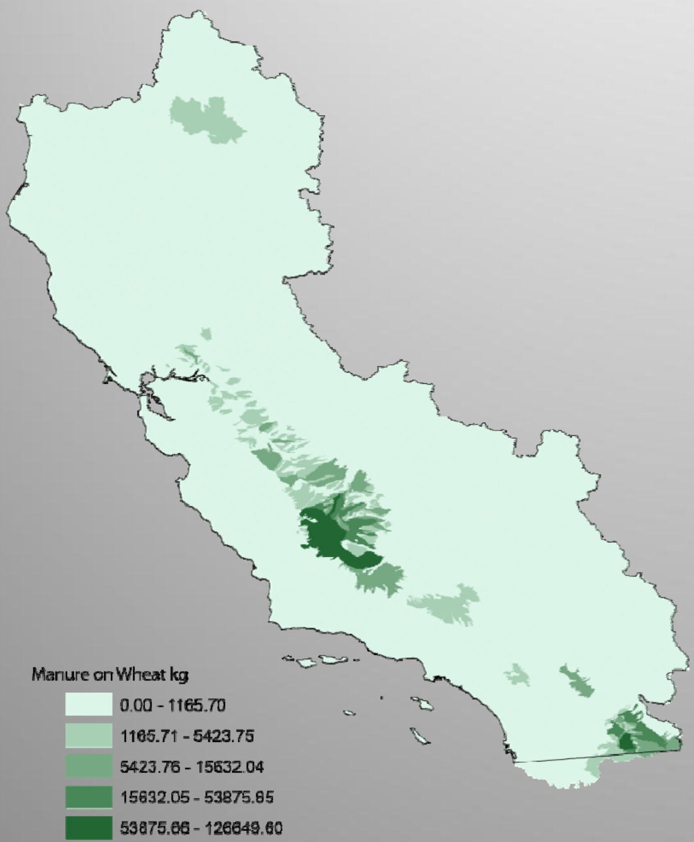


Natural Recharge

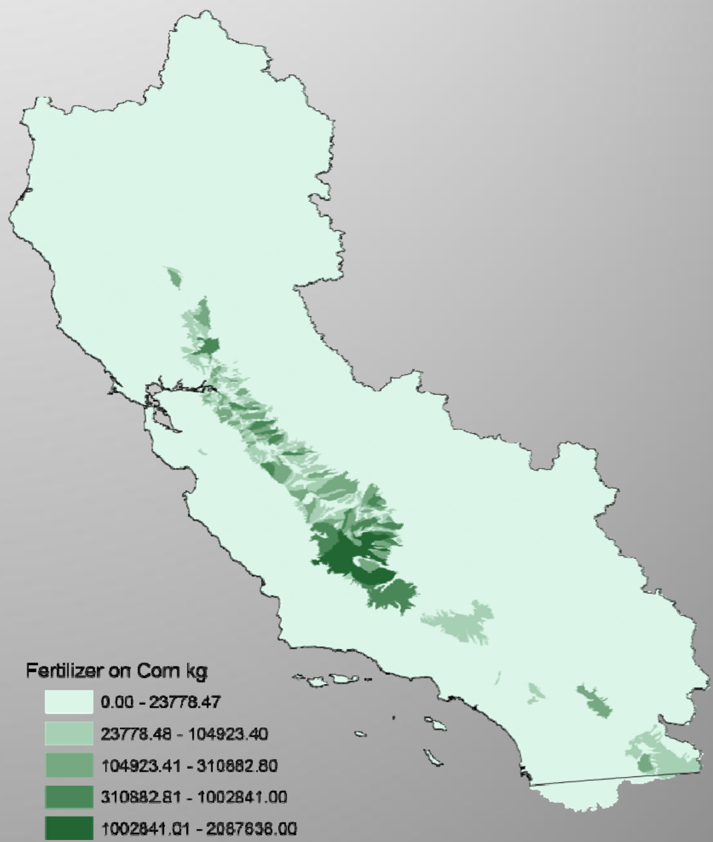


Example SPARROW Data Layers

Nitrogen from Manure



Fertilizer Application



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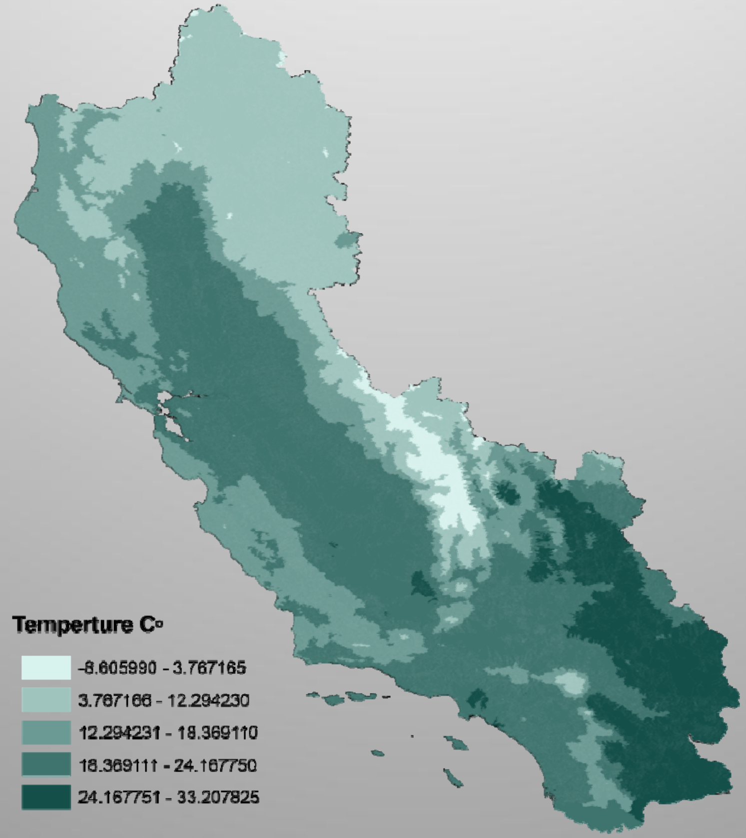
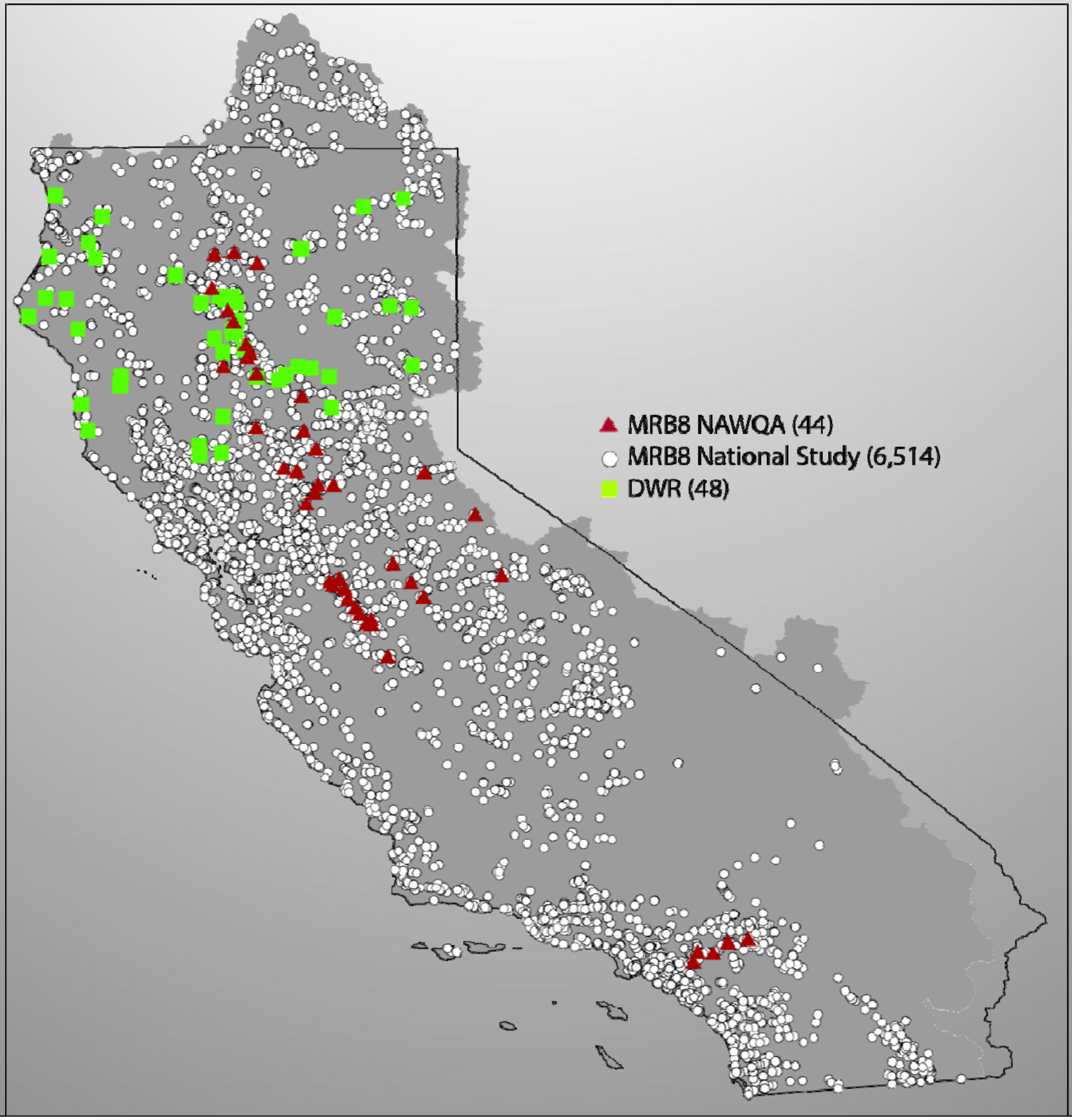
Example SPARROW Data Layers

Average Air Temperature



Distribution of Water Quality Sites



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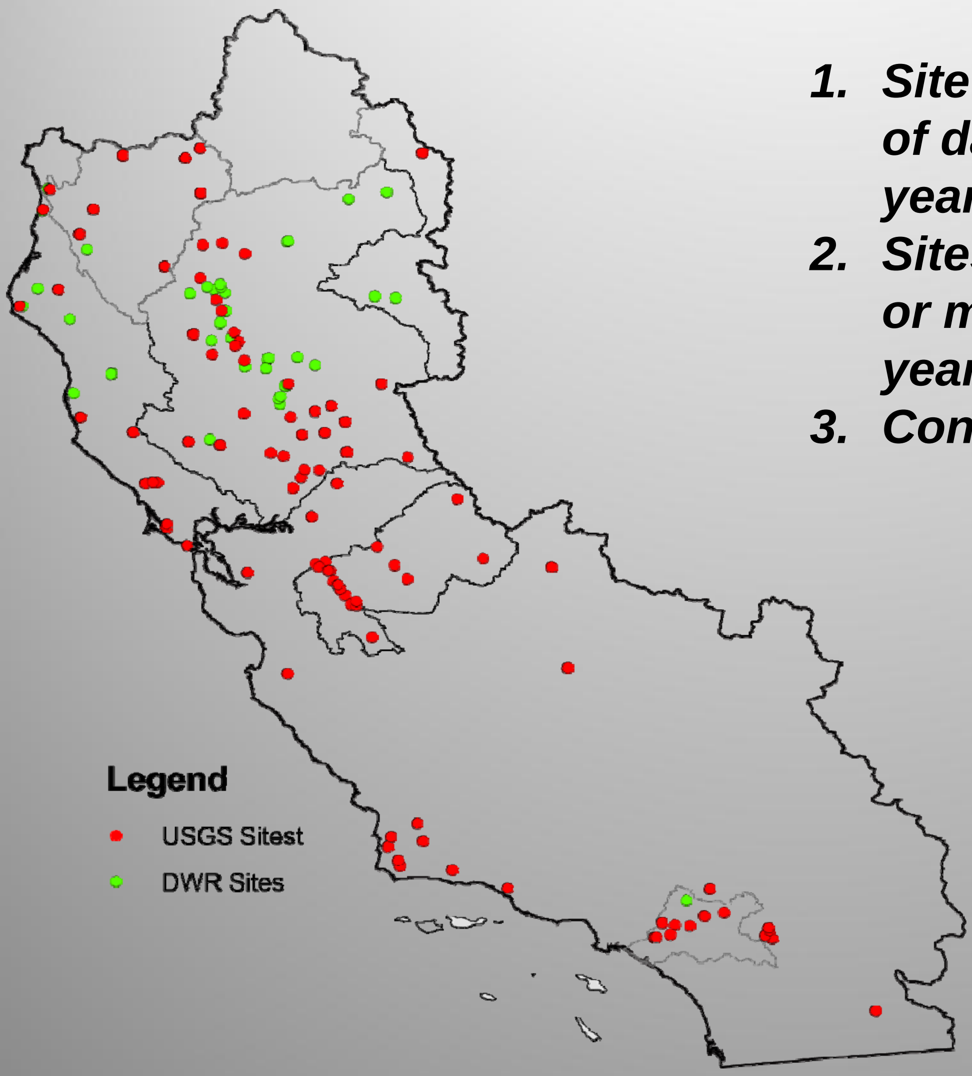
Sites Used For SPARROW Model



1. *Site must have at least 2 years of data spanning the 2002 base year.*
2. *Sites must have 15 observations or more throughout these 2 years.*
3. *Continuous flow data*

Water Quality Data Sources

- NAWQA data set
- **Kratzer, C.R**., Kent, R.H., Saleh, D.K., Knifong, D.L., Dileanis, P.D., and Orlando, J.L., 2011, Trends in nutrient concentrations, loads, and yields in streams in the Sacramento, San Joaquin, and Santa Ana Basins, California, 1975–2004: U.S. Geological Survey Scientific Investigations Report 2010-5228, 112 p.

http://pubs.usgs.gov/sir/2010/5228/


USGS Scientific Investigations Report 2010-5228: Trends in Nutrient Concentrations, Loads, and - Windows Internet Explorer

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Scientific Investigations Report 2010–5228

National Water-Quality Assessment Program

Trends in Nutrient Concentrations, Loads, and Yields in Streams in the Sacramento, San Joaquin, and Santa Ana Basins, California, 1975–2004

By Charles R. Kratzer, Robert H. Kent, Dina K. Saleh, Donna L. Knifong, Peter D. Dileanis, and James L. Orlando

ABSTRACT

A comprehensive database was assembled for the Sacramento, San Joaquin, and Santa Ana Basins in California on nutrient concentrations, flows, and point and nonpoint sources of nutrients for 1975–2004. Most of the data on nutrient concentrations (nitrate, ammonia, total nitrogen, orthophosphate, and total phosphorus) were from the U.S. Geological Survey's National Water Information System database (35.2 percent), the California Department of Water Resources (21.9 percent), the University of California at Davis (21.6 percent), and the U.S. Environmental Protection Agency's STOrage and RETrieval database (20.0 percent).

Point-source discharges accounted for less than 1 percent of river flows in the Sacramento and San Joaquin Rivers, but accounted for close to 80 percent of the nonstorm flow in the Santa Ana River. Point sources accounted for 4 and 7 percent of the total nitrogen and total phosphorus loads, respectively, in the Sacramento River at Freeport for 1985–2004. Point sources accounted for 8 and 17 percent of the total nitrogen and total phosphorus loads, respectively, in the San Joaquin River near Vernalis for 1985–2004. The volume of wastewater discharged into the Santa Ana River increased almost three-fold over the study period. However, due to improvements in wastewater treatment, the total nitrogen load to the Santa Ana River from point sources in 2004 was approximately the same as in 1975 and the total phosphorus load in 2004 was less than in 1975. Nonpoint sources of nutrients estimated in this study included atmospheric deposition, fertilizer application, manure production, and tile drainage. The estimated dry deposition of nitrogen exceeded wet deposition in the Sacramento and San Joaquin Valleys and in the basin area of the Santa Ana Basin, with ratios of dry to wet deposition of 1.7, 2.8, and 9.8, respectively. Fertilizer application increased appreciably from 1987 to 2004 in all three California basins, although manure production increased in the San Joaquin Basin but decreased in the Sacramento and Santa Ana Basins from 1982 to 2002. Tile drainage accounted for 22 percent of the total nitrogen load in the San Joaquin River near Vernalis for 1985–2004.

Nutrient loads and trends were calculated by using the log-linear multiple-regression model, LOADEST. Loads were calculated for water years 1975–2004 for 22 sites in the Sacramento Basin, 15 sites in the San Joaquin Basin, and 6 sites in the Santa Ana Basin. The average annual load of total nitrogen and total phosphorus for 1985–2004 in subbasins in the Sacramento and San Joaquin Basins were divided by their drainage areas to calculate average annual yield. Total nitrogen yields were greater than 2.45 tons per square mile per year [(tons/mi²)/yr] in about 61 percent of the valley floor in the San Joaquin Basin compared with only about 12 percent of the valley floor in the Sacramento Basin. Total phosphorus yields were greater than 0.34 (tons/mi²)/yr in about 43 percent of the valley floor in the San Joaquin Basin compared with only about 5 percent in the valley floor of the Sacramento Basin. In a stepwise multiple linear-regression analysis of 30 subbasins in the Sacramento and San Joaquin Basins, the most important explanatory variables (out of 11 variables) for the response variable (total nitrogen yield) were the percentage of land use in (1) orchards and vineyards, (2) row crops, and (3) urban categories. For total phosphorus yield, the most important explanatory variable was the amount of fertilizer application plus manure production.

Trends were evaluated for three time periods: 1975–2004, 1985–2004, and 1993–2004. Most trends in flow-adjusted concentrations of nutrients in the Sacramento Basin were downward for all three time periods. The decreasing nutrient trends in the American River at Sacramento and the Sacramento River at Freeport for 1975–2004 were attributed to the

First posted March 28, 2011

- Report PDF (15.5 MB)
- Data ZIP (13 MB)

For additional information contact:
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U.S. Geological Survey
6000 J Street, Placer Hall
Sacramento, California 95819
http://ca.water.usgs.gov/

Part or all of this report is presented in Portable Document Format (PDF); the latest version of Adobe Reader or similar software is required to view it. Download the latest version of Adobe Reader, free of charge.

Water Quality Loads for Calibration

Fluxmaster (Schwarz and others, 2006): is a

- log-linear multiple regression model.
- It provides a detrended load by removing the effects of time and random variations in hydrologic conditions.
- Calculates loads on different time steps.
- reports predictions only for those days that are contained in years specified.

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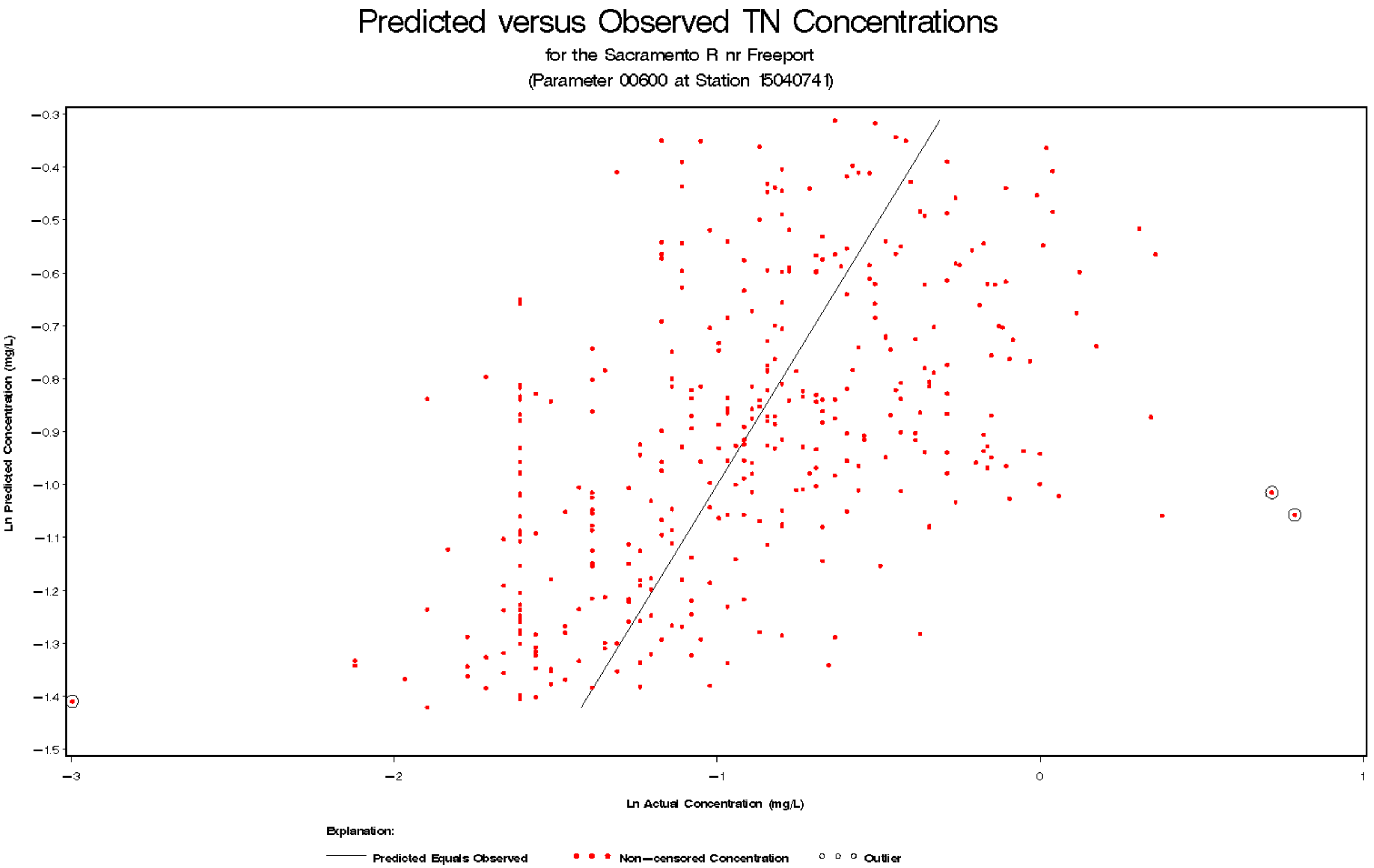
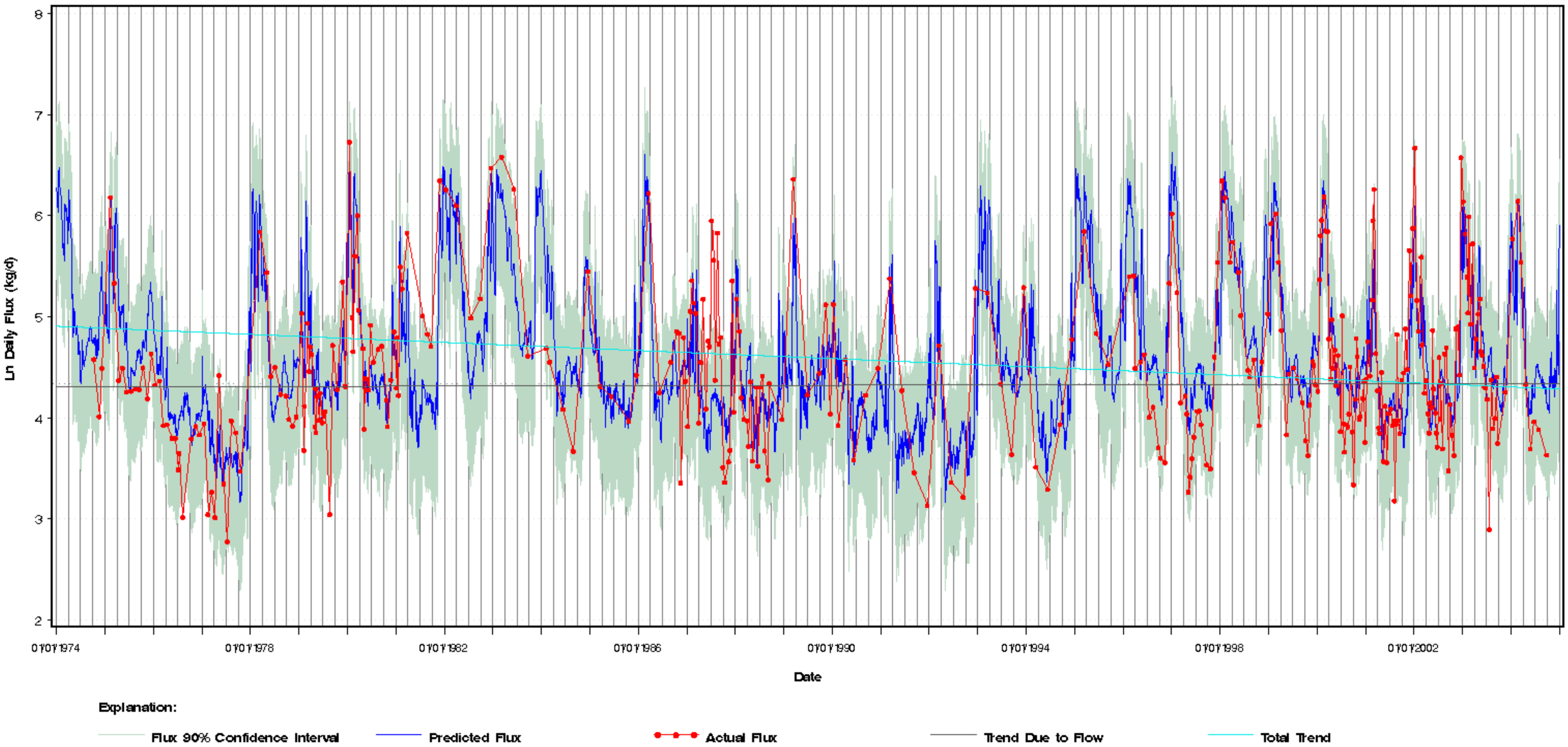
Fluxmaster output



Fluxmaster output

Detrended Actual and Predicted TN Flux
for the Sacramento R nr Freeport
(Parameter 00600 at Station 15040741)



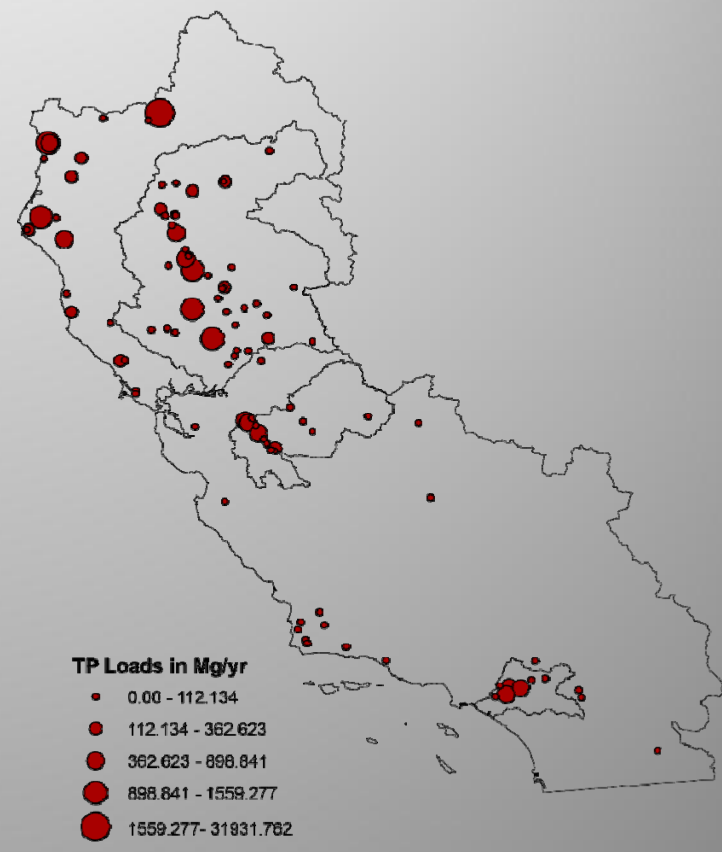
FLUX: period for avg.: 10/01/1970 – 09/30/2006 [36 prediction years], method: 2.3, SE avg. flux as pct.: 4.30%, trend: –1.51% [sig.];
WQ: N: 370 [0 censored], RMSE: 0.458, reference concentration: 0.58 mg/L; **FLOW:** trend: 0.11% [not sig.], variation[WQ sample/flow record]: 0.88

Predicted values are adjusted for retransformation bias, making them upward biased in log space.
The horizontal reference line without a label corresponds to the logarithm of flux for the normalization date 06/30/2002

Predicted Total Nitrogen and Phosphorus Loads for 2002

TN Loads

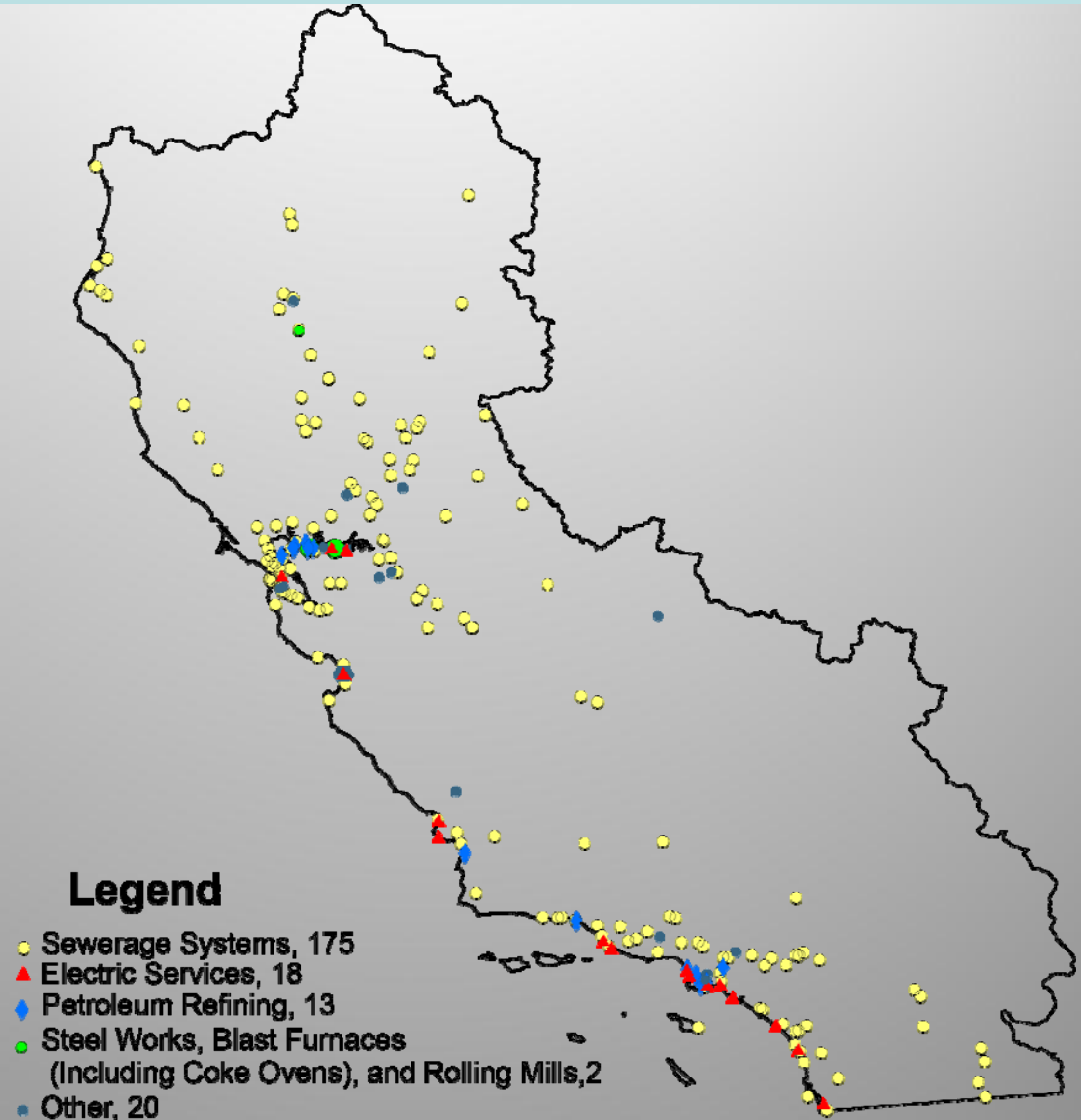
TP Loads



Output from Fluxmaster

Location of Point Source Sites

227 Sites:
208 Majors
19 Minors



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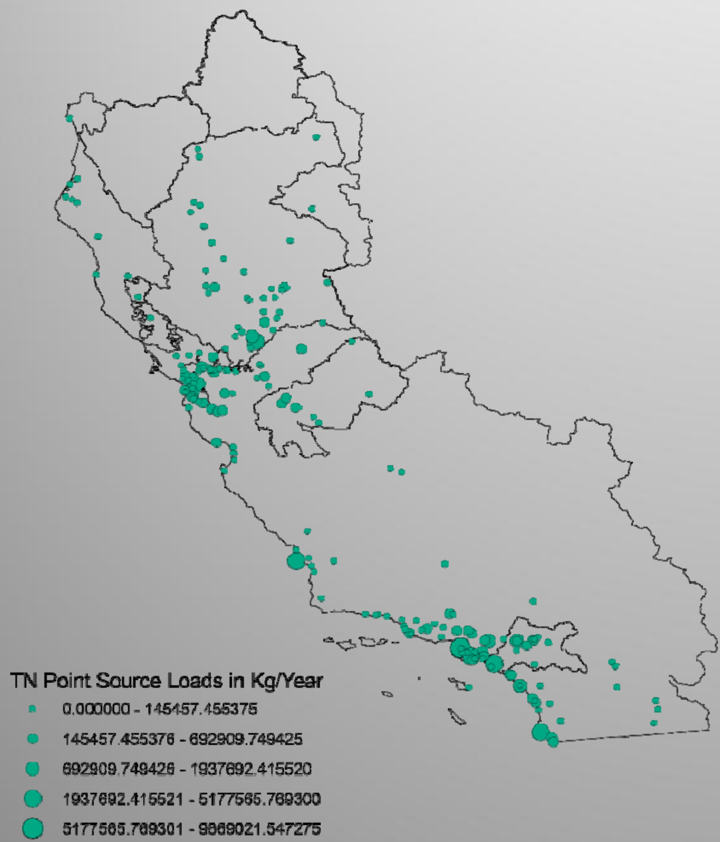
Slide 27

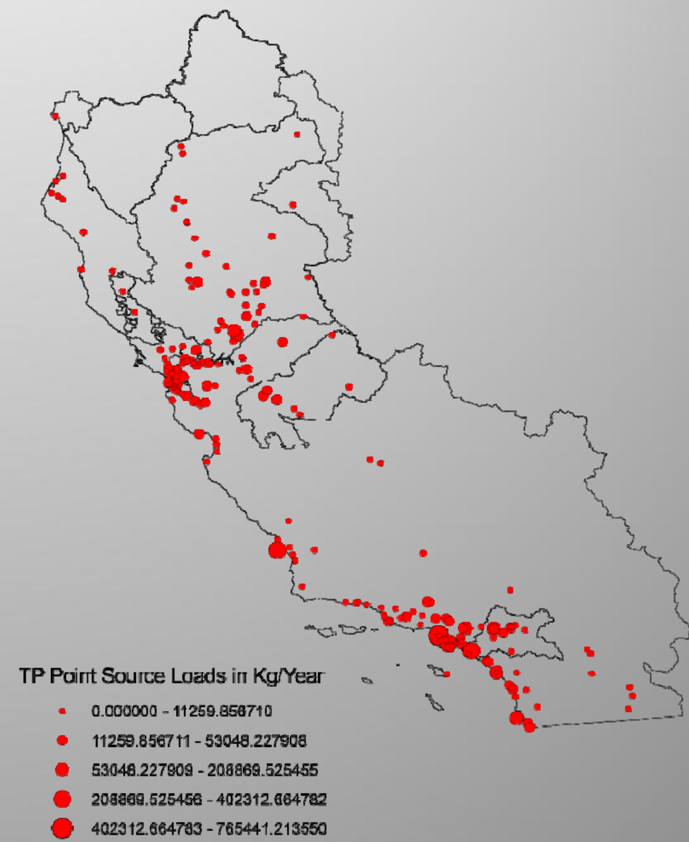
DS2 add or sites
Dina Saleh, 12/10/2010

Point Source Loads 2002

Total Nitrogen (TN)



Total Phosphorus (TP)



Output from McMan model

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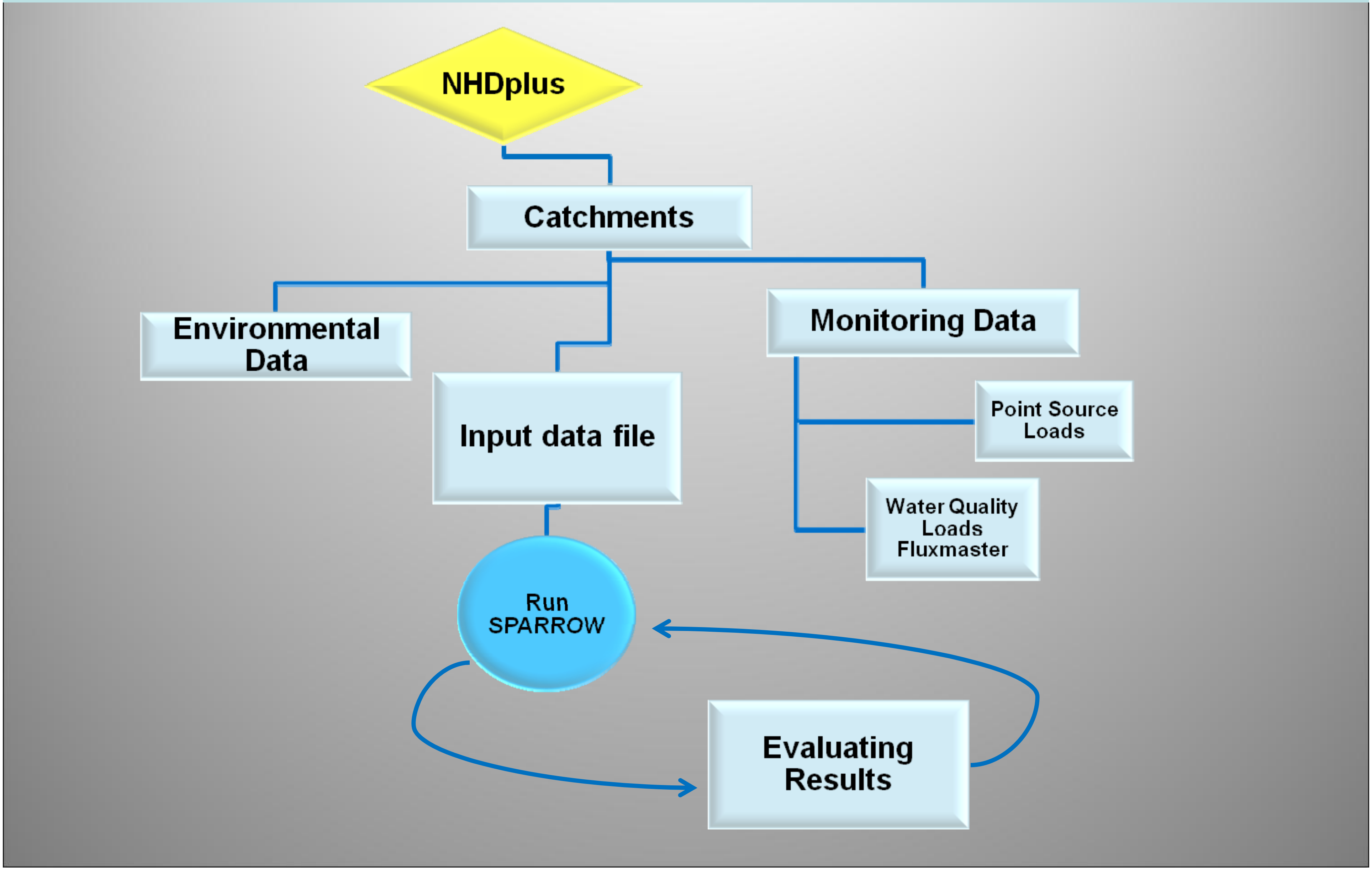
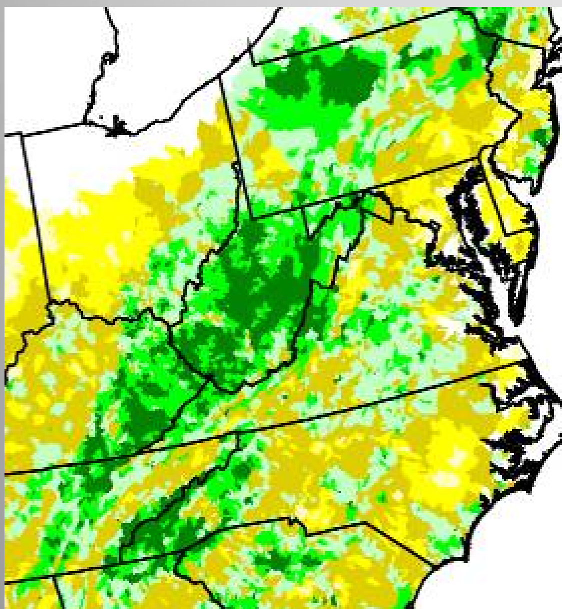
SPARROW Work Flow



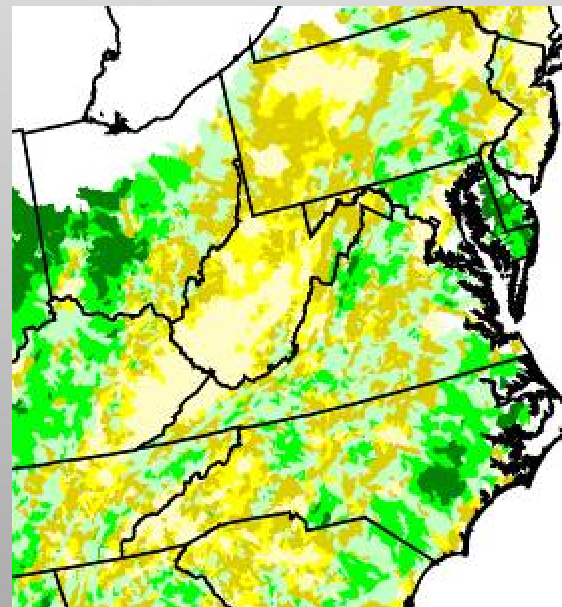
Examples from National Studies

SPARROW Predictions of Nitrogen Yield
Local Source Shares (Reach Incremental Drainage)

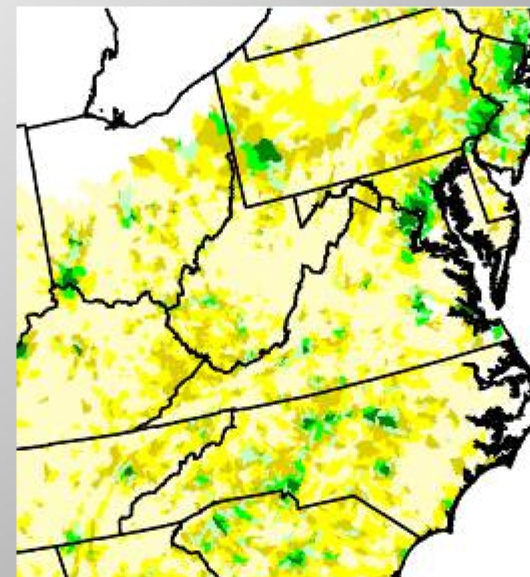
Atmospheric Deposition and Forests

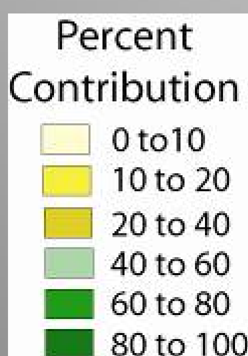


Agriculture



Urban Sources



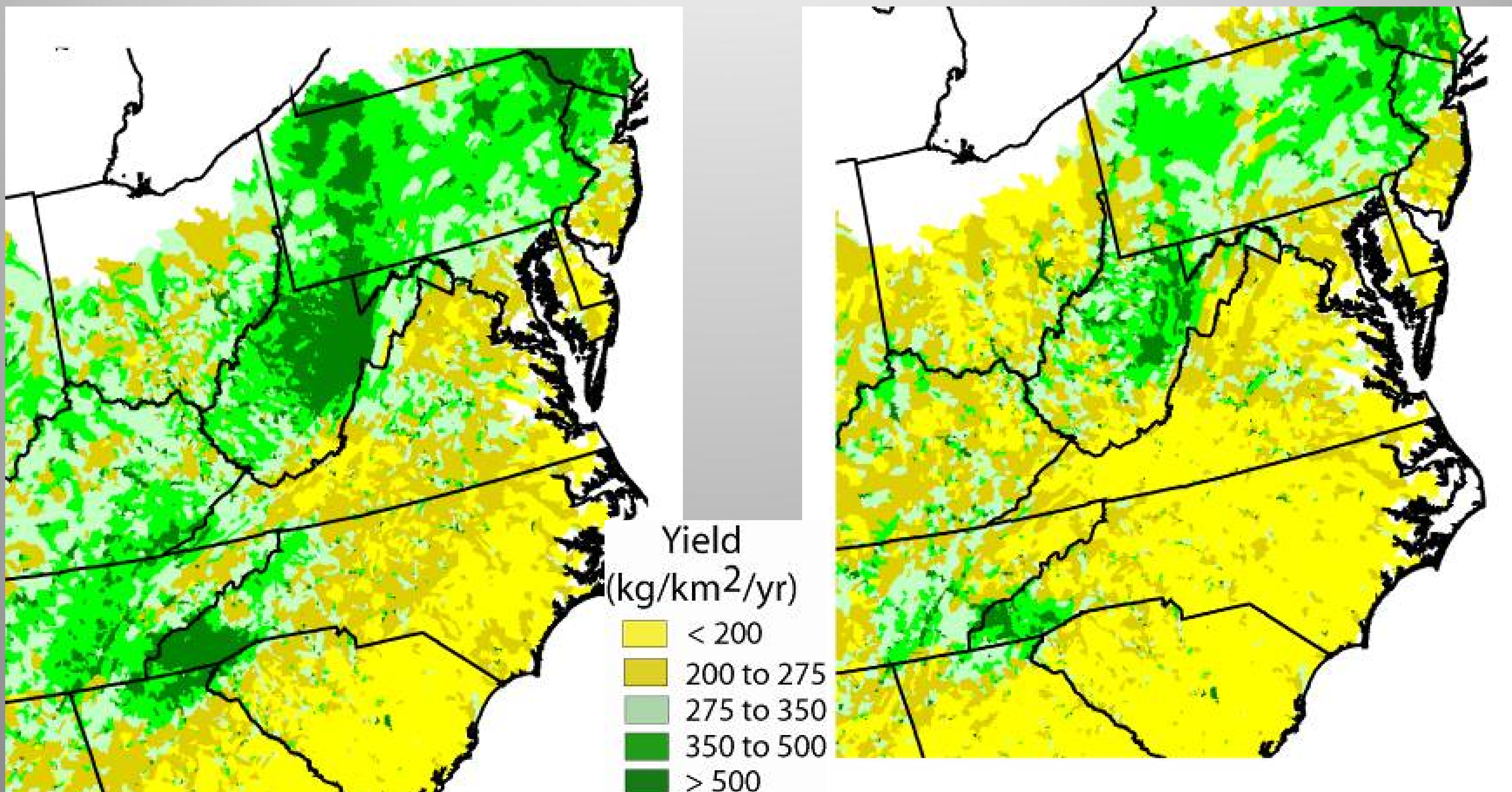


Based on model predictions from Alexander et al., 2008, *Environ. Sci. Technol.*, v 42

SPARROW Predictions of Nitrogen Yield Originating from Atmospheric Dep. and Forests

Incremental Yield (Delivered locally to Streams)

Delivered Yield (Delivered to Coastal Waters)



Based on model predictions from Alexander et al., 2008, *Environ. Sci. Technol.*, v 42

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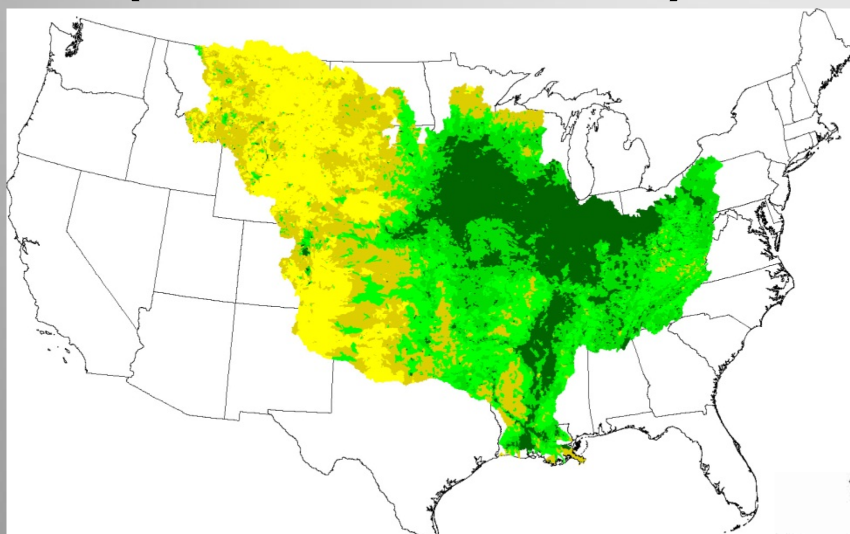
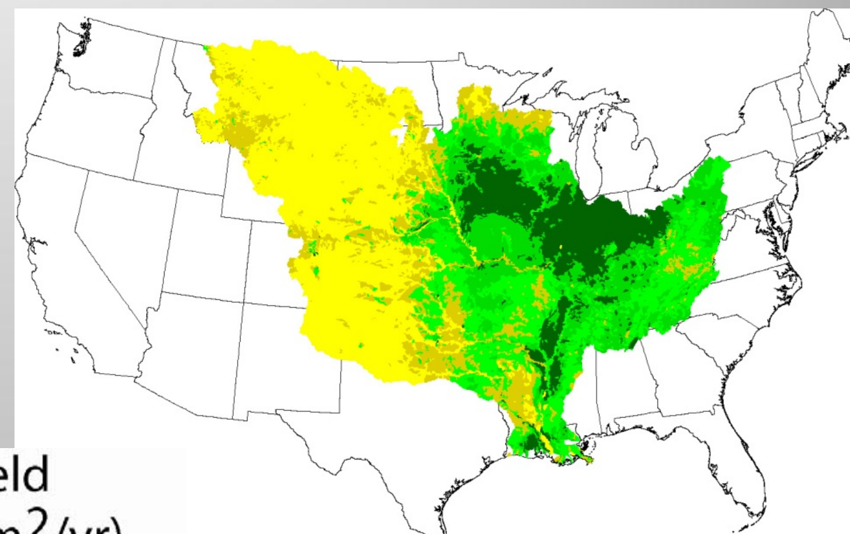
SPARROW Predictions of Nitrogen Yield

Incremental Yield (Delivered to Streams)



Total Yield (Delivered to Watershed Outlets)



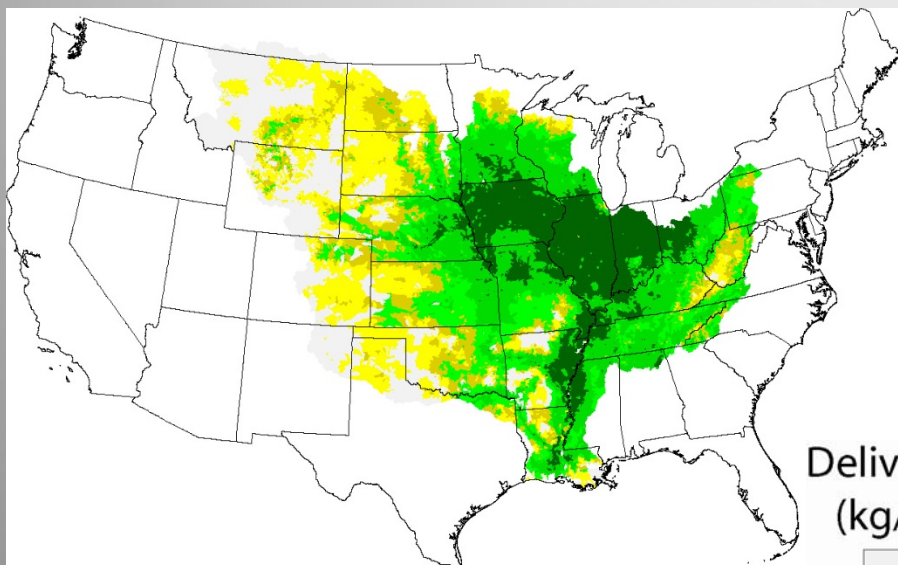
Yield ($kg/km^2/yr$)

- < 130
- 130 to 350
- 350 to 700
- 700 to 1,400
- > 1,400

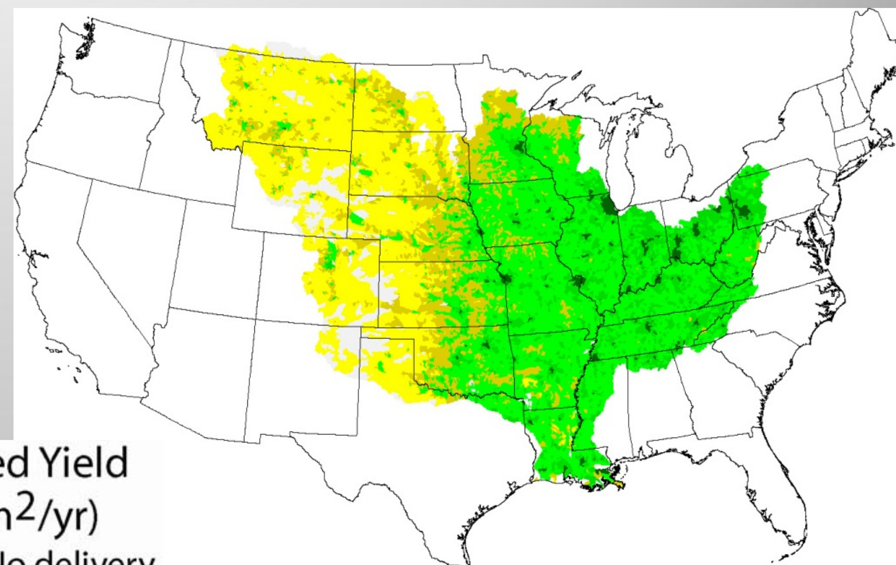
Based on model predictions from Alexander et al., 2008, *Environ. Sci. Technol.*, v 42

Total Nitrogen Delivery to the Gulf of Mexico for Selected Sources

Corn and Soybeans



Urban Sources



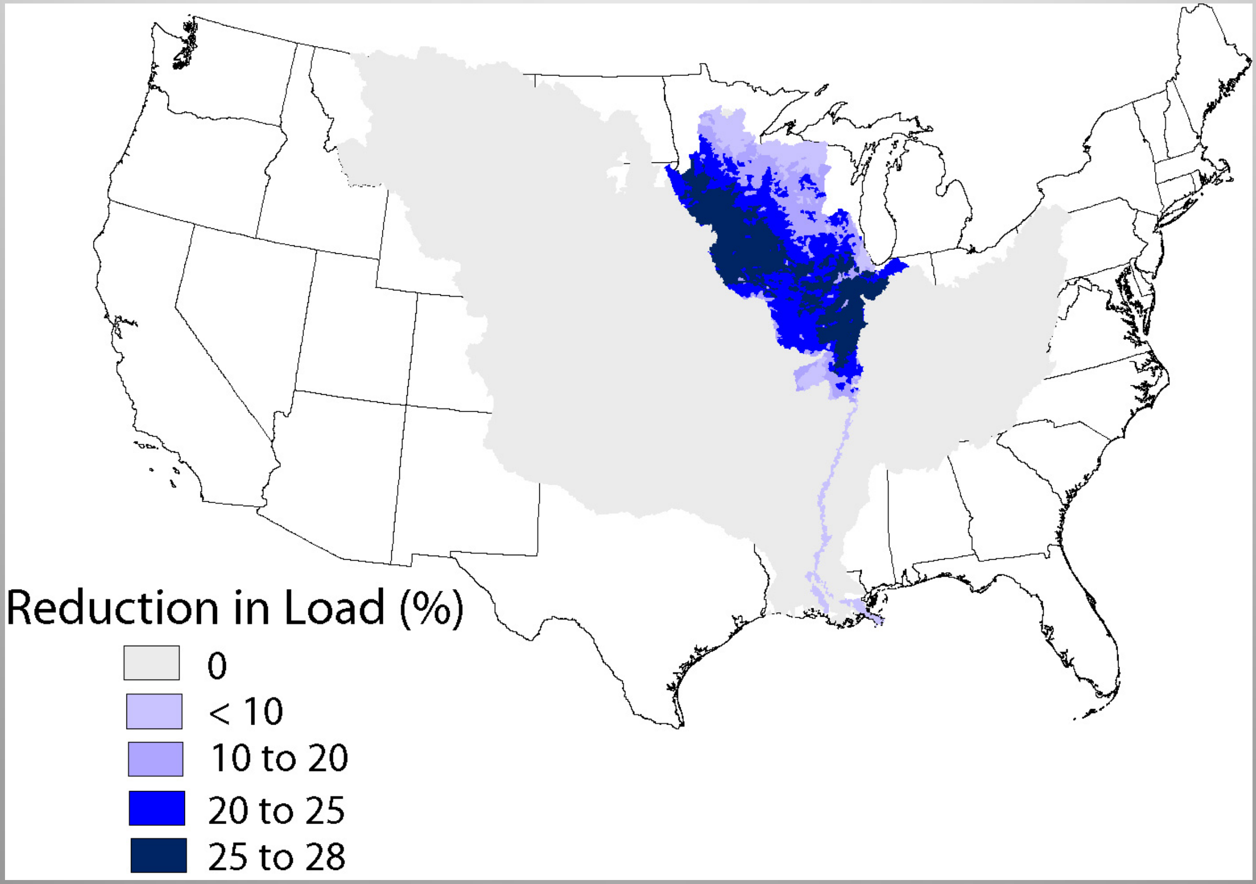
Delivered Yield ($kg/km^2/yr$)

- No delivery
- < 0.5
- 0.5 to 5
- 5 to 50
- 50 to 500
- > 500

Based on model predictions from Alexander et al., 2008, *Environ. Sci. Technol.*, v 42

Hypothetical Future Change in Total Nitrogen Load in Streams

Stream load response to 30% reduction in nitrogen inputs to farms

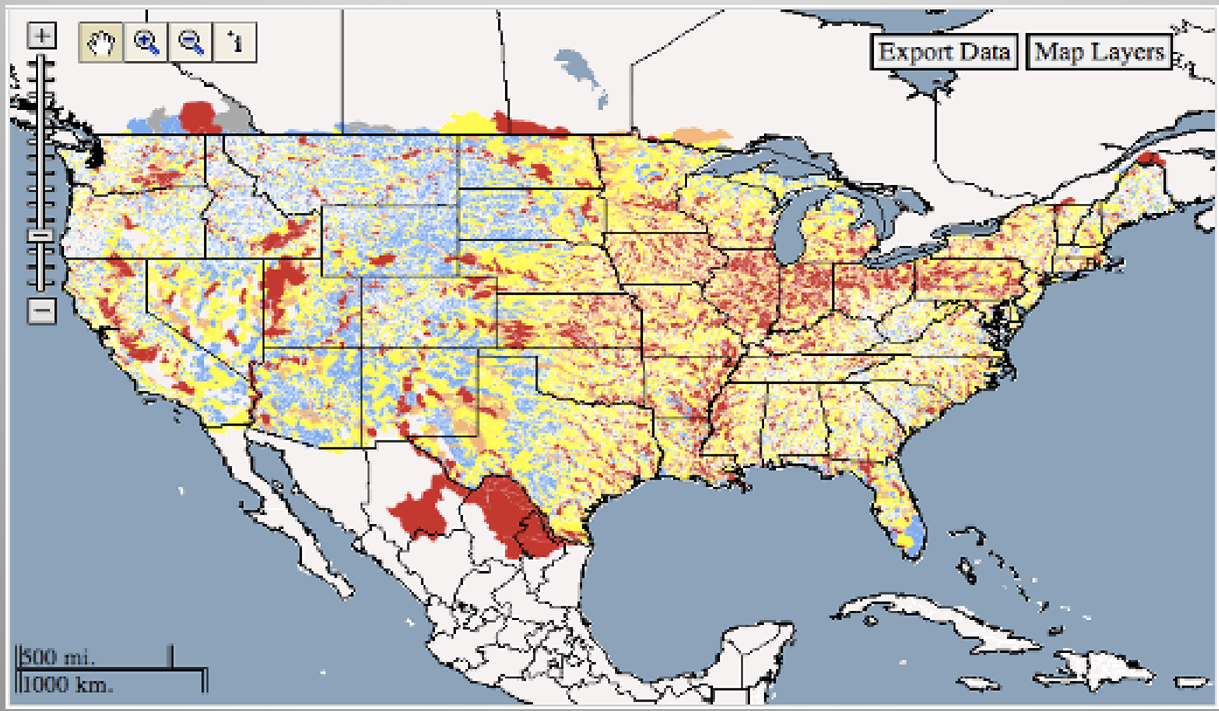


Based on SPARROW model from Alexander et al., 2008, *Environ. Sci. Technol.*, v 42

Current SPARROW Activities

Improved transparency and access to the model to inform management decisions

SPARROW Web-based decision support tool

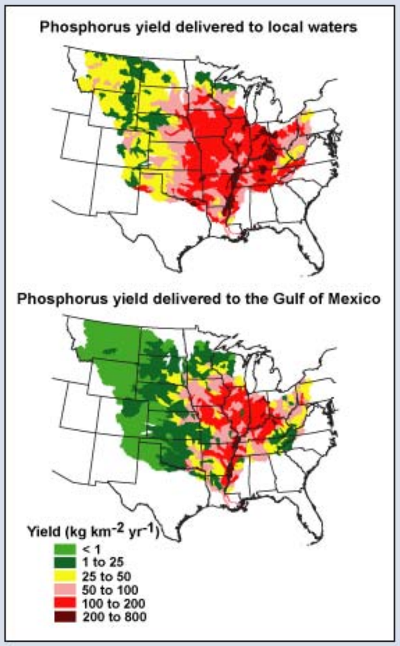


http://water.usgs.gov/nawqa/sparrow/

SPARROW Surface Water-Quality Modeling

NAWQA Home | Model Description | Fact Sheet | FAQs | Documentation | Software | Publications | Contacts | Training | Regional MRB Studies

SPARROW, a modeling tool for the regional interpretation of water-quality monitoring data. The model relates in-stream water-quality measurements to spatial transport. SPARROW empirically estimates the origin and fate of contaminants in river networks and quantifies uncertainties in model predictions.



SPARROW tracks nutrient delivery locally to the outlets of inland watersheds and regionally to coastal waters. Differences in phosphorus yield in the Mississippi River Basin shown above are caused by local and regional differences in phosphorus removal in streams and reservoirs during transport [Read more about these and other SPARROW results]

RECENT ACTIVITIES

- NEW SPARROW modeling of southeastern U.S. streams
- NEW Rankings of watershed nutrient yields in the Mississippi/Atchafalaya River Basin
- SPARROW Fact Sheet
- Studies of denitrification and nitrogen removal in streams
- SPARROW Major River Basin (MRB) Studies
- Phosphorus and nitrogen delivery to the Gulf of Mexico from the Mississippi River Basin

APPLICATIONS

The National Models
- Phosphorus and nitrogen delivery to the Gulf of Mexico from the Mississippi River Basin
- Moving from Monitoring to Prediction: The Quality of the Nation's Streams
- Natural background concentrations of nutrients in U.S. streams
- Atmospheric sources of nitrogen to major U.S. estuaries
- Effect of stream channel size on nitrogen delivery to the Gulf of Mexico
- Sources of nutrients in the Nation's streams (model predictions for HUC watersheds)
- A national model of suspended sediment

Nutrients in the Northeastern United States
- Regional total nitrogen and phosphorus models
- The role of headwater streams in downstream water quality
- New England SPARROW data viewer
- New England Interstate Water Pollution Control Commission (NEIWPCC)
- U.S. Environmental Protection Agency Region 1 Project

Nutrients in the Chesapeake Bay Watershed
- Application of the national models
- A regional nitrogen model
- Models for the late 1980s and the 1990s

Nutrients in the Southeast
- Nitrogen sources and loads in southeastern streams
- A Bayesian SPARROW nitrogen model
- Support of TMDL programs in North Carolina using SPARROW

Salinity in the Southwest
- Sources and sinks of dissolved solids

Future of SPARROW application in CA

- Simulate effects of climate change (Higher Temp longer growing season), change in precipitation, and the effects from changes in river flow.
- Simulating other constituents: Organic Carbon, Suspended Sediment, and other.
- Supporting local and regional TMDL development.

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Questions?