New England Sparrow Model

Potentially useful information for designing a stream water-quality network

Richard Moore and Keith Robinson
USGS, NH/VT District, Pembroke, NH

USGS science for a changing world

EPA United States Environmental Protection Agency

NEIWPCC

Today's Presentation

- What is SPARROW
- SPARROW model results for New England
- Introduce potential uses of SPARROW data
- designing a stream water-quality network

SPARROW *(Spatially Referenced Regressions On Watershed Attributes)*

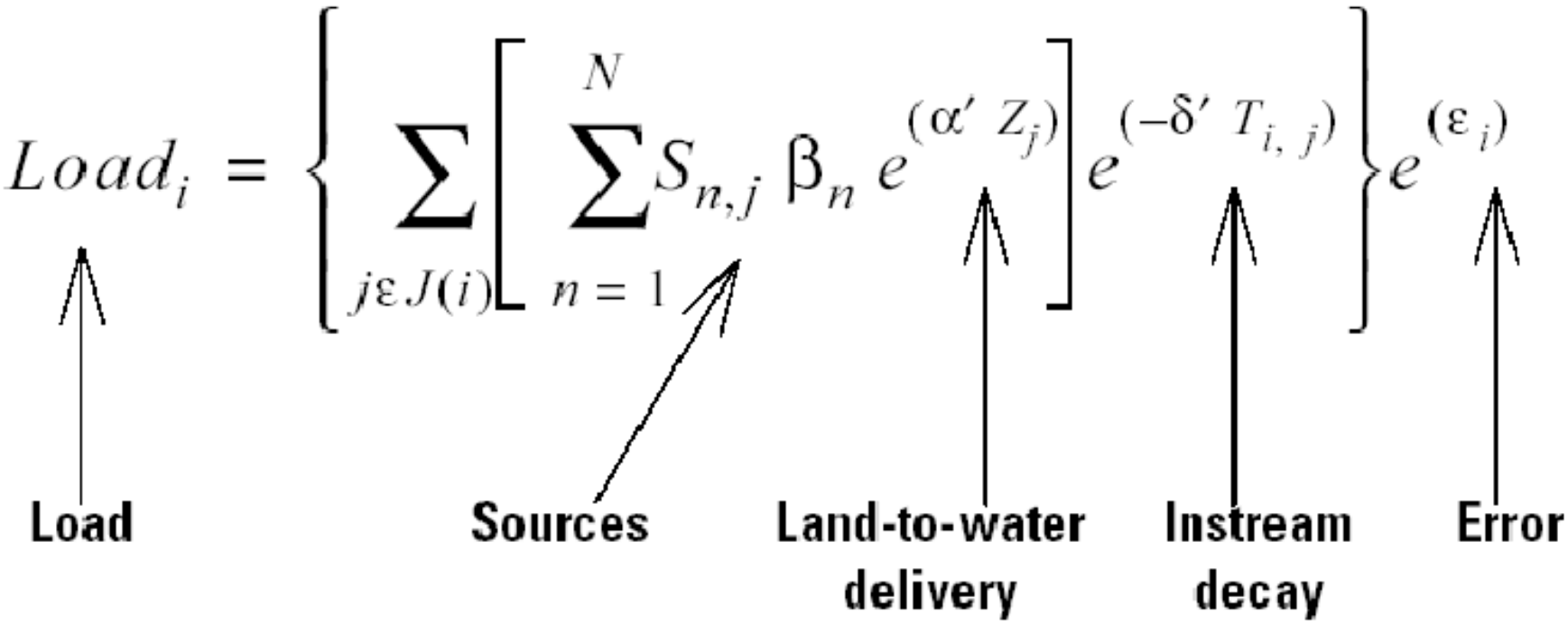
- Described in Smith and others, *Water Resources Research,* 33(12): 2781-2798

- An empirical approach relating observed water-quality data (TN and TP loads) to upstream watershed characteristics in a GIS framework

SPARROW *(Spatially Referenced Regressions On Watershed Attributes)*

- Incorporates variables to simulate in-stream processes
- Incorporates only statistically significant variables.

SPARROW
Estimated Equation



Hydrologic Network – the Back-bone of SPARROW

Schematic of a Nested Basin

Upstream monitoring station

Point source

Reach segment

Reach segment contributing area

Downstream monitoring station

Purpose of the New England Model is to support major water-quality management activities

- Nutrient criteria development - Ranges in nutrient levels in rivers and streams throughout the region
- TMDL program - Identification of factors (sources and watershed characteristics) affecting nutrient levels
- Coastal Water Assessments - Transport of nutrients by rivers (especially interstate) to coastal waters

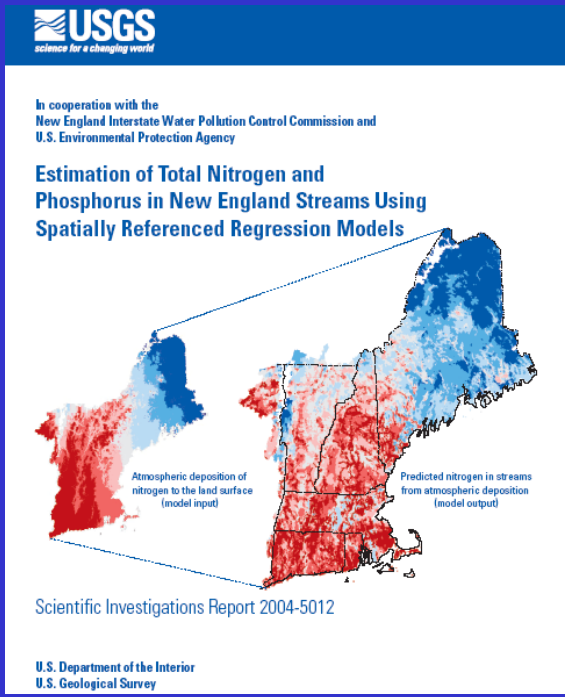
Design of the New England SPARROW Model

- Focus on Total Nitrogen and Total Phosphorus loads
- Model for the mid-1990s time period
- Improve on national model for more spatial detail and using local data sets
- Collaboration with EPA and NEIWPCC

Status of the New England SPARROW Modeling Effort

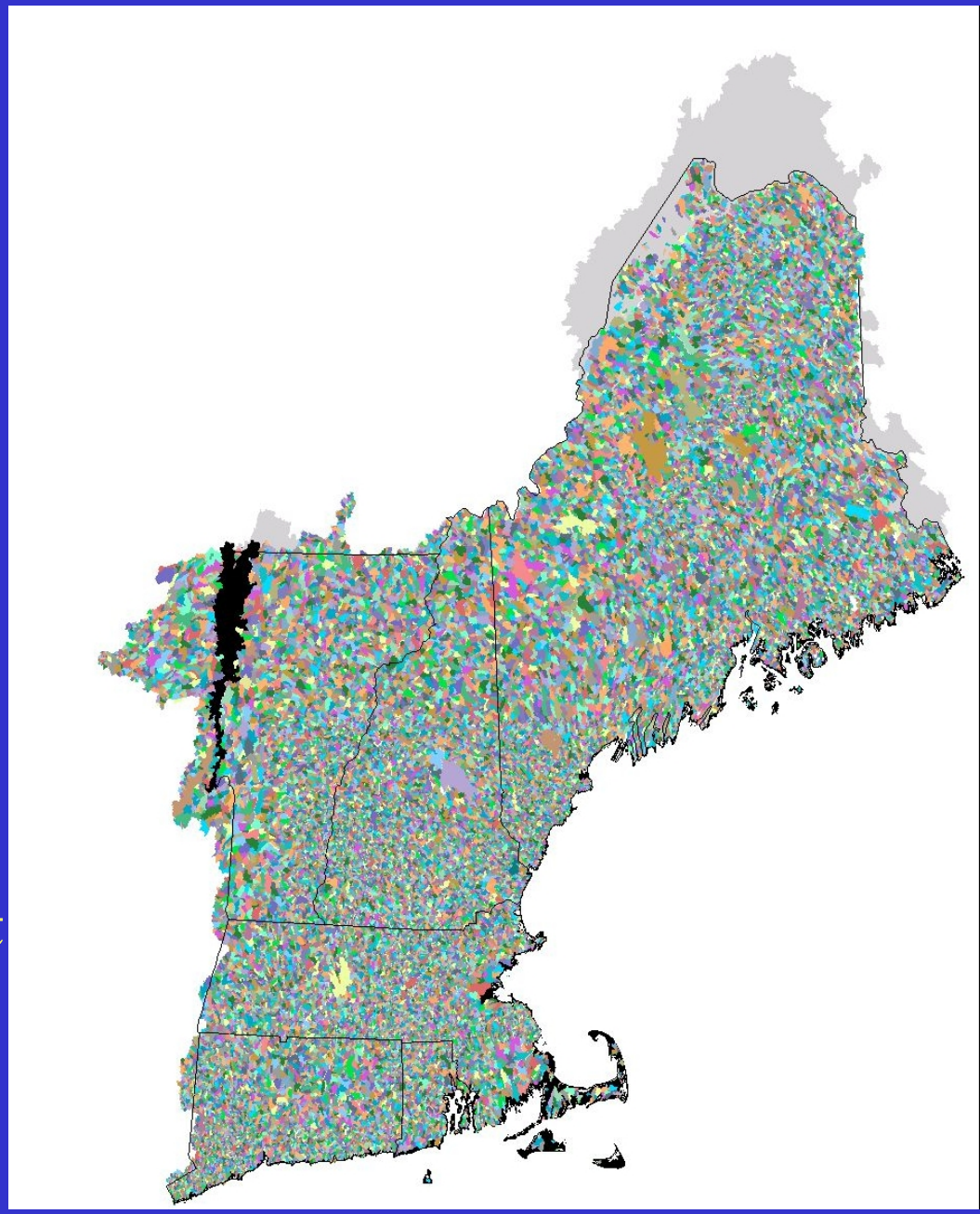
- Models are calibrated and predictions applied to the entire region
- Report is published and available as a pdf file at web site http://nh.water.usgs.gov/
- USGS/NEIWPCC proposal to make the datasets readily available

  – documenting SPARROW input and output datasets, making them available, and conducting state workshops for resource managers

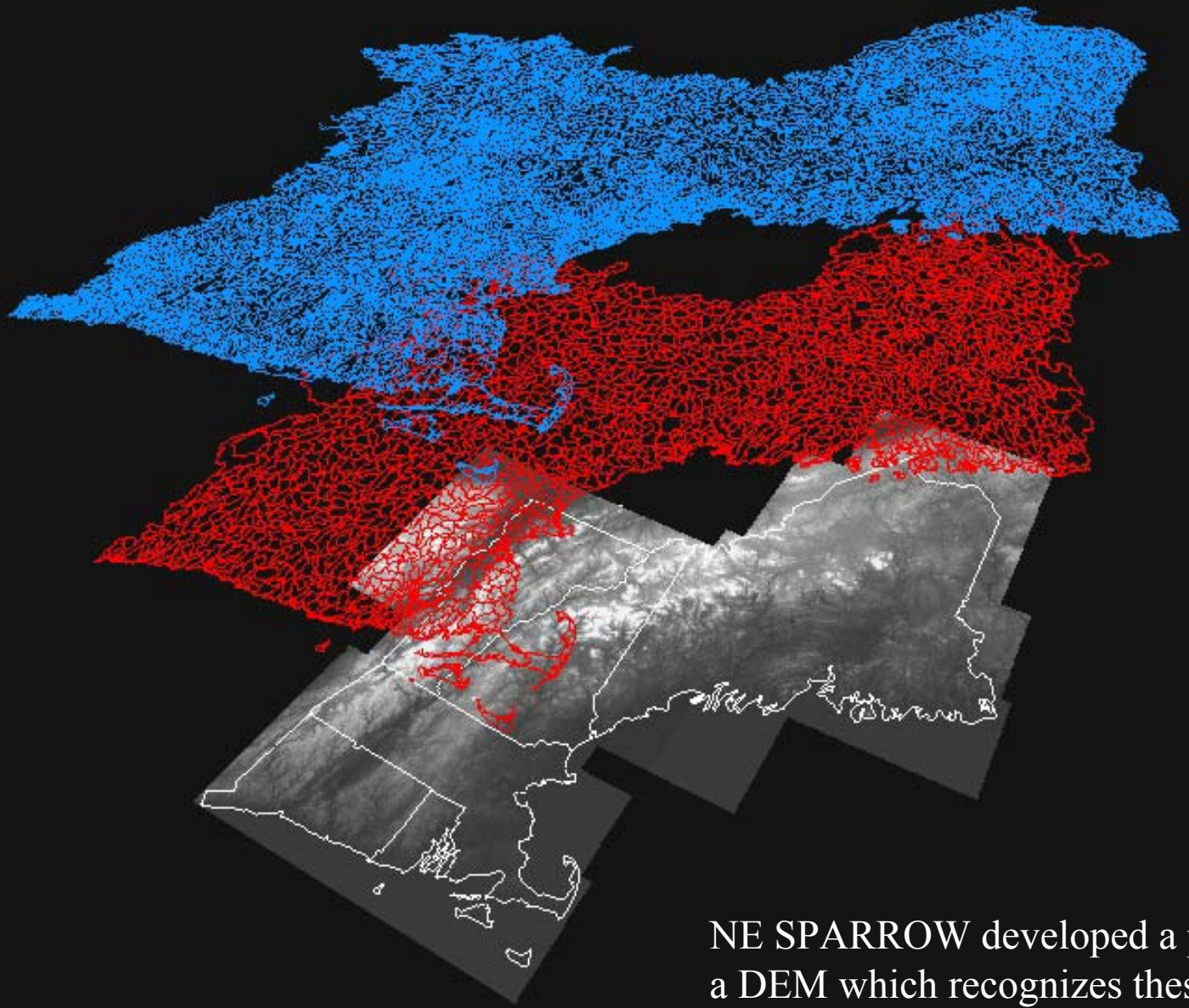


New England Model Watersheds and Streams Reaches

- Based on the National Hydrography Data Set (NHD)
- Approx 42,000 in model
- Average 1.7 mi^2 in size
- Corrected to NRCS 12-digit watersheds
- Hydrologically connected



Generation of NHD Reach Catchments Using a Hydrologically-Conditioned DEM Incorporating:

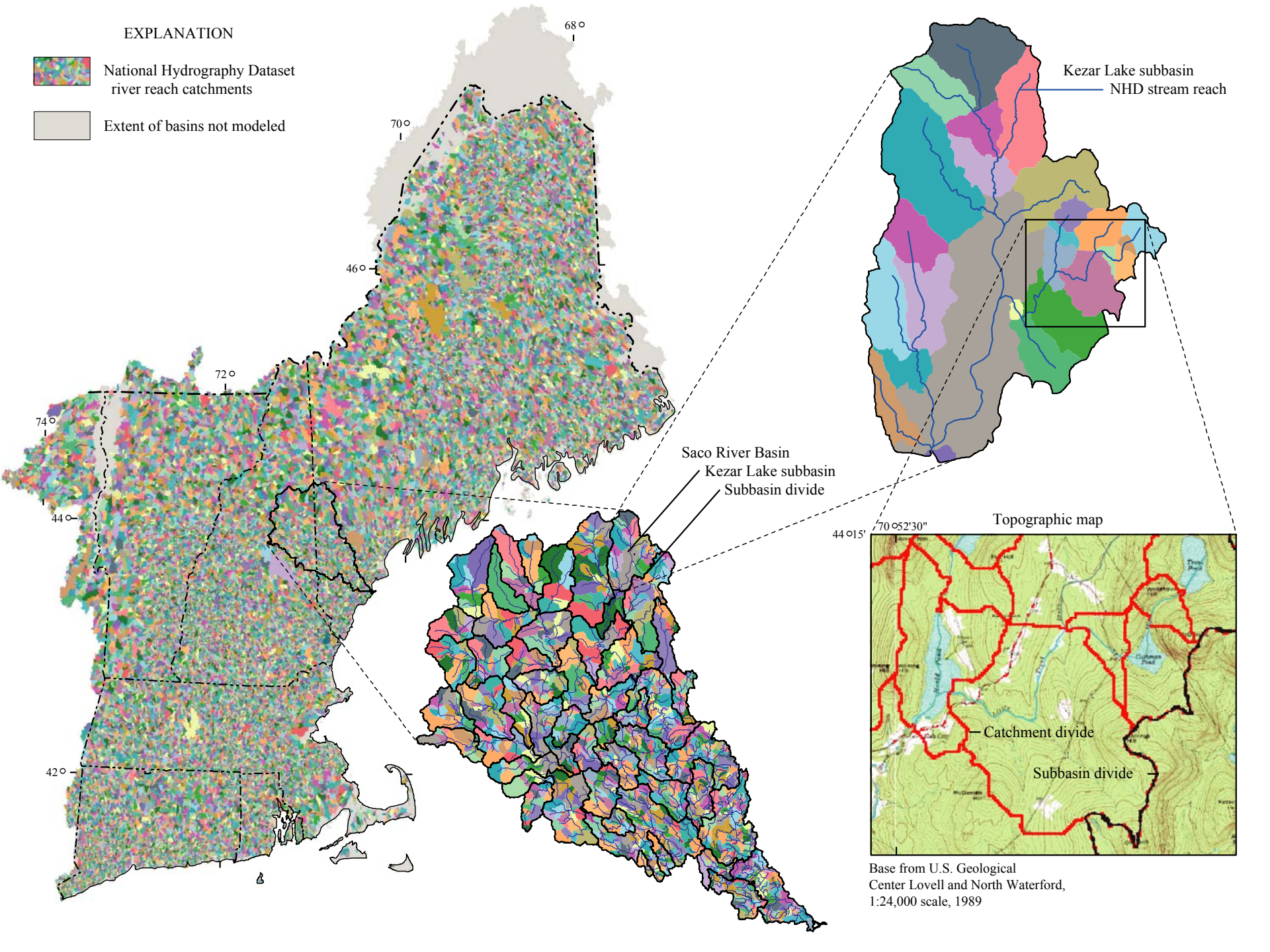


National Hydrography Dataset (NHD)

Watershed Boundary Dataset (WBD)

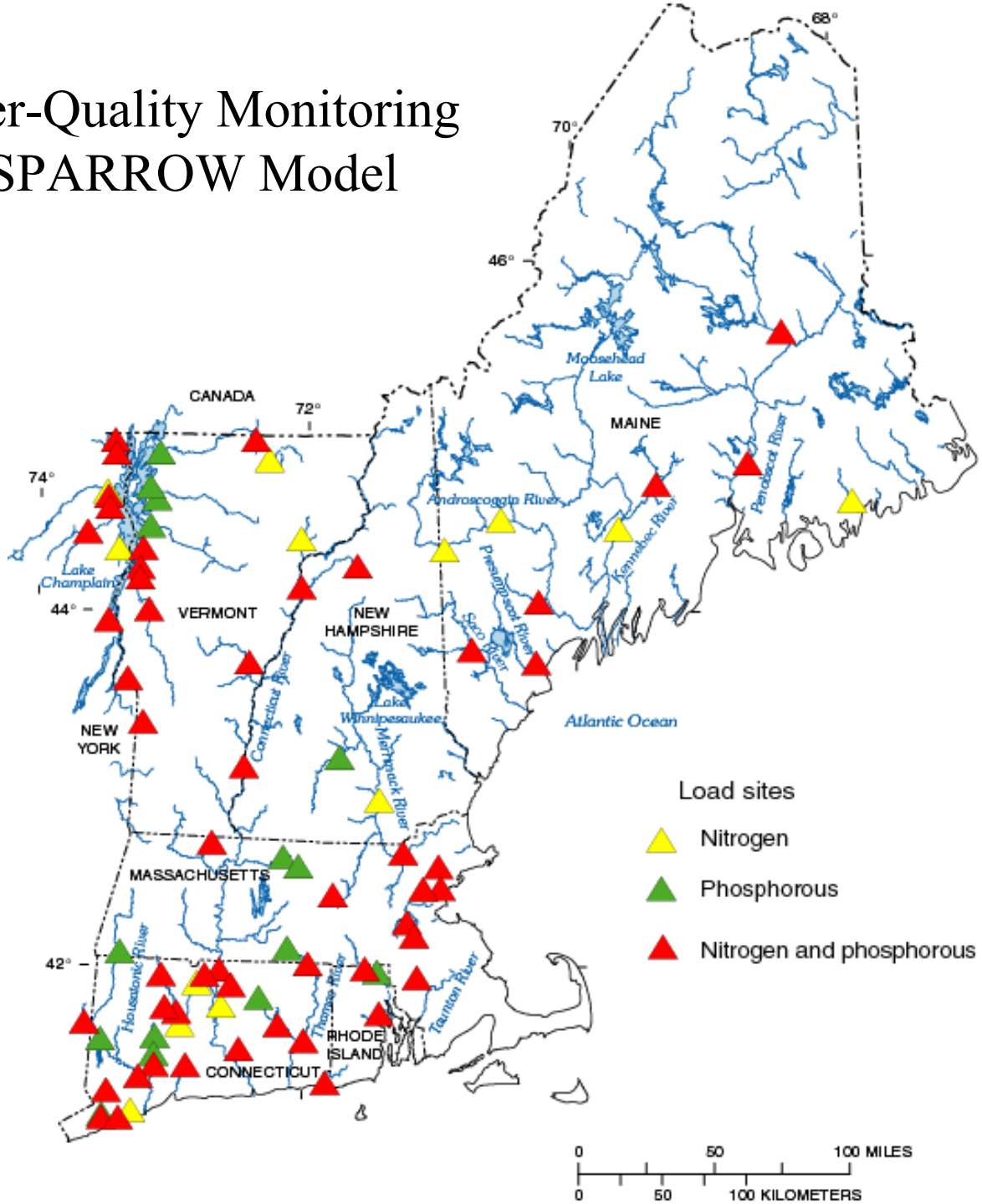
National Elevation Dataset (NED)

NE SPARROW developed a process to create a DEM which recognizes these three datasets



Base from U.S. Geological Center Lovell and North Waterford, 1:24,000 scale, 1989

Nutrient Water-Quality Monitoring Sites used in SPARROW Model



Nutrient (Dependent) Data to be Used in the Model

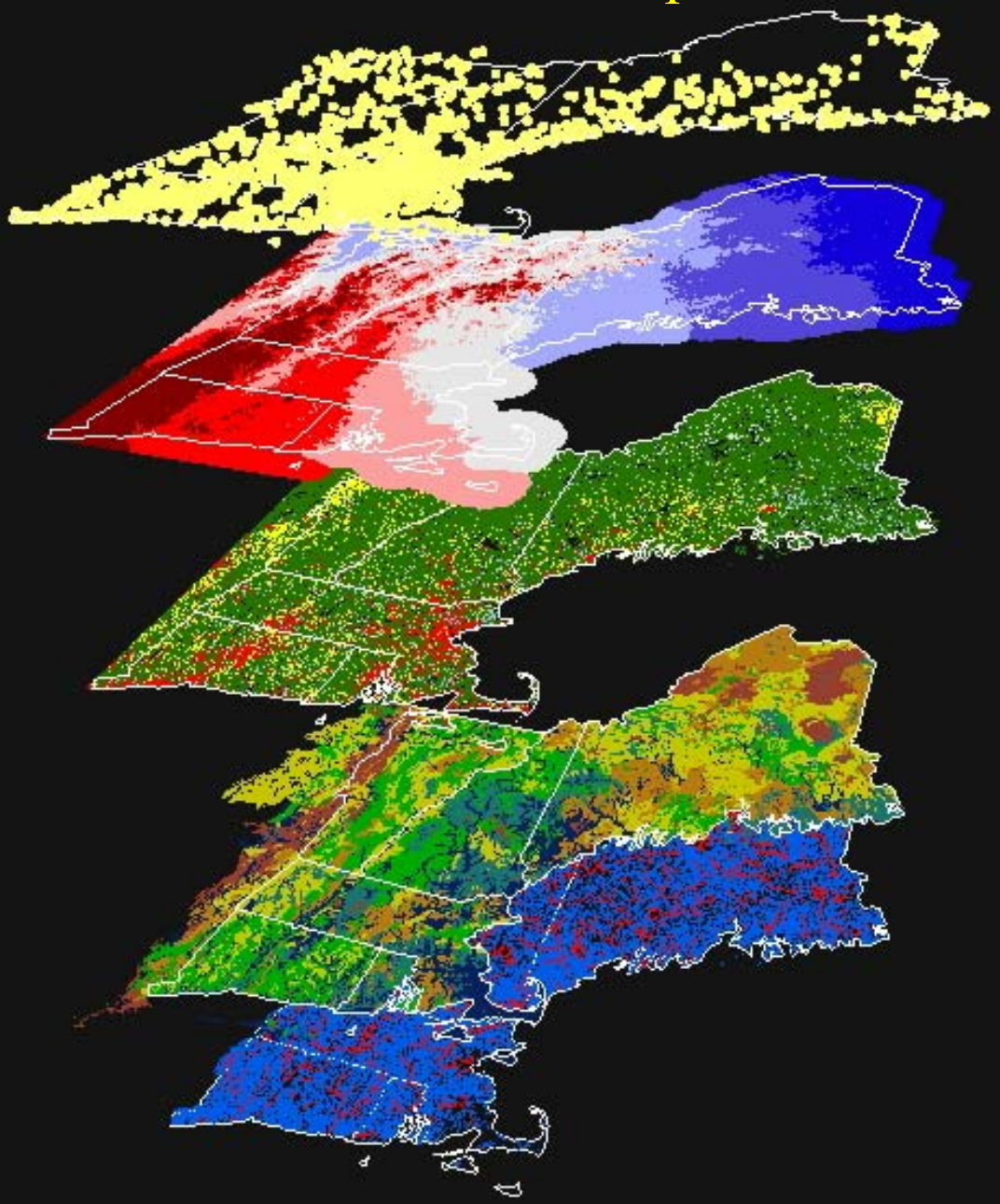
- Collected data from USGS, STORET, States, research studies during the 1980-2000 time period.

- Calculated discharge/nutrient relation to predict nutrient loads during all conditions of a hydrograph using the USGS Estimator Program.

  67 TP and 65 TN sites

- Mean annual loads for years of water-quality and streamflow data

NE SPARROW Model Input



Nutrient Sources

Point Source

Atmospheric deposition of nitrogen (Ollinger 1992)

National Land Cover Dataset 1992
- Agriculture
- Developed
- Forest

Processes

Land to water delivery

Soil permeability – STATSGO

In-stream loss

Mean annual stream-flow
Reservoir detention

Model Calibration Results for the New England SPARROW Nitrogen Model

R-squared = .95, MSE = 0.16

Variable SOURCES	Bootstrap model coefficient	Standard error of coefficient	p-value
Municipal wastewater-treatment facilities	1.13	0.36	<.005
Atmospheric deposition	.36	.07	<.005
Cultivated agricultural land ($kg/km^2/y$)	910	362	.005
Developed urban land ($kg/km^2/y$)	988	385	.010

Model Calibration Results for the New England SPARROW Nitrogen Model (cont.)

R-squared = .95, MSE = 0.16

Variable	Bootstrap model coefficient	Standard error of coefficient	p-value
Delivery variable:			
Natural Log of Soil Permeability	**0.36**	**0.14**	**<.005**
Decay Variable:			
Stream decay for streams <= 100 cfs (per day)	**.71**	**.52**	**.065**

Model Calibration Results for the New England SPARROW Phosphorus Model

R-squared = .94, MSE = 0.23

Variable SOURCES	Bootstrap model coefficient	Standard error of coefficient	p-value
Municipal wastewater-treatment facilities and pulp and paper	1.28	0.22	<.005
Forested Land ($kg/km^2/y$)	12.7	4.1	<.005
Cultivated agricultural land ($kg/km^2/y$)	110	27.5	<.005
Developed urban land ($kg/km^2/y$)	37.8	14.3	.005

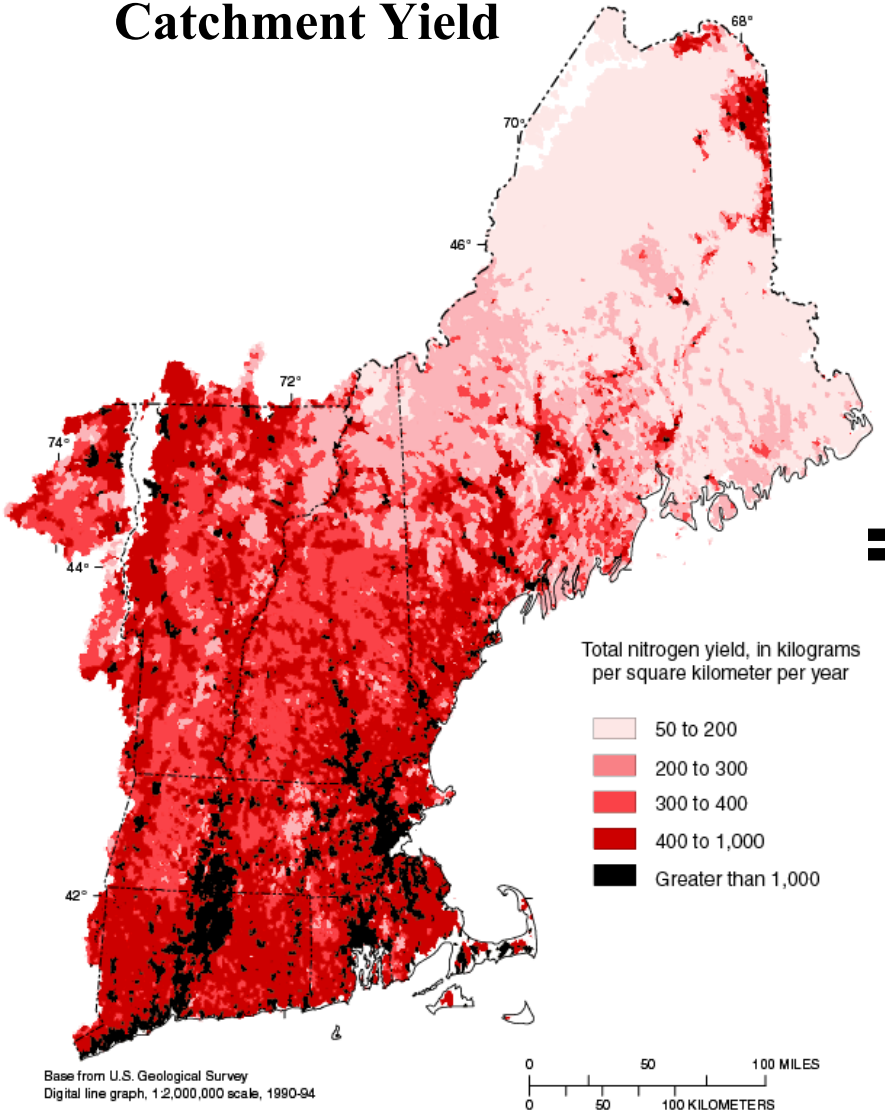
Model Calibration Results for the New England SPARROW Phosphorus Model (cont.)

R-squared = .94, MSE = 0.23

Variable	Bootstrap model coefficient	Standard error of coefficient	p-value
Decay variables:			
Reservoir decay for small lakes and reservoirs (<= 10 km^2) (m/y)	**105**	**59.7**	**.04**
Decay Variable: Stream decay for streams <= 100 cfs (per day)	**.42**	**.41**	**.125**

SPARROW Model Results:

Predicted Total Nitrogen Catchment Yield



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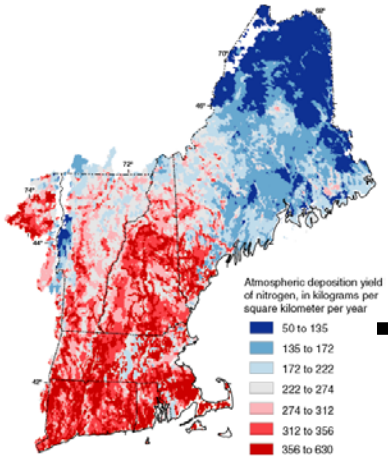
Contributions to Total Nitrogen from each source



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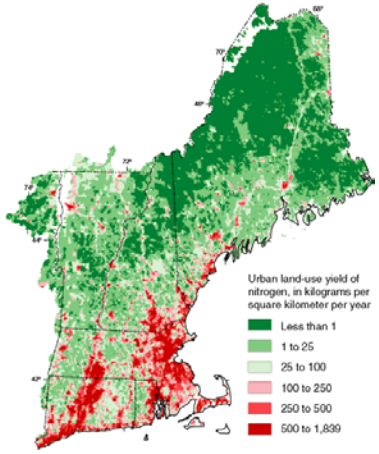
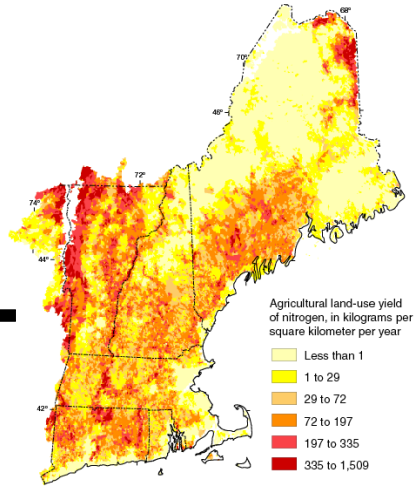


Atmospheric **Urban**

+



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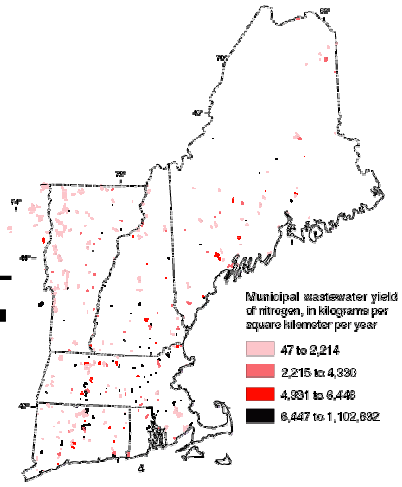
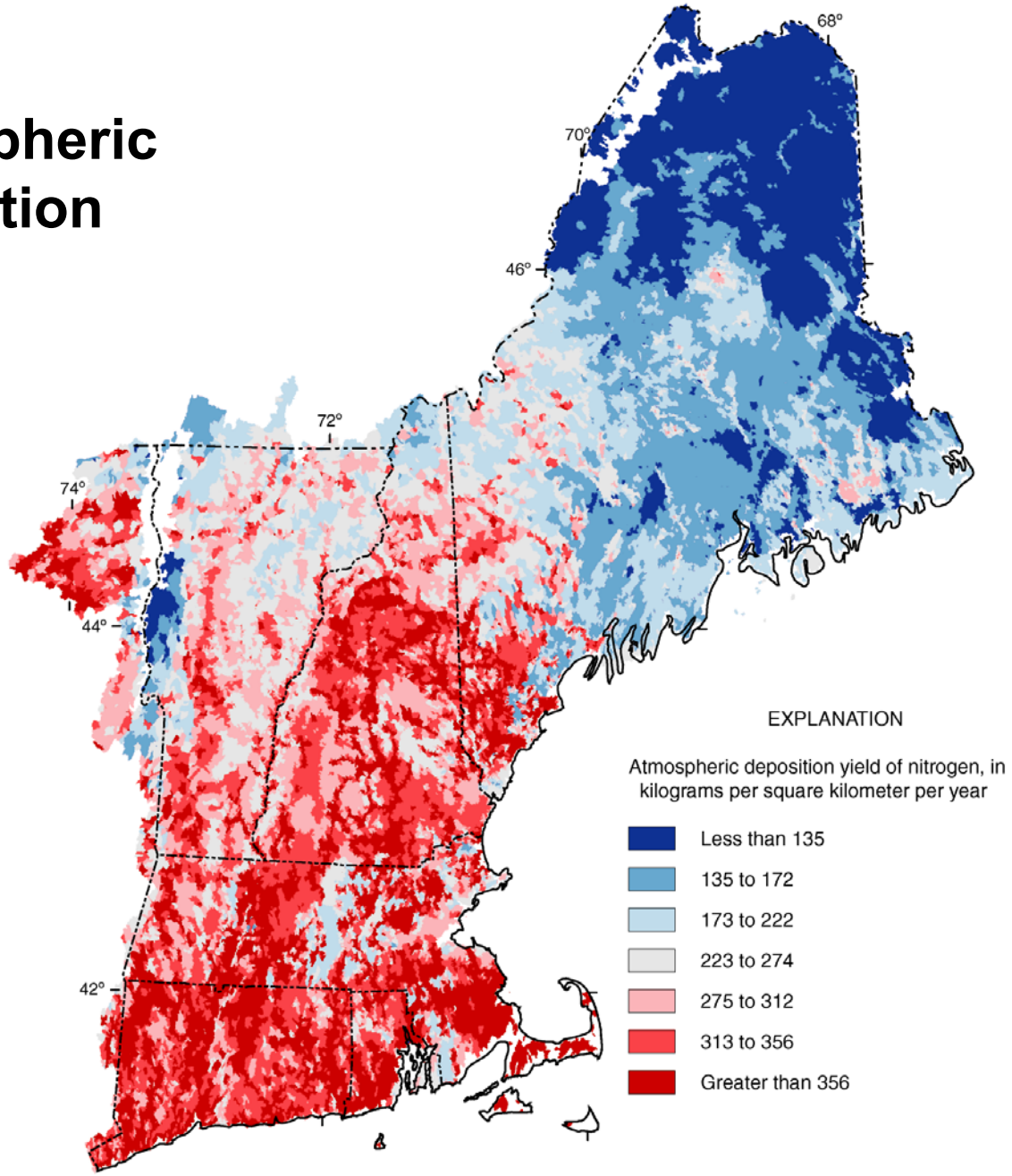


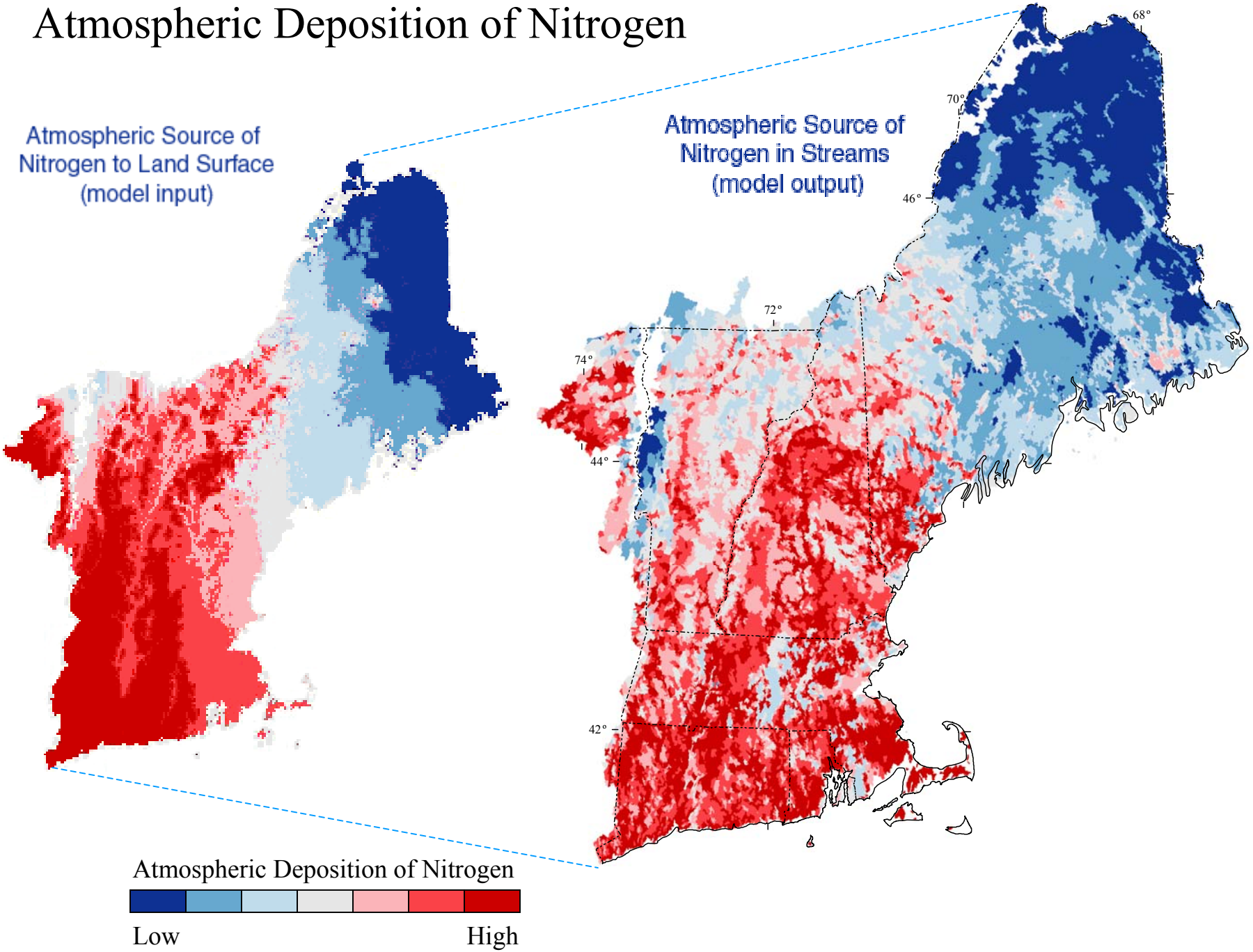
Agriculture **Point Source**

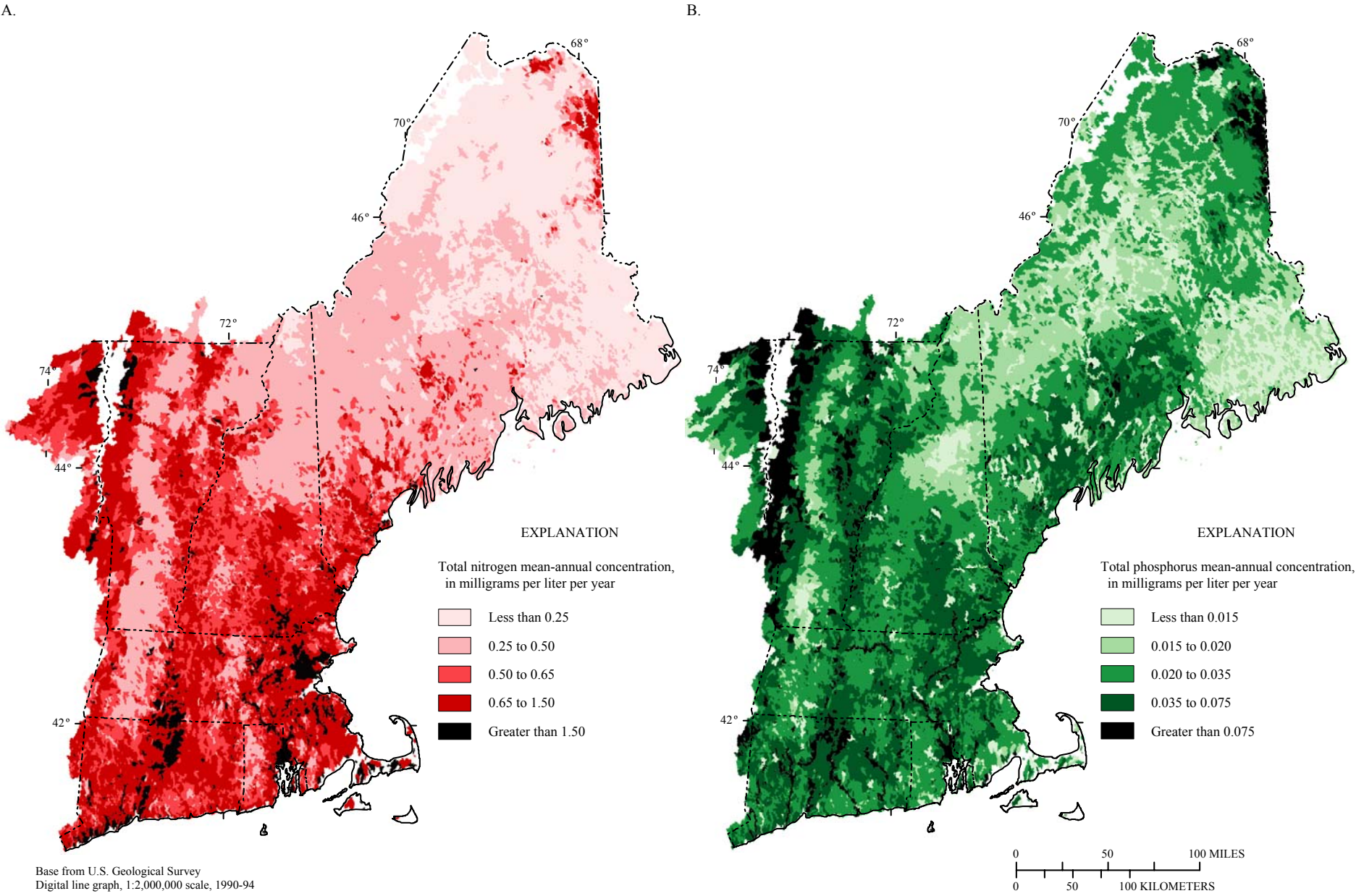
SPARROW Model Results:

Atmospheric Deposition



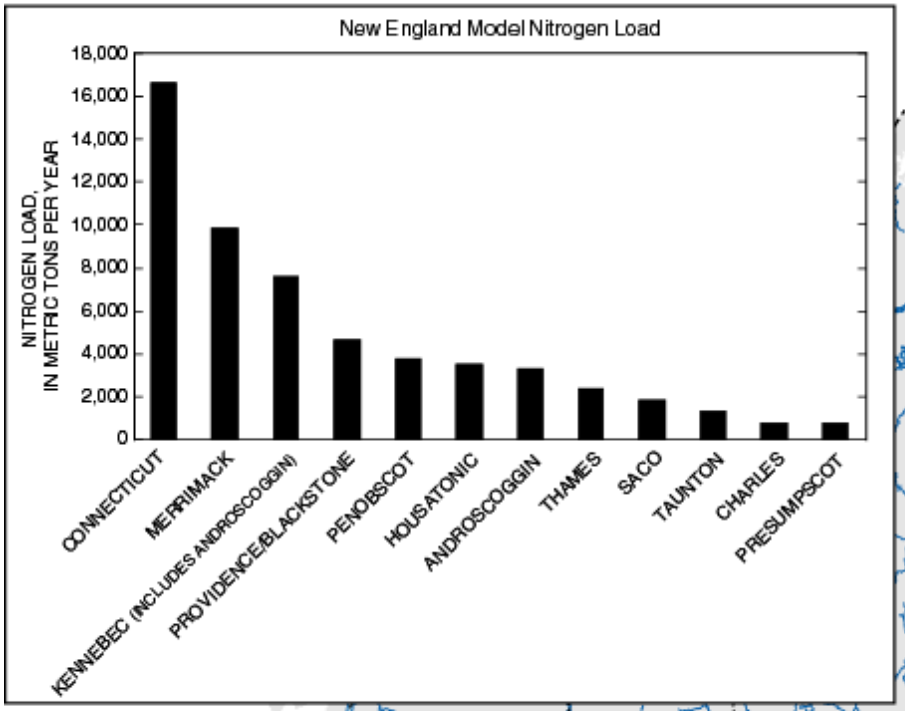
Atmospheric Deposition of Nitrogen

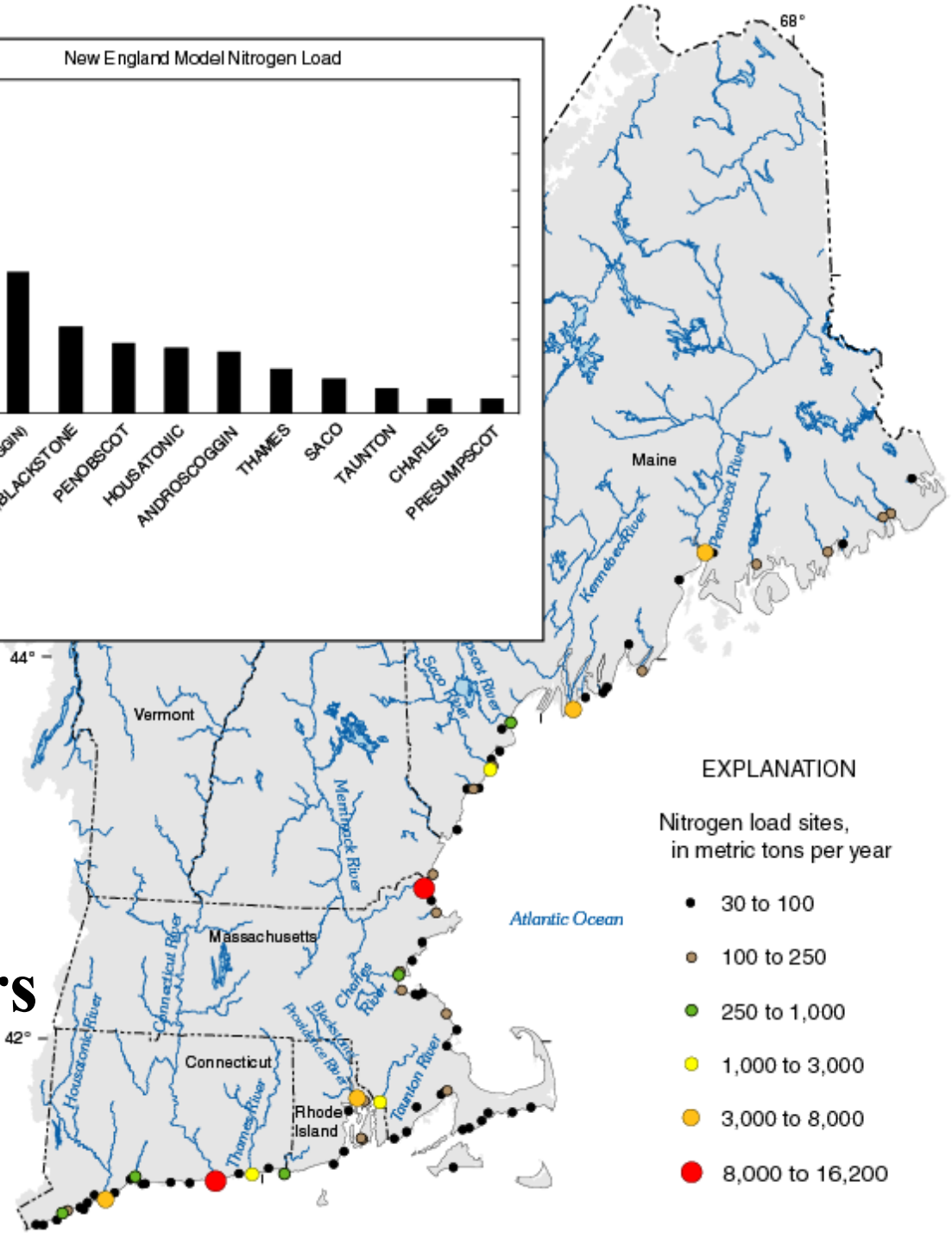




Estimated Mean Annual concentration of (A) Nitrogen and (B) phosphorus.

Assessing Nutrient Loadings to Coastal Waters





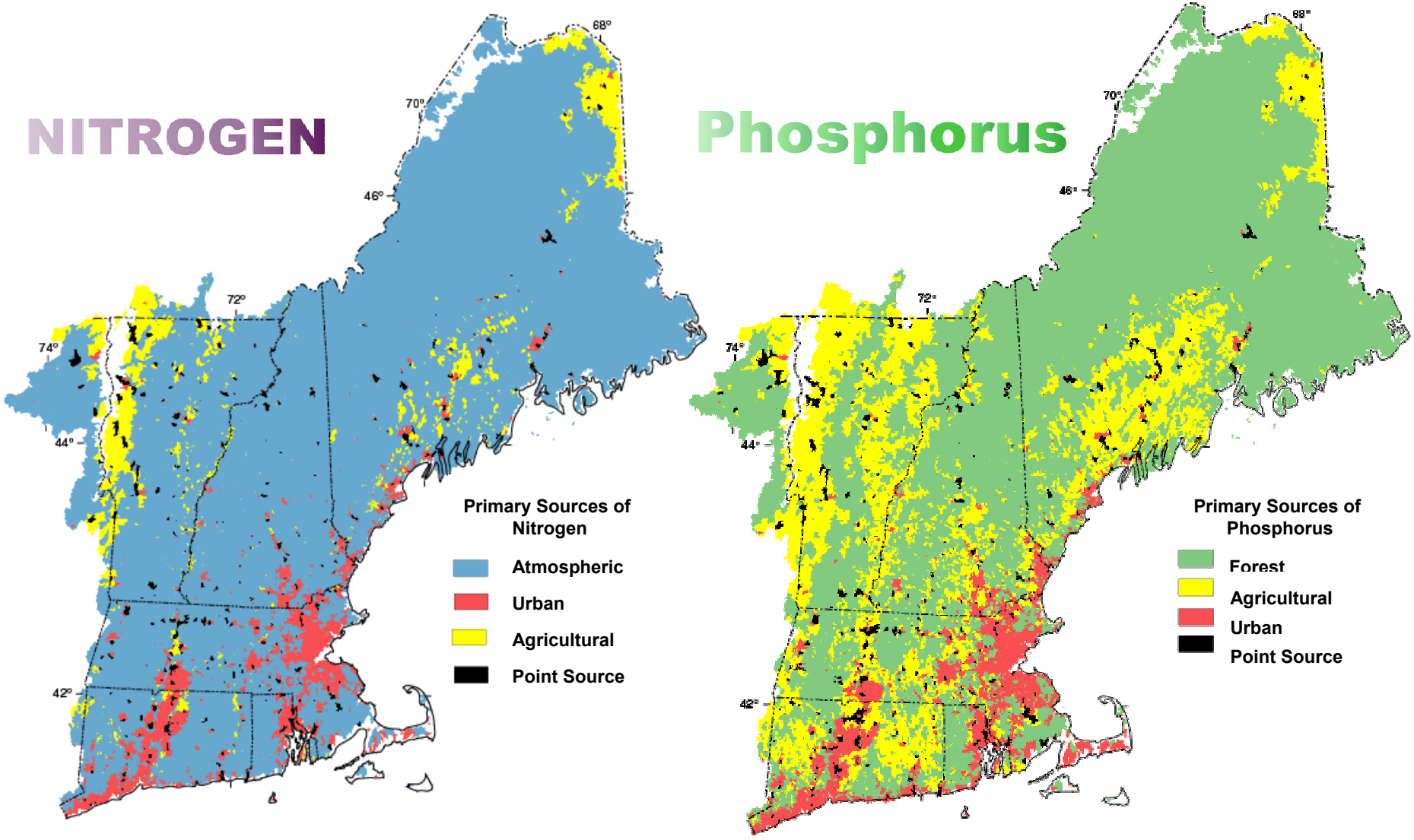
Model Strengths (cont.)

- *SPARROW has been recognized by the National Academy of Sciences and National Research Council as a suggested regional assessment tool, specifically for TMDLs*

Potential use of SPARROW data in designing a stream water-quality monitoring network

- SPARROW identifies sources

SPARROW Model Results:
Identifying Primary Sources of Nutrients

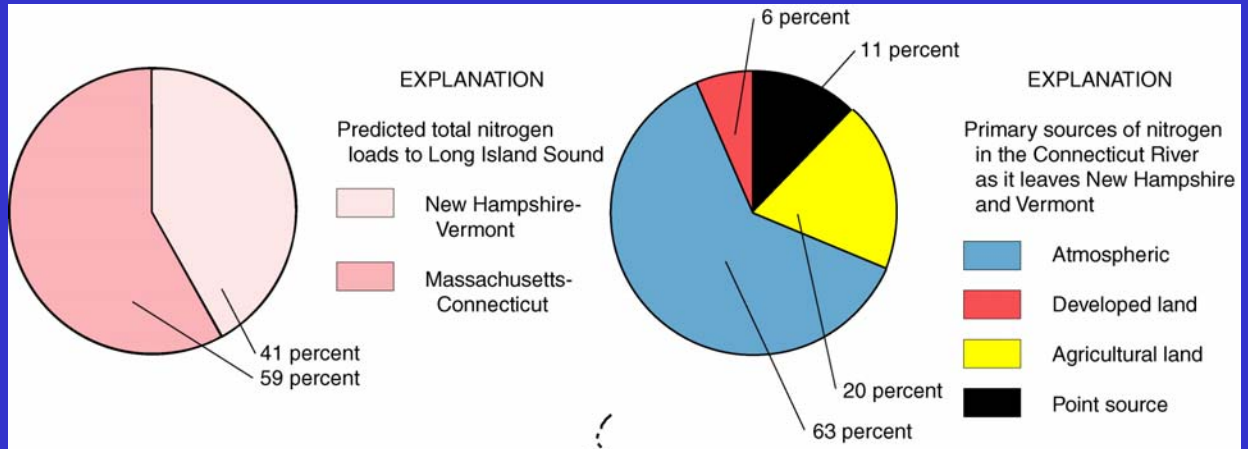


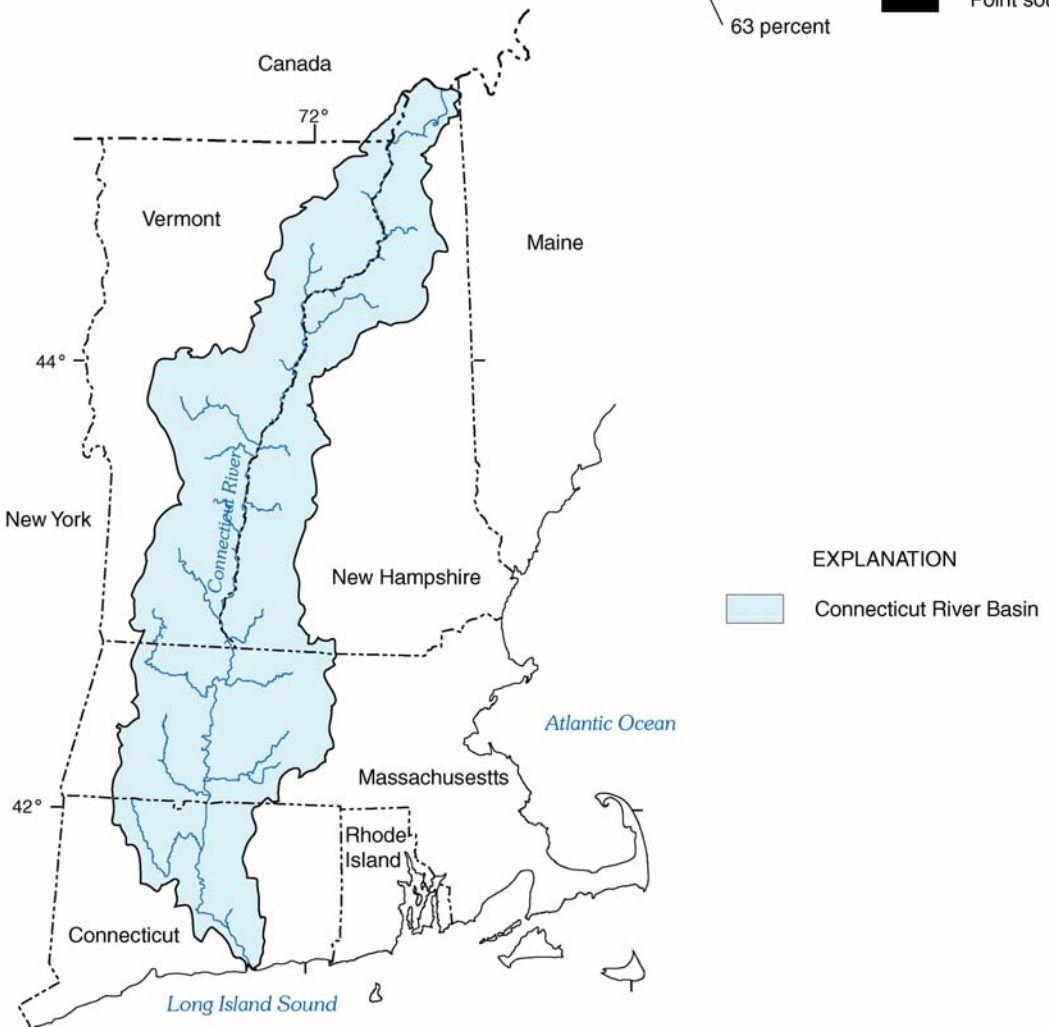
Potential use of SPARROW data in designing a stream water-quality monitoring network (cont.)

- Nutrient attenuation was identified as an important issue
- Data defining nitrogen loss from reservoirs is sparse (variable was not included in the model)

Utility of New England SPARROW Model Results for Nitrogen Loading Assessments

An Example from the Connecticut River Basin

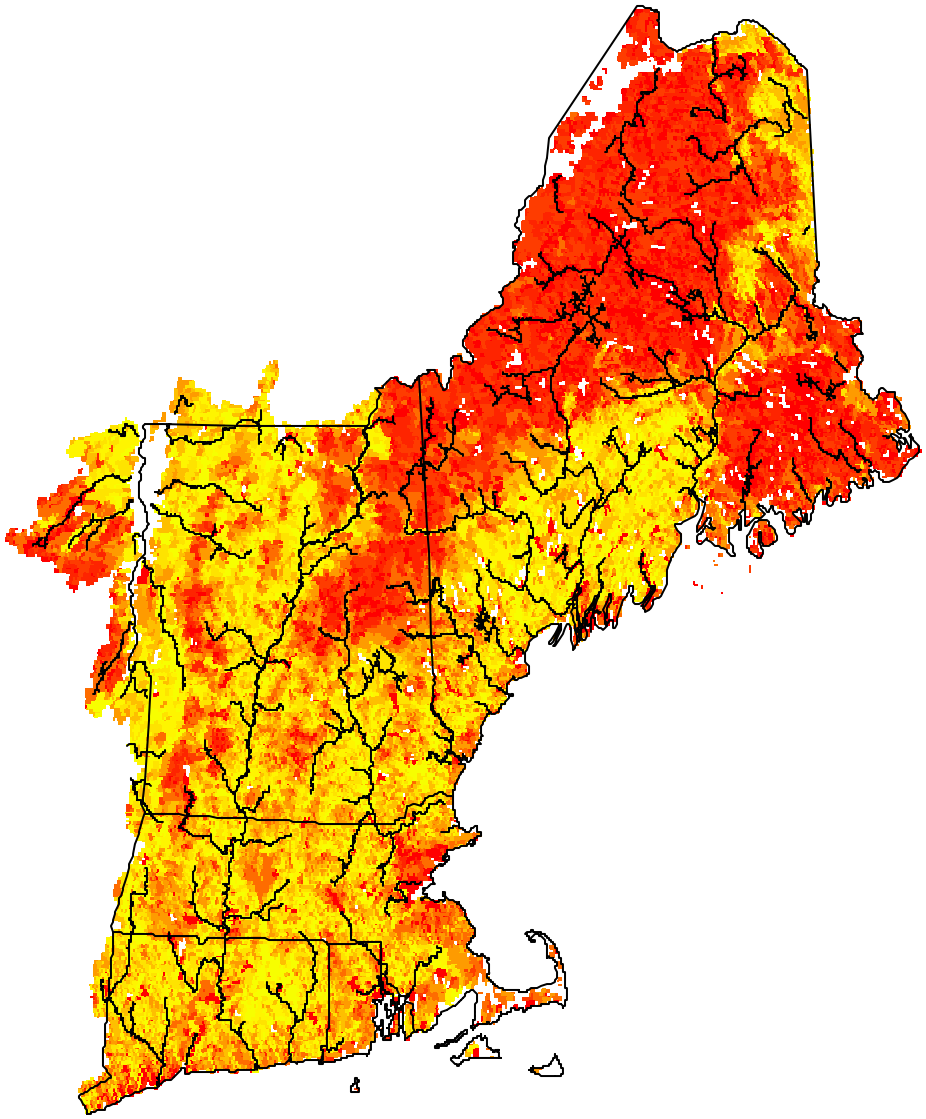




Potential use of SPARROW data in designing a stream water-quality monitoring network (cont.)

- SPARROW quantified estimates of uncertainty
- Results can be expressed in terms of probability of exceeding a specific mean-annual concentration

SPARROW phosphorus load percent error



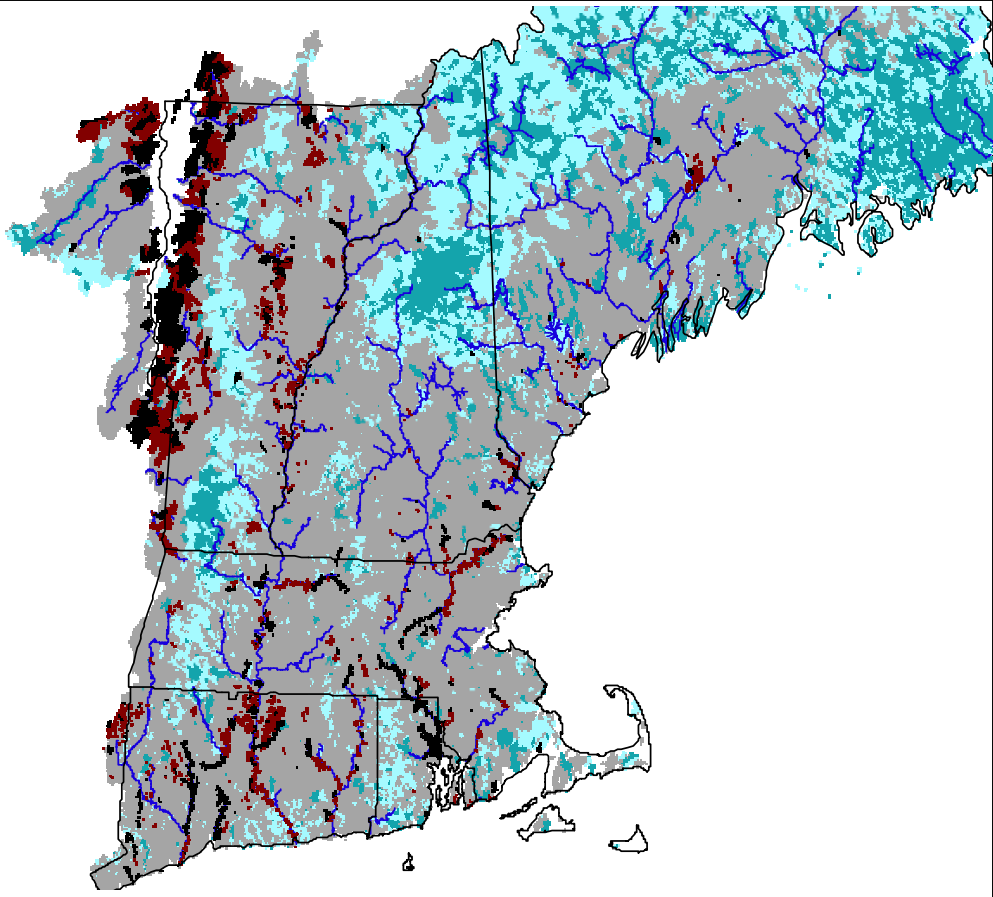
Percent error

- less than 45
- 45 - 46
- 47 - 48
- 49 - 50
- 51 - 53
- greater than 53

- rivers
- state borders

SPARROW

Probability of exceeding a specific mean-annual concentration



Probability of exceeding 0.05 mg/l Phosphorus

- less than 10 %
- 10 to 25 %
- 25 to 75 %
- 75 to 90 %
- Greater than 90 %

THE
END