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An Improved Understanding of Nitrogen and Phosphorus Delivery : Results from Refined Regional SPARROW Models

By
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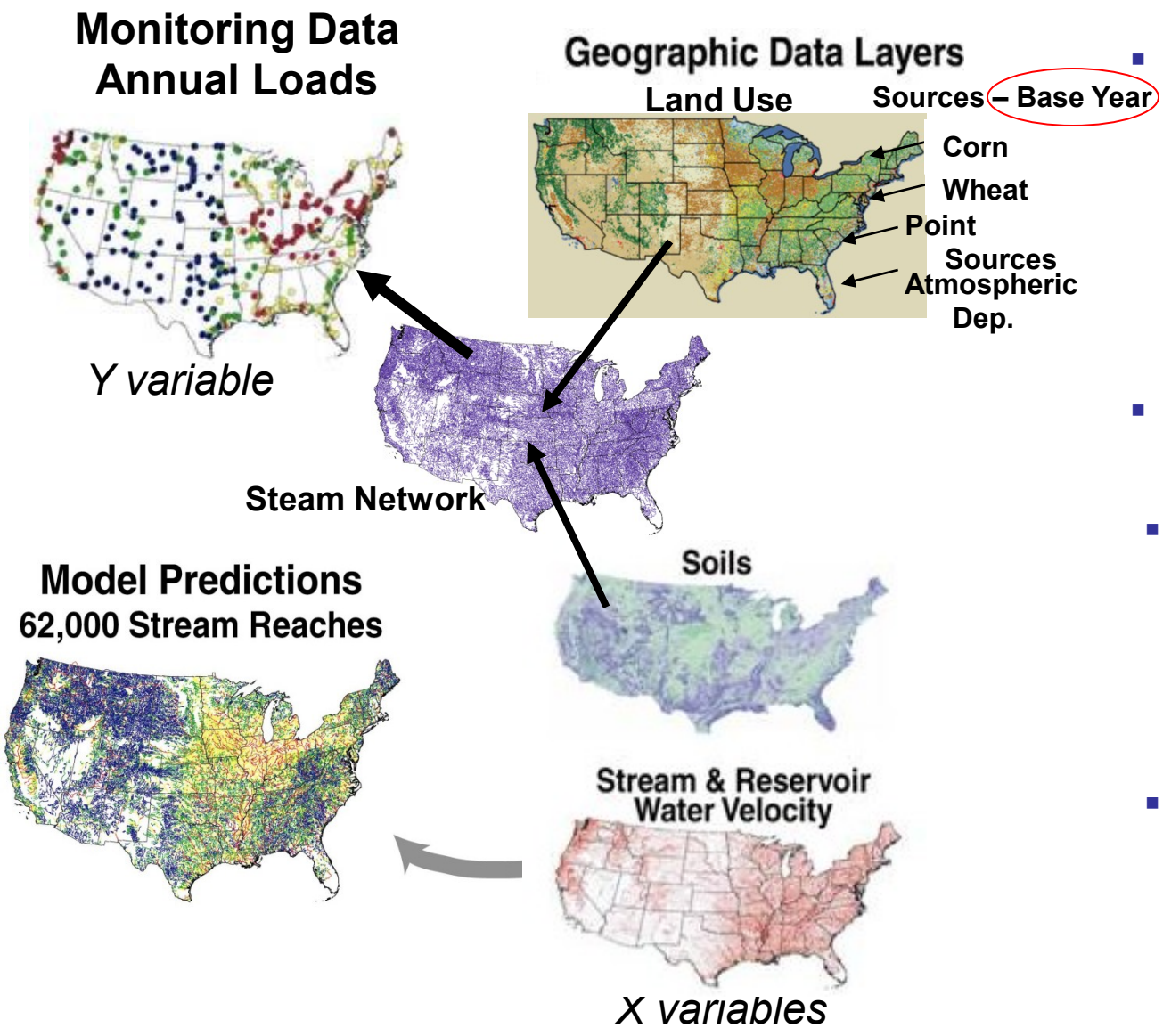
U.S. Department of the Interior
U.S. Geological Survey

Approach - SPARROW Water-Quality Model -

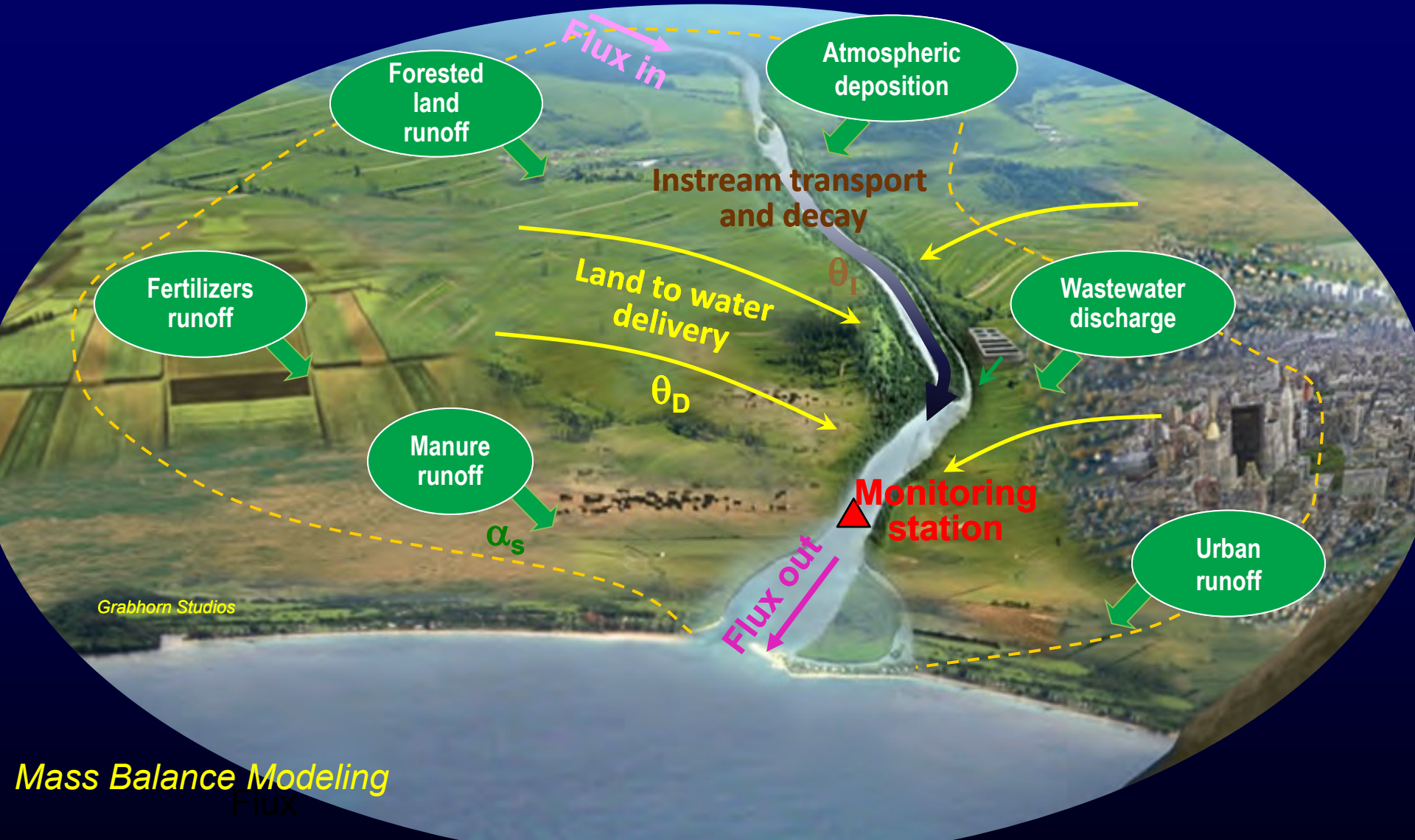
SPAtially Referenced Regression on Watershed Attributes

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



- Mass Balance Model with spatially variable deliveries. Hybrid statistical/ mechanistic process structure. Data-driven, nonlinear estimation of parameters
- Separates land and in-stream processes
- **Predictions of mean-annual flux reflect long-term, net effects of nutrient supply and loss processes in watersheds**
- Once calibrated, the model has physically interpretable coefficients; model supports hypothesis testing and uncertainty estimation

SPARROW: SPAtially Referenced Regression on Watershed Attributes Model

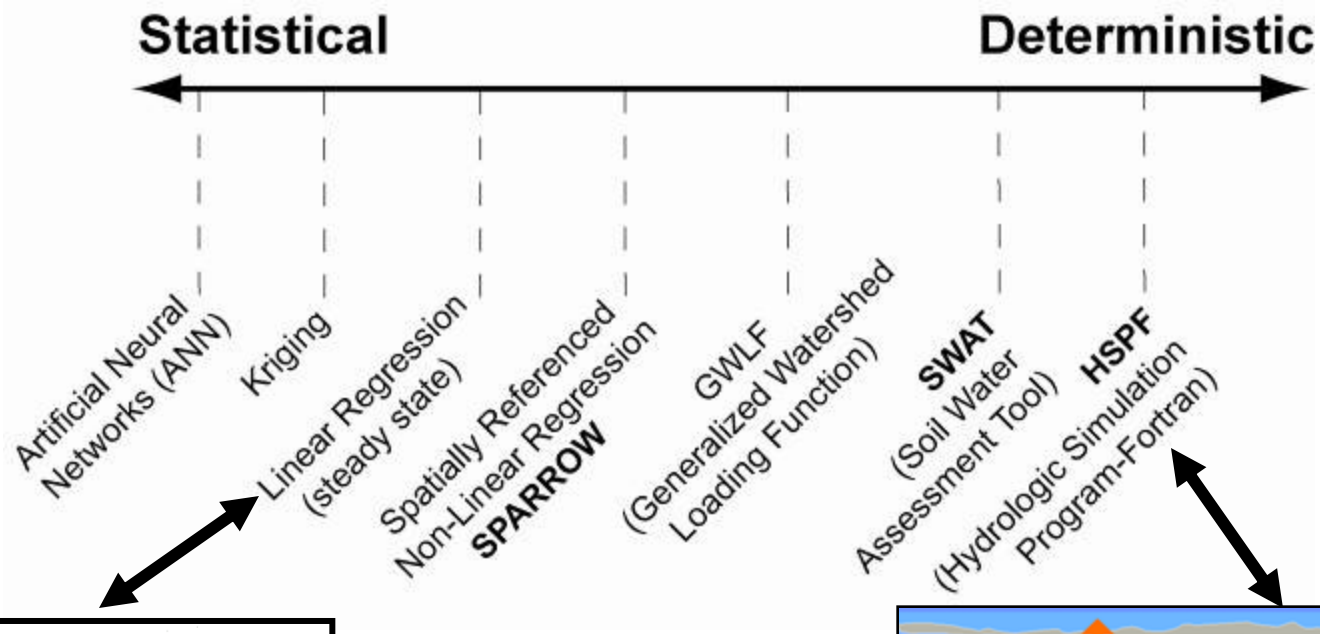


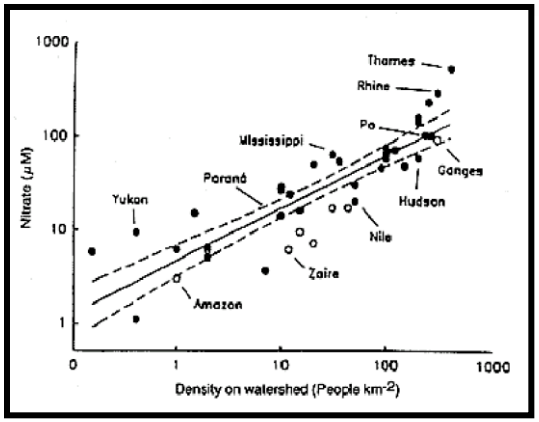
Mass Balance Modeling

Flux

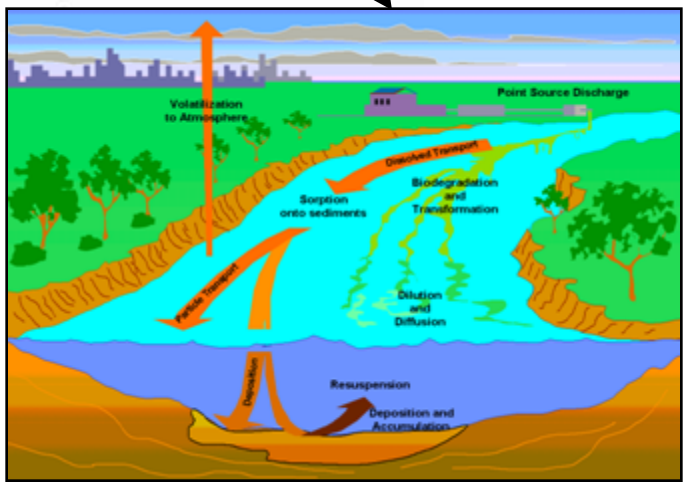
Target = Flux out = Flux in + (α_s Sources x θ_D Delivery) – θ_I Instream Decay

Watershed Modeling Continuum





Cole et al. 1997



SWAT Users Manual

Regional Models part of the NAWQA Program

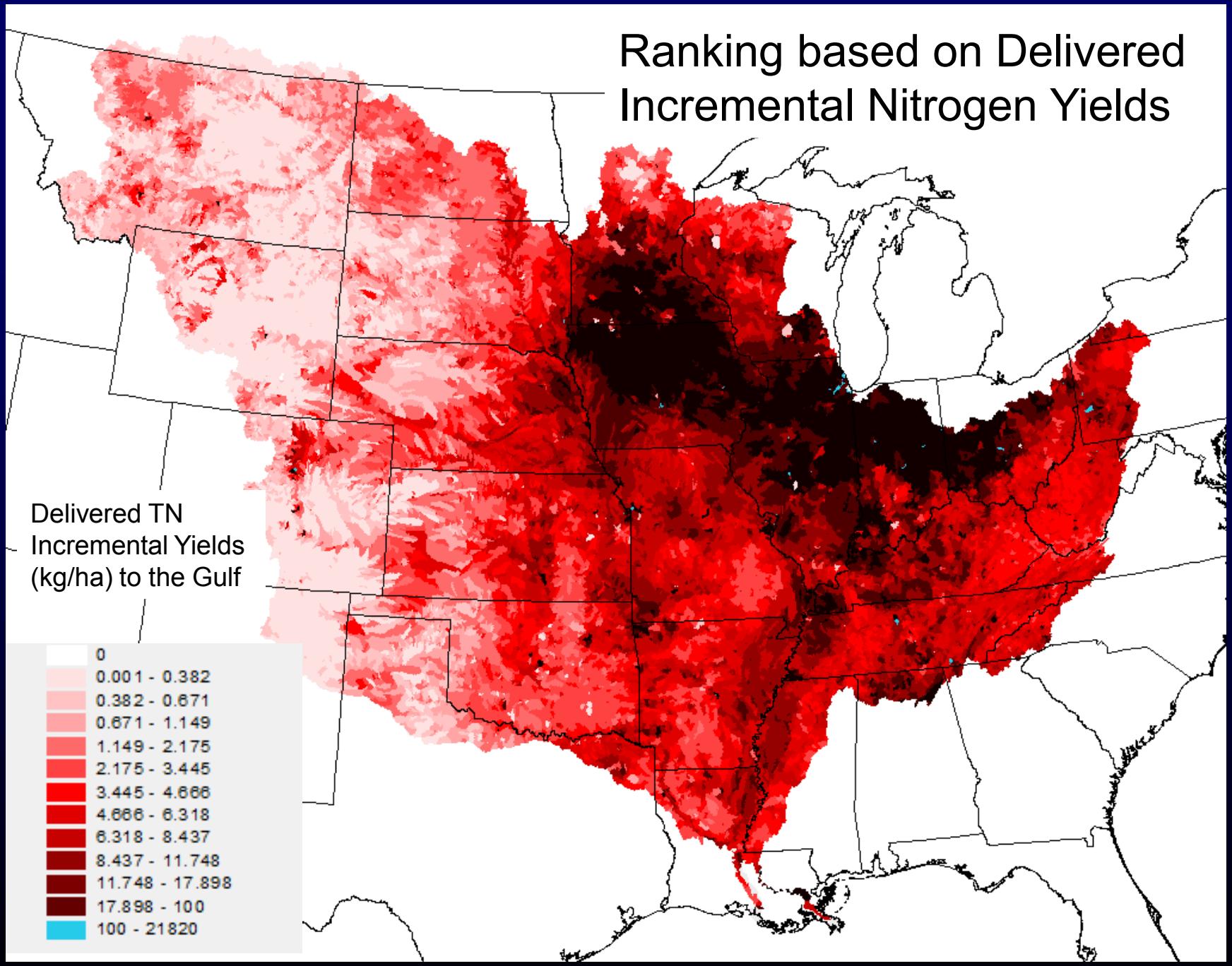
2002 SPARROW Models

MRB SPARROW
Lead Scientists
Coordinator – Steve Preston

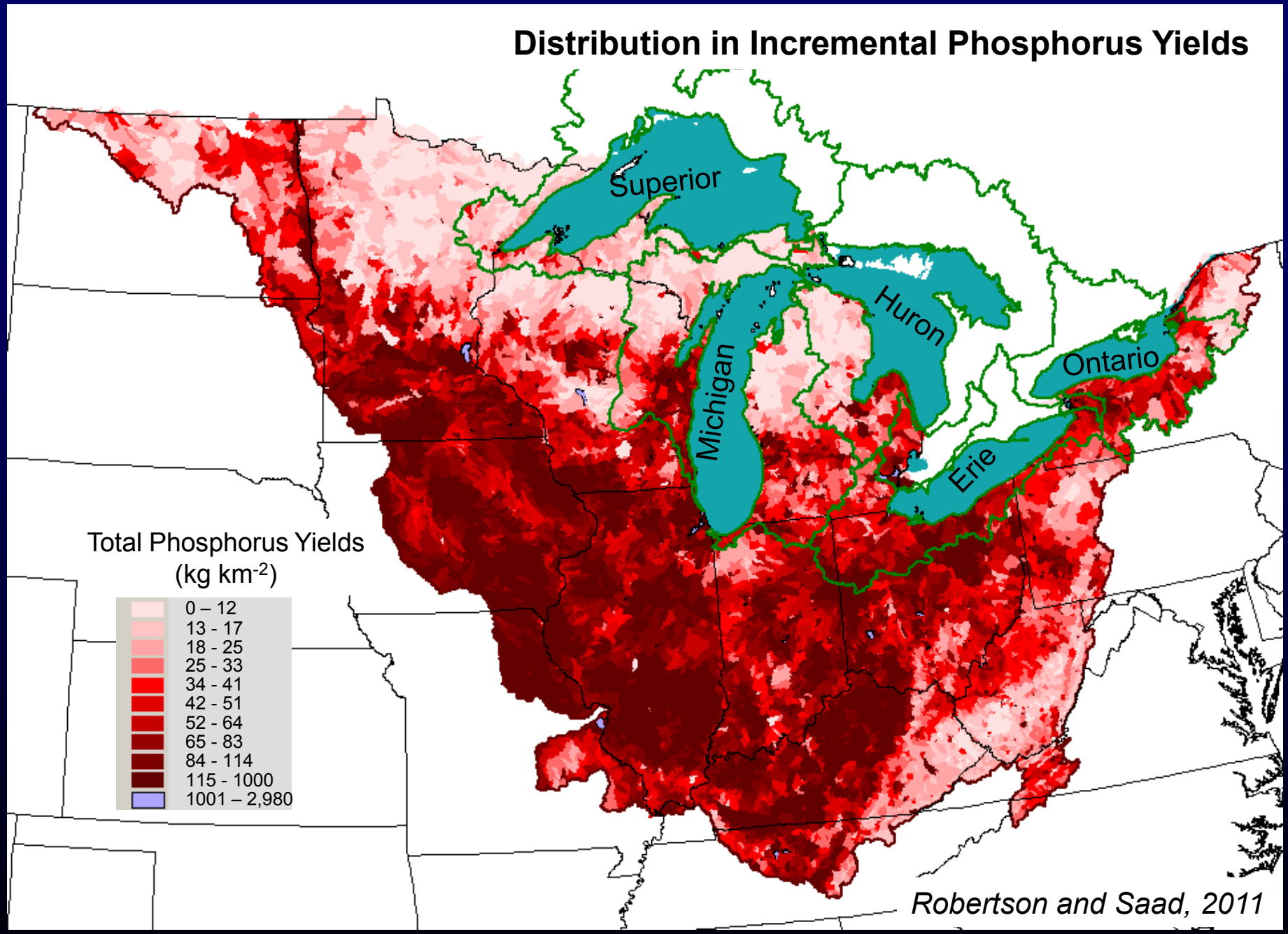
Robertson & Saad, WI

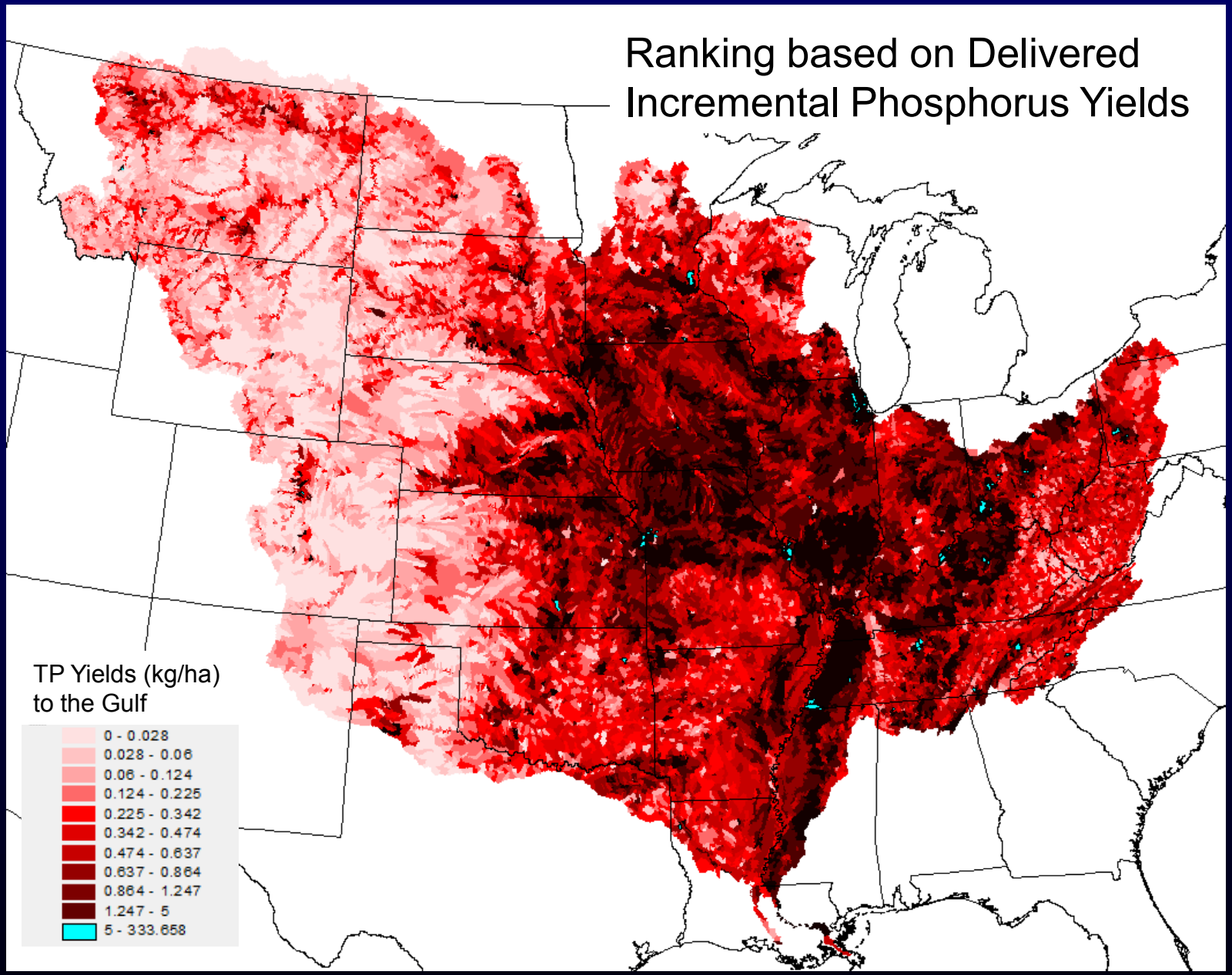
All Published in 2011 in JAWRA

Ranking based on Delivered Incremental Nitrogen Yields



Distribution in Incremental Phosphorus Yields

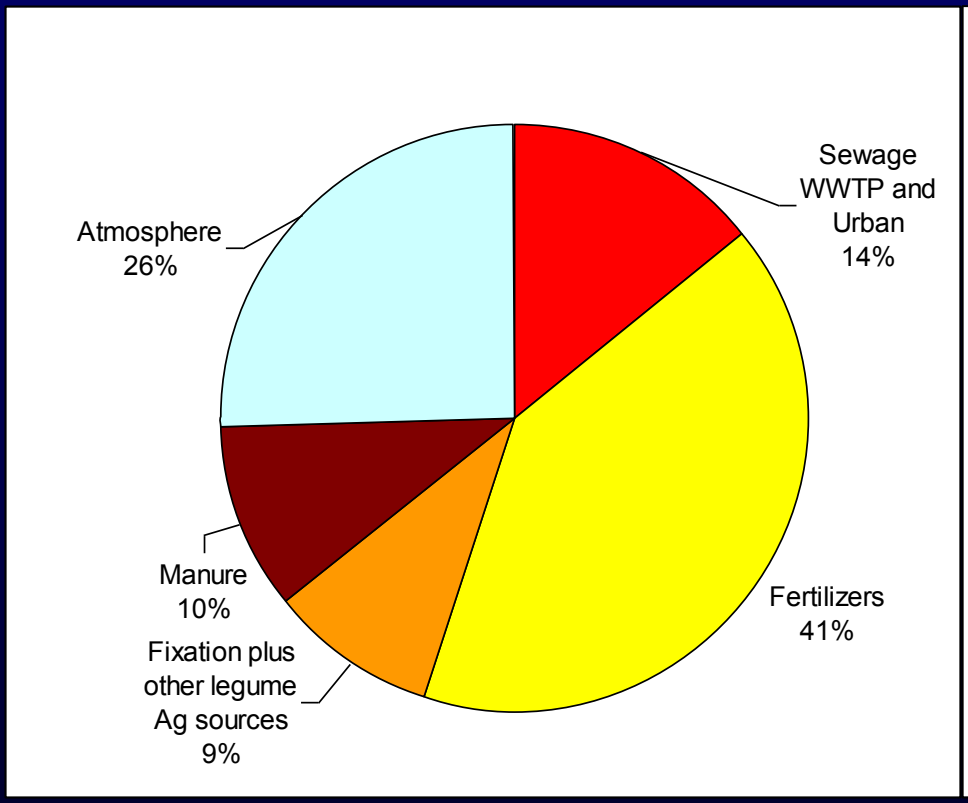




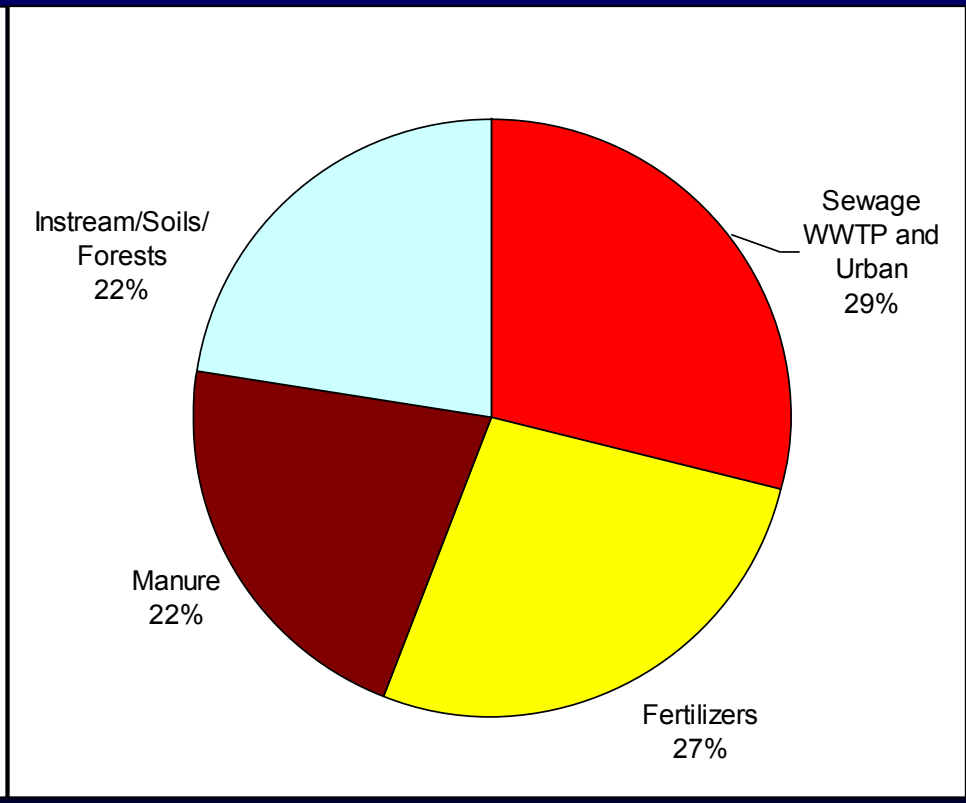
Robertson and Saad, 2013

Sources of Nutrients to the Gulf of Mexico

Total Nitrogen



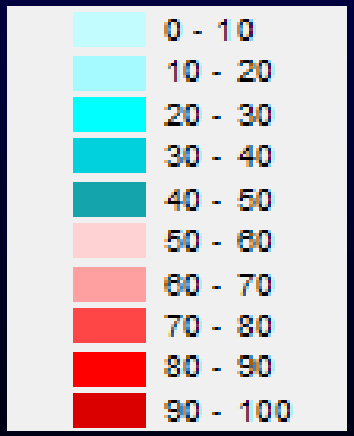
Total Phosphorus

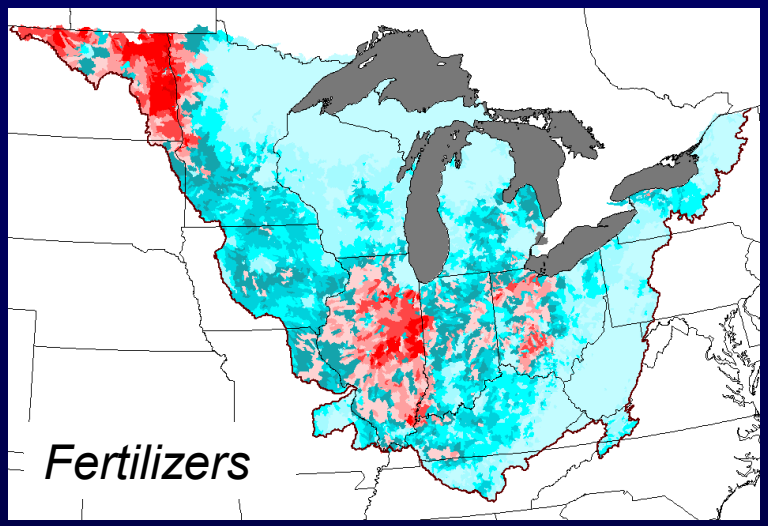


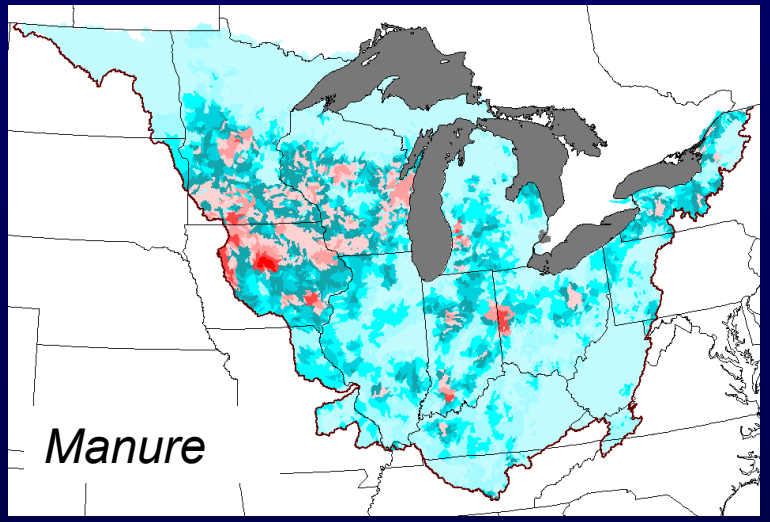
Robertson and Saad, 2013

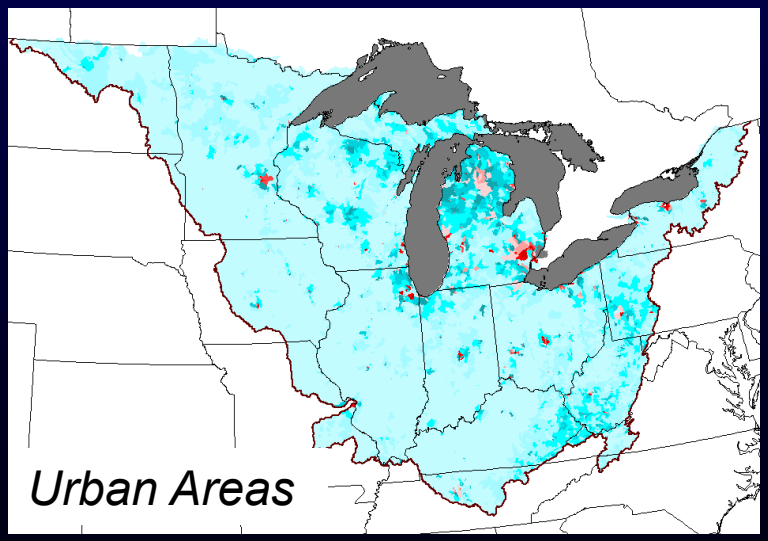
Relative Importance of Various Phosphorus Sources – Spatially Explicit

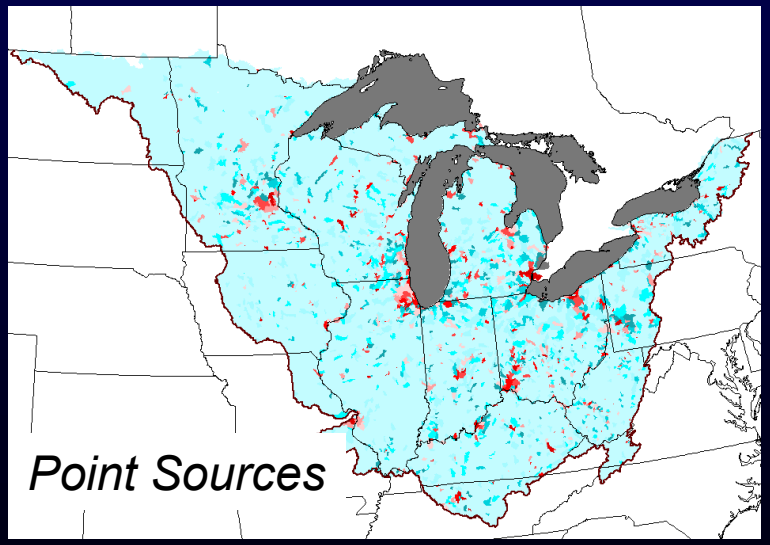
Percent of Source to Total Incremental Load







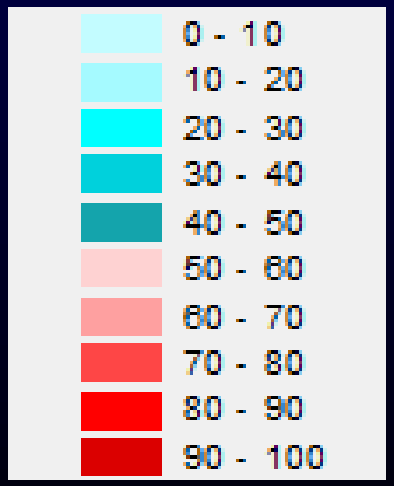




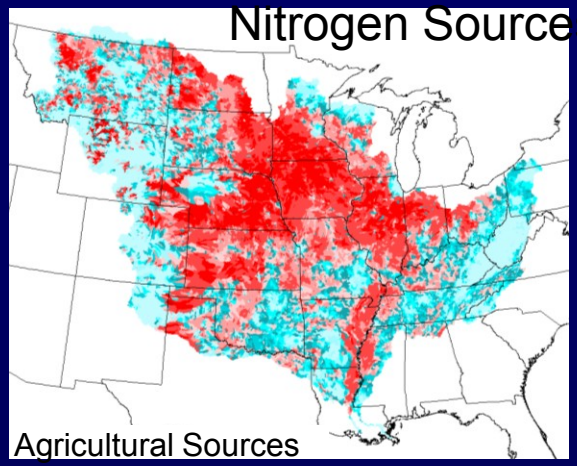
Robertson and Saad, 2011

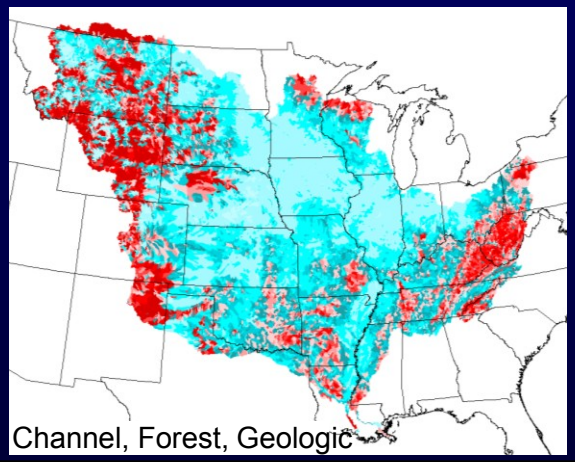
Sources of Nutrients Throughout the MARB

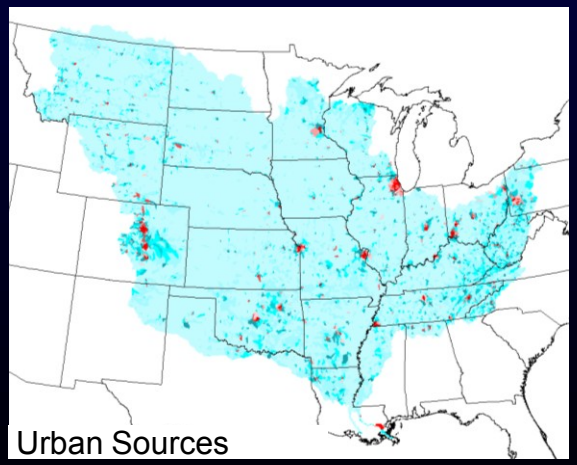
Percent of Source to Total Incremental Load



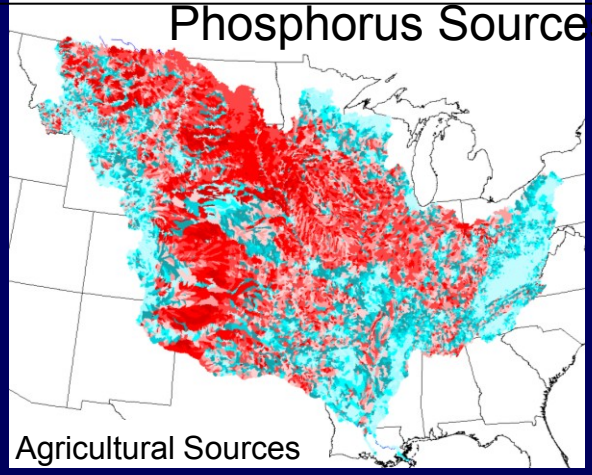
Nitrogen Sources

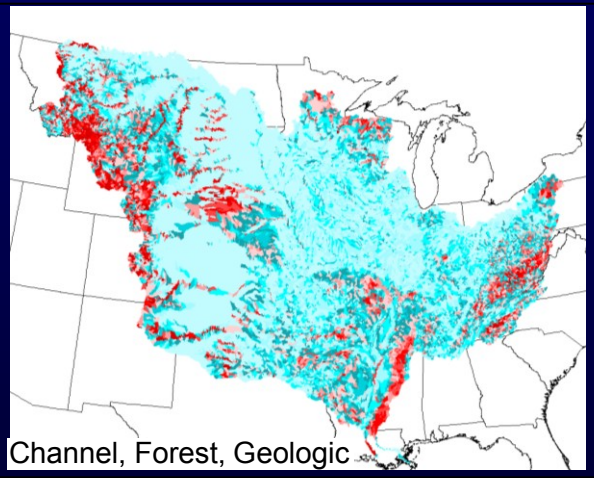


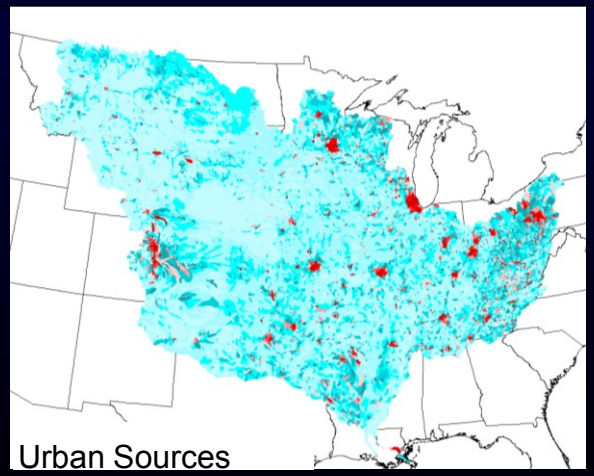




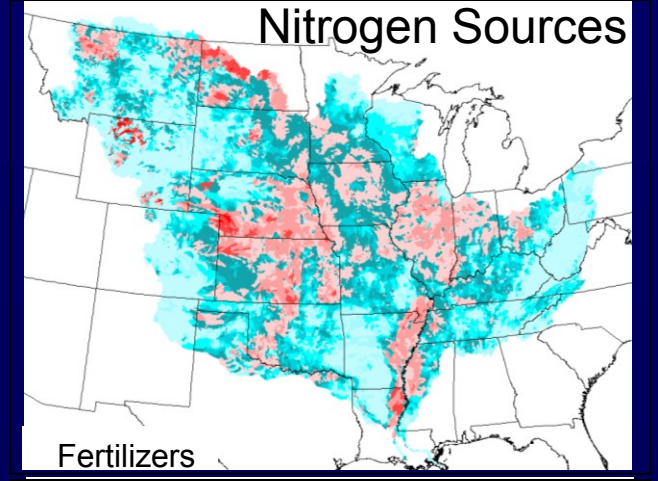
Phosphorus Sources

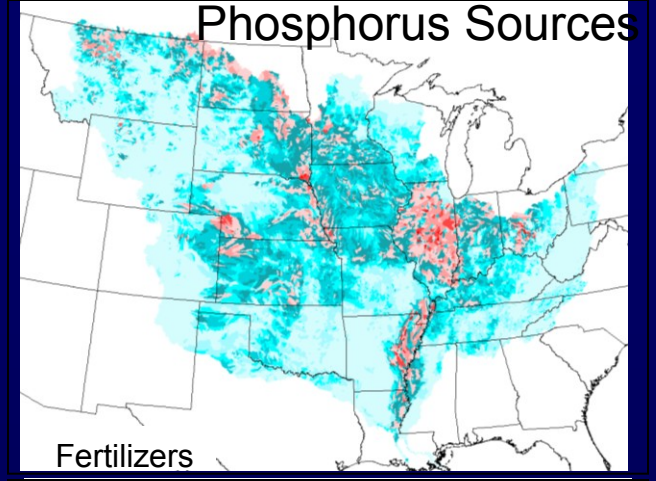


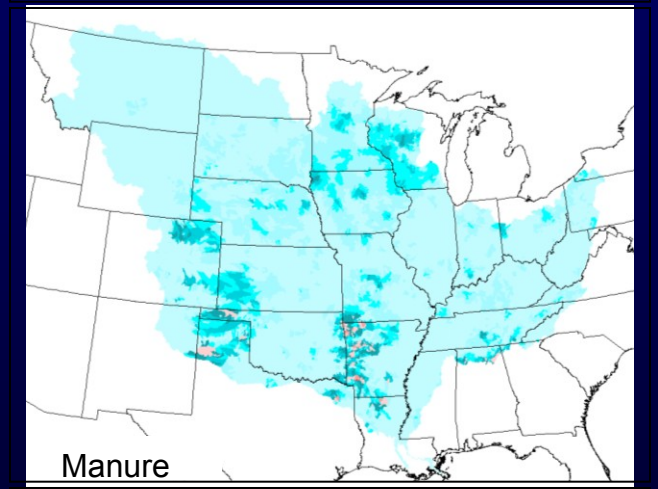


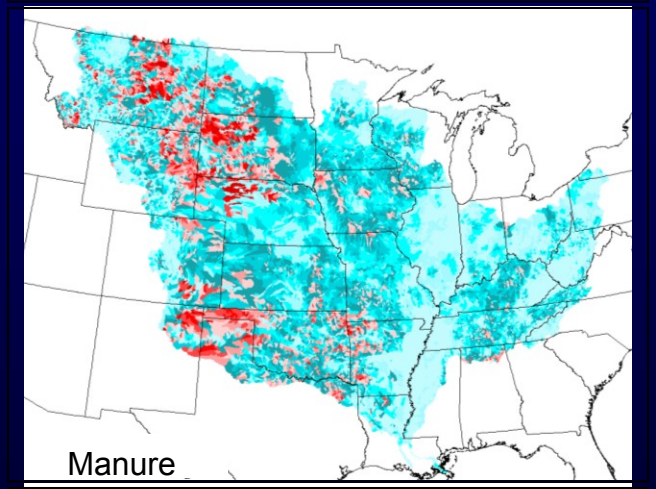


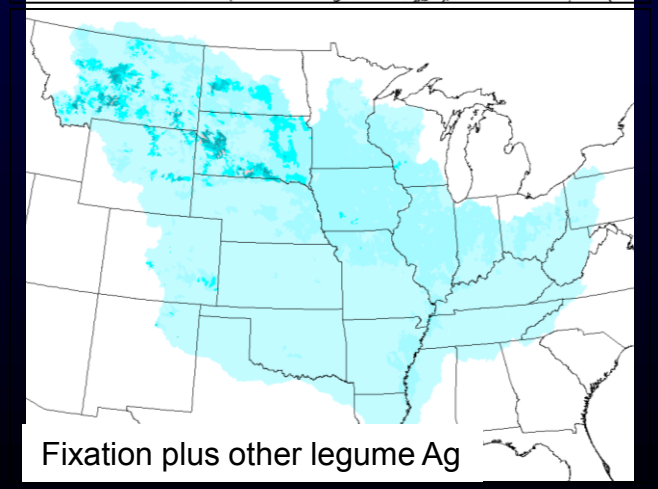
Agricultural Sources Throughout the MARB

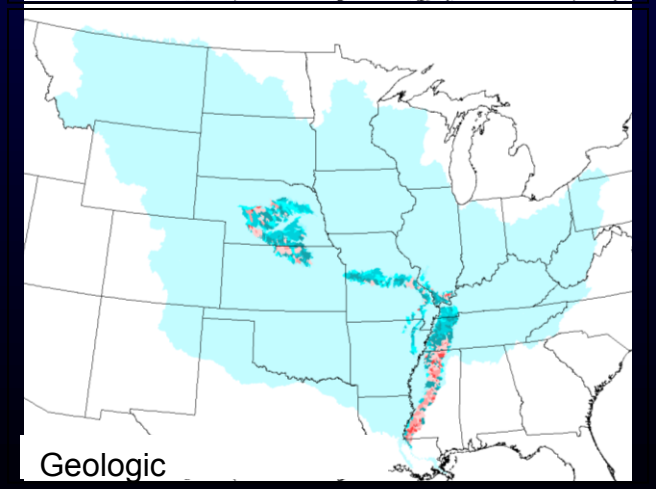




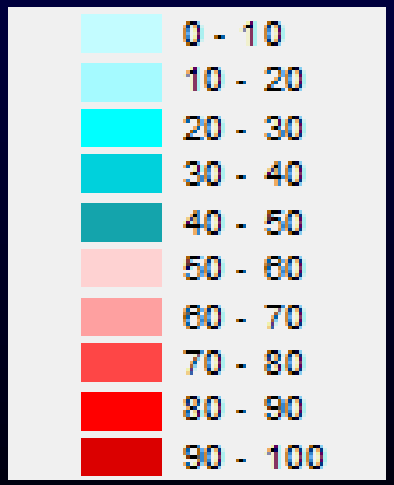




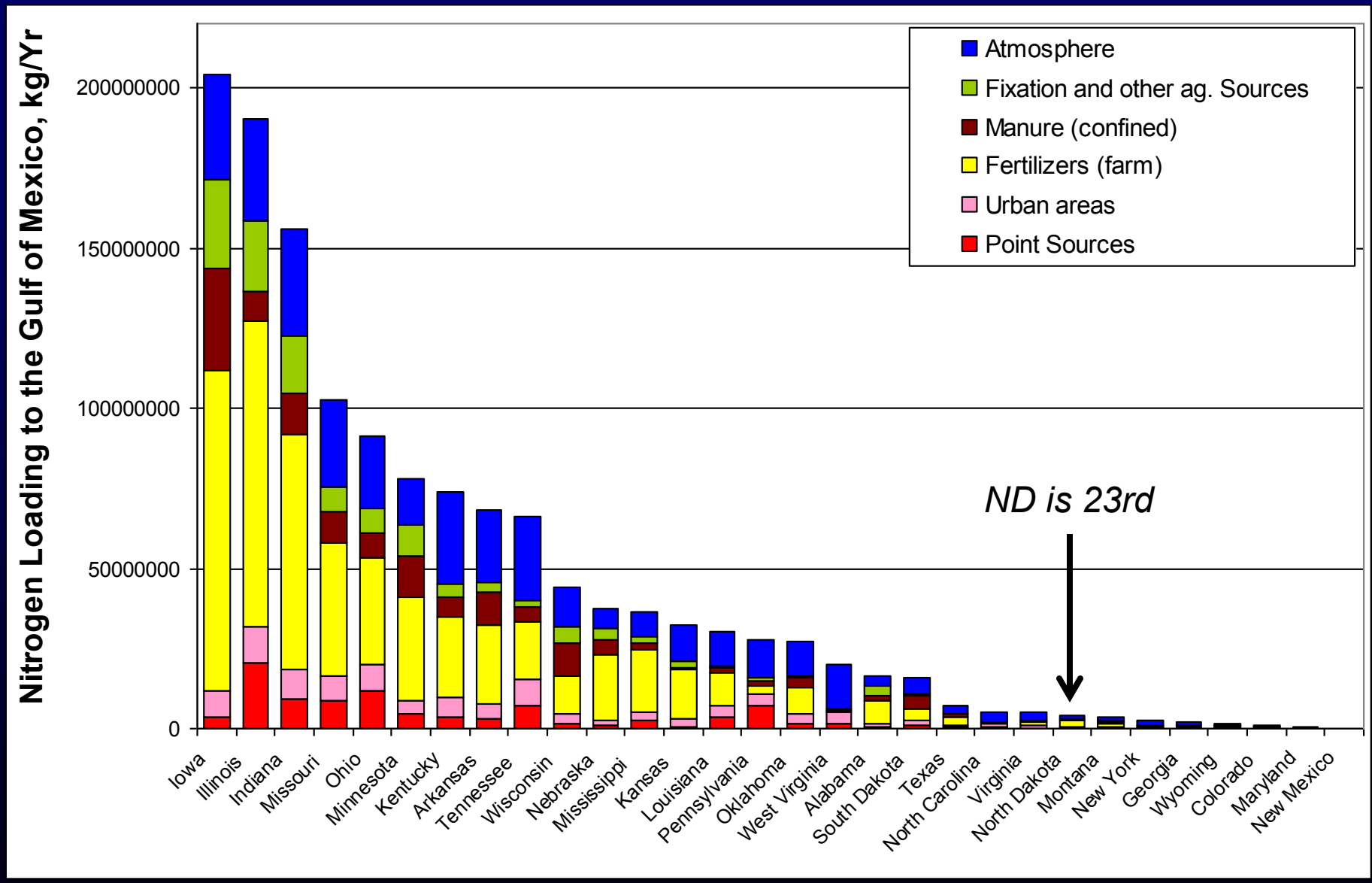




Percent of Source to Total Incremental Load

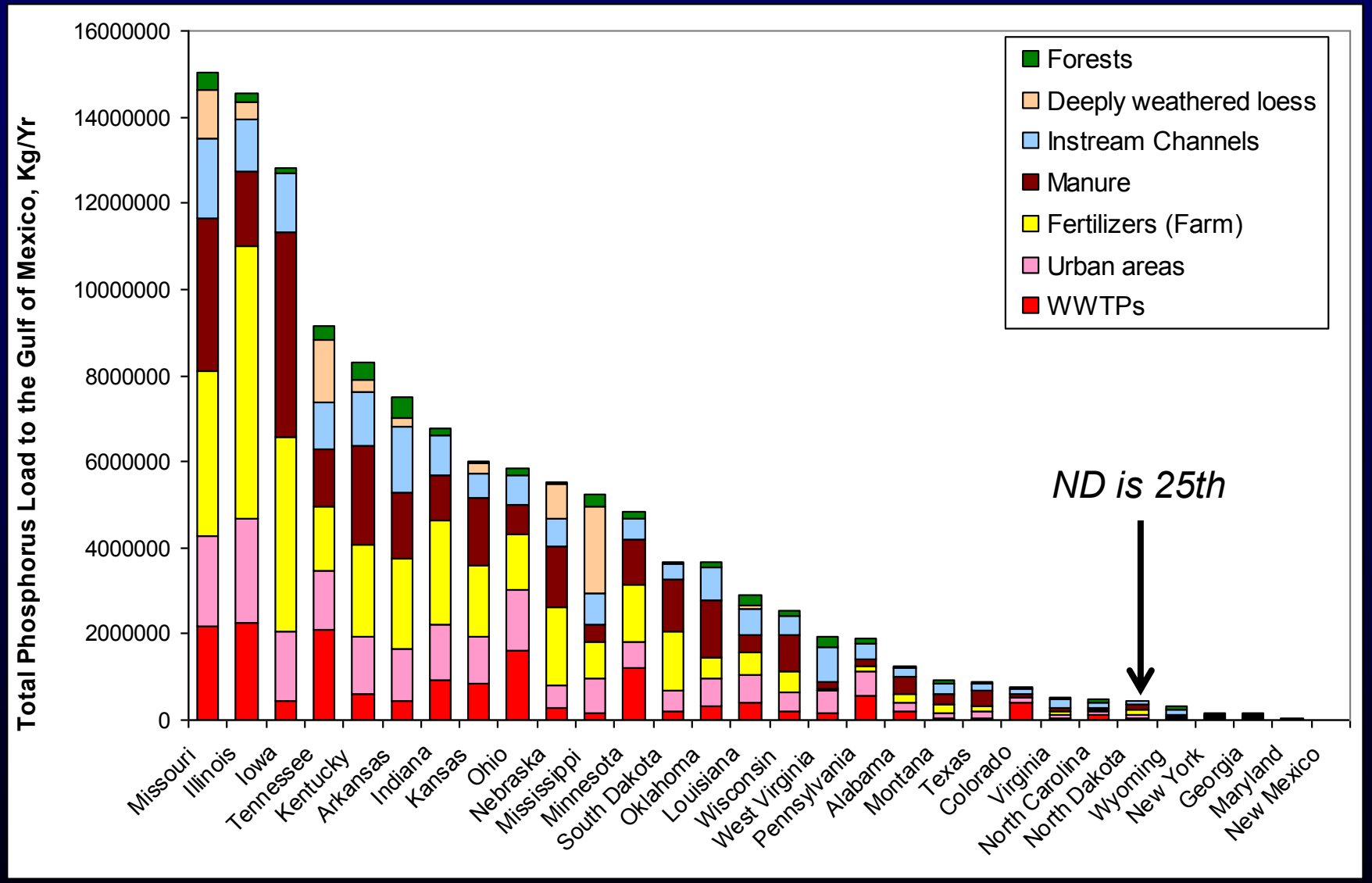


Ranking of State Contributions to the Gulf of Mexico from the MARB



Robertson et al., 2014

Ranking of State Contributions to the Gulf of Mexico from the MARB



Robertson et al., 2014

Methods to demonstrate results and help guide decisions > Nutrient Reduction Strategies

1. ***SPARROW Mapper –***

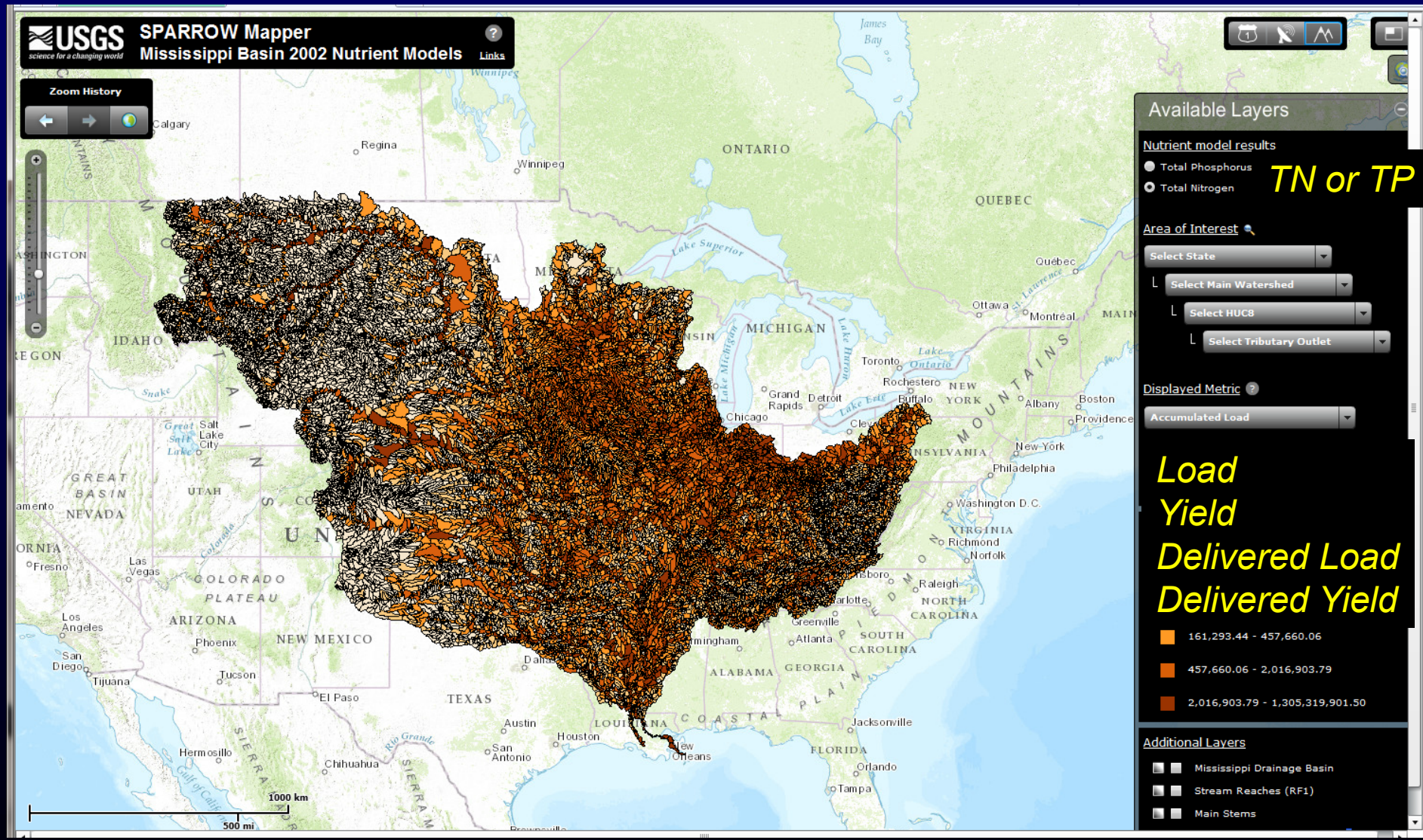
   Easy and simple way to get SPARROW results, especially by hydrologic and political boundaries.

http://wim.usgs.gov/SparrowMRB3/SparrowMRB3Mapper.html#

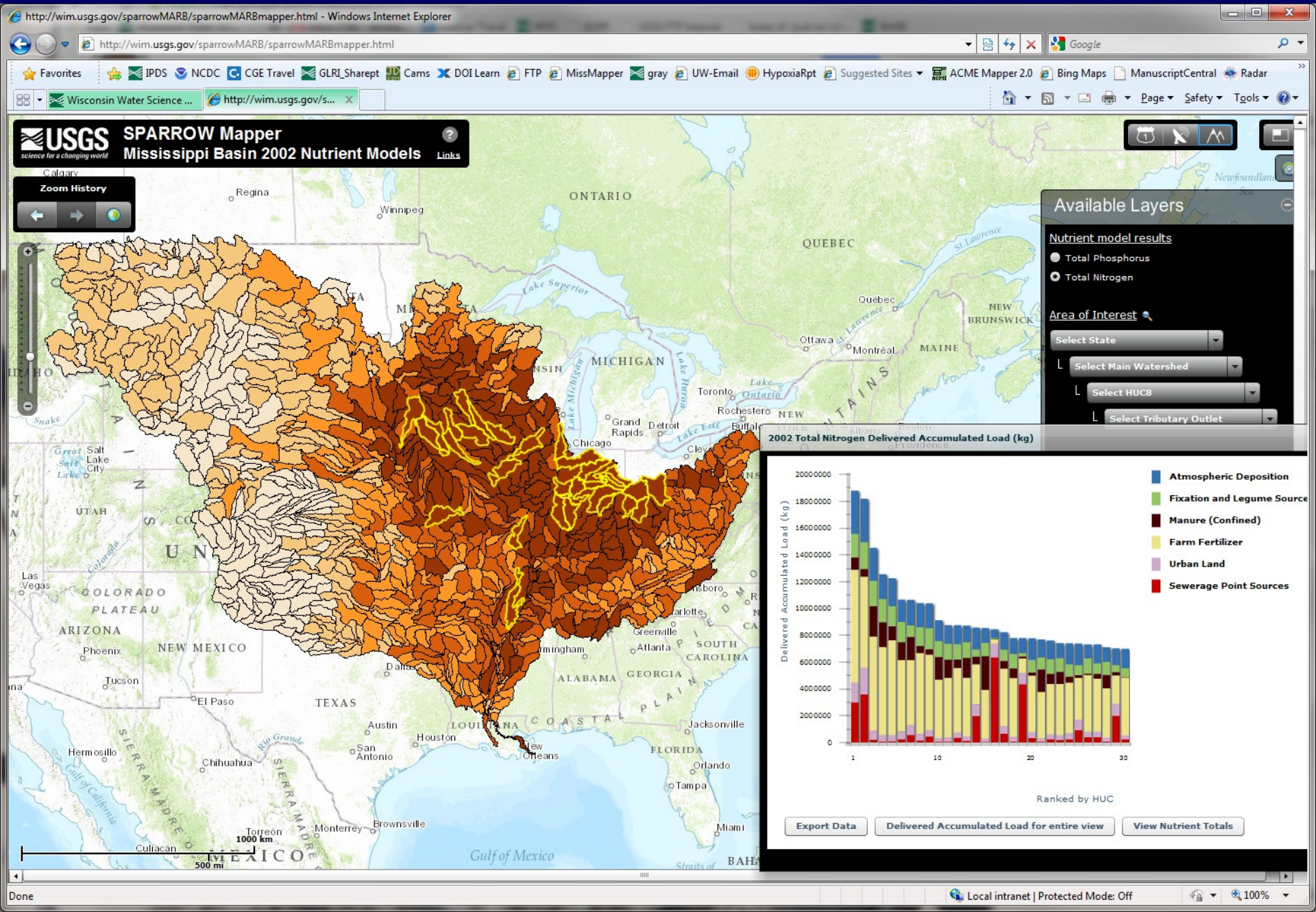
http://wim.usgs.gov/SparrowGL/SparrowGLMapper.html#

http://wim.usgs.gov/SparrowMARB/SparrowMARBMapper.html#

Mississippi/Atchafalaya River Basin (MARB) SPARROW MAPPER



MARB SPARROW MAPPER



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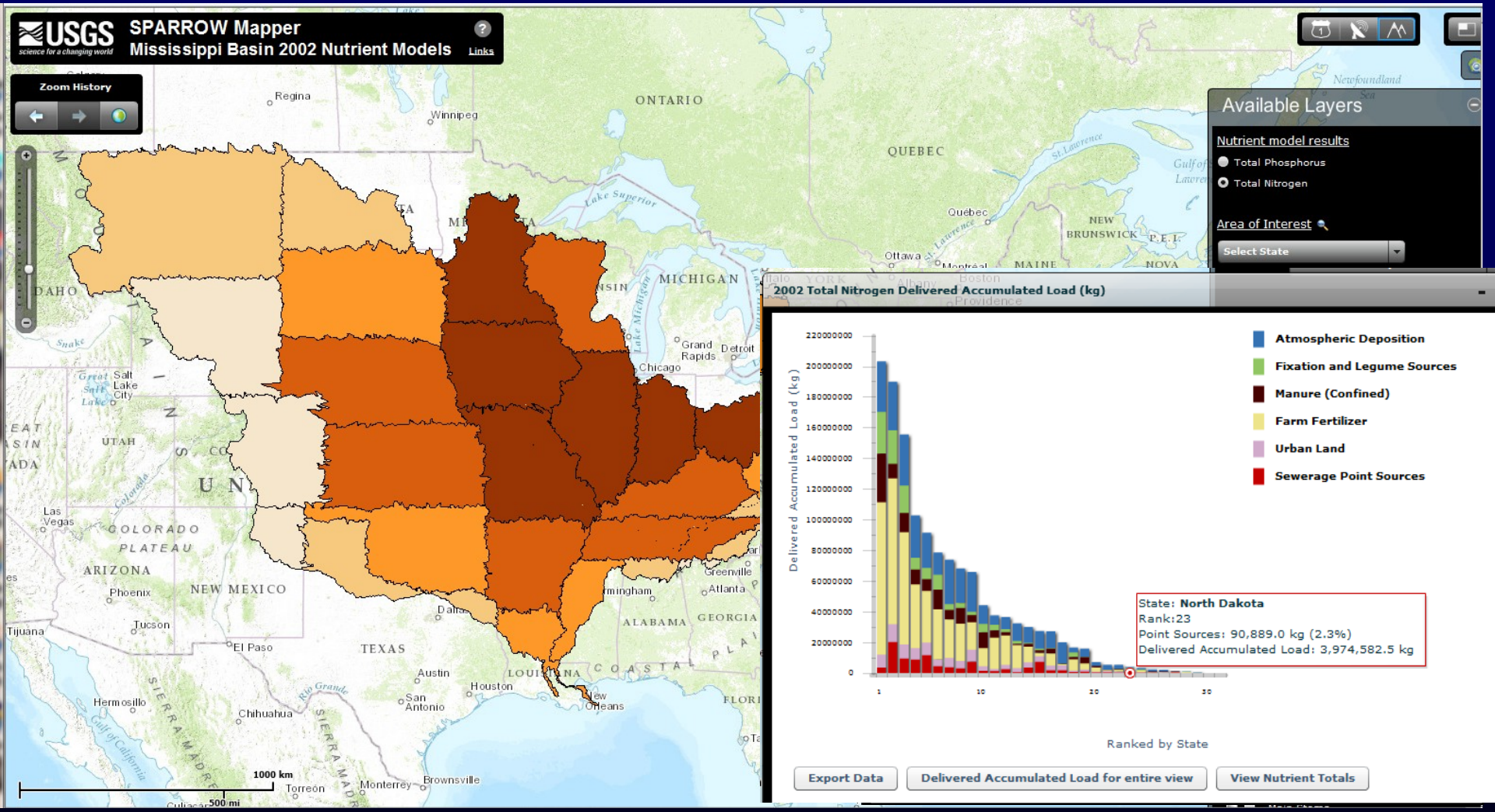
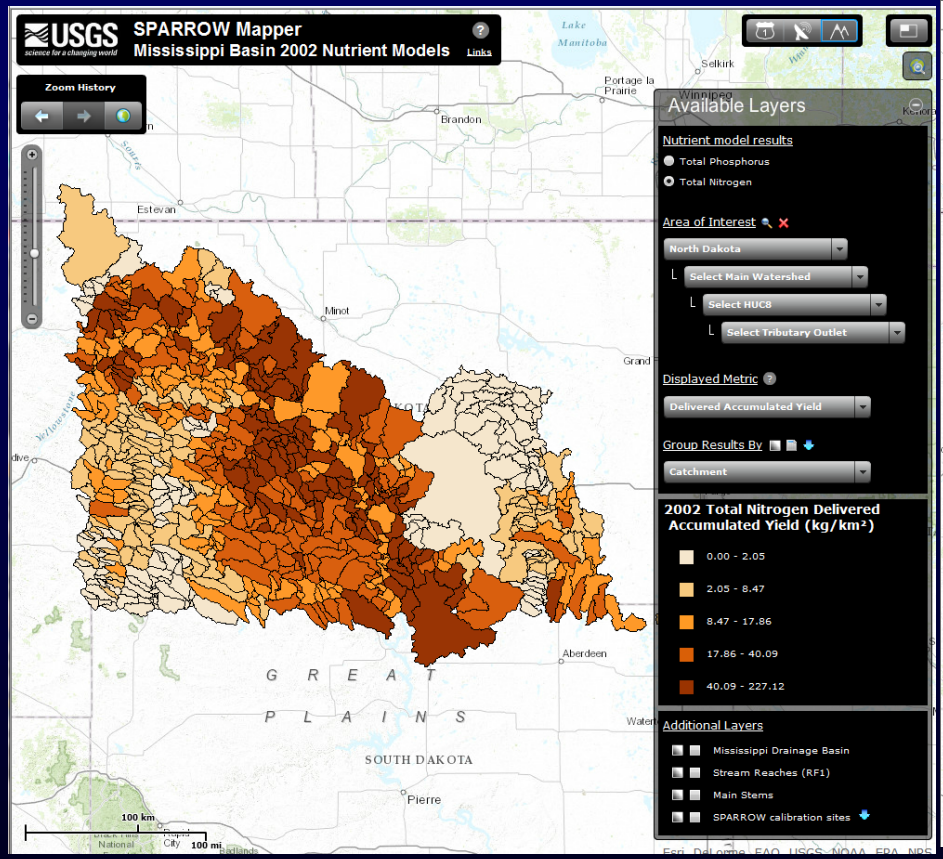
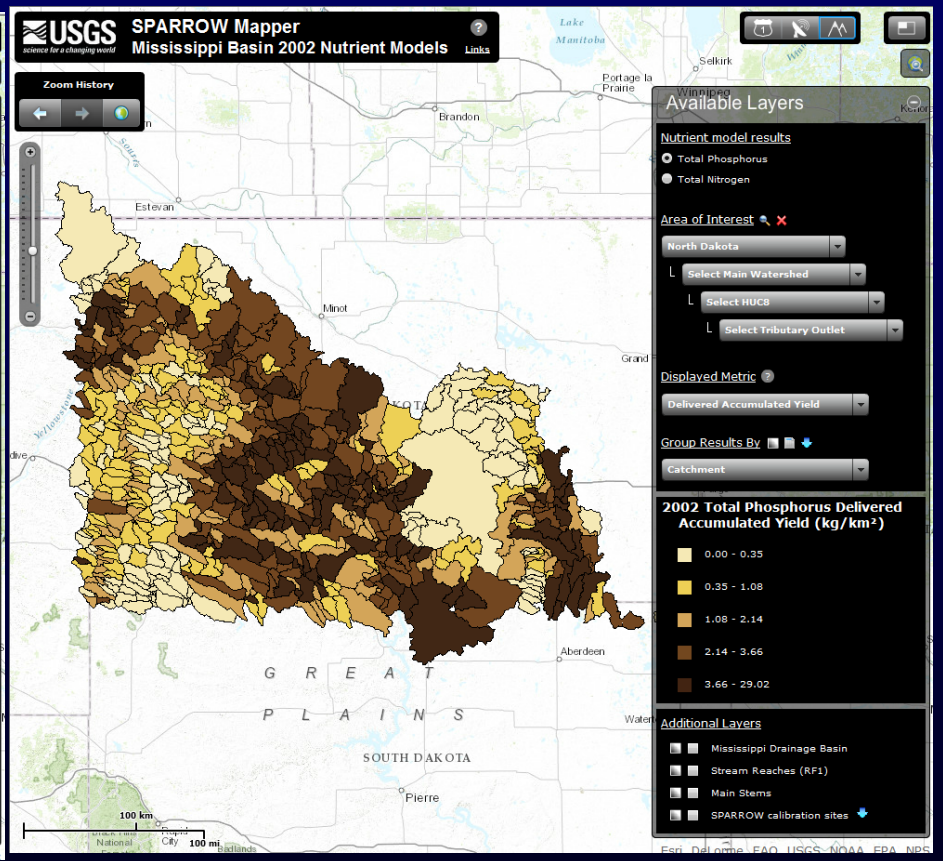
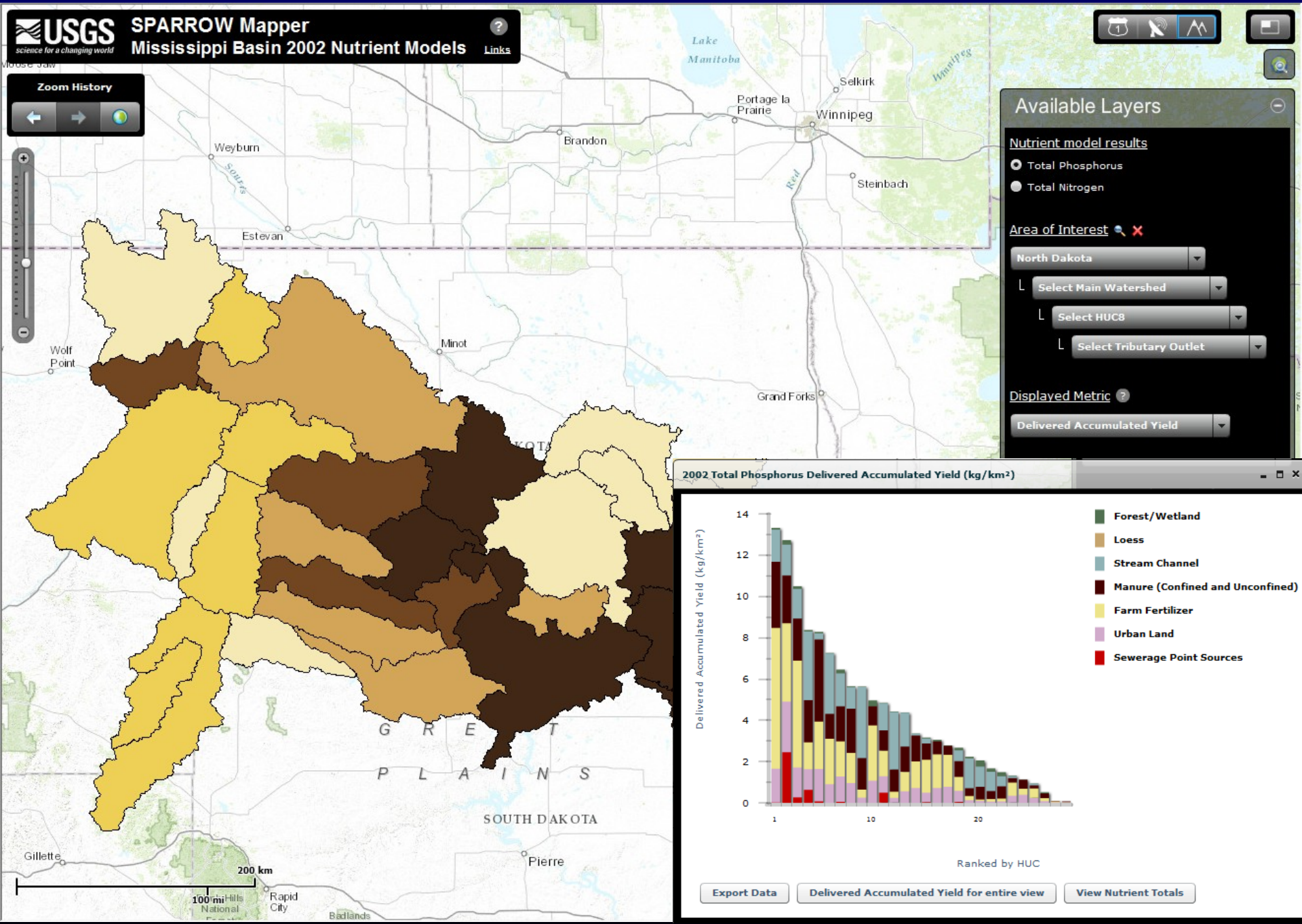


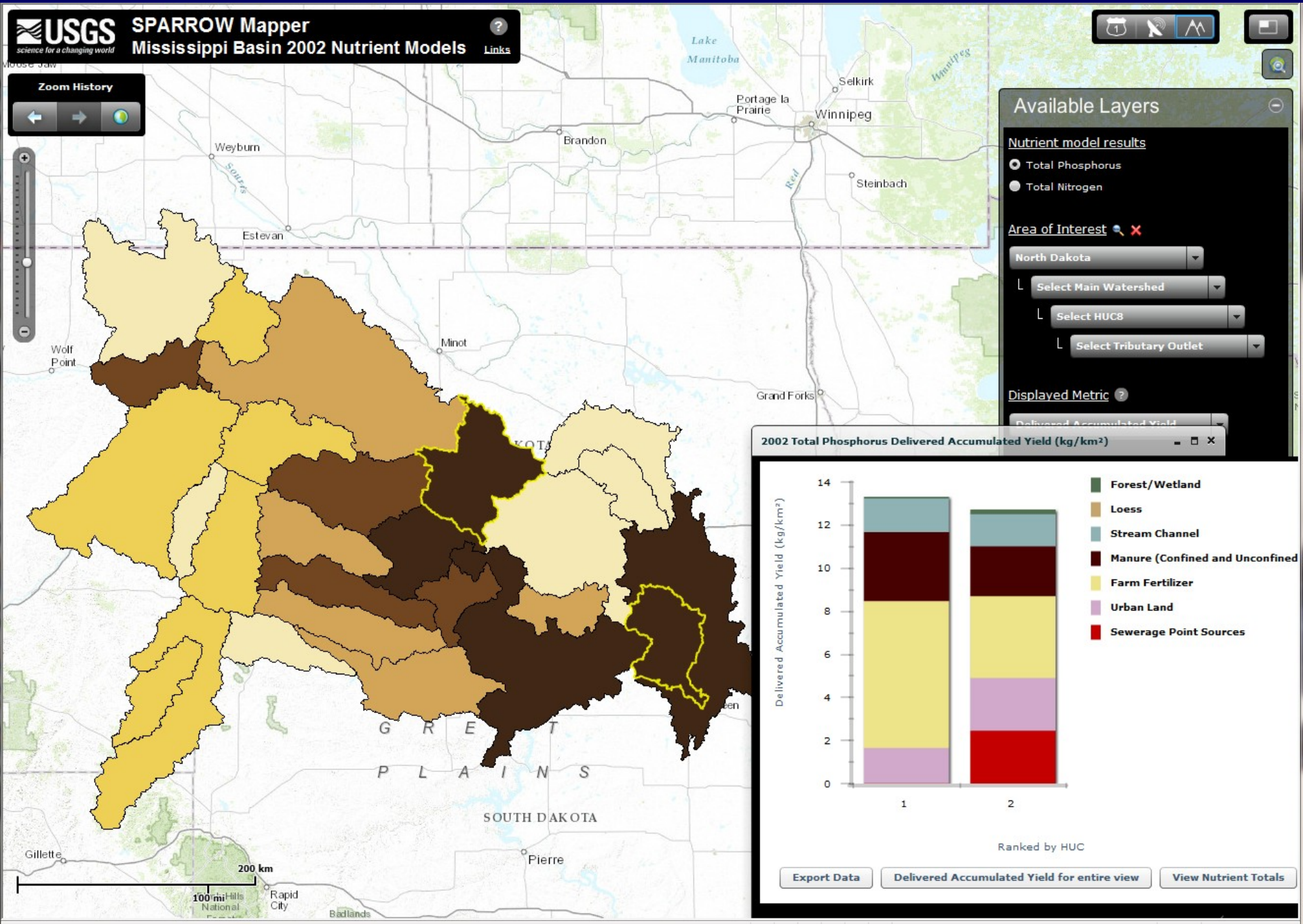
Total Nitrogen



Total Phosphorus




USGS
science for a changing world
SPARROW Mapper
Mississippi Basin 2002 Nutrient Models
Links
Zoom History
Available Layers
Nutrient model results
Total Phosphorus
Total Nitrogen
Area of Interest
North Dakota
Select Main Watershed
Select HUC8
Select Tributary Outlet
Displayed Metric
Delivered Accumulated Yield
2002 Total Phosphorus Delivered Accumulated Yield (kg/km²)
Delivered Accumulated Yield (kg/km²)
Ranked by HUC
Forest/Wetland
Loess
Stream Channel
Manure (Confined and Unconfined)
Farm Fertilizer
Urban Land
Sewerage Point Sources
Export Data
Delivered Accumulated Yield for entire view
View Nutrient Totals
Lake Manitoba
Winnipeg
Selkirk
Portage la Prairie
Brandon
Weyburn
Estevan
Steinbach
Minot
Wolf Point
Grand Forks
GREAT PLAINS
SOUTH DAKOTA
Gillette
Pierre
Rapid City
Badlands
200 km
100 mi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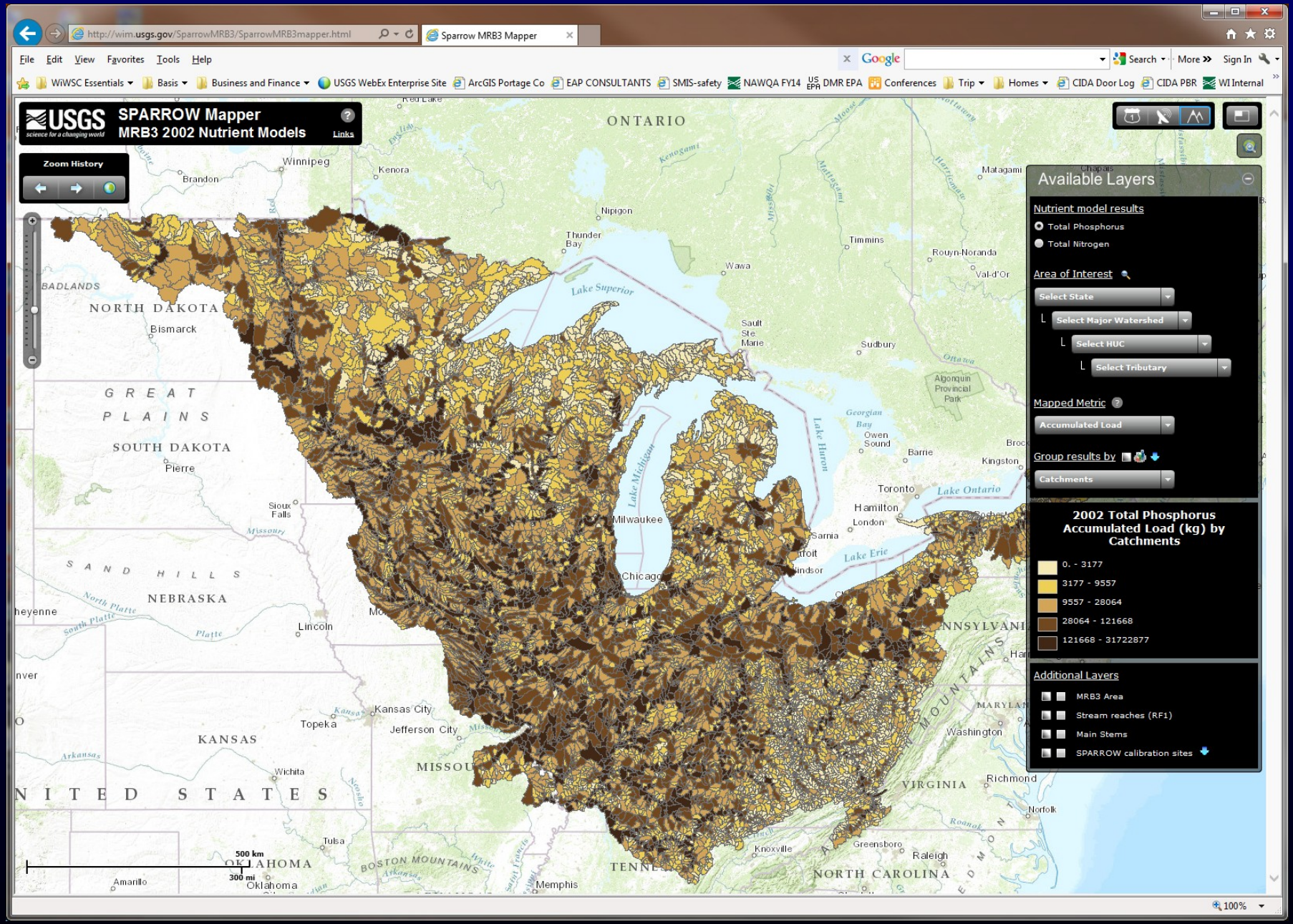
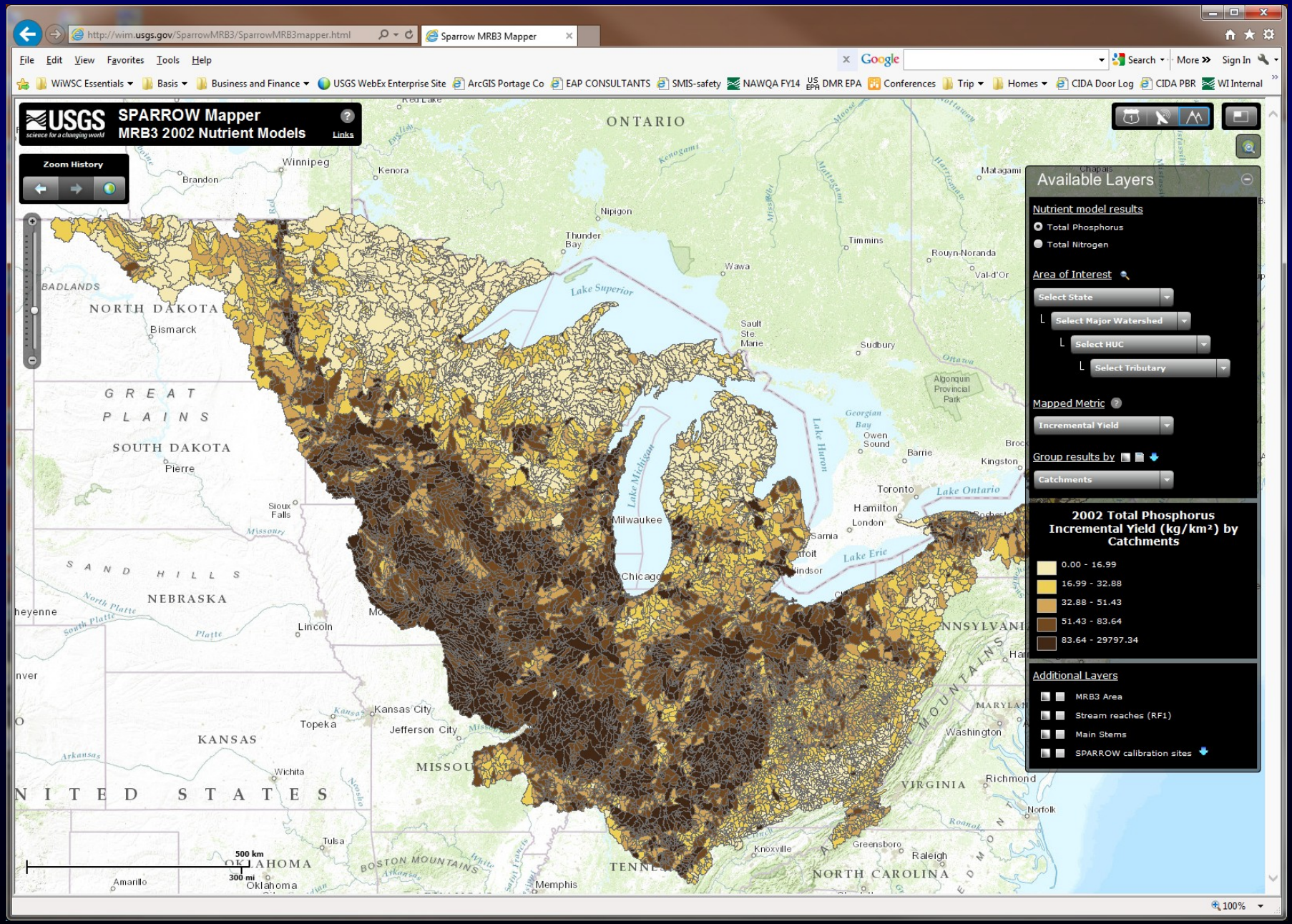
2002 Total Phosphorus Delivered Accumulated Yield (kg/km²)
Delivered Accumulated Yield (kg/km²)
14
12
10
8
6
4
2
0
1
2
Ranked by HUC
Forest/Wetland
Loess
Stream Channel
Manure (Confined and Unconfined
Farm Fertilizer
Urban Land
Sewerage Point Sources
Export Data
Delivered Accumulated Yield for entire view
View Nutrient Totals

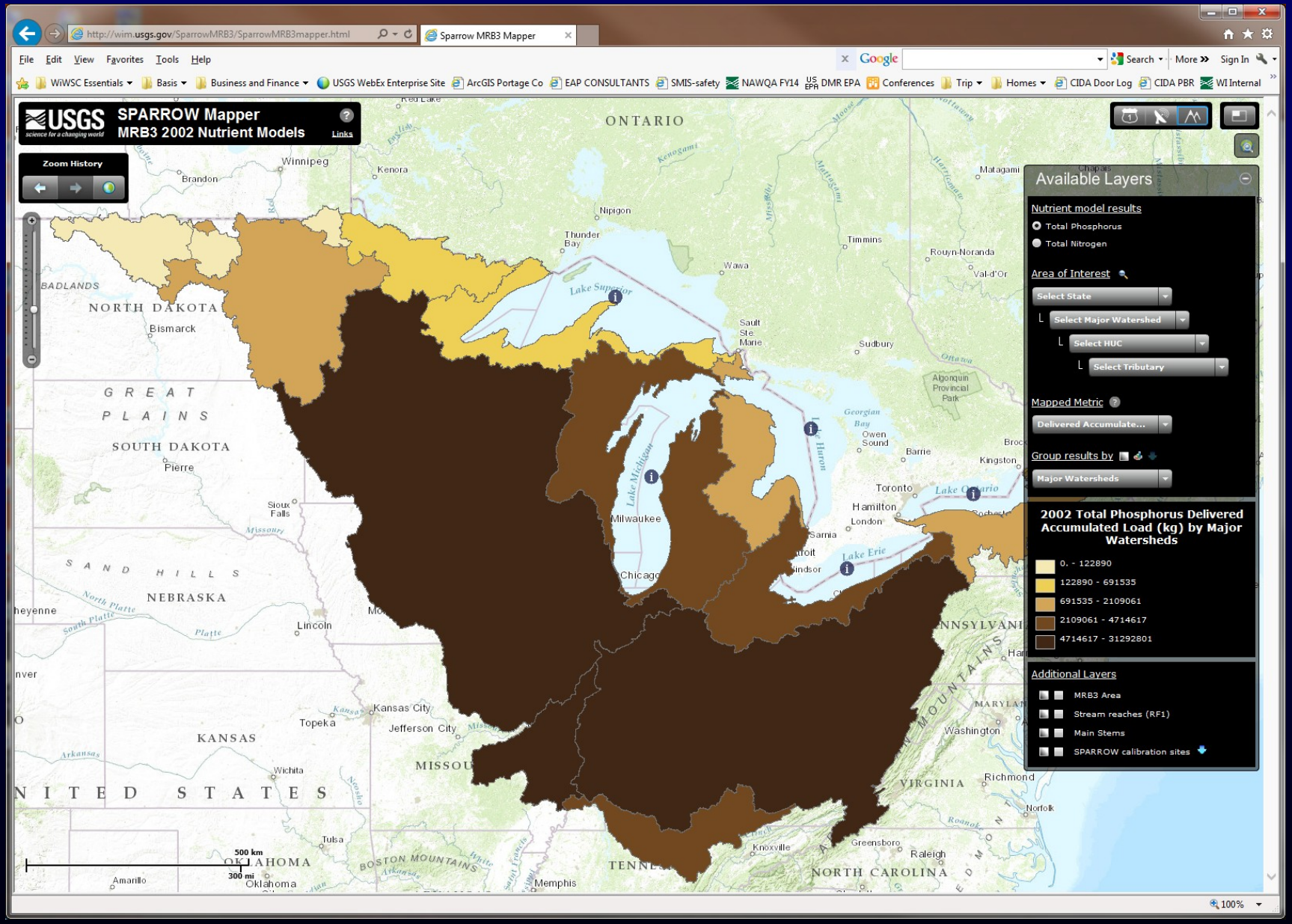
MRB3 SPARROW Mapper for P Loads – shown by SPARROW Catchment

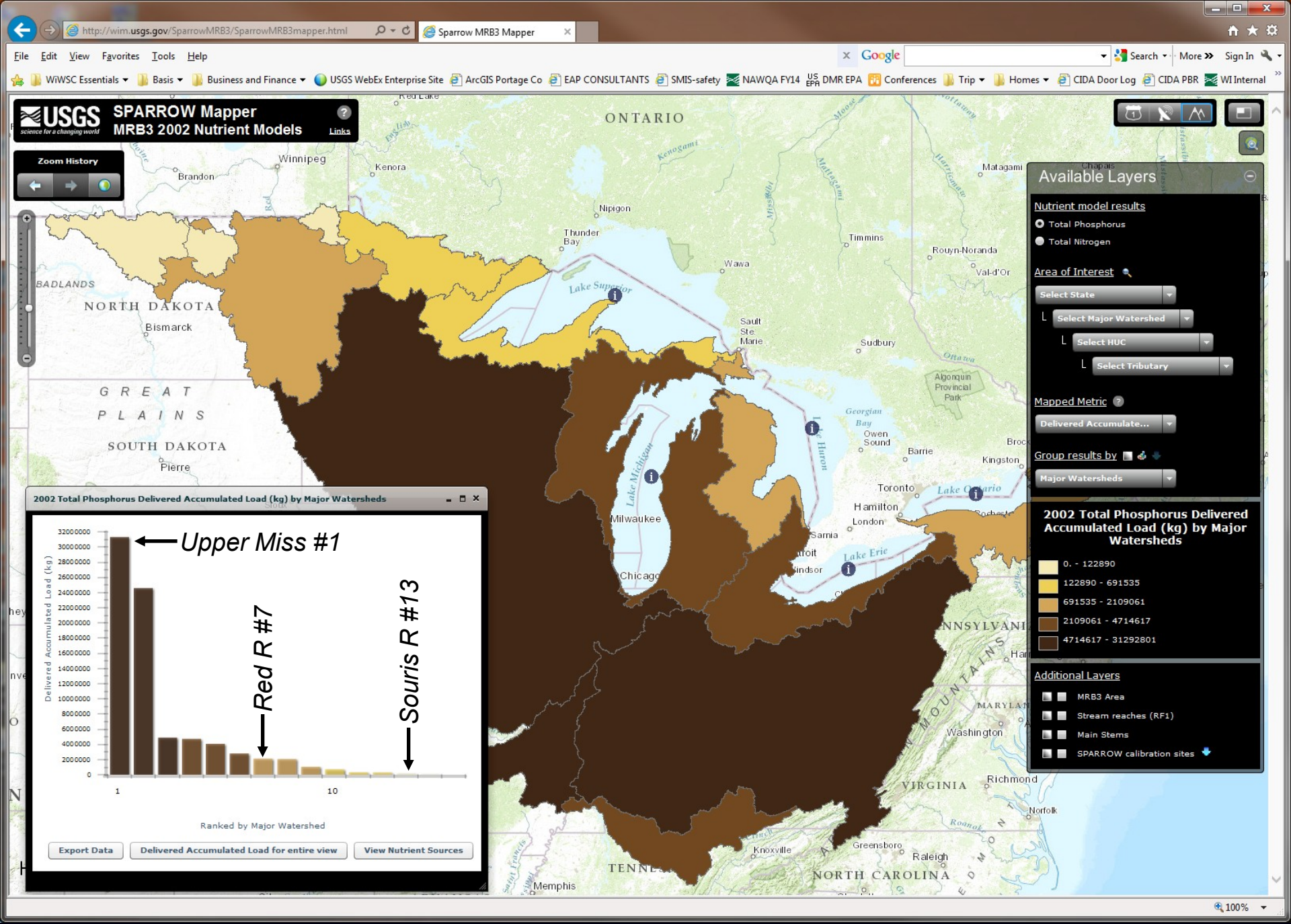


MRB3 SPARROW Mapper for P Yields – shown by SPARROW Catchment



MRB3 SPARROW Mapper for Delivered P Yields – shown by Major Watershed





http://wim.usgs.gov/SparrowMRB3/SparrowMRB3mapper.html
Sparrow MRB3 Mapper
File Edit View Favorites Tools Help
WiWSC Essentials Basis Business and Finance USGS WebEx Enterprise Site ArcGIS Portage Co EAP CONSULTANTS SMIS-safety NAWQA FY14 DMR EPA Conferences Trip Homes CIDA Door Log CIDA PBR WI Internal
USGS
SPARROW Mapper
MRB3 2002 Nutrient Models
Links
Zoom History
ONTARIO
Winnipeg
Brandon
Kenora
Nipigon
Thunder Bay
Wawa
Timmins
Rouyn-Noranda
Val-d'Or
Matagami
Chapais
Lake Superior
Sault Ste. Marie
Sudbury
Algonquin Provincial Park
Georgian Bay
Owen Sound
Barrie
Kingston
Toronto
Hamilton
London
Sarnia
Lake Huron
Lake Michigan
Lake Ontario
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Milwaukee
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BADLANDS
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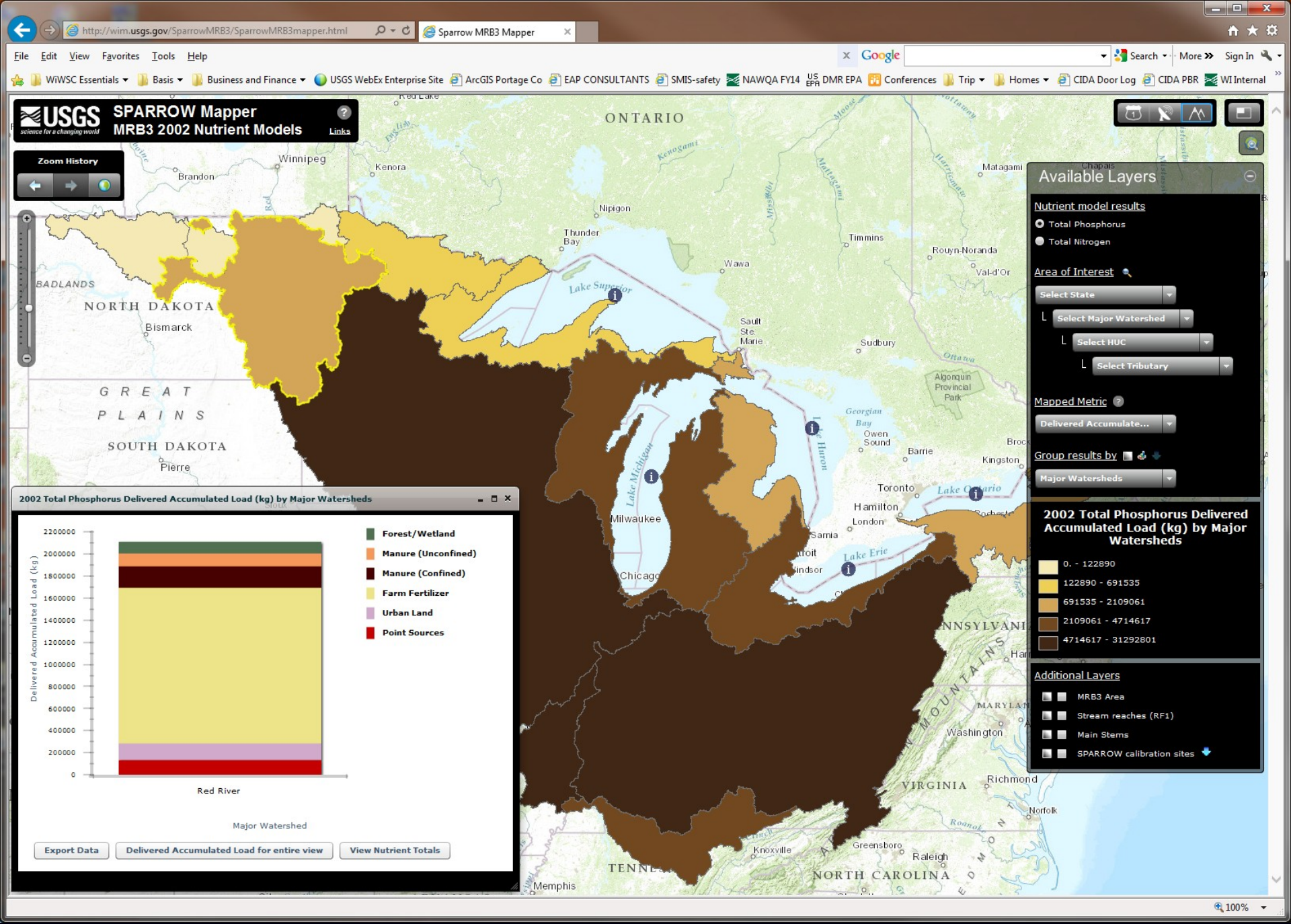
SOUTH DAKOTA
Pierre
Available Layers
Nutrient model results
Total Phosphorus
Total Nitrogen
Area of Interest
Select State
Select Major Watershed
Select HUC
Select Tributary
Mapped Metric
Delivered Accumulate...
Group results by
Major Watersheds
2002 Total Phosphorus Delivered Accumulated Load (kg) by Major Watersheds
0. - 122890
122890 - 691535
691535 - 2109061
2109061 - 4714617
4714617 - 31292801
Additional Layers
MRB3 Area
Stream reaches (RF1)
Main Stems
SPARROW calibration sites
2002 Total Phosphorus Delivered Accumulated Load (kg) by Major Watersheds
Upper Miss #1
Red R #7
Souris R #13
Delivered Accumulated Load (kg)
Ranked by Major Watershed
Export Data
Delivered Accumulated Load for entire view
View Nutrient Sources
Washington
Richmond
Norfolk
VIRGINIA
Knoxville
Greensboro
Raleigh
NORTH CAROLINA
Memphis
100%



http://wim.usgs.gov/SparrowMRB3/SparrowMRB3mapper.html
Sparrow MRB3 Mapper
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Search
More
Sign In
WiWSC Essentials
Basis
Business and Finance
USGS WebEx Enterprise Site
ArcGIS Portage Co
EAP CONSULTANTS
SMIS-safety
NAWQA FY14
DMR EPA
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CIDA Door Log
CIDA PBR
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science for a changing world
SPARROW Mapper
MRB3 2002 Nutrient Models
Links
Zoom History
ONTARIO
Winnipeg
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Wawa
Timmins
Rouyn-Noranda
Val-d'Or
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Sault Ste. Marie
Sudbury
Algonquin Provincial Park
Georgian Bay
Owen Sound
Barrie
Kingston
Toronto
Hamilton
London
Lake Ontario
Lake Huron
Lake Michigan
Milwaukee
Chicago
Sarnia
Lake Erie
Windsor
BADLANDS
NORTH DAKOTA
Bismarck
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SOUTH DAKOTA
Pierre
Red Lake
Kenogami
Mattagami
Harricanaw
Ottawa
Moose
Missisibi
Red
Winnipeg
Available Layers
Nutrient model results
Total Phosphorus
Total Nitrogen
Area of Interest
Select State
Select Major Watershed
Select HUC
Select Tributary
Mapped Metric
Delivered Accumulate...
Group results by
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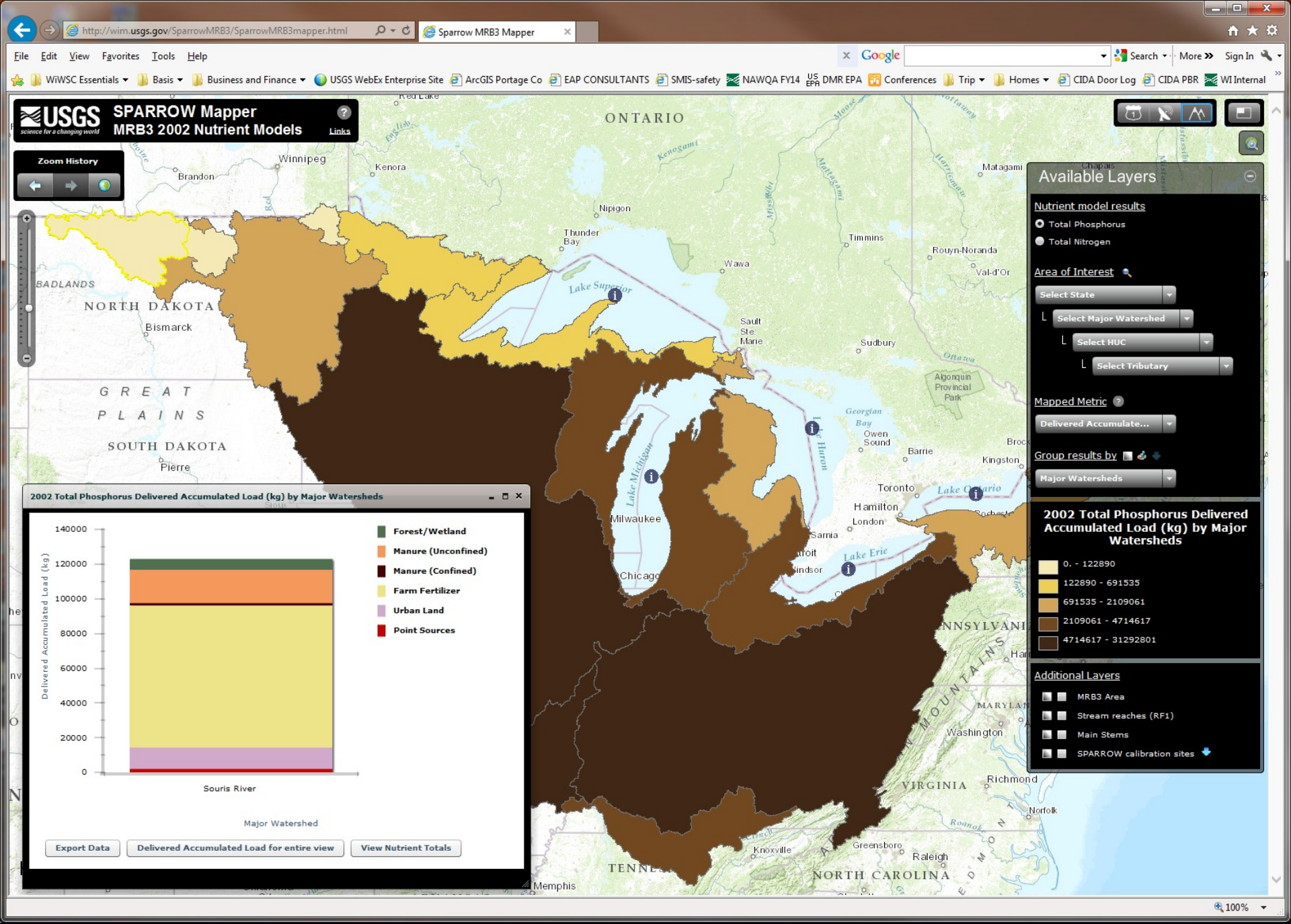
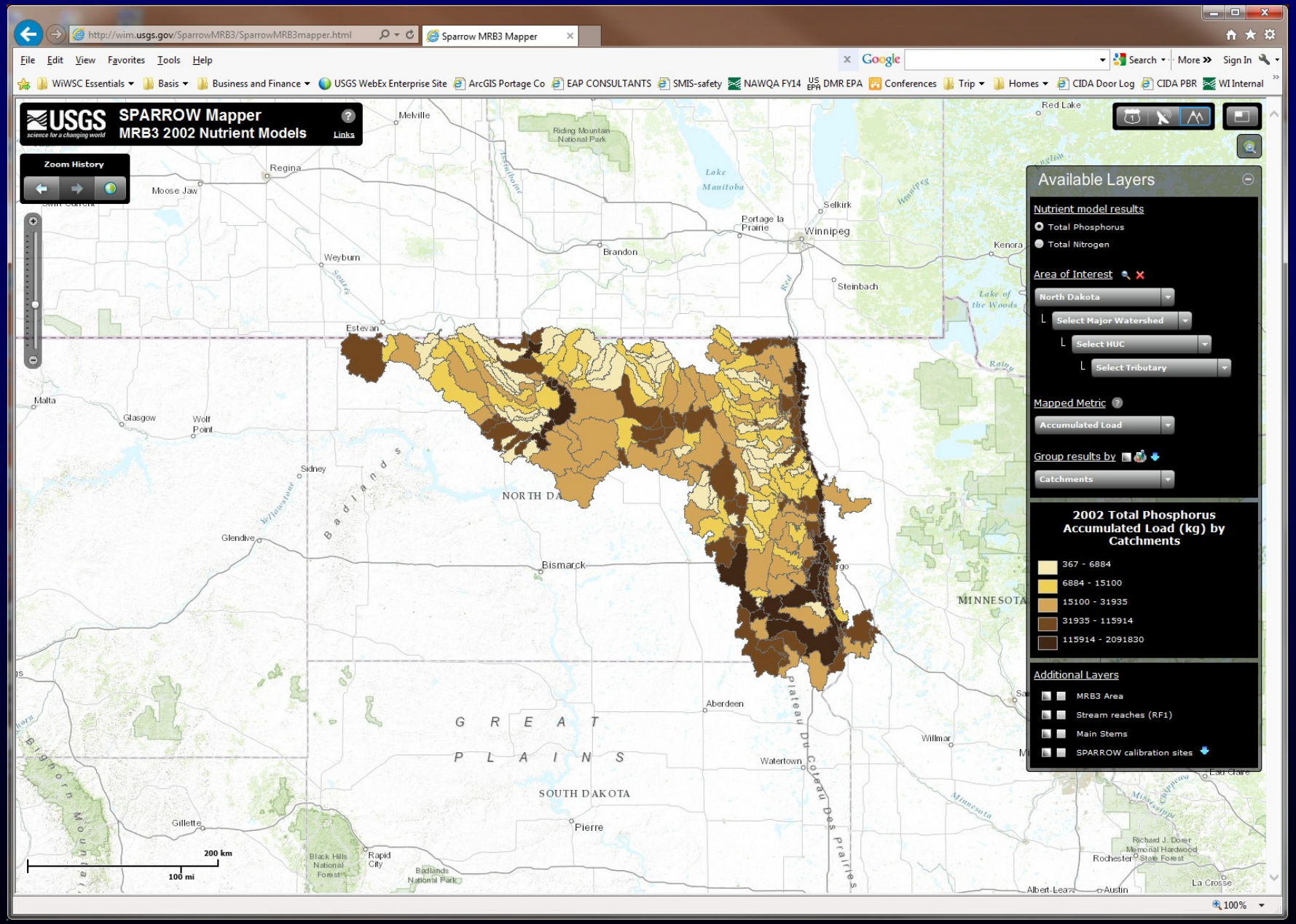
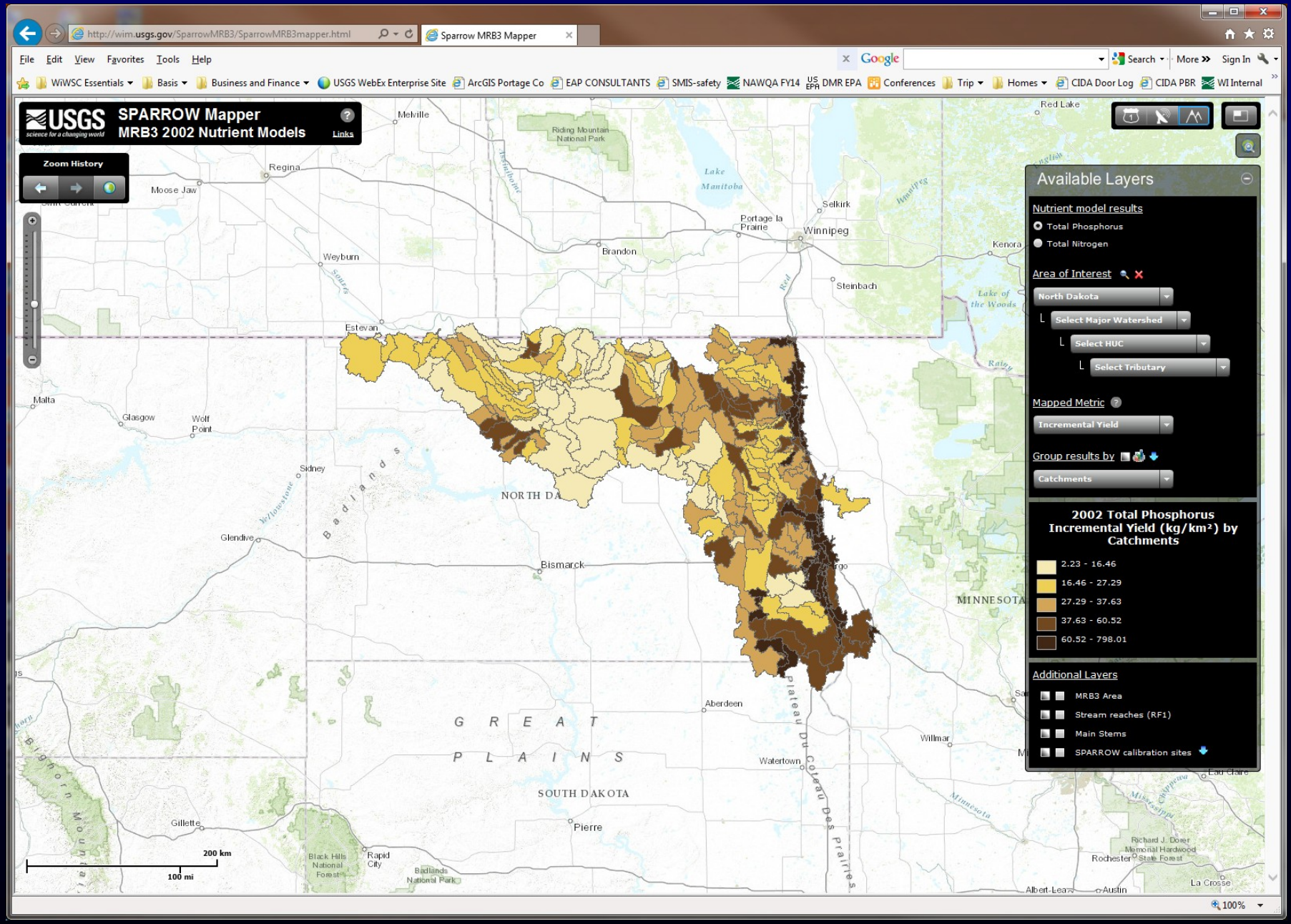
122890 - 691535
691535 - 2109061
2109061 - 4714617
4714617 - 31292801
Additional Layers
MRB3 Area
Stream reaches (RF1)
Main Stems
SPARROW calibration sites
2002 Total Phosphorus Delivered Accumulated Load (kg) by Major Watersheds
Delivered Accumulated Load (kg)
2200000
2000000
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
Red River
Major Watershed
Forest/Wetland
Manure (Unconfined)
Manure (Confined)
Farm Fertilizer
Urban Land
Point Sources
Export Data
Delivered Accumulated Load for entire view
View Nutrient Totals
PENNSYLVANIA
MARYLAND
Washington
VIRGINIA
Richmond
Norfolk
Roanoke
Knoxville
Greensboro
Raleigh
NORTH CAROLINA
TENNESSEE
Memphis
100%


SPARROW Mapper
MRB3 2002 Nutrient Models
Links
Zoom History
Available Layers
Nutrient model results
Total Phosphorus
Total Nitrogen
Area of Interest
Select State
Select Major Watershed
Select HUC
Select Tributary
Mapped Metric
Delivered Accumulate...
Group results by
Major Watersheds
2002 Total Phosphorus Delivered Accumulated Load (kg) by Major Watersheds
0. - 122890
122890 - 691535
691535 - 2109061
2109061 - 4714617
4714617 - 31292801
Additional Layers
MRB3 Area
Stream reaches (RF1)
Main Stems
SPARROW calibration sites
2002 Total Phosphorus Delivered Accumulated Load (kg) by Major Watersheds
Forest/Wetland
Manure (Unconfined)
Manure (Confined)
Farm Fertilizer
Urban Land
Point Sources
Delivered Accumulated Load (kg)
140000
120000
100000
80000
60000
40000
20000
0
Souris River
Major Watershed
Export Data
Delivered Accumulated Load for entire view
View Nutrient Totals
ONTARIO
NORTH DAKOTA
SOUTH DAKOTA
GREAT PLAINS
BADLANDS
Winnipeg
Brandon
Bismarck
Pierre
Thunder Bay
Nipigon
Wawa
Sault Ste. Marie
Sudbury
Timmins
Matagami
Rouyn-Noranda
Val-d'Or
Kenora
Red Lake
Lake Superior
Lake Michigan
Lake Huron
Lake Erie
Lake Ontario
Georgian Bay
Owen Sound
Barrie
Kingston
Toronto
Hamilton
London
Sarnia
Milwaukee
Chicago
Detroit
Windsor
Algonquin Provincial Park
Ottawa
Washington
Richmond
Norfolk
Virginia
Knoxville
Greensboro
Raleigh
North Carolina
Memphis
100%

Just looking at the North Dakota part of MRB3 – Accumulated Load



Just looking at the North Dakota part of MRB3 – Incremental Yield



Methods to demonstrate results and help guide decisions

2. Decision Support System Scientists/Managers – Capable of using to visualize SPARROW output and run various scenarios.

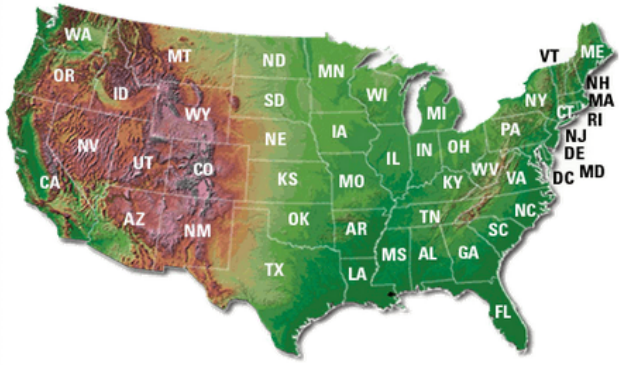
http://cida.usgs.gov/sparrow/

Booth et al., 2011

SPARROW Decision Support System

Find a Model by Geographic Location:

Select a region or state. When a state is selected, all models containing that state are listed.



Iowa

Find a Model by Modeled Constituent:

Any

Models matching your criteria (click a model to show details)

- Mississippi/Atchafalaya Basin Total Nitrogen Model - 2002
- Mississippi/Atchafalaya Basin Total Phosphorus Model - 2002
- National Suspended Sediment Model - 1992
- National Total Nitrogen Model - 1992
- National Total Organic Carbon Model
- National Total Phosphorus Model - 1992
- Total Nitrogen Model for the Great Lakes, Ohio, Upper Mississippi, and Souris-Red-Rainy Region - 2002
- Total Nitrogen Model for the Missouri River Basin - 2002
- Total Phosphorus Model for the Great Lakes, Ohio, Upper Mississippi, and Souris-Red-Rainy Region - 2002
- Total Phosphorus Model for the Missouri River Basin - 2002

Documentation and Further Reading

- What is SPARROW?
- What is SPARROW Decision Support?
- SPARROW Applications & Documentation
- SPARROW DSS FAQs

Tutorial Videos

Select a video...

Watch now >>

Found a bug or have a comment?

Please send bugs, suggestions and questions to the SPARROW Decision Support System Administrator.

Selected Model

Mississippi/Atchafalaya Basin Total Phosphorus Model - 2002

Explore this model in the Decision Support System >>

Modeled Constituent:	Phosphorus
Base Year:	2002
Stream Network:	Enhanced River Reach File 2.0 *Geometry and additional reach and network attribute data are available with the stream network data, which is available as a separate download.*
Model Updates:	View this model's updates

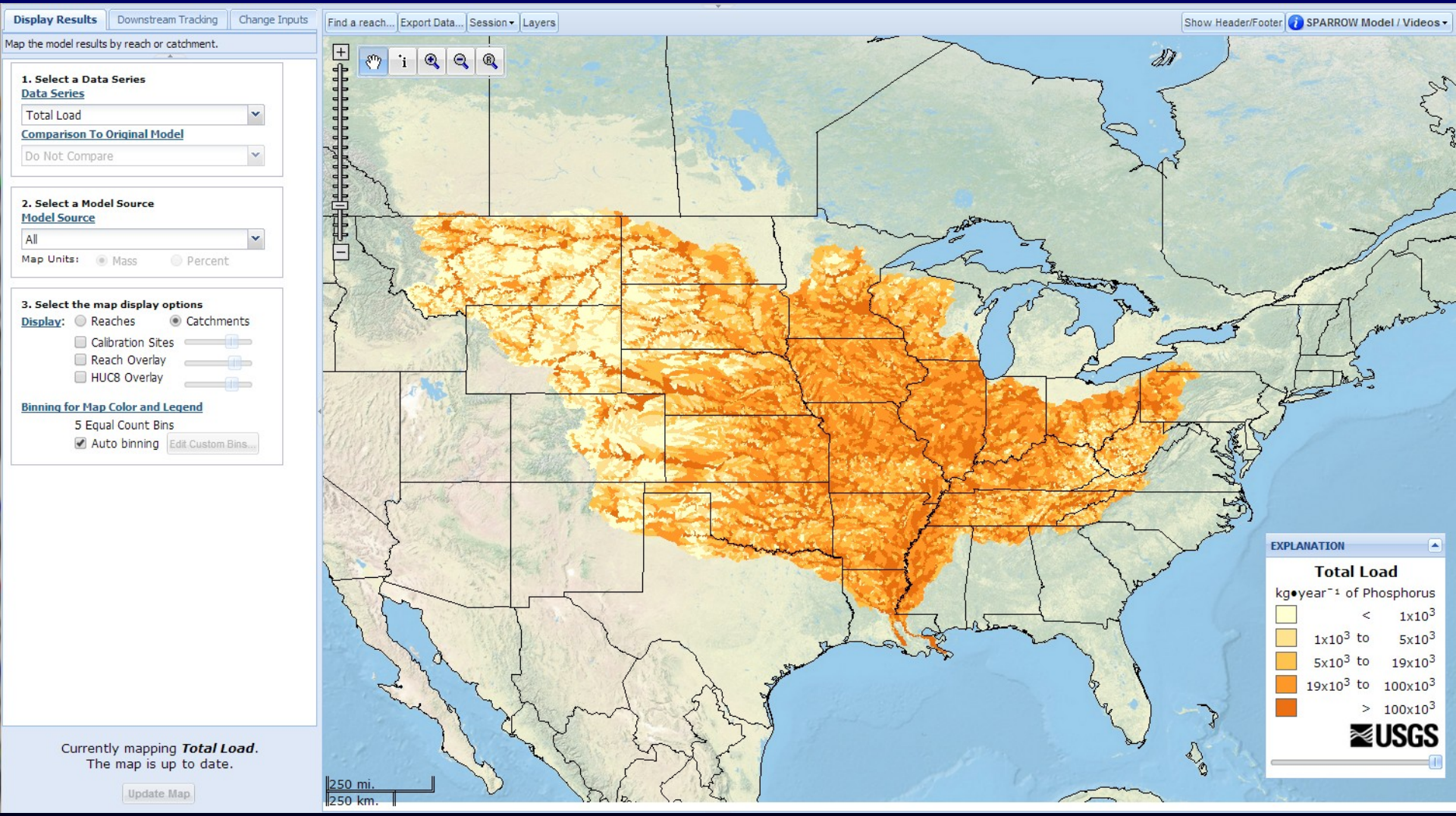
Watershed Based Sessions

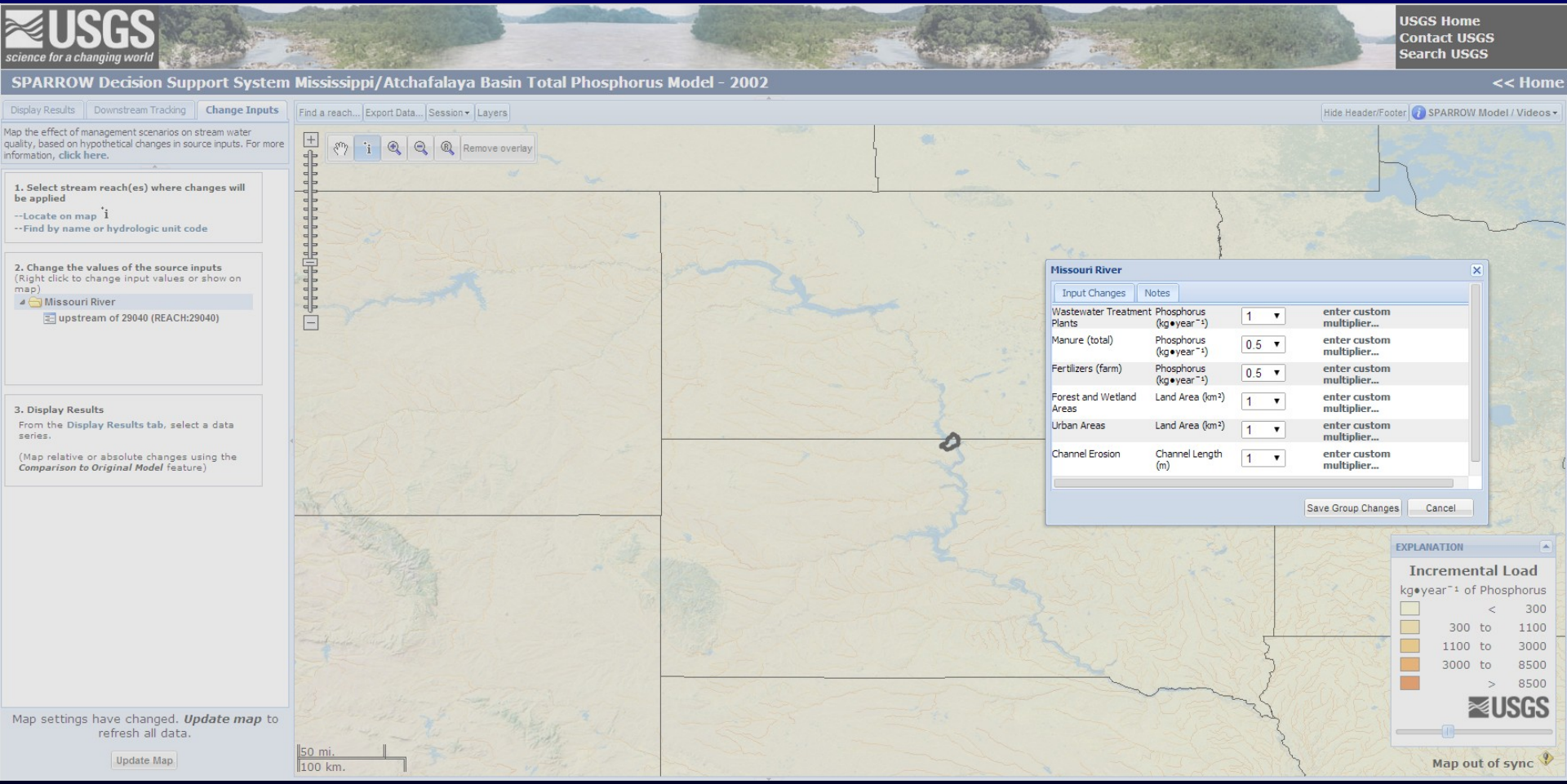
To start the DSS with the outlet river reach of a major watershed selected for downstream tracking, select a watershed and click *Go*.

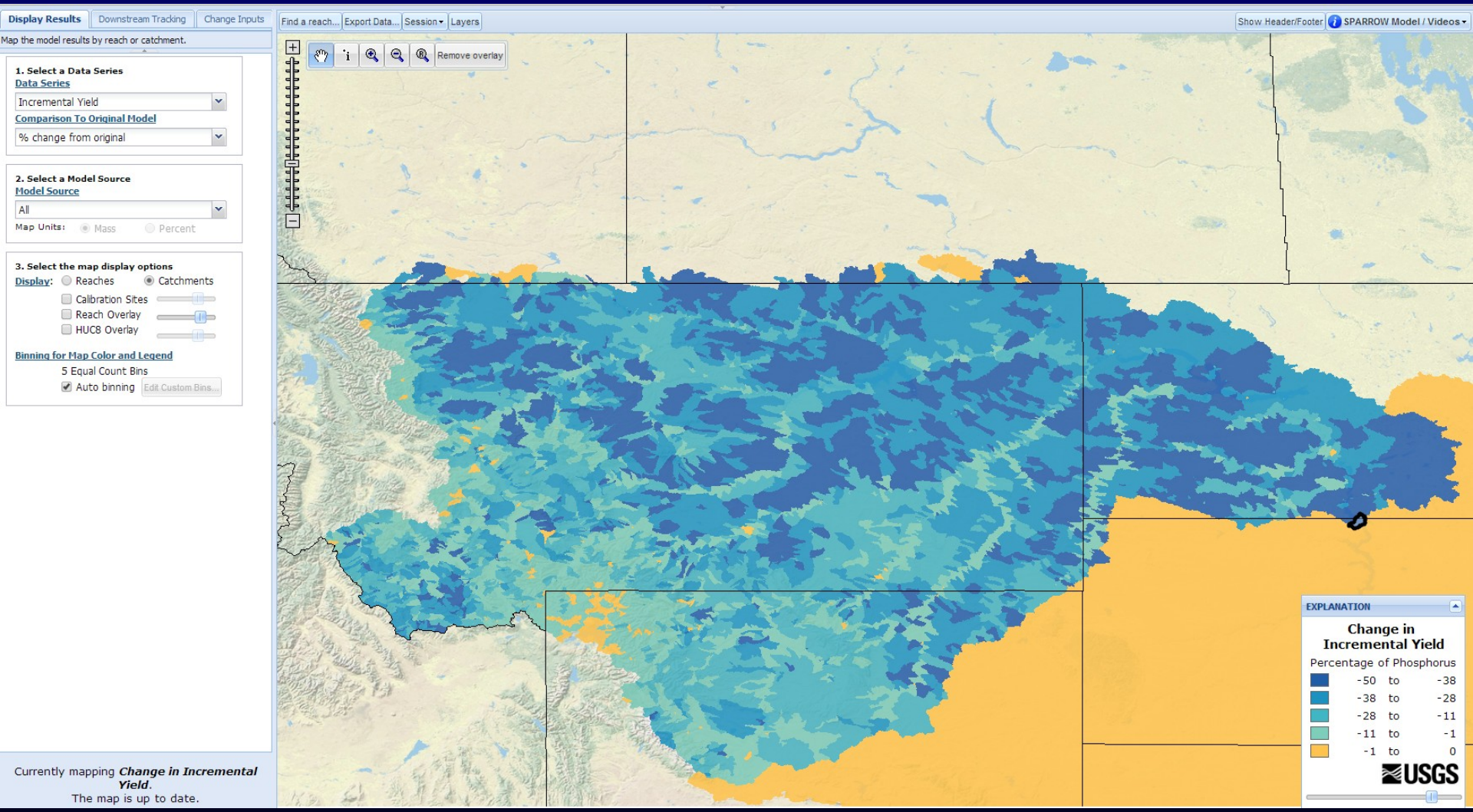
Go >>

Scenario Based Sessions

To start the DSS with a predefined scenario, click on the link for one of the scenarios below.


Display Results
Downstream Tracking
Change Inputs
Map the model results by reach or catchment.
1. Select a Data Series
Data Series
Total Load
Comparison To Original Model
Do Not Compare
2. Select a Model Source
Model Source
All
Map Units: Mass Percent
3. Select the map display options
Display: Reaches Catchments
Calibration Sites
Reach Overlay
HUC8 Overlay
Binning for Map Color and Legend
5 Equal Count Bins
Auto binning
Edit Custom Bins...
Currently mapping Total Load.
The map is up to date.
Update Map
Find a reach...
Export Data...
Session
Layers
Show Header/Footer
SPARROW Model / Videos
EXPLANATION
Total Load
kg•year⁻¹ of Phosphorus
< 1x10³
1x10³ to 5x10³
5x10³ to 19x10³
19x10³ to 100x10³
> 100x10³
USGS
250 mi.
250 km.


USGS
science for a changing world
USGS Home
Contact USGS
Search USGS
SPARROW Decision Support System Mississippi/Atchafalaya Basin Total Phosphorus Model - 2002
<< Home
Display Results
Downstream Tracking
Change Inputs
Map the effect of management scenarios on stream water quality, based on hypothetical changes in source inputs. For more information, click here.
1. Select stream reach(es) where changes will be applied
--Locate on map
--Find by name or hydrologic unit code
2. Change the values of the source inputs
(Right click to change input values or show on map)
Missouri River
upstream of 29040 (REACH:29040)
3. Display Results
From the Display Results tab, select a data series.
(Map relative or absolute changes using the Comparison to Original Model feature)
Map settings have changed. Update map to refresh all data.
Update Map
Find a reach...
Export Data...
Session
Layers
Hide Header/Footer
SPARROW Model / Videos
Remove overlay
Missouri River
Input Changes
Notes
Wastewater Treatment Plants
Phosphorus (kg•year⁻¹)
1
enter custom multiplier...
Manure (total)
Phosphorus (kg•year⁻¹)
0.5
enter custom multiplier...
Fertilizers (farm)
Phosphorus (kg•year⁻¹)
0.5
enter custom multiplier...
Forest and Wetland Areas
Land Area (km²)
1
enter custom multiplier...
Urban Areas
Land Area (km²)
1
enter custom multiplier...
Channel Erosion
Channel Length (m)
1
enter custom multiplier...
Save Group Changes
Cancel
EXPLANATION
Incremental Load
kg•year⁻¹ of Phosphorus
< 300
300 to 1100
1100 to 3000
3000 to 8500
> 8500
USGS
50 mi.
100 km.
Map out of sync


Display Results
Downstream Tracking
Change Inputs
Map the model results by reach or catchment.
1. Select a Data Series
Data Series
Incremental Yield
Comparison To Original Model
% change from original
2. Select a Model Source
Model Source
All
Map Units: Mass Percent
3. Select the map display options
Display: Reaches Catchments
Calibration Sites
Reach Overlay
HUC8 Overlay
Binning for Map Color and Legend
5 Equal Count Bins
Auto binning
Edit Custom Bins...
Currently mapping Change in Incremental Yield.
The map is up to date.
Find a reach...
Export Data...
Session
Layers
Remove overlay
Show Header/Footer
SPARROW Model / Videos
EXPLANATION
Change in Incremental Yield
Percentage of Phosphorus
-50 to -38
-38 to -28
-28 to -11
-11 to -1
-1 to 0
USGS

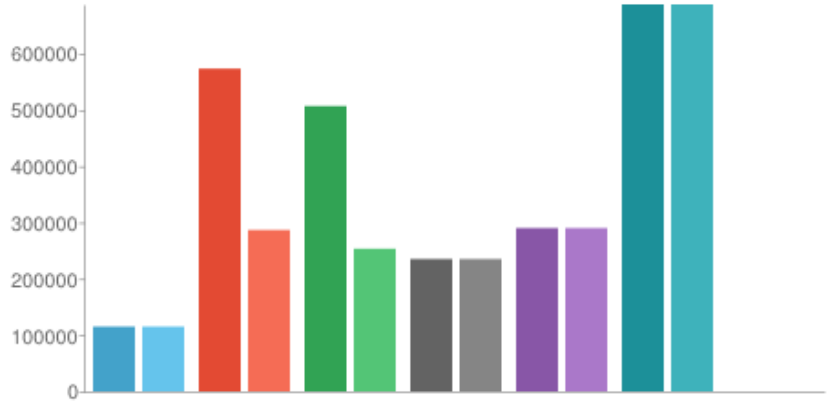
MISSOURI R (ID: 29040)

Reach/Catchment Info | Model Source Inputs | Predicted Values | **Graphs**

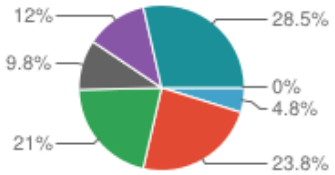
Sources

Orig.	Adj.		Orig.	Adj.	
		Wastewater Treatment Plants			Manure (total)
		Fertilizers (farm)			Forest and Wetland Areas
		Urban Areas			Channel Erosion
		Loess Soils			

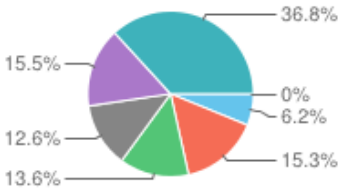
Total Phosphorus Load by Source (kg year⁻¹)



Share of Total Phosphorus Load by Source - Original



Share of Total Phosphorus Load by Source - Adjusted



OK | Cancel

MISSOURI R (ID: 29040)

Reach/Catchment Info | Model Source Inputs | **Predicted Values** | Graphs

Current Mapped Value: 7.14 kg•km^{-2}•yr^{-1} of Phosphorus (Incremental Yield)

Predicted Values (Data Series)

Source	Original (Phosphorus kg•year^{-1})	% of Load (Orig.)	Adjusted (Phosphorus kg•year^{-1})	% of Load(Adj.)	% Change
Total Load					
Wastewater Treatment Plants Total L...	115,077	4.8	115,077	6.2	0
Manure (total) Total Load	573,253	23.8	286,627	15.3	-50
Fertilizers (farm) Total Load	506,760	21.0	253,380	13.6	-50
Forest and Wetland Areas Total Load	235,110	9.8	235,110	12.6	0
Urban Areas Total Load	290,095	12.0	290,095	15.5	0
Channel Erosion Total Load	687,324	28.5	687,324	36.8	0
Loess Soils Total Load	0	0.0	0	0.0	0
Total Load	2,407,620	100.0	1,867,614	100.0	-22
Incremental Load					
Wastewater Treatment Plants Increm...	0	0.0	0	0.0	0
Manure (total) Incremental Load	1,056	48.7	528	39.8	-50
Fertilizers (farm) Incremental Load	629	29.0	314	23.7	-50
Forest and Wetland Areas Increment...	50	2.3	50	3.7	0
Urban Areas Incremental Load	434	20.0	434	32.7	0
Channel Erosion Incremental Load	0	0.0	0	0.0	0
Loess Soils Incremental Load	0	0.0	0	0.0	0
Incremental Load	2,167	100.0	1,325	100.0	-39

OK | Cancel

Larger Regional Models - NAWQA

RF1 (HUC11) > NHD Plus Scale(1:100,000) (HUC14)
2002 Inputs > 2012 Inputs

References:

Robertson, D.M., Saad, D.A., Schwarz, G.E., 2014, Spatial Variability in Nutrient Transport by HUC8, State, and Subbasin Based on Mississippi/Atchafalaya River Basin SPARROW Models: Journal of the American Water Resources Association.

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Robertson, D.M. and D.A. Saad, 2011. Nutrient Inputs to the Laurentian Great Lakes by Source and Watershed Estimated Using SPARROW Watershed Models. Journal of the American Water Resources Association. v. 47, p. 1011-1033, DOI: 10.1111/j.1752-1688.2011.00574.x.

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Saad, D.A., G.E. Schwarz, D.M. Robertson, and N.L. Booth, 2011. A Multi-Agency Nutrient Dataset Used to Estimate Loads, Improve Monitoring Design, and Calibrate Regional Nutrient SPARROW Models. Journal of the American Water Resources Association, v. 47, p. 933-949, DOI: 10.1111/j.1752-1688.2011.00575.x

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Alexander, R.B., Smith, R.A., Schwarz, G.E., Boyer, E.W., Nolan, J.V., and Brakebill, J.W., 2008, Differences in phosphorus and nitrogen delivery to the Gulf of Mexico from the Mississippi River Basin. Environmental Science and Techology, v. 42, n. 3, p. 822-830.