Modeling Nutrient Trading in the Ohio River Basin:

Theoretical and Practical Considerations

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Watershed Area Resource Management Framework - WARMF

The WARMF Model was designed 10 years ago as a modeling tool for general Watershed analysis. It is only a decision support tool which can be used to help design a Water Quality Trading Program.
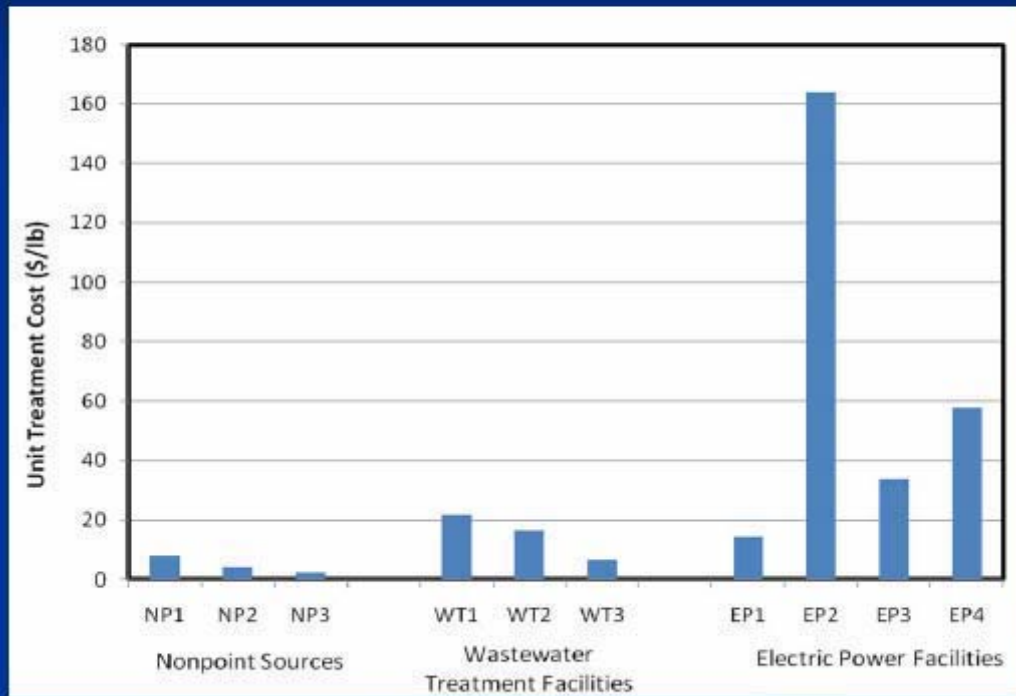
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There can be monetary benefits in using Watershed Modeling to develop a Nutrient Trading Program for both companies and communities

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Treatment Costs

Electric Power is much more expensive because it costs more to remove nitrate from water.

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Selecting a Pilot Project Basin

- Ohio River Basin chosen based on:
  - High nutrient loading
  - Pending regulatory program will create potential WQT credit demand
  - Presence of multiple sources of N & P
  - Regulatory climate favorable to WQT
  - Presence of numerous coal-fired power plants with potential or actual N loads

The Ohio River Basin was chosen by EPRI more than a year ago.

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Ohio River Basin
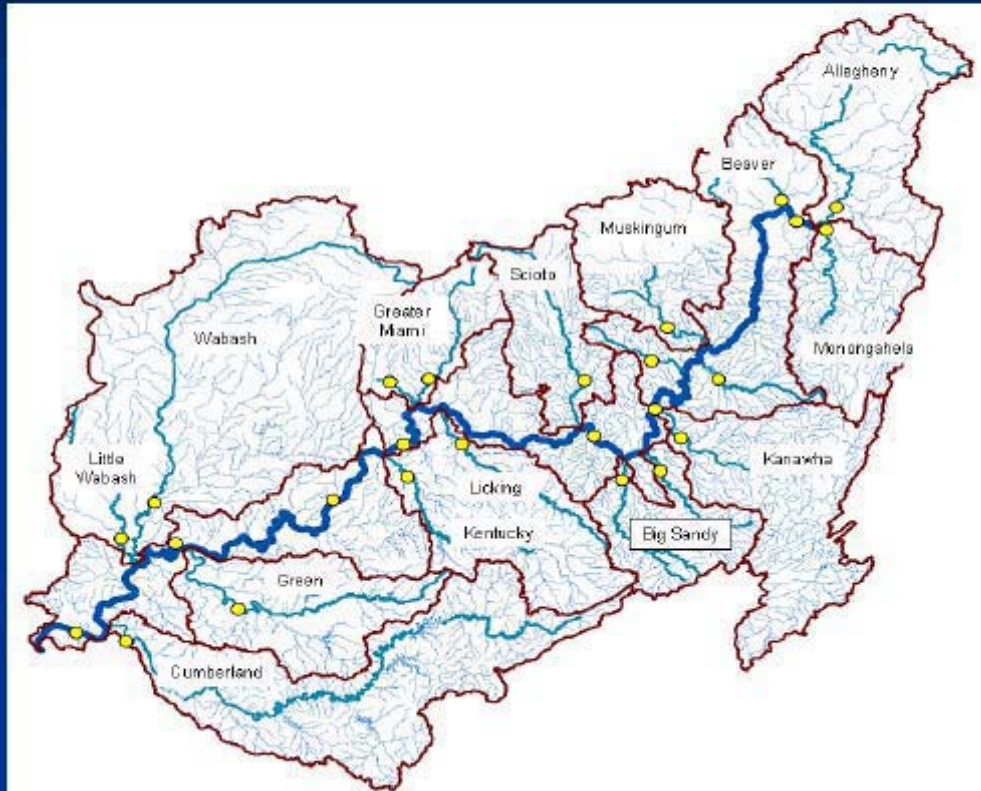
The Basin is very large and can be easily subdivided into smaller regions. Models can be created and analyzed for the whole basin, as larger regions, as well as for smaller areas. Detailed models should be completed for the Muskingum, Scioto and Greater Miami regions by the end of Summer 2009.

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Ohio Basin

Ohio River Power Stations
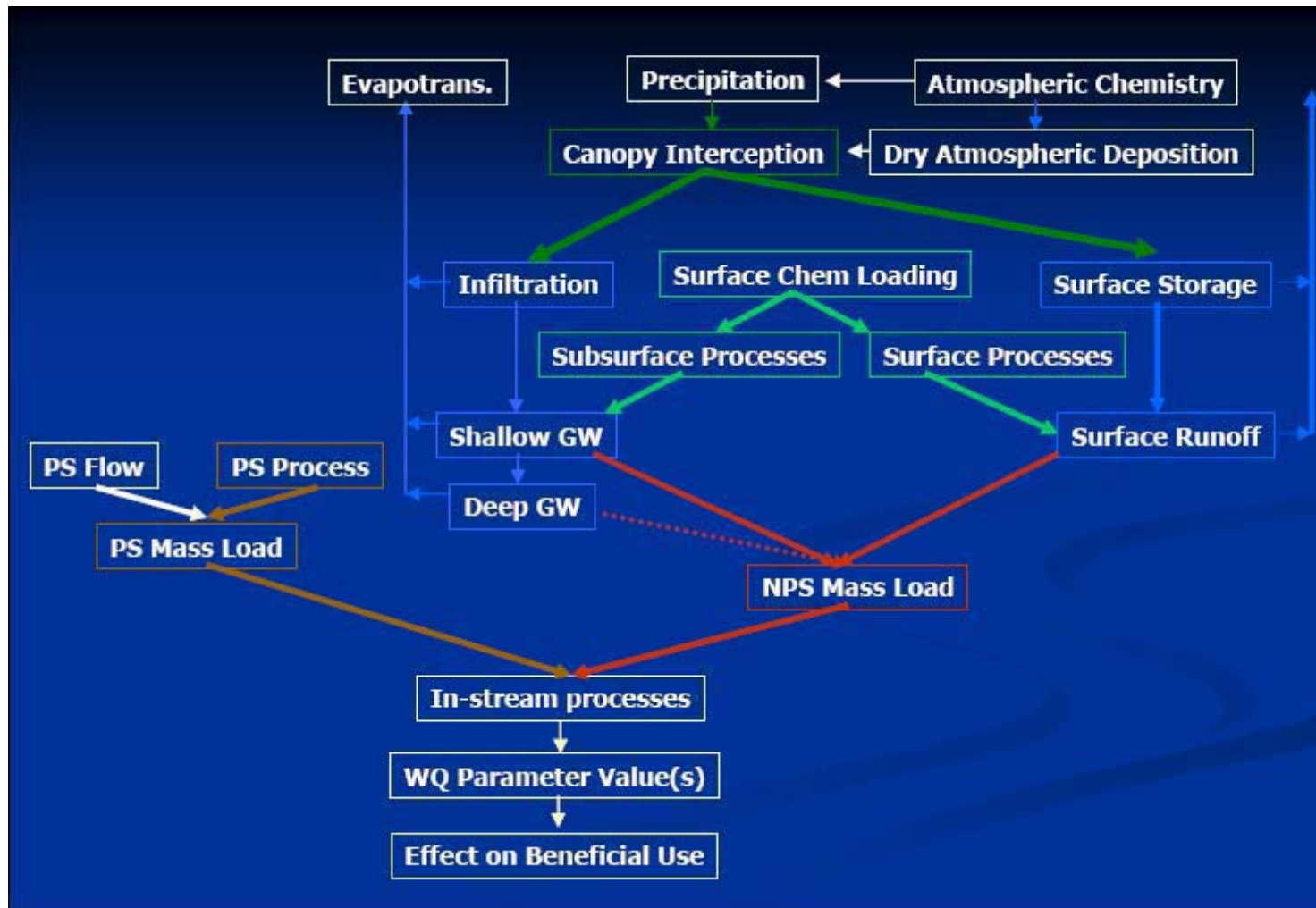
WARMF is approved of and used by the EPA.
Because the model is currently available for free it could be more easily utilized by other organizations.

Examples of Surface Chemicals: Pesticides, septic tanks.
Red Arrows indicate nonpoint sources
Brown Arrows indicate point sources

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WARMF Model Input Needs

- Topography (DEM)
- Land use (urban, ag, crop types)
- Soil data
- Meteorology
- Point source data (flow, loads, timing)
- Non-point source data (loads, timing)
- Water management data (GW pumping, reservoir mgmt, locks & dams, …)
- Observed flow and water quality data

Topography – USGS, Land Use (Crop Types, Best Management Practices) – USDA, Soil – USGS, PS – USEPA, NPS, Water Management Data – ORSANCO, USEPA
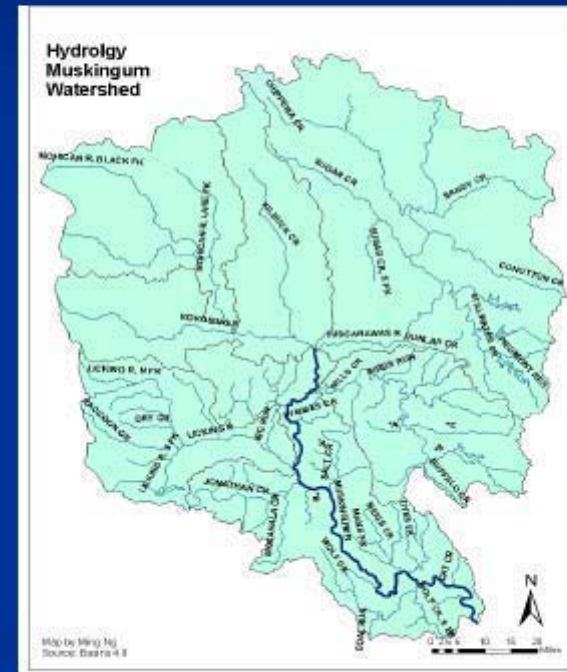
Q: What kind of flow data?

A: Daily flow makes the model more accurate, but any timescale will be useful.

If anyone has a lead on more data *please let us know*. The more data we have, and the more specific that data is, the better the model will be.

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Watershed Characteristics
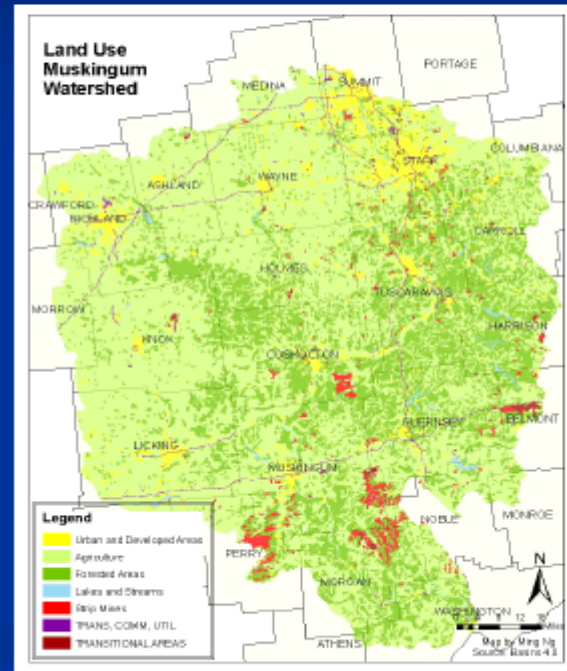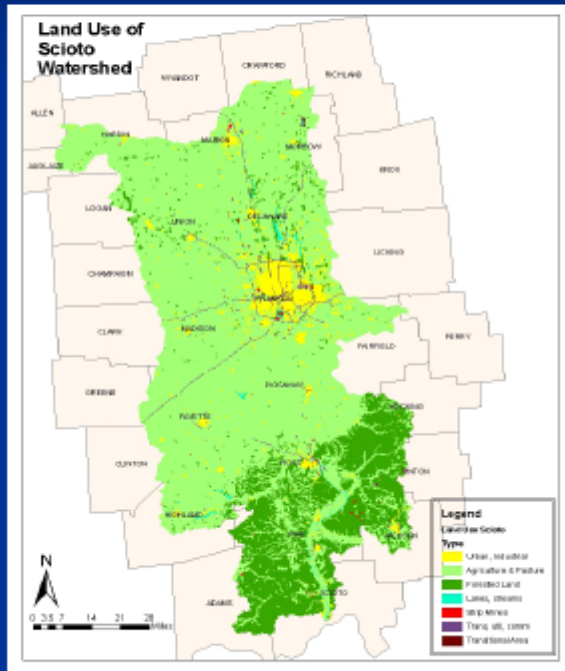
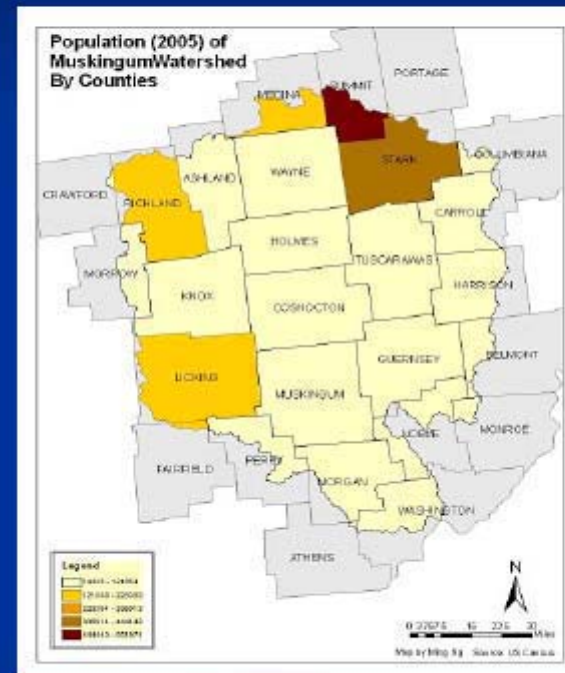EPRI | ELECTRIC POWER RESEARCH INSTITUTE
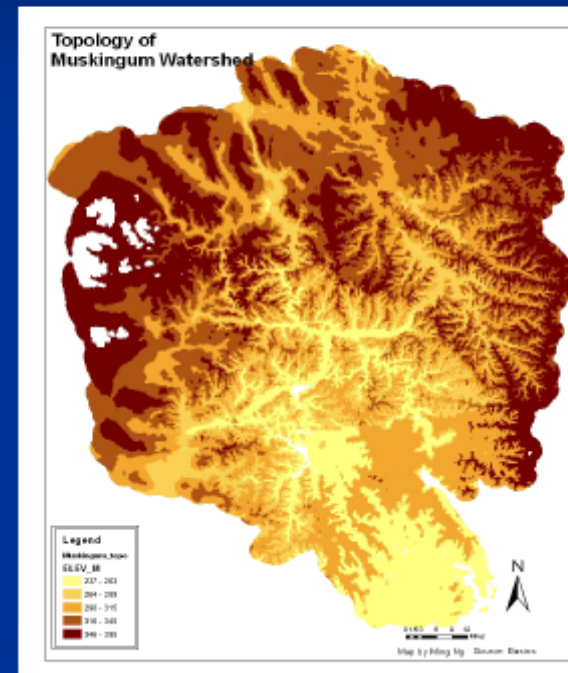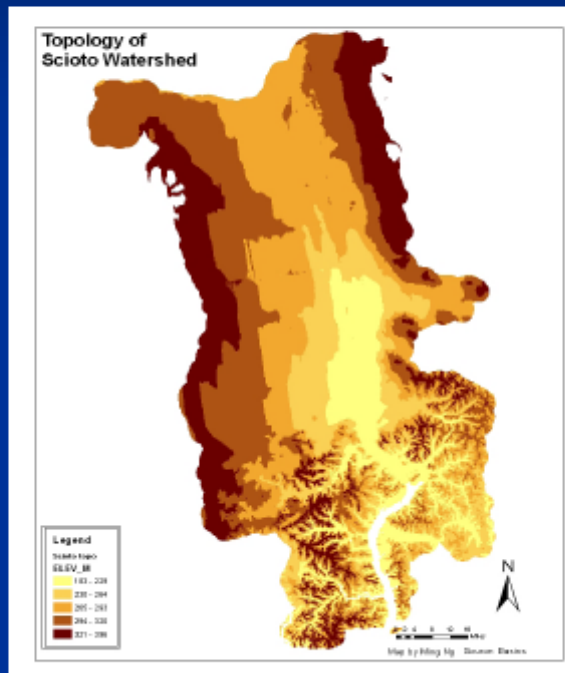
Watershed Characteristics

Uses USGS data and has a GIS component which is incorporated into model.
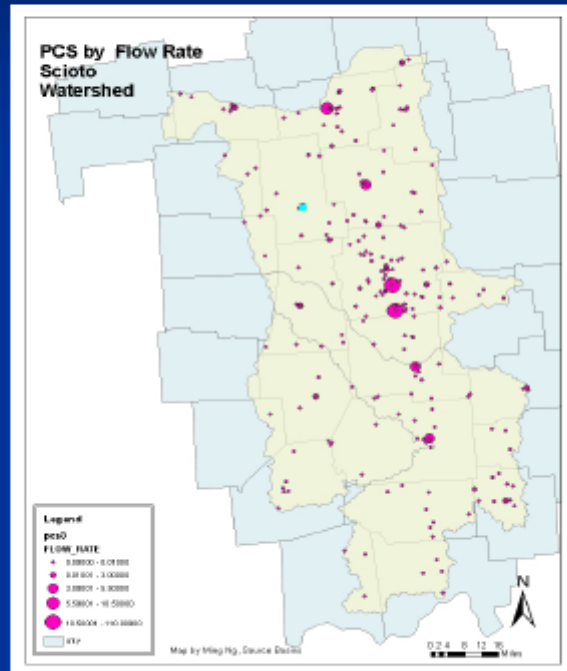
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Watershed Characteristics

Watershed Characteristics
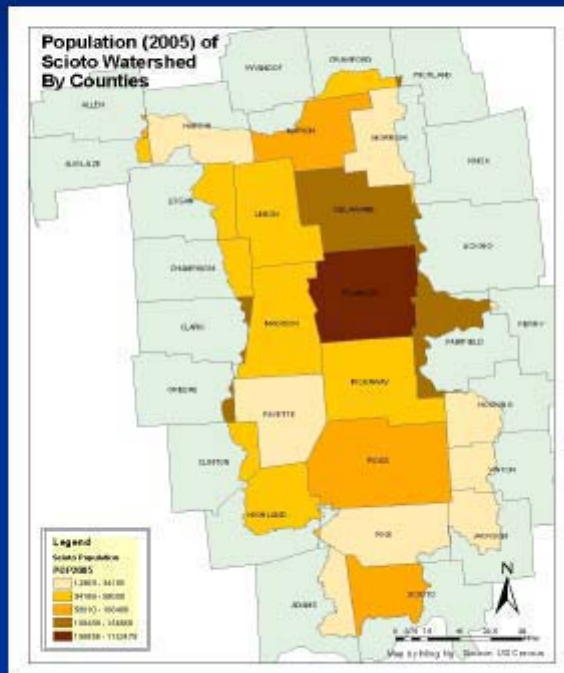
Information from the US Census on population data helps estimate loading.

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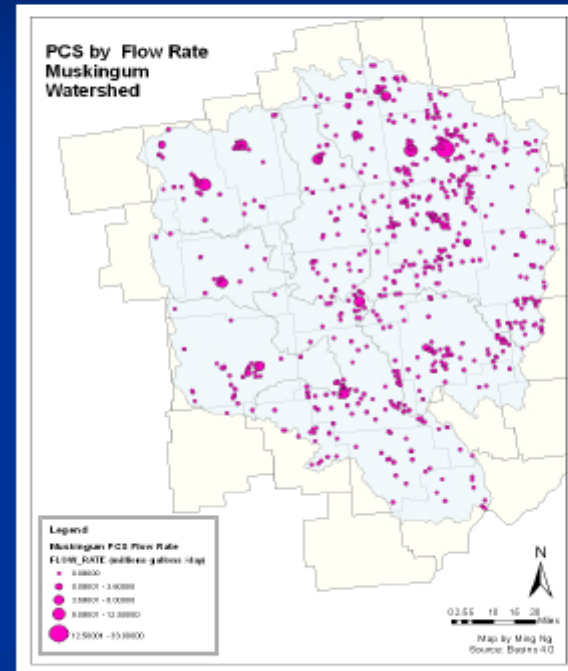
The PCS by Flow Rate data helps to identify larger waste treatment plants which may be good candidates for a larger Nutrient Trading Program.

Q: How much of the info from the PCS is up-to-date?

A: The PCS data is from 1999 to 2007. Prior to 1999 the data was recorded in a different way. As new data is posted in the EPA Website it will be pulled down and incorporated into the WARMF Model.
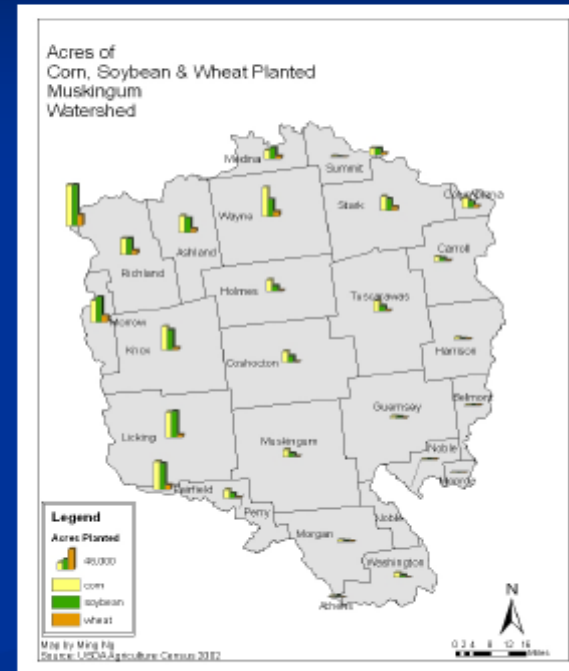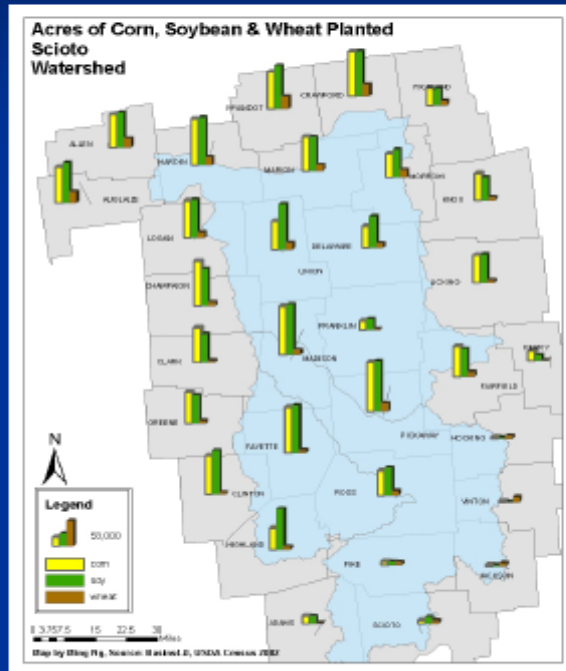
Q: Do you take the info by hand?

A: The process used to be done by hand, but has since been automated.
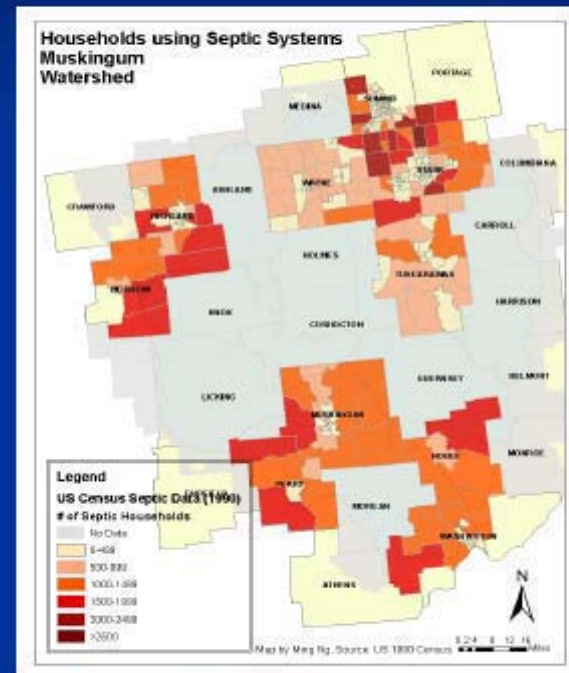
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Watershed Characteristics

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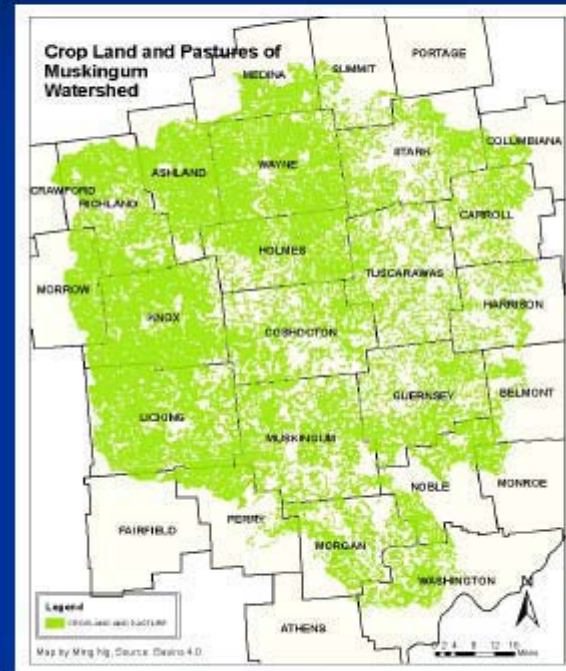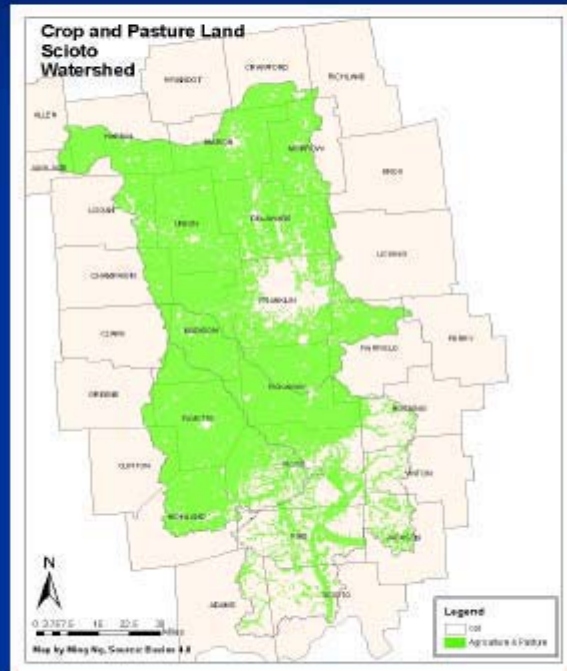
Watershed Characteristics
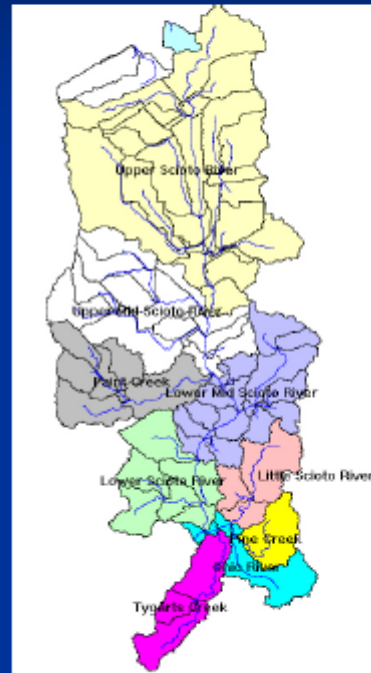

Data comes from Fertilizer Use and Sale.

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Watershed Characteristics
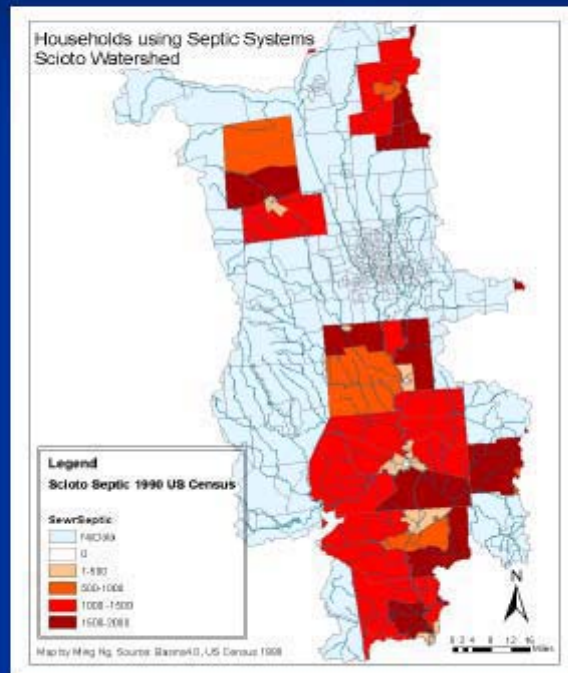
Where it is available, data on Septic Systems is gleaned from the US Census. Where not available, information about population is used to estimate septic system use.

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Watershed Delineation

Smaller systems/units of analysis

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Point Sources in Model

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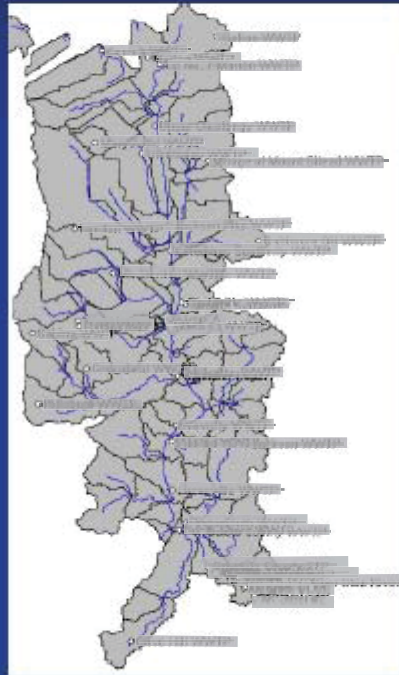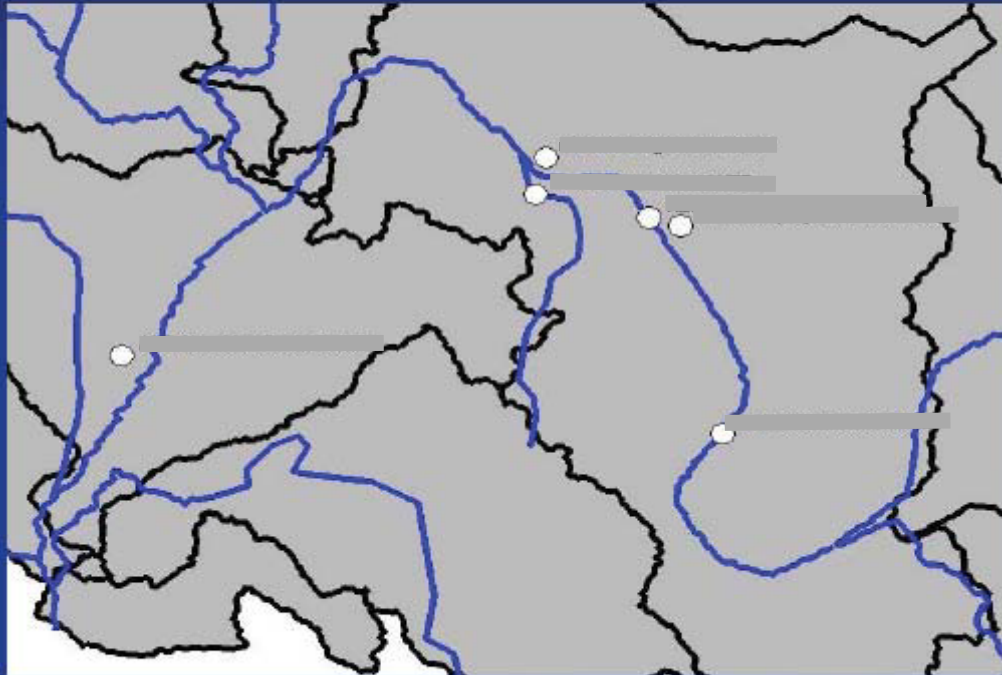
The more resolution there is in the data the better the model will be.

Point Sources in Model

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Flow & WQ Monitoring

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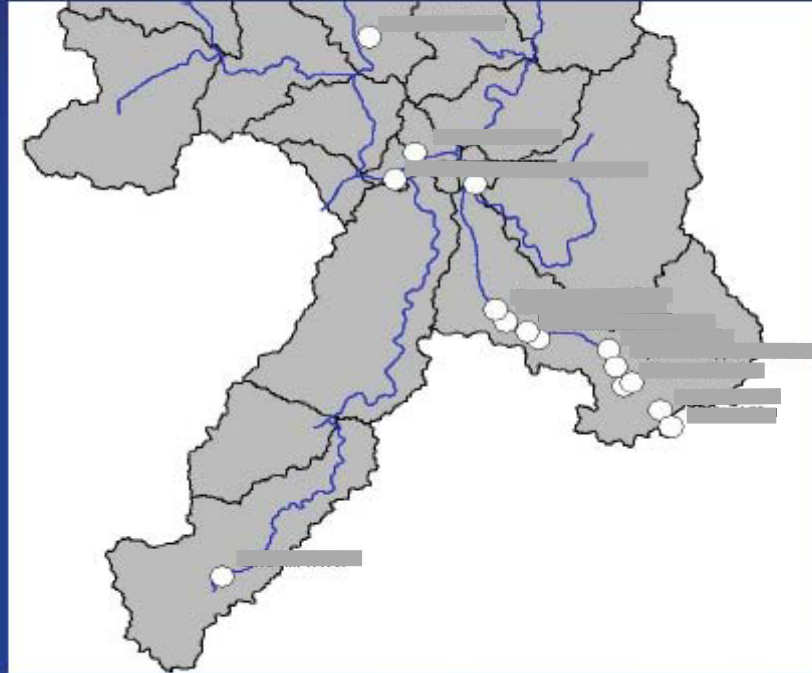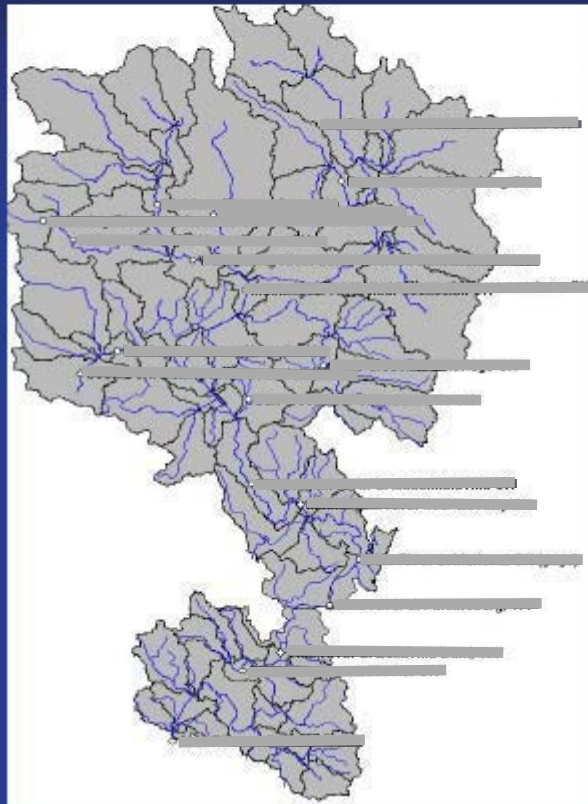
Flow & WQ Monitoring
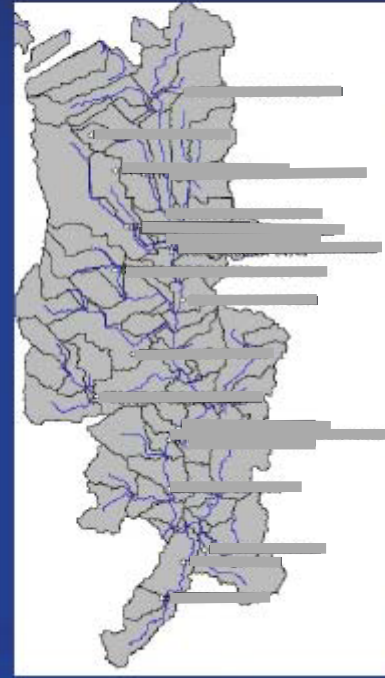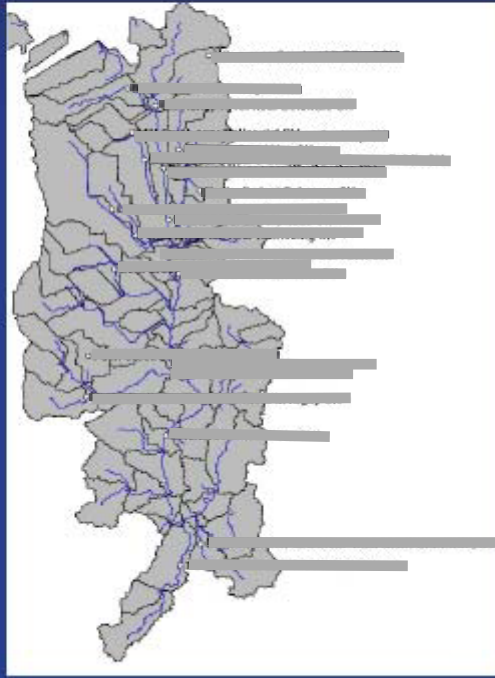
Total Nitrogen (TN) Areas with Potential

Reference level = 1.2 mg/L

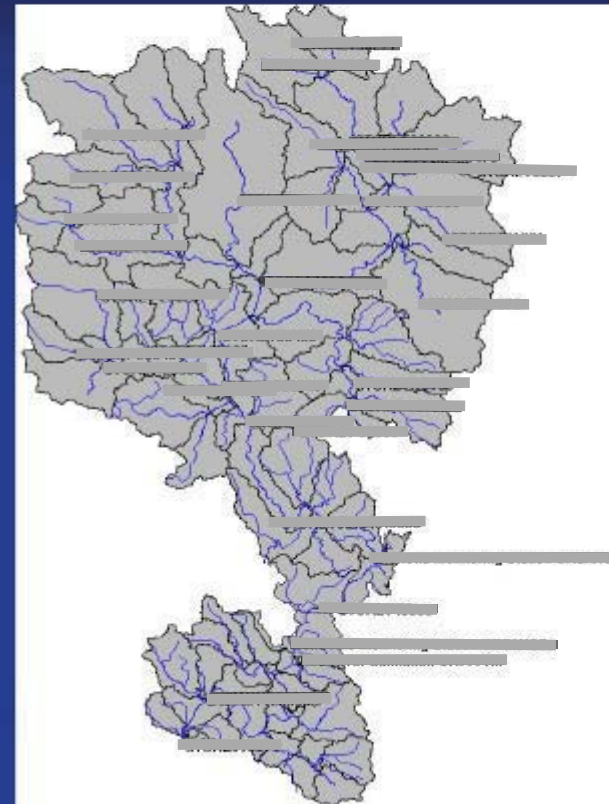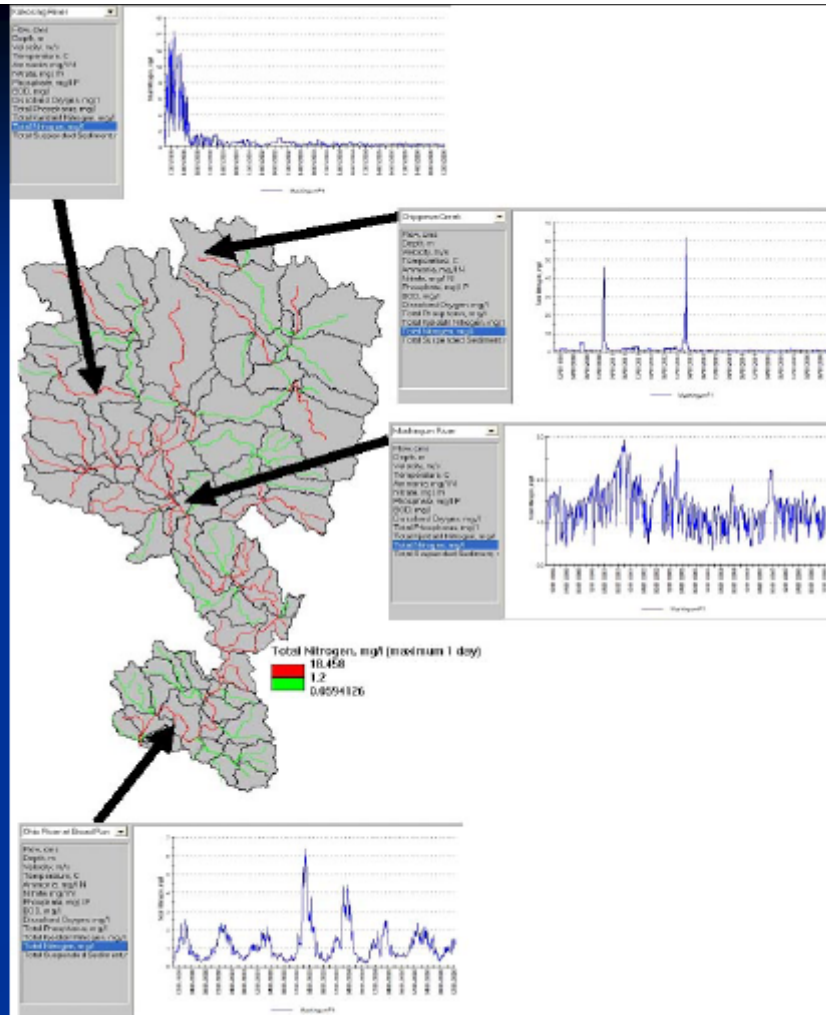Red = Above the Reference Level
Green = Below the Reference Level

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Total Nitrogen Areas with Potential
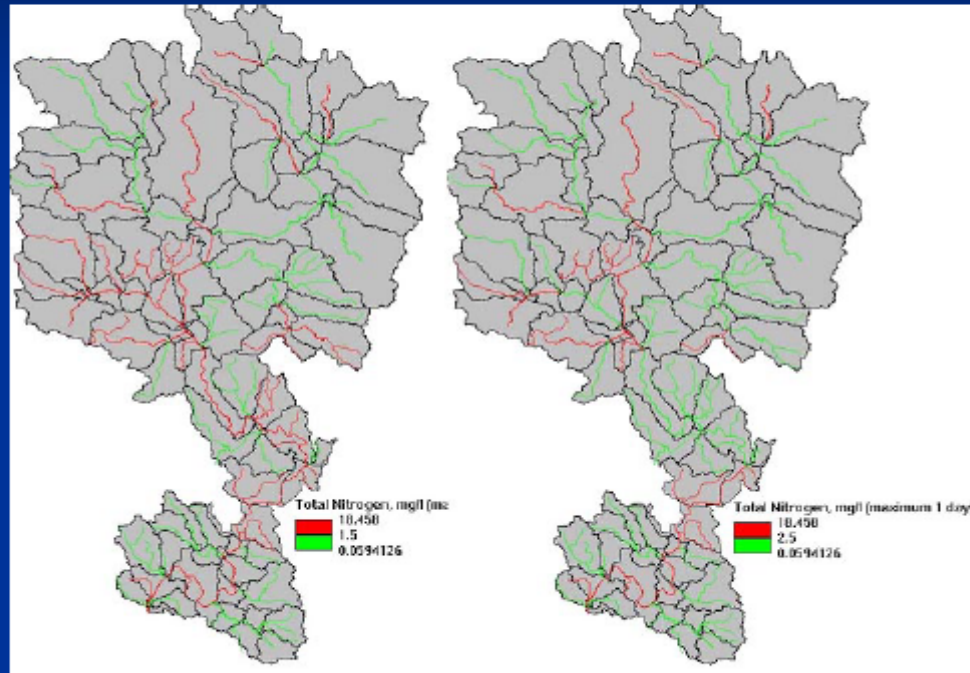
Reference level =   1.5 mg/L   2.5 mg/L

Q: Are these examples based on field data?
A: No, the examples are based on simulated data.
The model has to have good data so that stakeholders have confidence in the model.

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Total Nitrogen (TN) Areas with Potential

Reference level = 1.2 mg/L

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Total Nitrogen Areas with Potential

Reference level =   1.5 mg/L   2.5 mg/L

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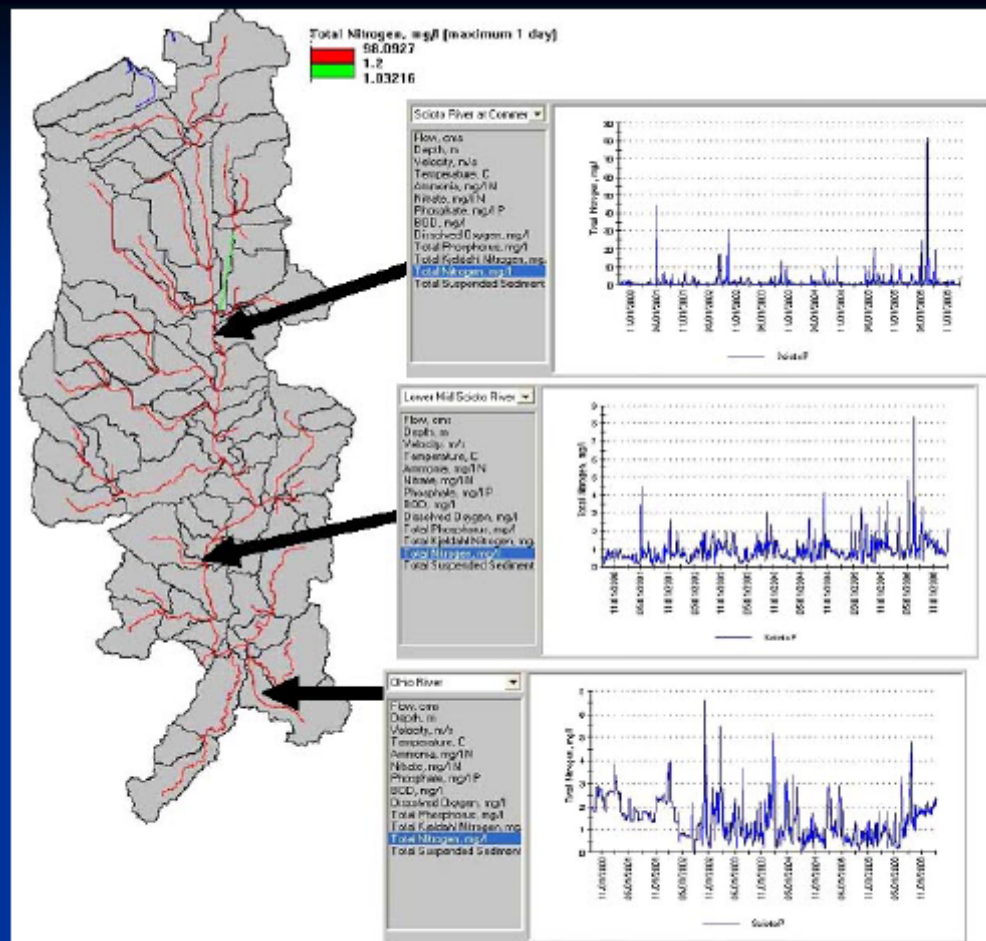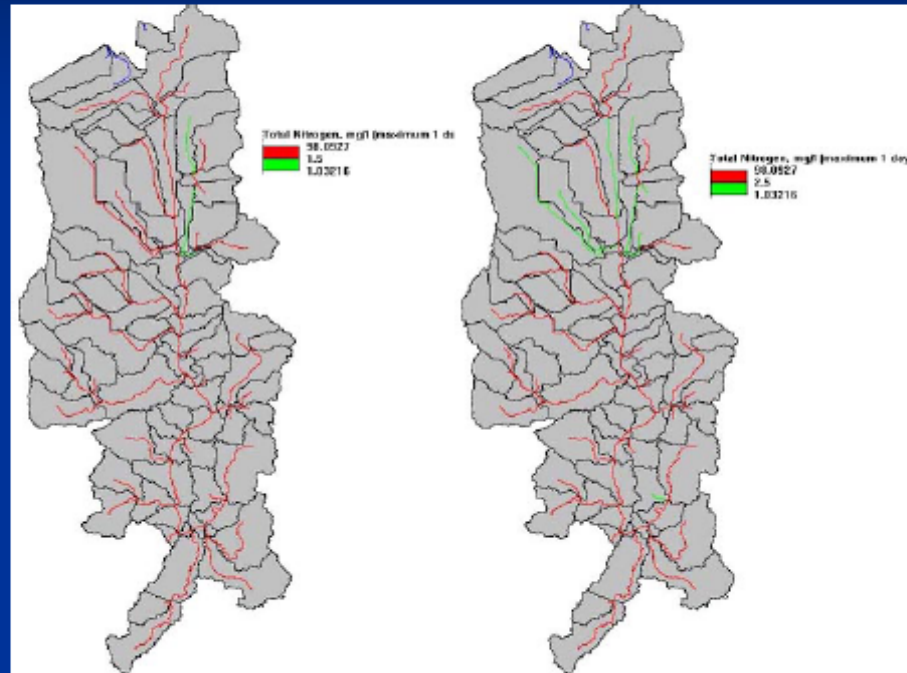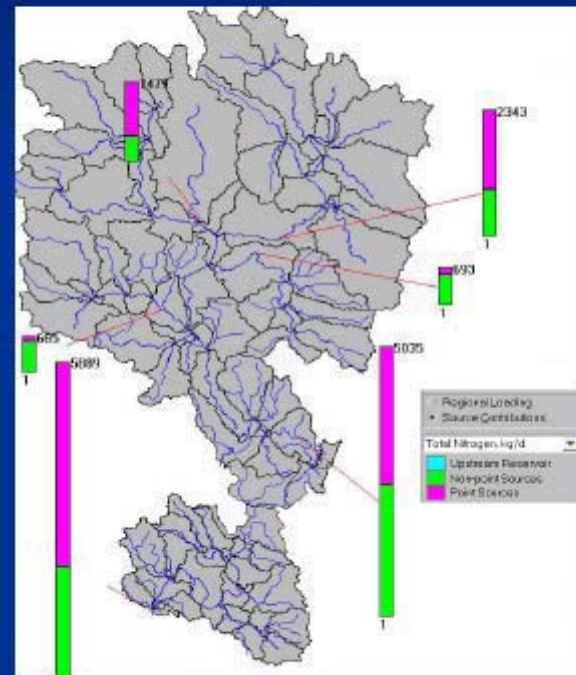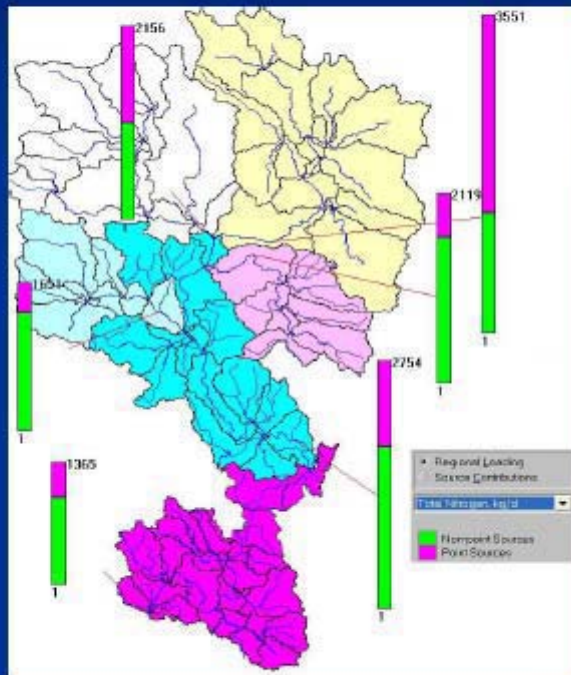
TN Load

Figure out the load at different locations.
Magenta = Point Source
Green = Nonpoint Source
Left Image = River
Right Image = Land
Shows the overall magnitude of trading area

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TN Load

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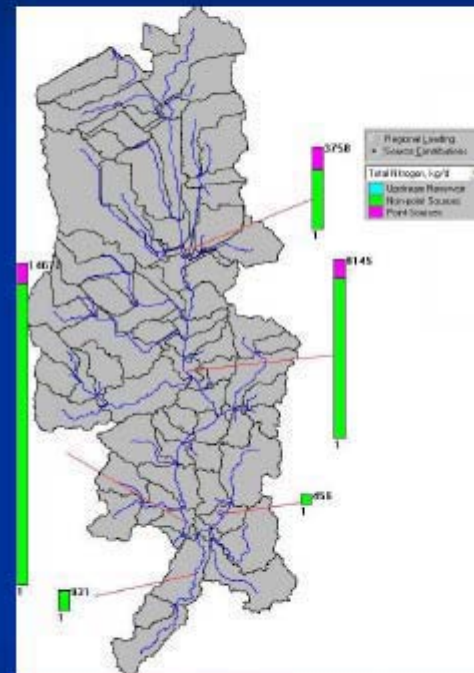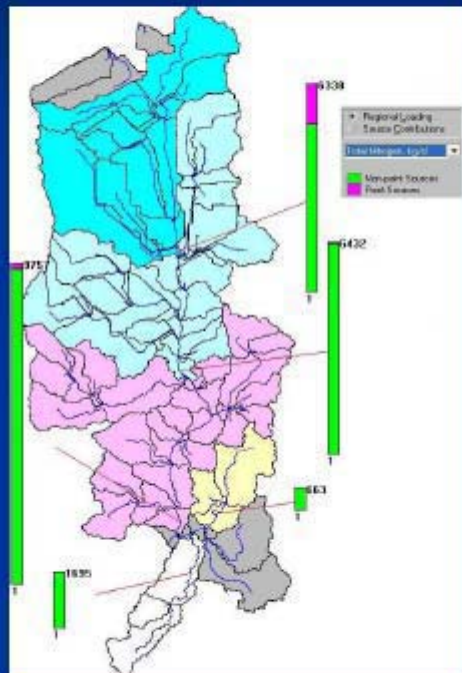
Focus Area: Muskingum Discharge

- TN Fluxes (kg/d):
  - Local Point Sources: 209*
  - Local Non-Point Sources: 3,410 excess applied / 424 to river
  - Regional Non-Point Sources: 7,303 excess applied / 691 to river

*Based on data reported to USEPA NPDES program from 1999 to 2006

The 424 to the river is both surface and groundwater
Here is where you could bring the Nitrogen Oxide Credits.

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Temporal Pattern of WQ Exceedance

Looking for patterns and trying to discern the reasons for spikes and lows in the simulated data.

Focus Area: Ohio at Broad Run

- TN Fluxes (kg/d):
  - Local Point Sources: 191*
  - Local Non-Point Sources: 945 excess applied / 253 to river
  - Regional Non-Point Sources: 6,250 excess applied / 578 to river
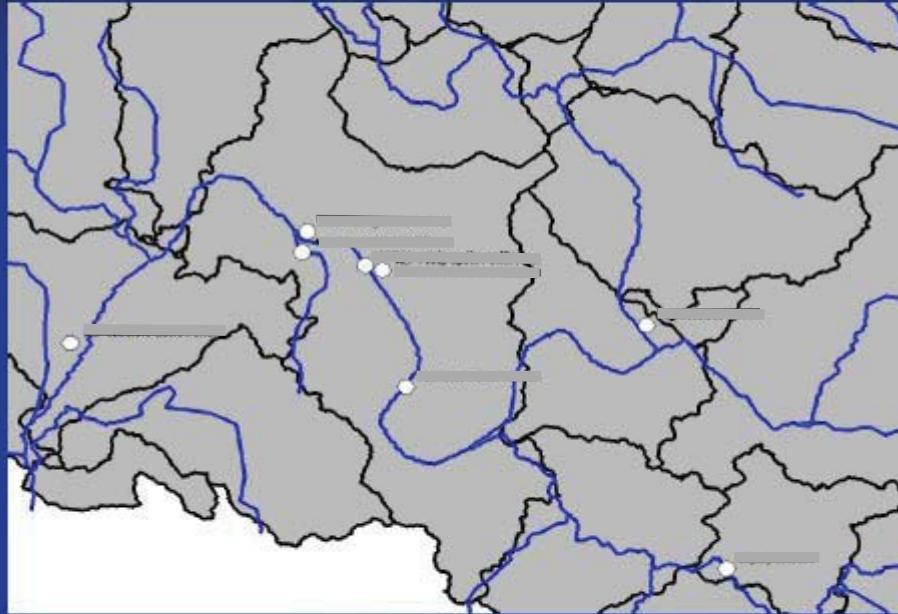
*Based on data reported to USEPA NPDES program from 1999 to 2006

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Temporal Pattern of WQ Exceedance

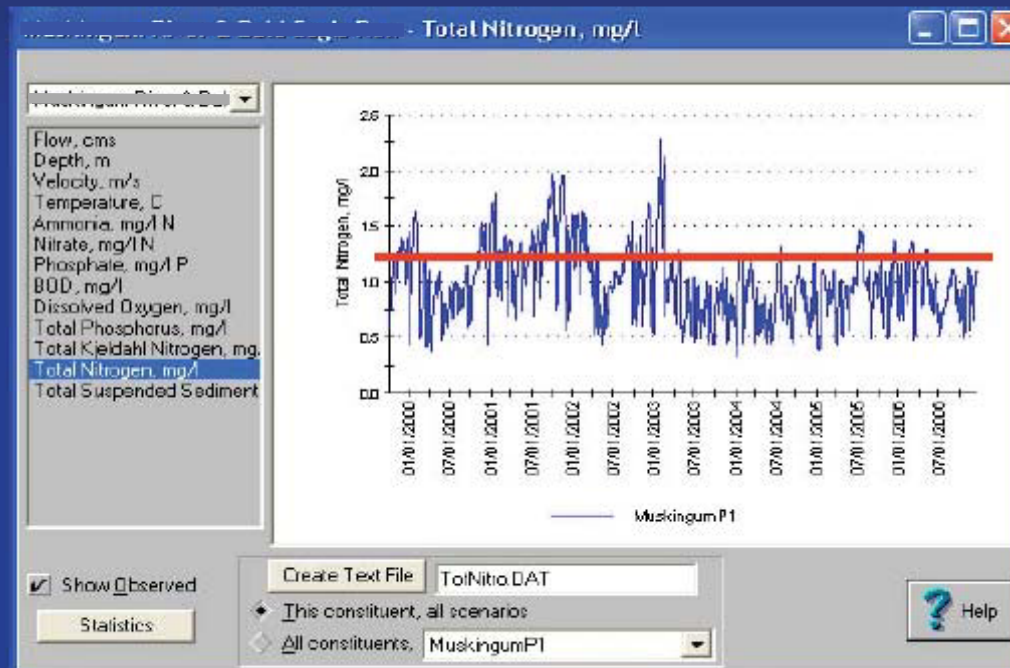EPRI | ELECTRIC POWER RESEARCH INSTITUTE
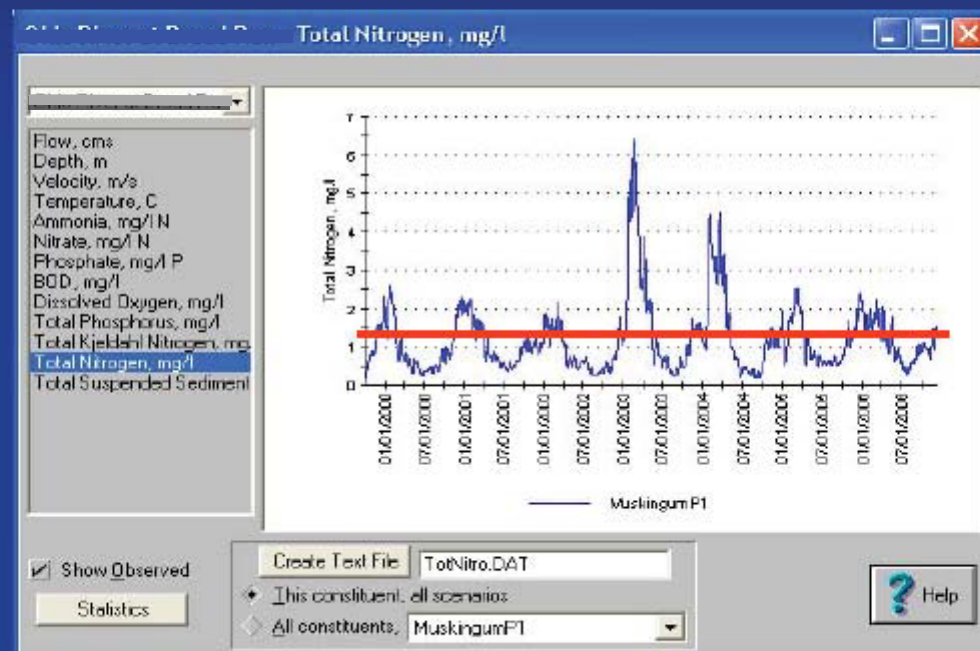
Key Findings

- WARMF model can be used to:
  - Identify WQ Areas for Potential Trading
  - Understand temporal pattern of WQ exceedances
  - Determine extent of local/regional trading areas
  - Assess magnitude of loads in a given trading area
  - Evaluate "trading ratios"
    - lb per lb?
    - distance between trades (fate and transport considerations)

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How would we take the information to apply the model to trading?

Q: Where did the "Reference Level" of 1.2 come from?
A: "Reference Level" of 1.2 is *not* a current standard but is based on a possibility that has been discussed in the area.

Q: Does the 1.2 "Reference Level" refer to In-Stream or Total Effluent Limits?
A: The 1.2 "Reference Level" is considered in-stream.

Q: Is the EPA Using WARMF?
A: Yes, as well as many state agencies across the country.

Q: How difficult/resource intensive is it to apply to other areas?
A: It is a question of scale and interest. Depending on the size/complexity of the watershed, the data available, and the level of detail desired in the model, it could be simple or more difficult.

The PCS Database will be better populated in the future, but for now is very labor intensive. Databases are getting better but sometimes Point sources are difficult to find, and they don't always monitor very well.

Q: There are concerns about the WARMF model because of how labor intensive it is, but are there general concerns/initial thoughts about using the tool to develop a trading program?

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Q: Did the agency contribute $ to the development of WARMF?
A: They may have historically contributed to the EPRI project that developed WARMF. The USEPA has certified the model. The current modeling effort is being funded by EPRI under a Technology Innovation grant.

Other Comments:

This is the first program to model the outcome of a trading program before trading even starts. The model will be very useful for determining the structure of a trading program, transport issues, trading ratios, and for optimizing the ecological outcome of a trading program. Of course, the ecological optimization will need to balanced, and in some cases compromised, in order to ensure the social, economic, and political elements are supported. After the trading program is established, WARMF will continue to be helpful for adoptive management by showing how the actual trading program data compares with the original model.

The EPA would probably be very excited about EPRI's work

Please direct questions to Jessica Fox, EPRI Project Manager, jfox@epri.com, 650-855-2138

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