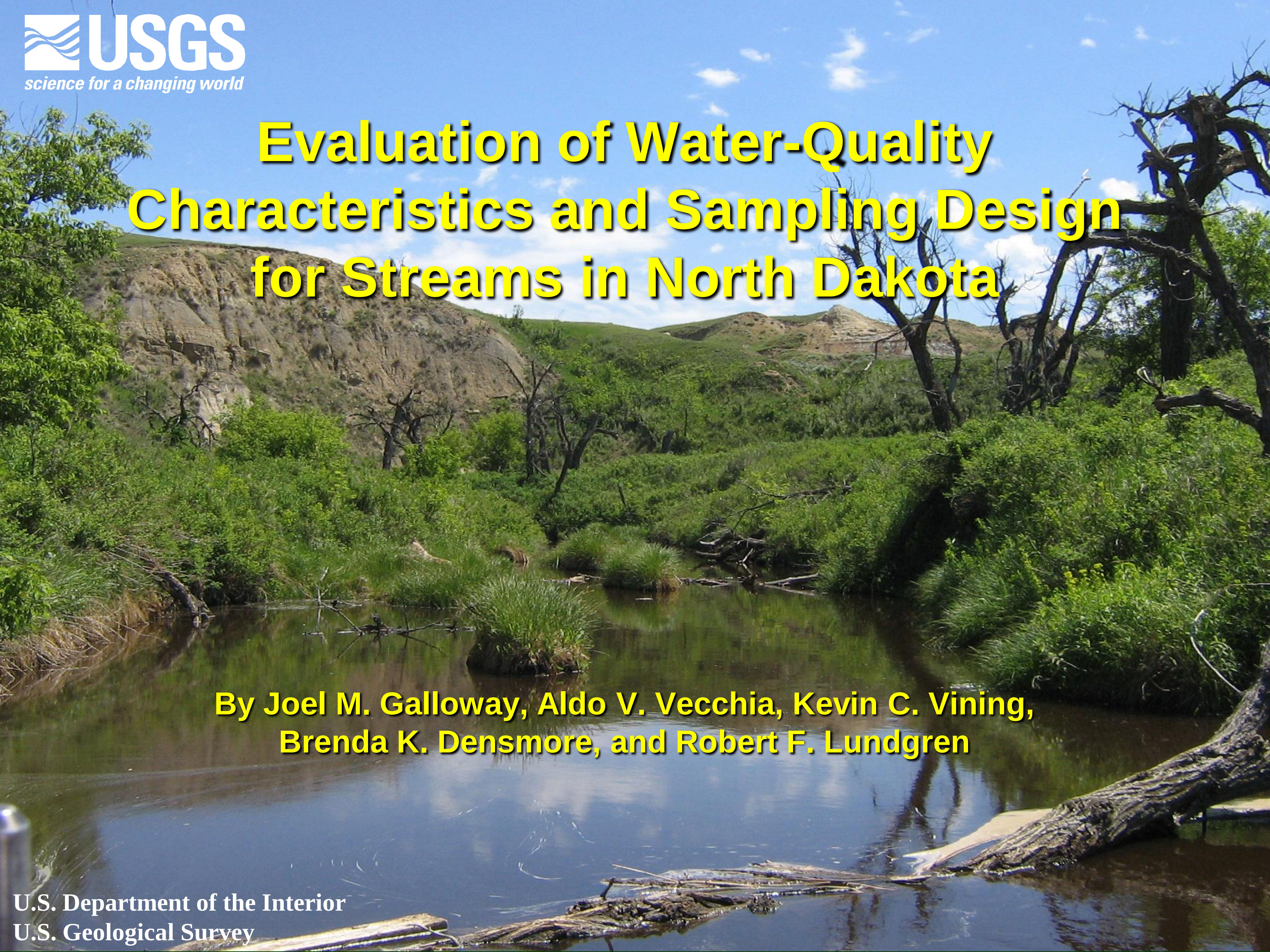

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science for a changing world

Evaluation of Water-Quality Characteristics and Sampling Design for Streams in North Dakota

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

Background

- Various agencies have conducted water-quality sampling programs and projects for streams in ND for a number of years for various purposes.
- Programs and projects have different sampling designs, water-quality constituents, and different laboratories
- Objectives vary among the programs, some of the programs overlap spatially and temporally, and the various sampling designs may not be the most efficient or relevant to changing program objectives

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Current Data Collection

- NDDH Ambient Water-Quality Network
  - 34 sites – 8 sites monitored by USGS, 26 sites by NDDH
  - Stream samples collected 8 times per year – January, April, May (2 samples), June, July, August, October
  - Samples analyzed for major ions, trace metals, nutrients, sediment, bacteria
- NDSWC High-Low Flow Sampling Program
  - 83 sites – samples collected 2 times per year, one during high flow (March-June) one during low – flow (August-October)
  - Samples analyzed for major ions and trace metals
- USGS Sampling Networks
  - Souris River Basin - 3 sites sampled 7 times per year
  - James River - 2 sites sampled 5 times per year
- Redundancy
  - 25 sites are both Ambient and High-Low sites
  - 2 sites are both Ambient and USGS-Souris River sites

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Purpose and Scope

1. Provide descriptive statistics and summaries of water-quality data from sites throughout the State;
2. Determine trends and loads for selected constituents and sites with sufficient concentration and streamflow data;
3. Determine an efficient state-wide network sampling design for monitoring future water-quality conditions

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Outline

- Analysis methods
- Spatial distribution of concentrations
- Loads and Yields
- Trends
- Sampling design

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Analysis Methods

- Examined all data available from 1970-2008 - Data obtained from USGS NWIS database, USEPA STORET database, and electronic files from NDDH
- Trace elements – only used data collected after Jan.1, 1993 because of changes in analytical and field collection methods

- Certain constituents were not evaluated because of large range of laboratory detection limits, highly variable field collection, and variable laboratory analysis methods
    - Fecal indicator bacteria, chlorophyll, organic compounds

- Data screening yielded 186 sites across the State with 10 or more samples for most constituents

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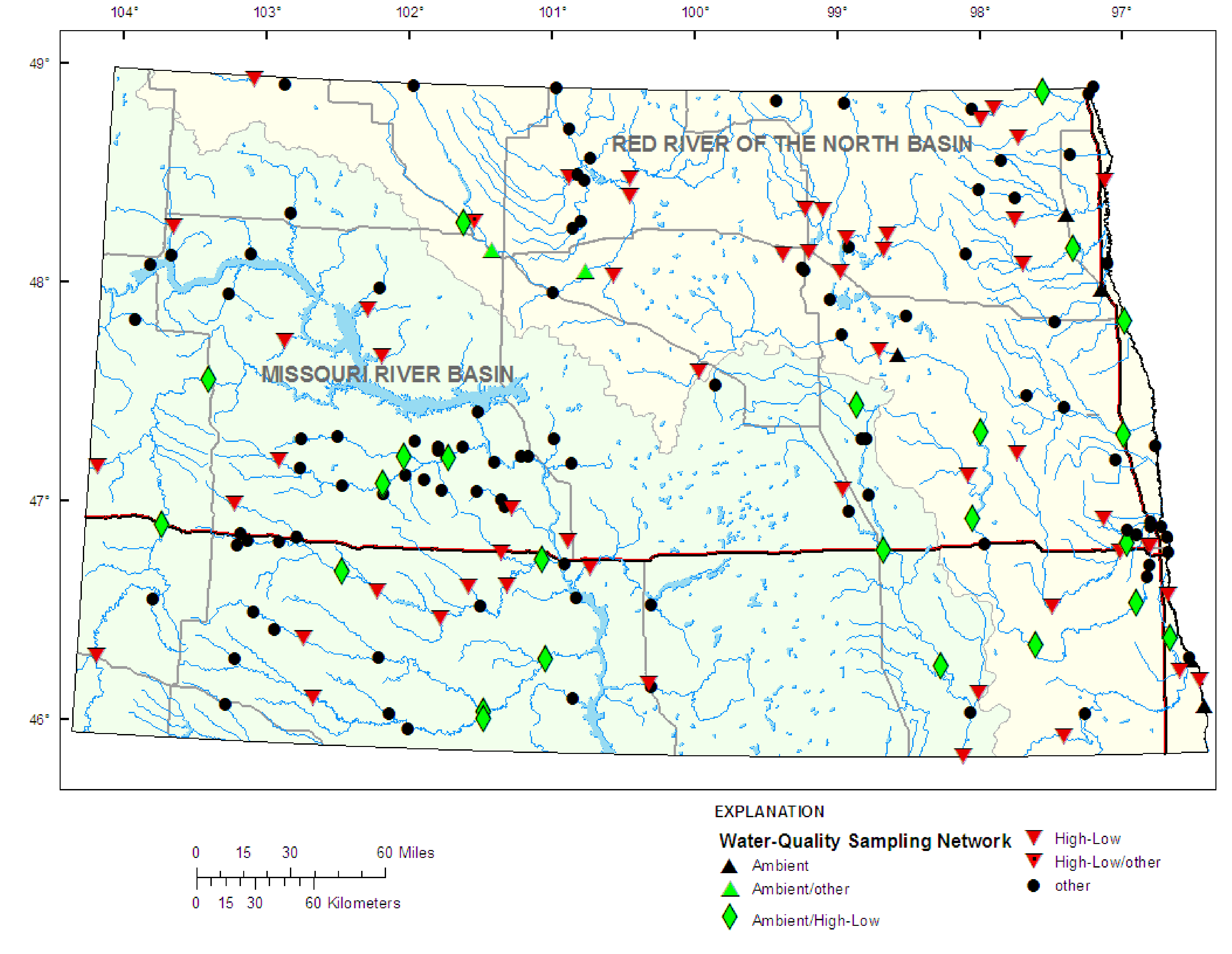
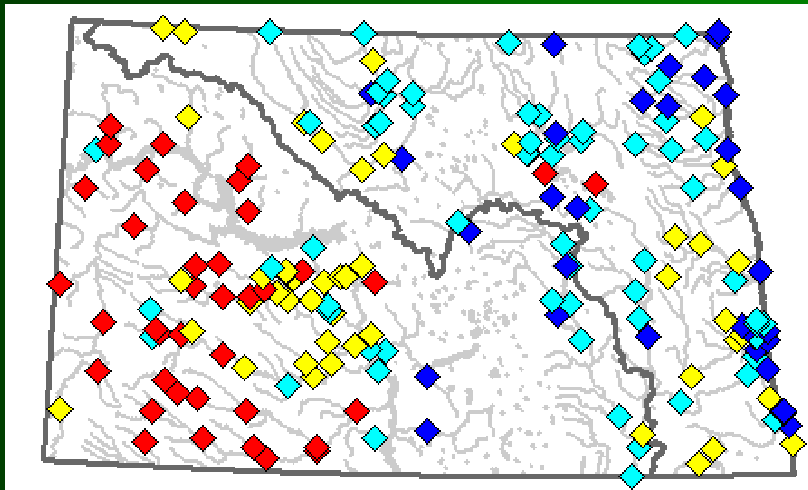


104°
103°
102°
101°
100°
99°
98°
97°
49°
48°
47°
46°
RED RIVER OF THE NORTH BASIN
MISSOURI RIVER BASIN
0 15 30 60 Miles
0 15 30 60 Kilometers
EXPLANATION
Water-Quality Sampling Network
Ambient
Ambient/other
Ambient/High-Low
High-Low
High-Low/other
other

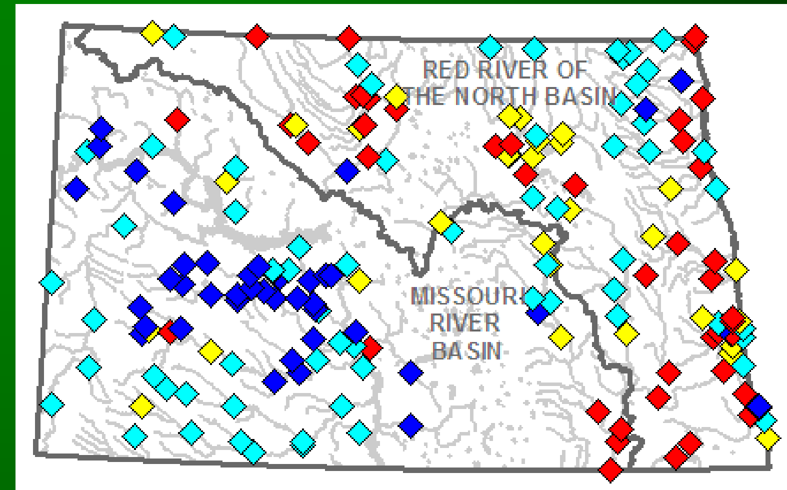
SPATIAL DISTRIBUTION - MEDIAN CONCENTRATIONS

Sulfate



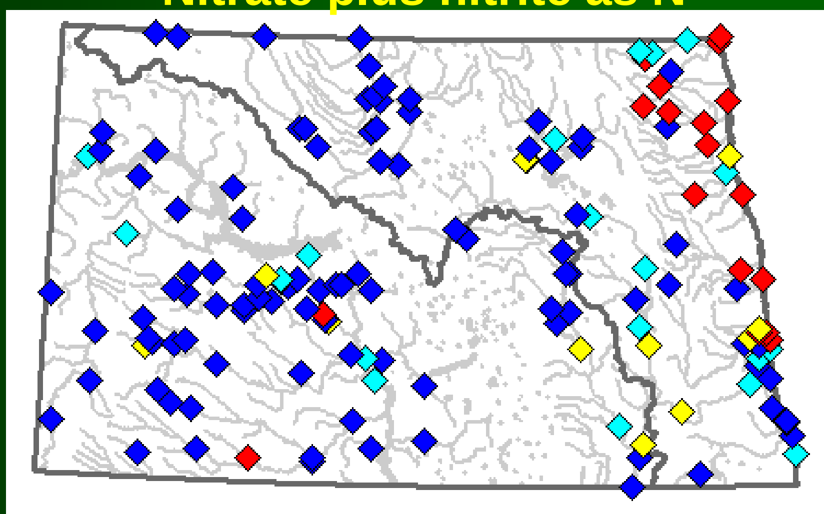
20 - 150 | 150 - 250 | 250 - 500 | greater than 500

Chloride



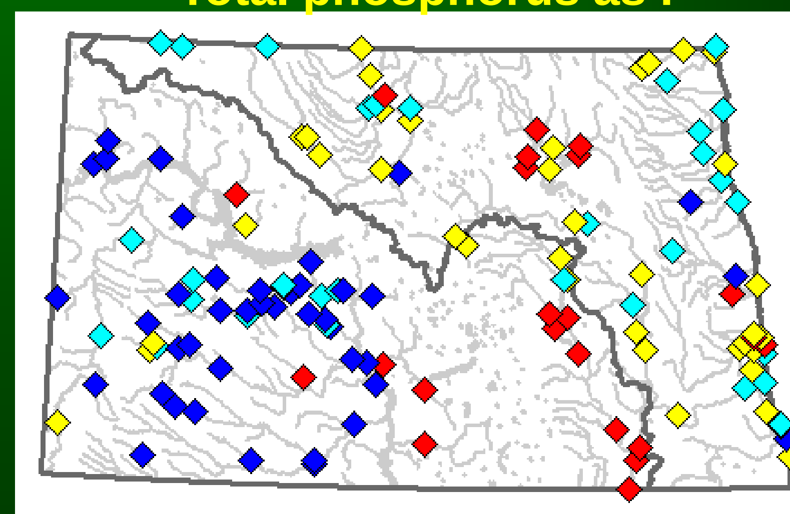
less than 4.0 - 8.0 | 8.0 - 16.0 | 16.0 - 24.0 | greater than 24.0

Nitrate plus nitrite as N



less than 0.10 | 0.11 - 0.20 | 0.21 - 0.30 | greater than 0.30

Total phosphorus as P



less than 0.01 - 0.10 | 0.11 - 0.20 | 0.21 - 0.30 | greater than 0.30

Loads and Yields

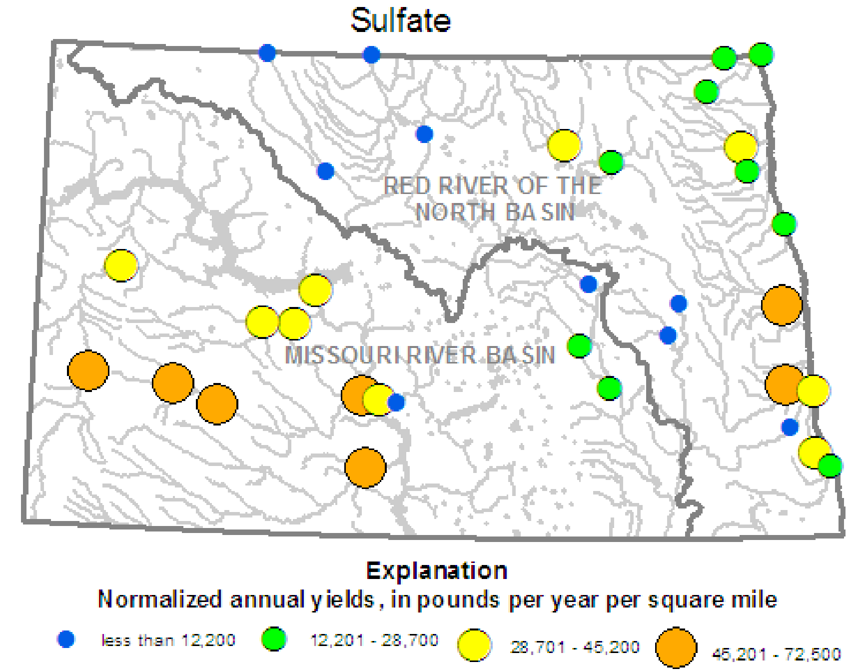
- Loads and Yields were estimated for sulfate, TDS, nitrogen, phosphorus, TOC, and suspended sediment
- 34 sites were selected with sufficient data to determine reasonable estimates of load
- Loads (tons/yr) were estimated using LOADEST to determine regression models:

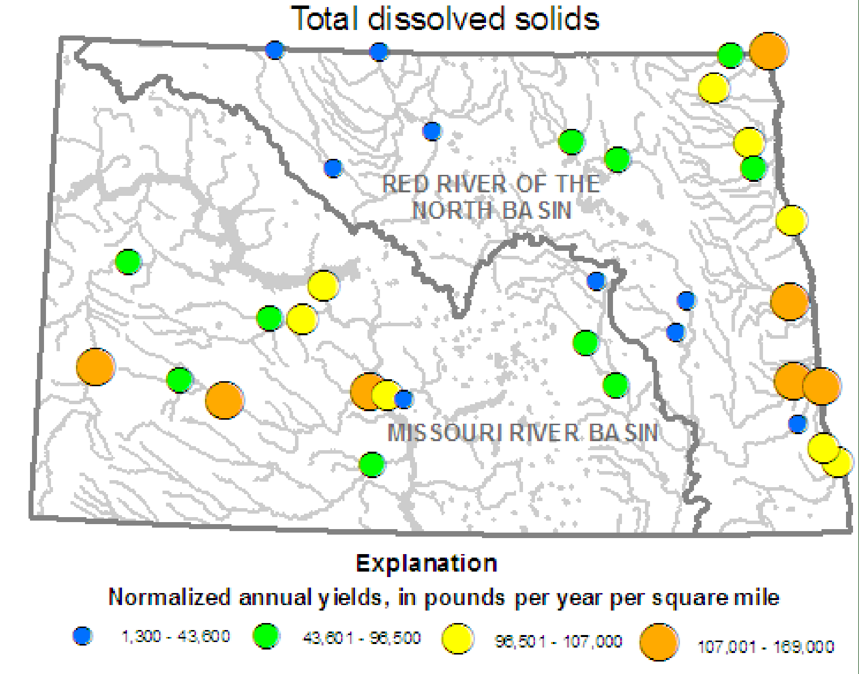
$$\ln(\text{Load}) = \beta_0 + \beta_1 * \ln(\text{Daily Streamflow}) + \beta_2 * (\text{Time}) + \underbrace{\beta_3 * \sin(2\pi\text{Time}) + \beta_4 * \cos(2\pi\text{Time})}_{\text{Seasonality}}$$

- Yields ($tons/yr/mi^2$) were calculated from the estimated loads:

Load (tons/yr) / Drainage area (mi^2)

Sulfate and TDS Yields





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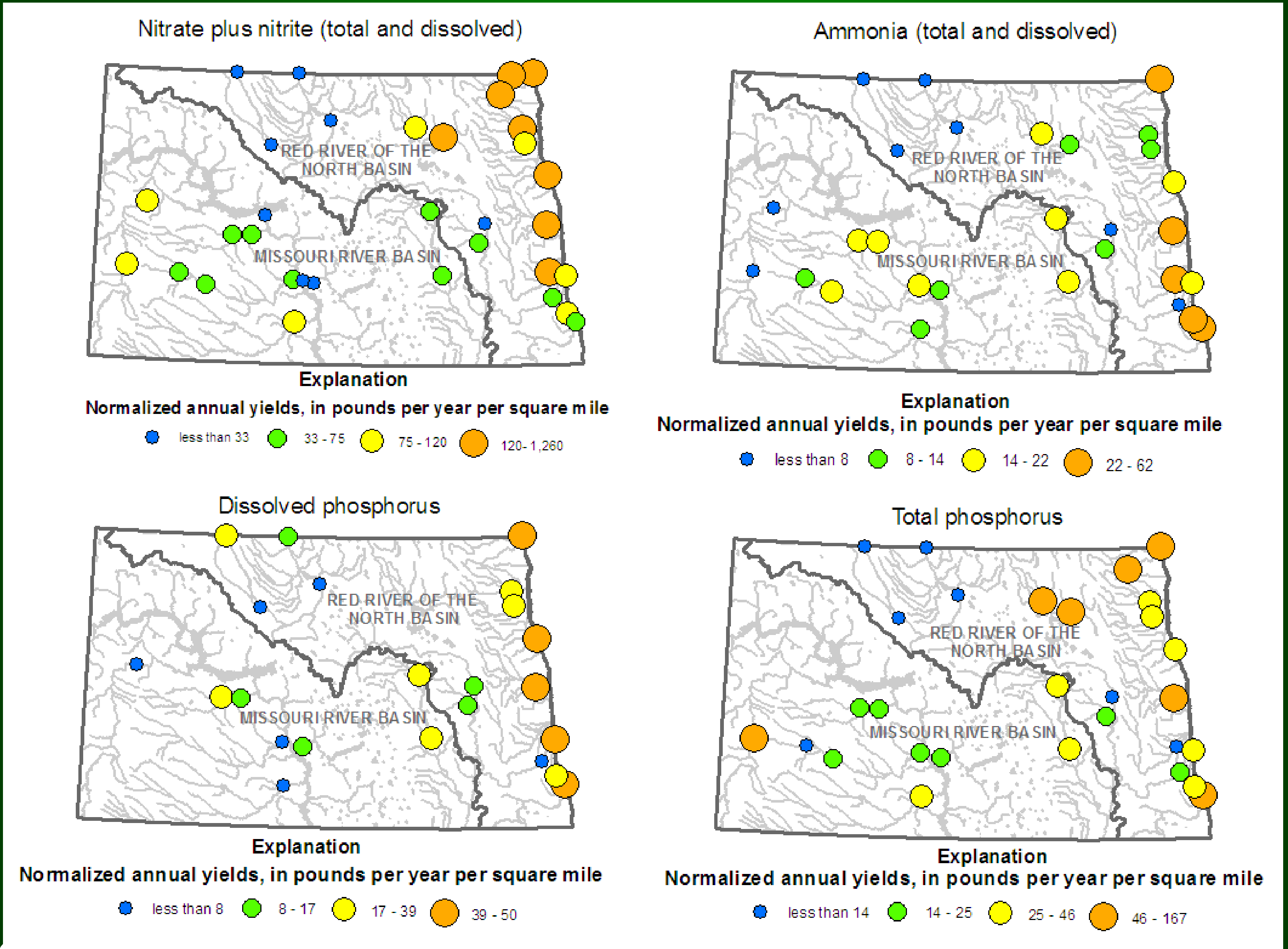
Nutrient Yields



Trends

- Used time series model (QWTREND) to evaluate flow-related variability and trends in historical concentrations. Significant trends were determined using maximum likelihood estimation and generalized likelihood ratio tests
- Selected 10 sites with sufficient data

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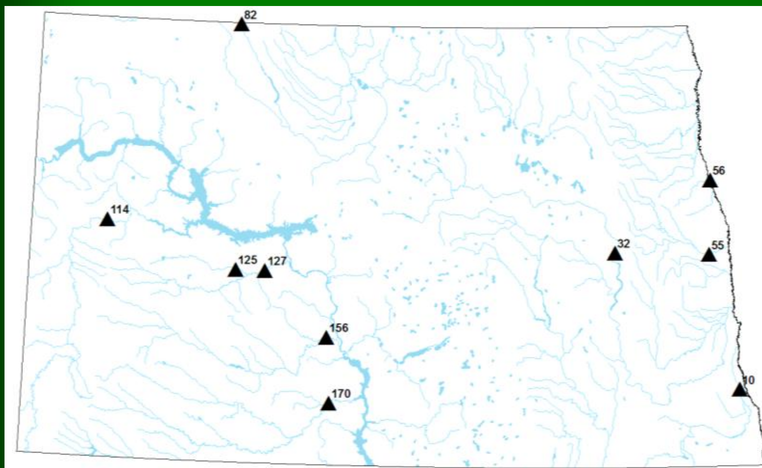
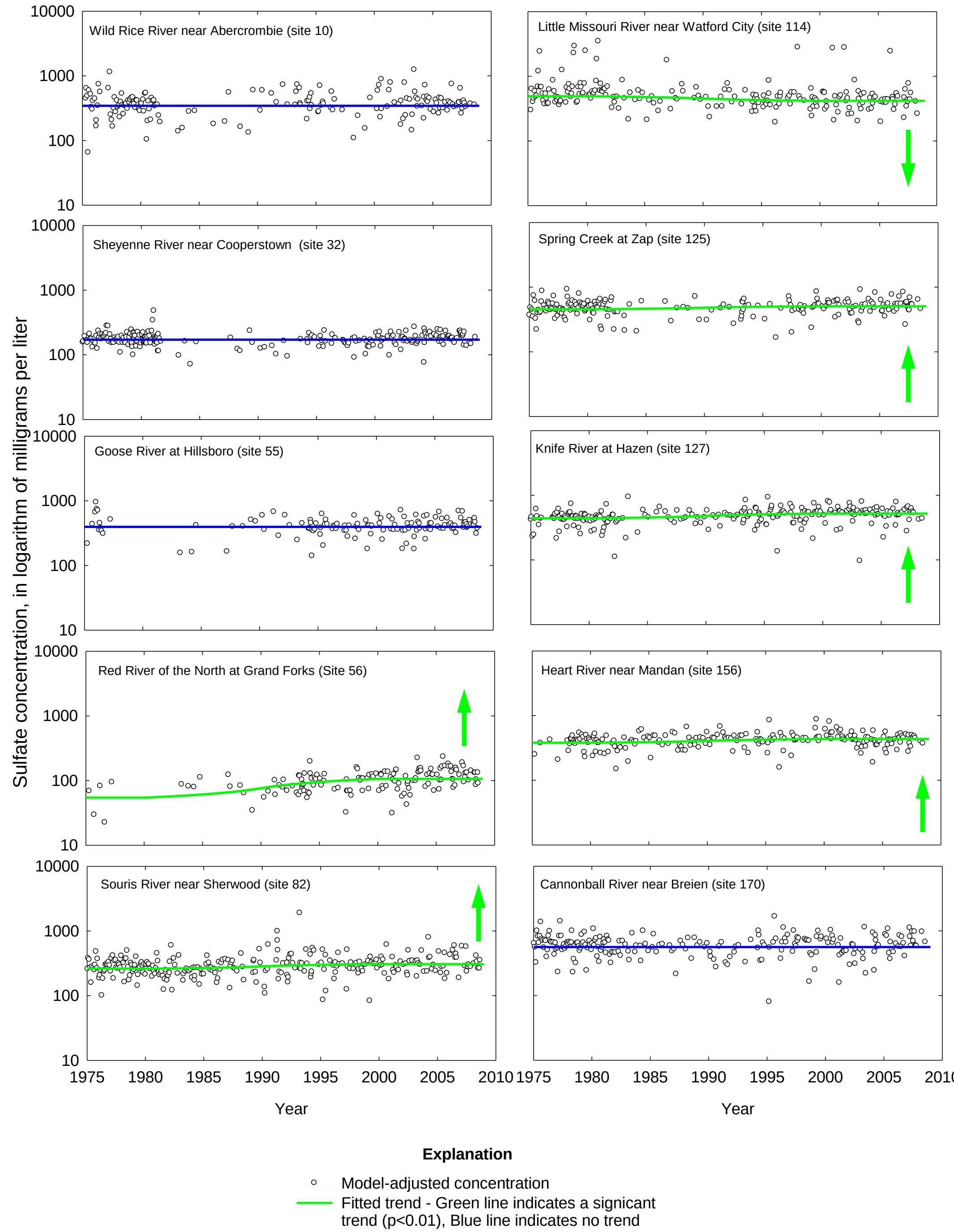
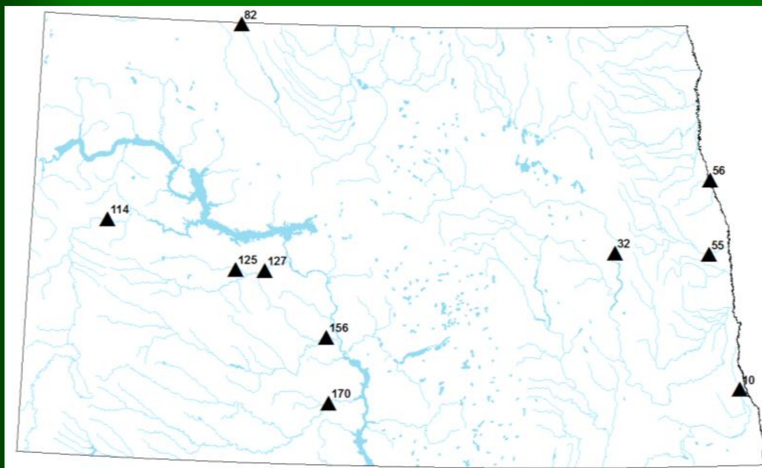
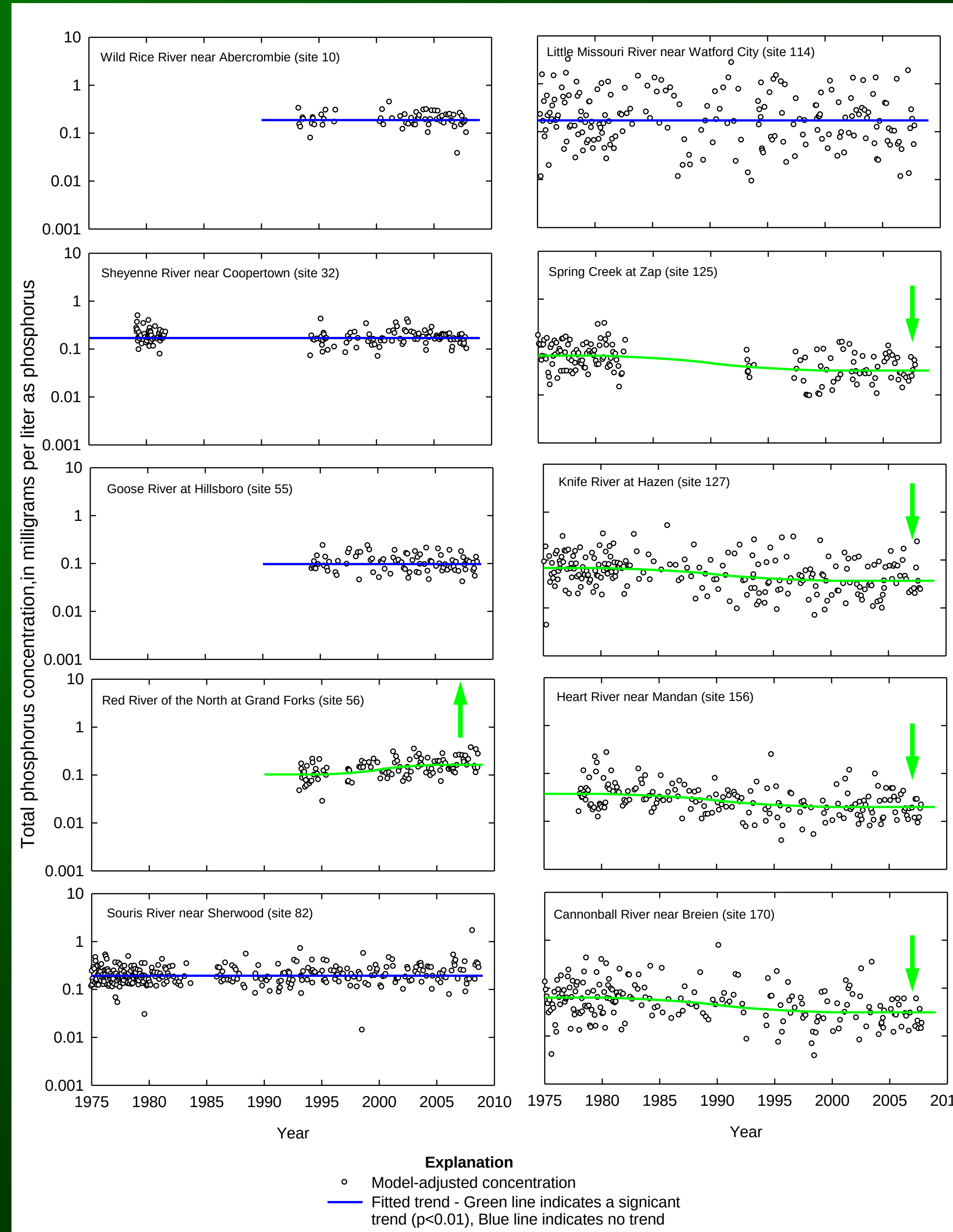
Sulfate Trends



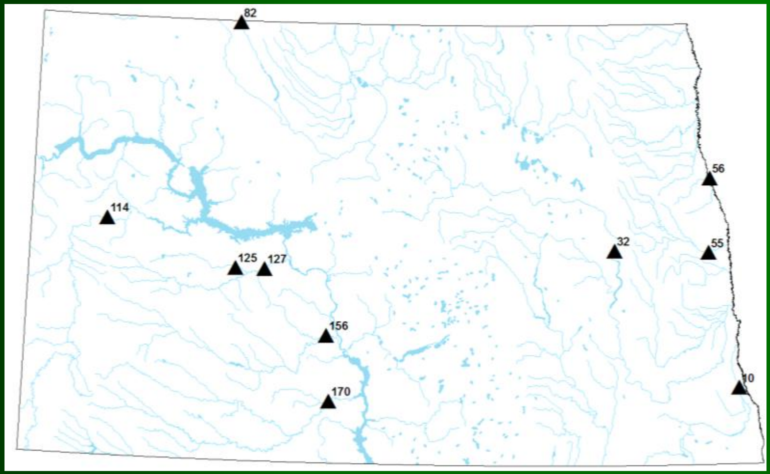


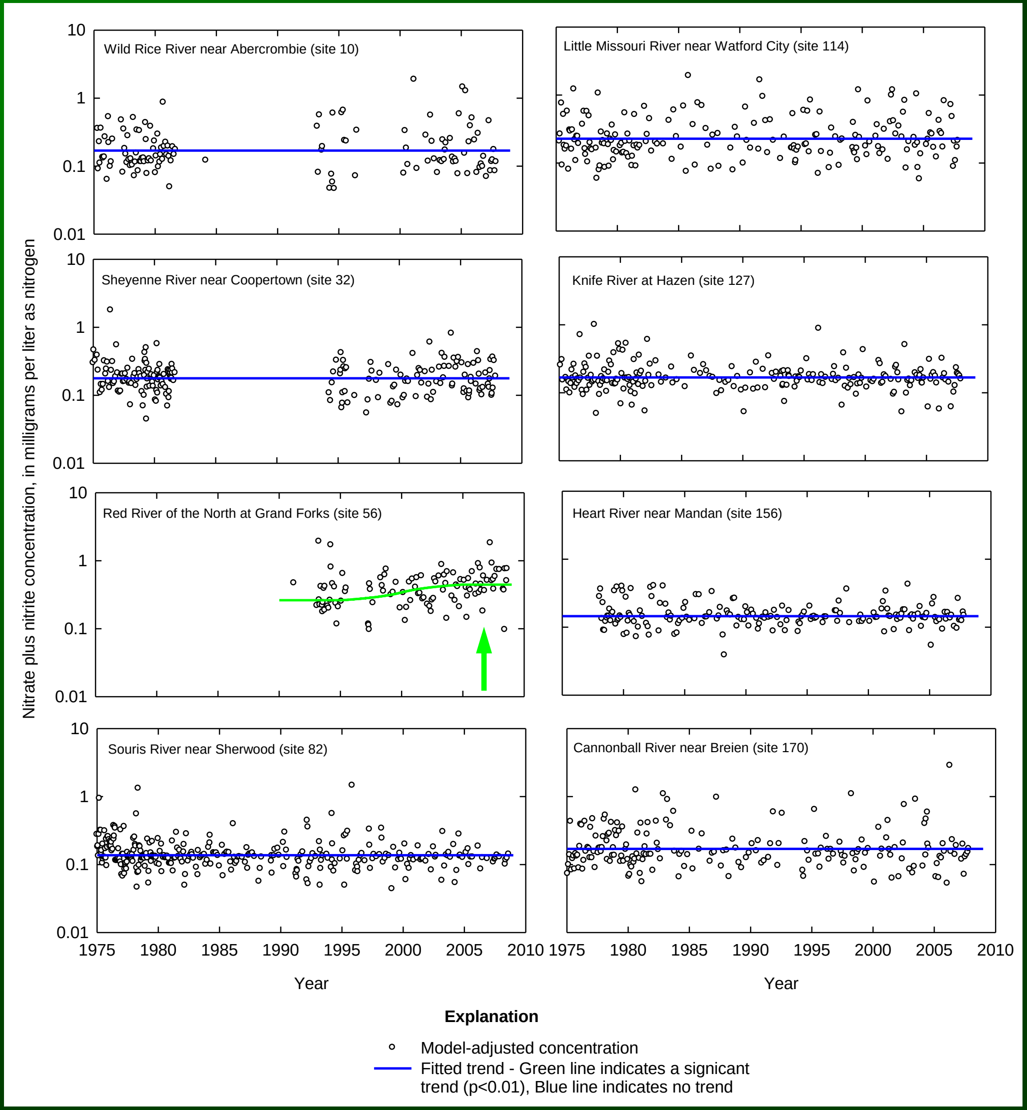
Total Phosphorus Trends





Nitrate plus Nitrite Trends





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Statewide Sampling Network Design

- When/how often to sample (temporal design)
- Where to sample (spatial design)
- Look for efficient designs
  - Highest sensitivity to detect at-site trends for a given cost (ie, number of samples)
  - Sites selected to reduce redundancy, hence maximize information for characterizing spatial water-quality variability

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Temporal Design

- Measure sensitivity using characteristic trends
- Definition: the characteristic trend of a design for a particular season is the size of trend, in percent per year, that has an 80 percent chance of being detected after 5 years of sampling
- Seek to minimize the CHTND (ie, maximize sensitivity) over all seasons and constituents.
- For this analysis, “good” sensitivity was achieved if all of the CHTND’s were less than 20 percent for sulfate and TDS and less than 40 percent for nutrients

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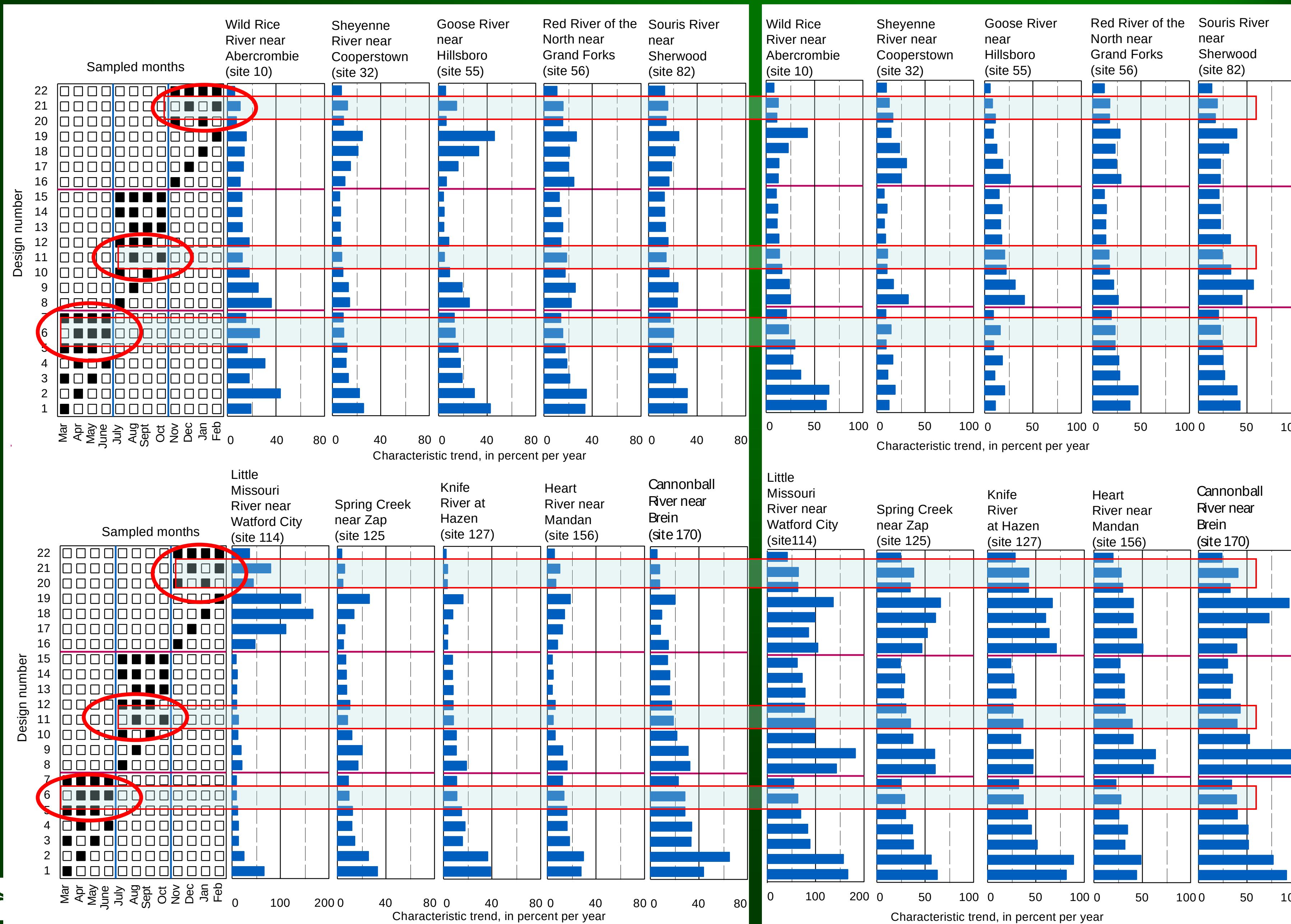
SAMPLE DESIGN - FREQUENCY

SULFATE

TOTAL PHOSPHORUS



Temporal Design Results

- Overall most efficient design for detecting trends in concentrations of major ions and nutrients consisted of six samples per year:

  ➔ **Level 2 design**; 6 samples (Apr, May, June, August, October, January)

- For better estimation of loads, extra samples in May and July were added to the Level 2 design:

  ➔ **Level 1 design**; 8 samples (Apr, May(2), June, July, August, October, January) [current ambient design]

- A less expensive but reasonable design for sites in smaller drainages:

  ➔ **Level 3 design**; 4 samples (Apr, June, July, August)

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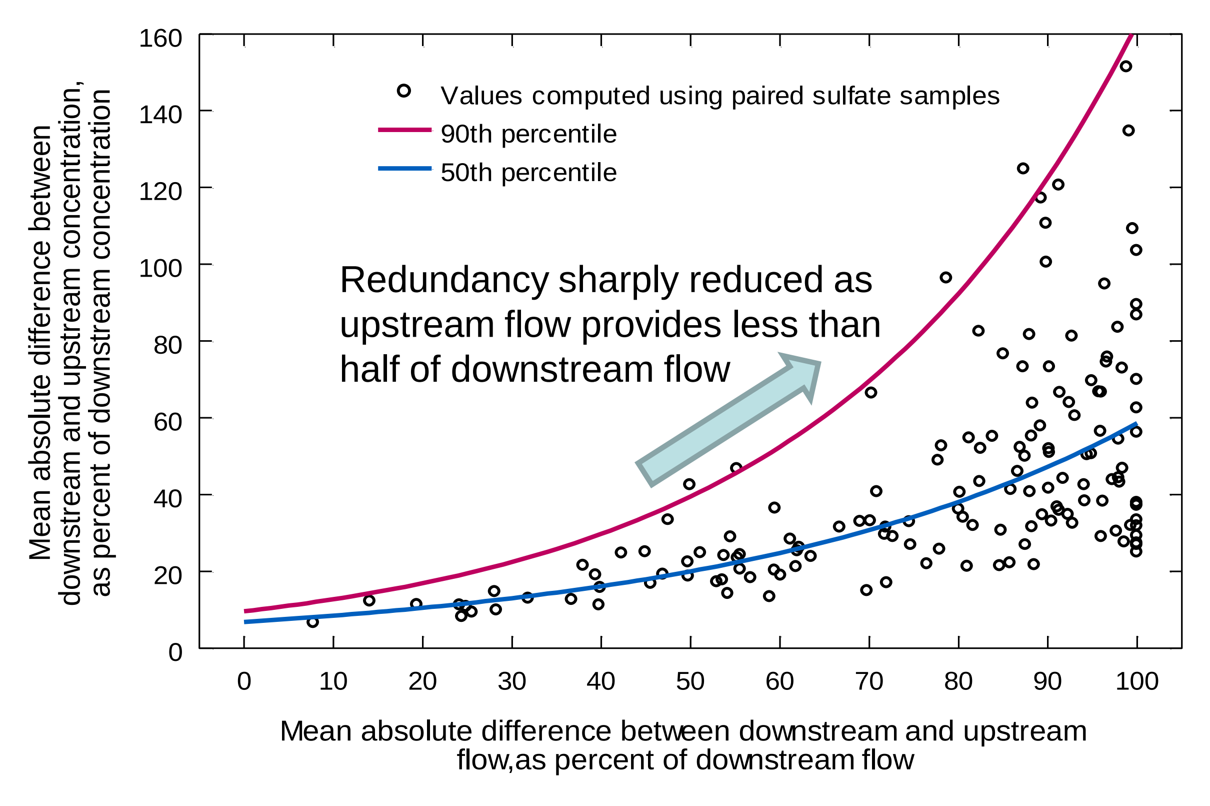
Spatial design considerations

How far apart should sites be spaced, and where in the drainage basins should they be placed, to maximize information on spatial variability of water quality?



Paired (in time) concentration samples from nested sites were used to evaluate redundancy in relation to differences in flow contributions

Implications: Sites should be spread as uniformly as possible to represent roughly equal incremental flows, starting with large basins and working toward smaller basins. Concentrations in really small basins are highly variable and cannot be predicted from larger basins.

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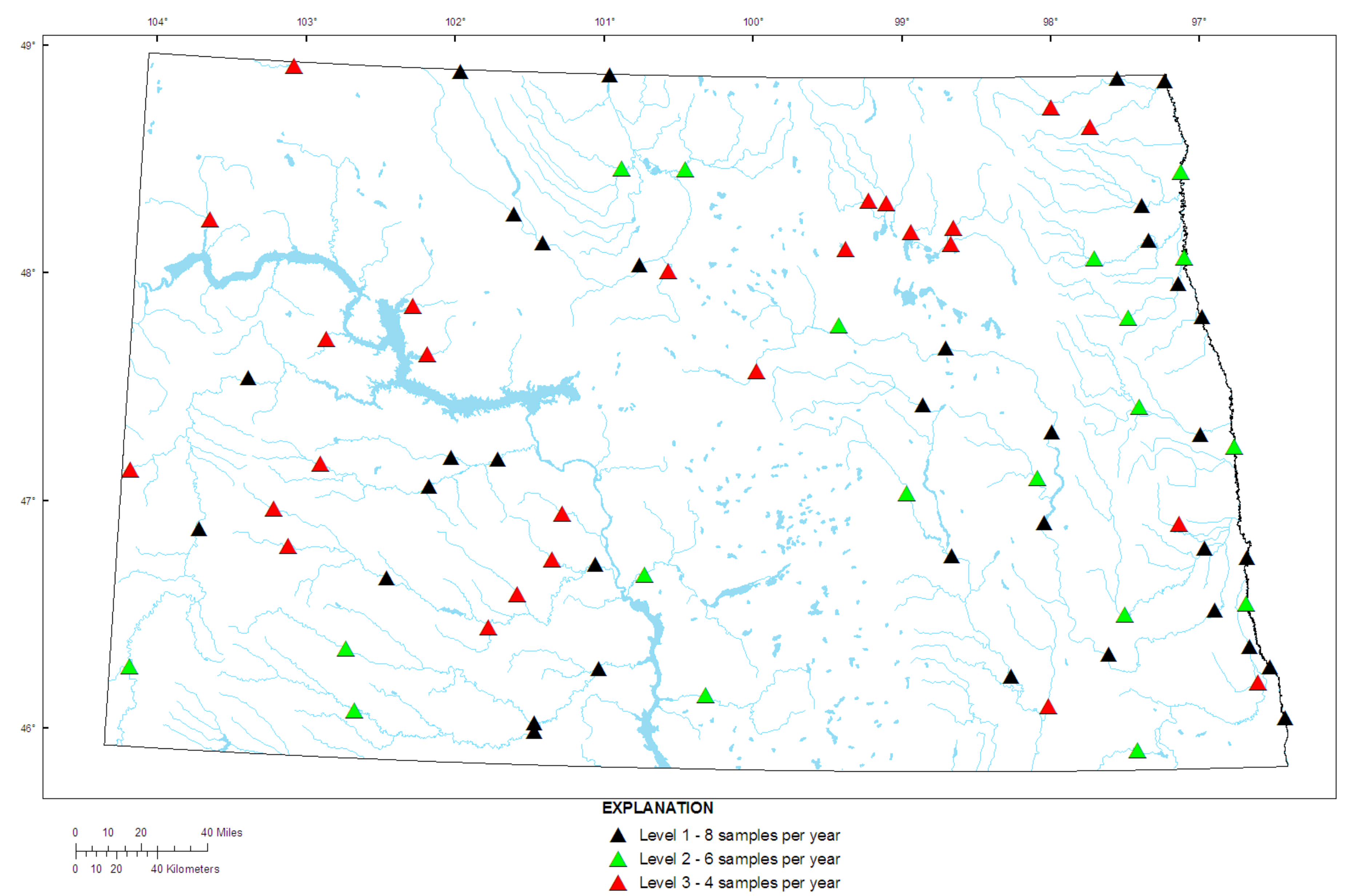
Sampling Design – Spatial Network



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Sample Design summary

Current Sampling networks

Sampling program	Number of sites	Sampling frequency	Total number of samples	Constituent groups
Ambient	34	8	272	Majors, Trace metals, Nutrients, bacteria, sediment
High-Low	81	2	174*	Majors, Trace metals
other	6	5-7	32	Majors, Trace metals, Nutrients,sediment

Total 478

Current Sampling networks

Sampling program	J	F	M	A	M	J	J	A	S	O	N	D
Ambient	X			X	2	X	X	X		X		
High-Low					X			X				
other		X			X	X	X	X	X		X	

New sampling network design

Design level	Number of sites	Sampling frequency	Total number of samples	Constituent groups	Objective
1	36	8	288	Majors, Trace metals, Nutrients, bacteria, sediment	Trends, Loads
2	17	6	102	Majors, Trace metals, Nutrients	Fill gaps in trends network
3	26	4	104	Majors, Trace metals, Nutrients	Fill gaps in spatial coverage

Total 494

Level	J	F	M	A	M	J	J	A	S	O	N	D
1	X			X	2	X	X	X		X		
2	X			X	X	X		X		X		
3				X		X		X		X		

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ANY QUESTIONS?

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