North Dakota's Water Quality Monitoring Program for Surface Waters:
An Ambient Monitoring Program Case History

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9th National Monitoring Conference
May 1, 2014
Cincinnati, OH

Programs, Projects and Studies

- Ambient Water Quality Monitoring Network for Rivers and Streams
- Biological Monitoring and Assessment Program for Rivers and Streams
- Ecoregion Reference Station Network
- Lake Water Quality Assessment Program
  - Lake Sakakawea
  - Devils Lake
- Missouri River Mainstem Monitoring Program
- Fish Tissue Contaminant Surveillance Program
- Wetland Monitoring and Assessment Program
- Impaired Waterbody Monitoring/TMDL Development Program
- Nonpoint Source Pollution Management Program Monitoring
- Other Monitoring and Assessment Related Activities
  - Support Projects and Special Studies
  - Complaint Investigations
  - Fish Kill Investigations

Programs, Projects and Studies

- National Aquatic Resource Surveys
  - EMAP Western Pilot Project
  - 2007 National Lake Assessment
  - 2008/2009 National Rivers and Streams Assessment
  - 2011 National Wetland Condition Assessment
    - State Intensification
  - 2012 National Lake Assessment
    - State Intensification
  - 2013/2014 National River and Streams Assessment
    - State Intensification

North Dakota Water Quality Monitoring Council

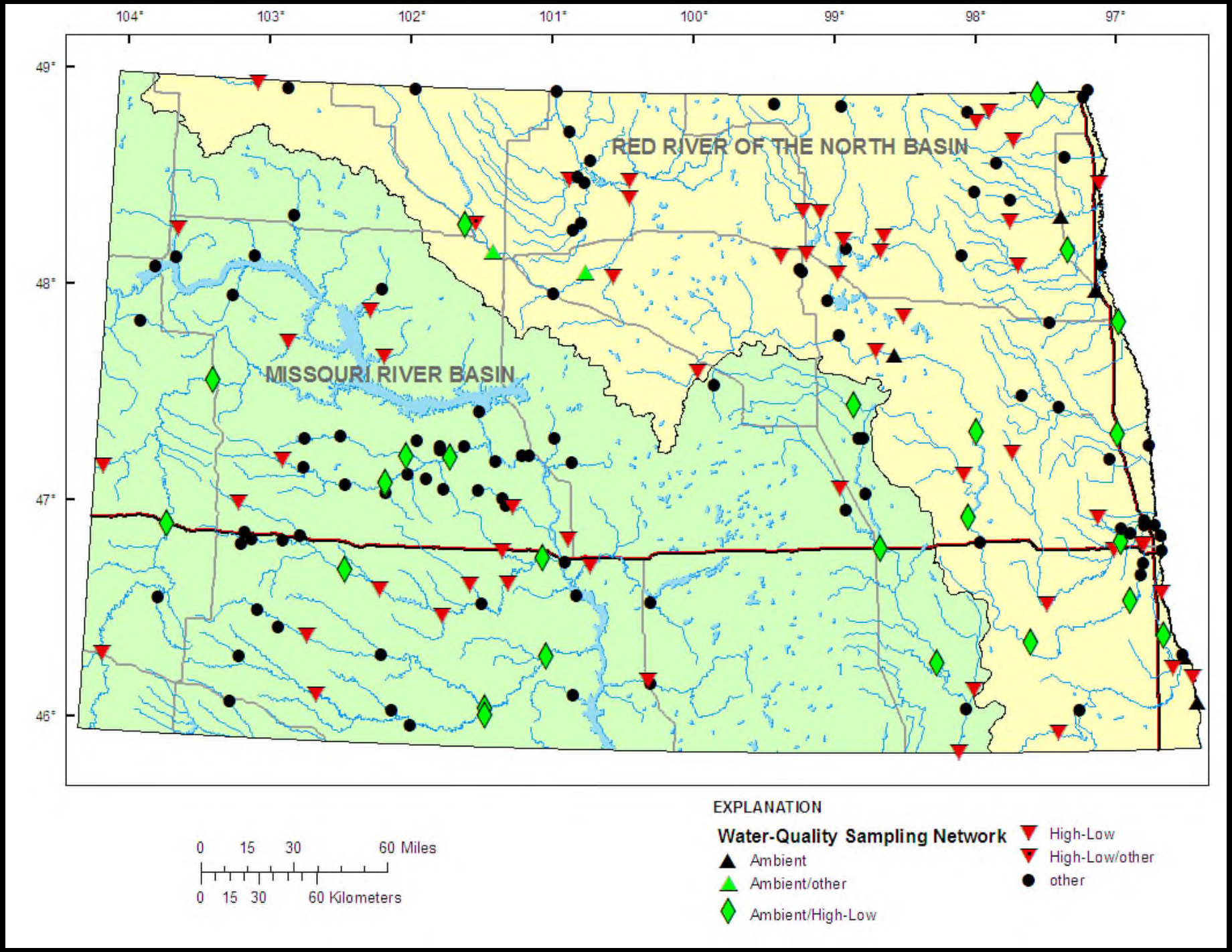
- Formed in 2009 as part of the state monitoring strategy
- **Mission:** To promote and facilitate collaboration for effective collection, analysis, and sharing of water quality data.
- **Vision:** Provide information necessary for the effective management, protection, and improvement of water quality in North Dakota.
- Water Quality Monitoring Conferences in 2012 and 2014
- Over 30 members, including state and federal agencies, organizations, academia, agricultural groups, and cities

North Dakota Water Quality Monitoring Council

- Provides review and comment on the elements of the state monitoring strategy
- Recommended review of the state ambient river and stream water quality monitoring program
- Conducted through a USGS analysis and review of current ambient water quality monitoring programs
  - Recommendations provided in a report entitled "Evaluation of Water Quality Characteristics and Sampling Design for Streams in North Dakota, 1970-2008" (http://pubs.er.usgs.gov/publication/sir20125216)

USGS Program Review

- 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
- NDSWC High-Low Flow Sampling Program
  - 81 sites – samples collected 2 times per year, one during high flow (March-June) one during low –flow (August-October)
- USGS Sampling Networks
  - Souris River Basin
    - 4 sites – sampled 7 times per year
    - 1 site – currently sampled by EC
  - 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


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

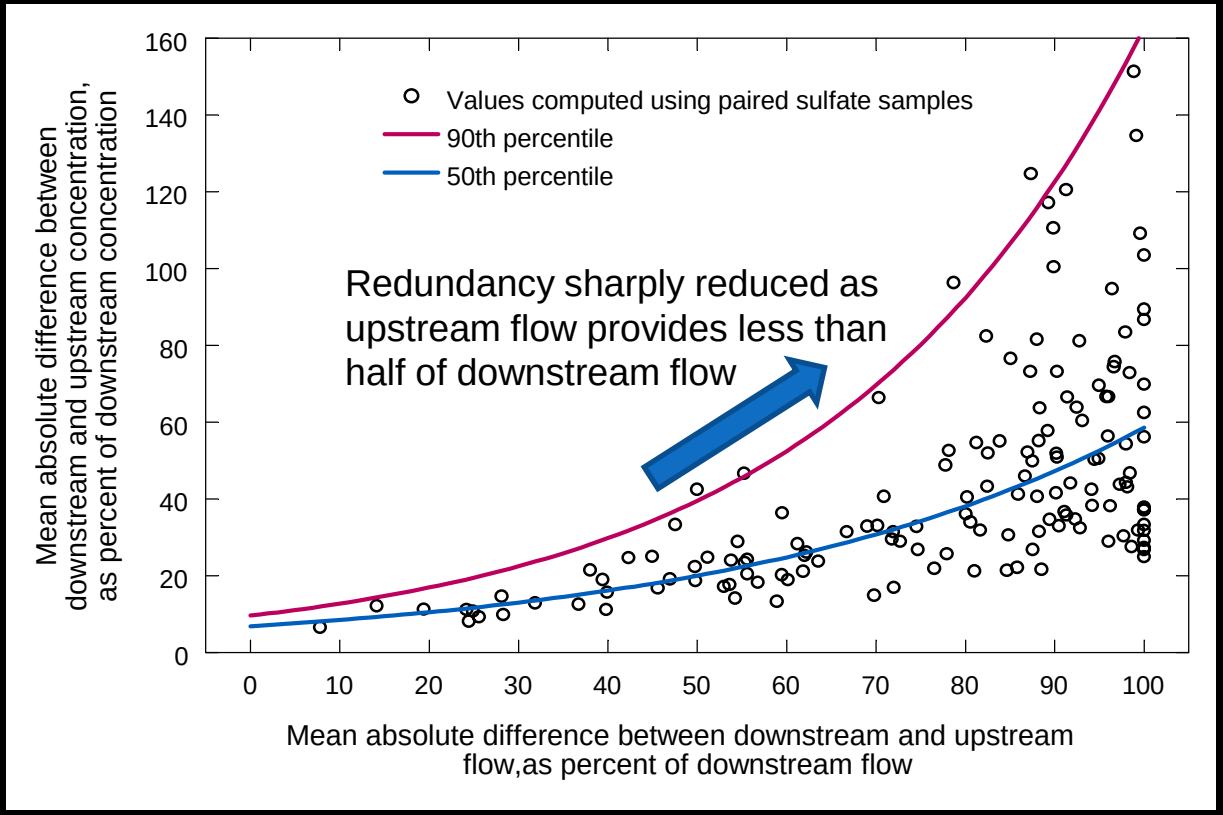
Sample Design

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

Spatial design considerations

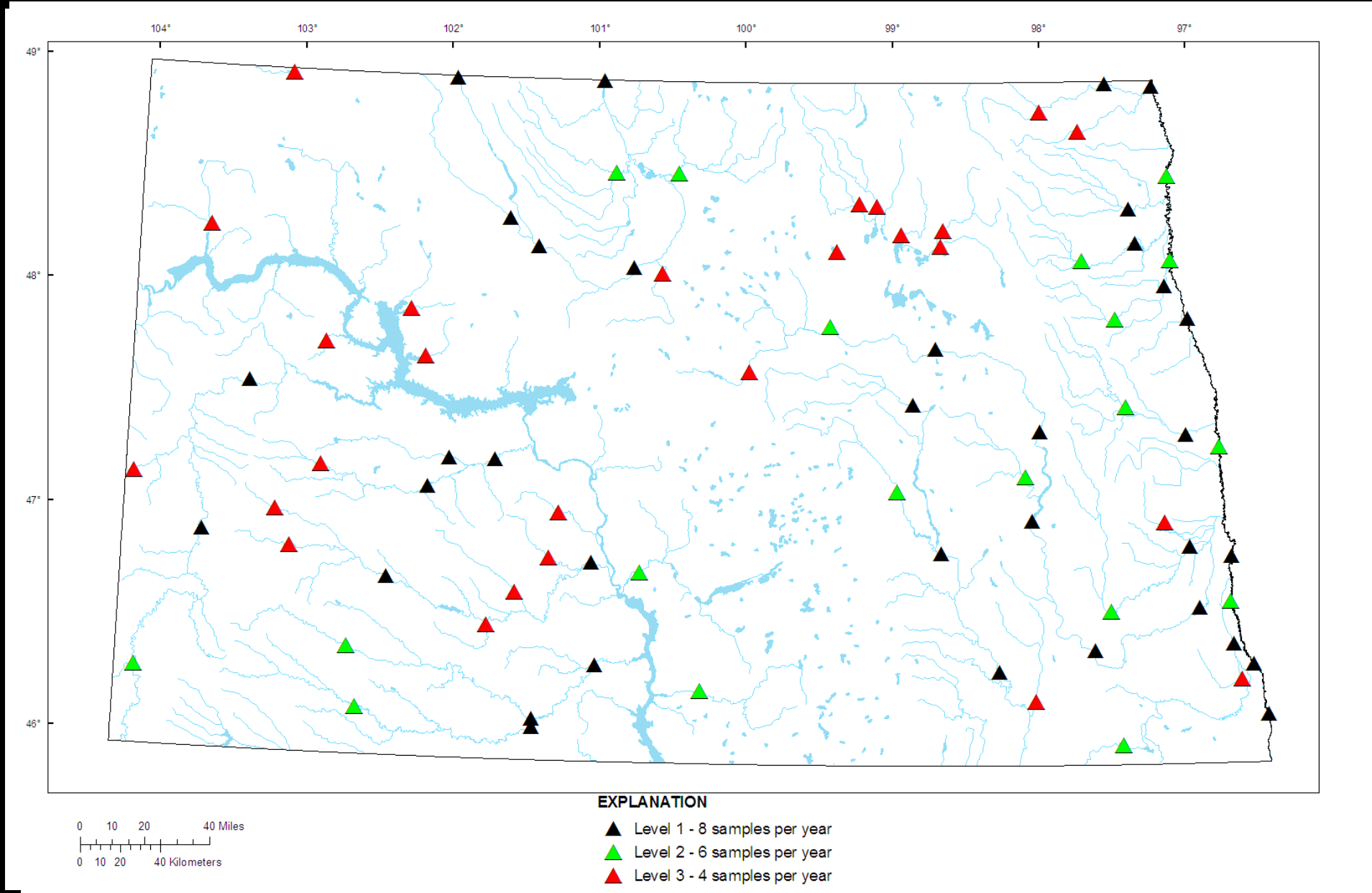
How far apart should sites be spaced, and where in the drainage basins should they be placed, to maximize information on spatial variability of water quality?

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.

Sampling Design – Spatial Network

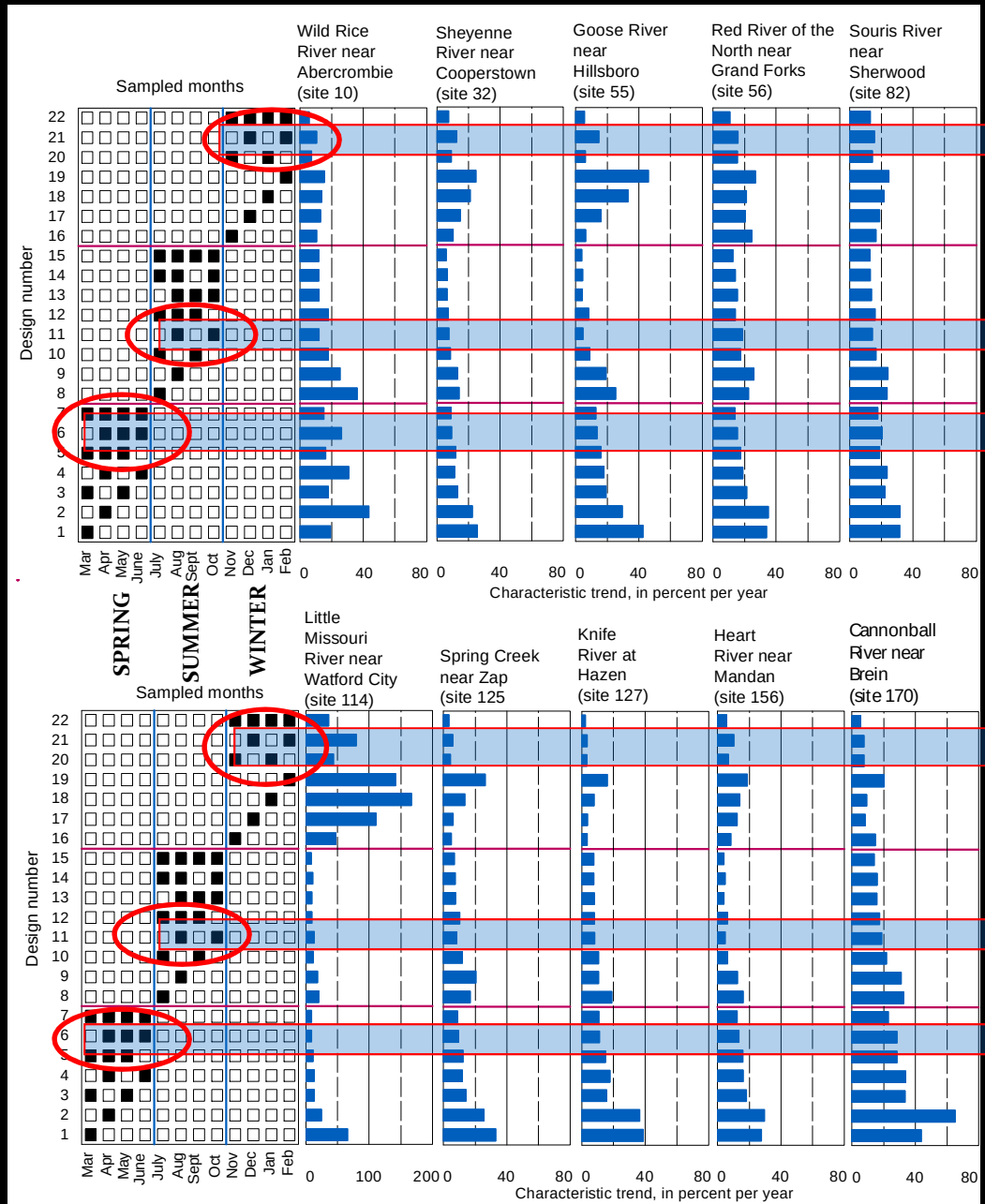


Temporal Design Trends

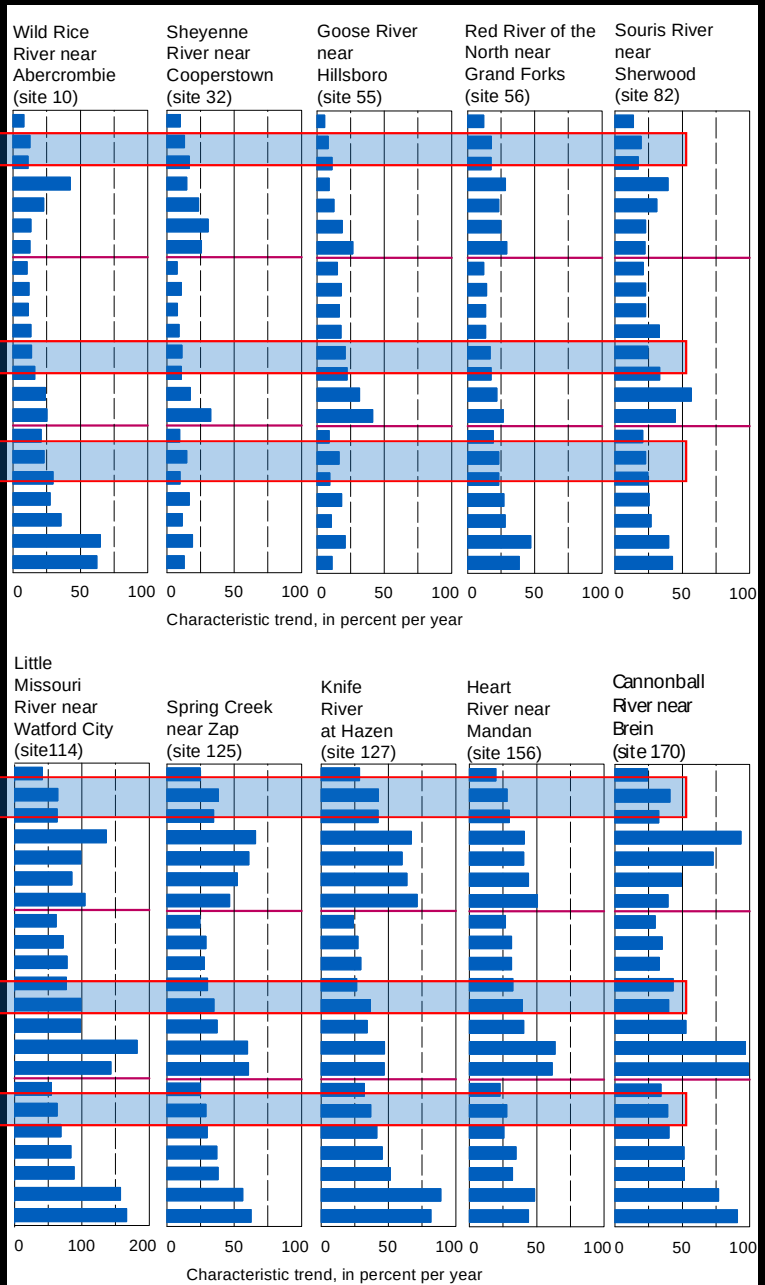
- Measure sensitivity using characteristic trends
- Definition: the characteristic trend (CHTND) of a design for a particular season is the size of trend, in percent per year, that has an 80 percent chance of being detected after 5 years of sampling
- Seek to minimize the CHTND (i.e., maximize sensitivity) 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

SAMPLE DESIGN - Trends

SULFATE



TOTAL PHOSPHORUS



Temporal Design - Loads

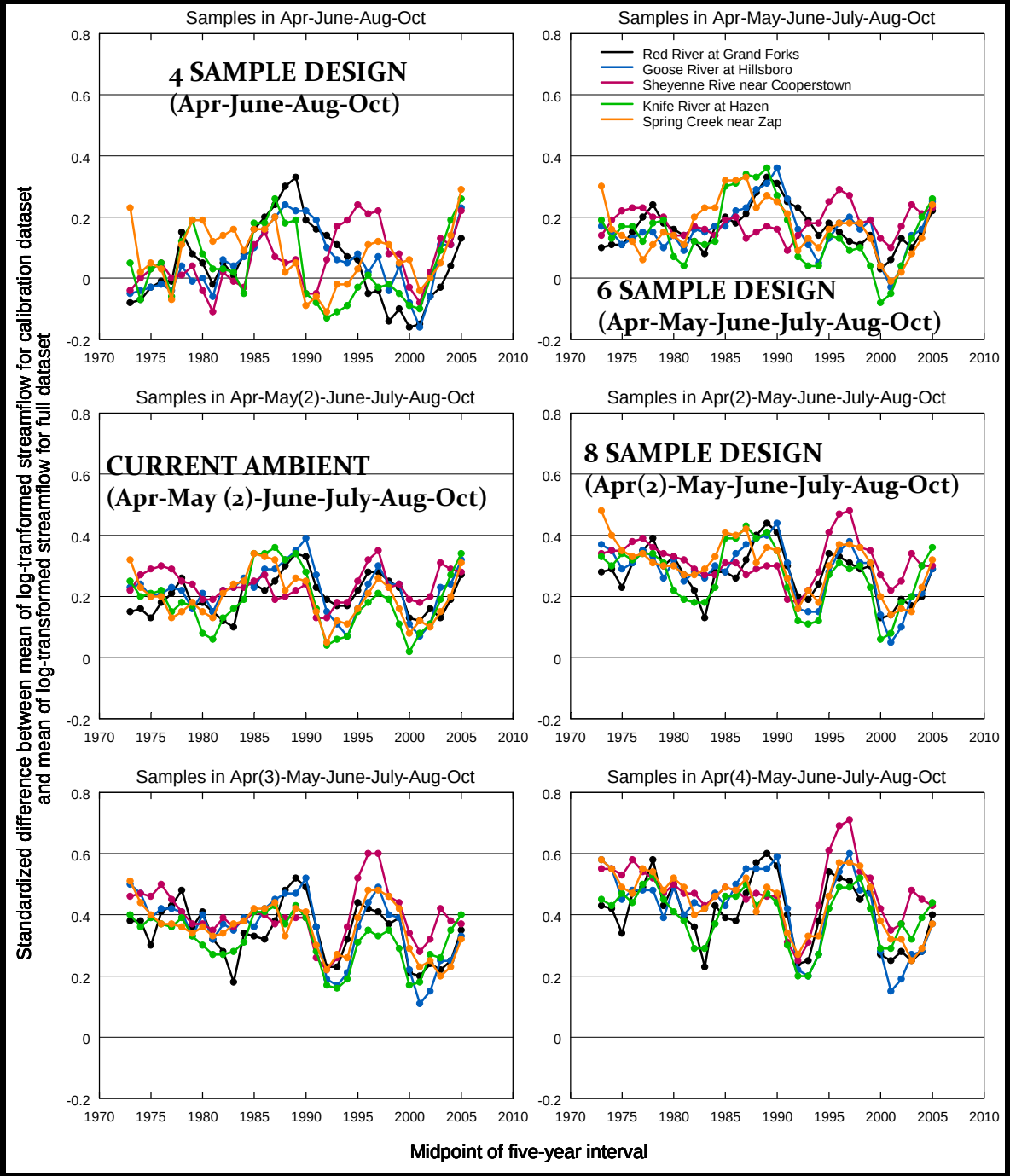
- Loads are estimated by regression analysis of conc. with flow
- Although important to define the conc. at the full range of flow at a site – if the high-flow conditions are not adequately included in the sampling, the estimated annual loads may be lower than what is actually occurring at the site.
- Gilroy and others (1990) developed a close approximation to the RMSE of the estimated total load for an N-day period
- RMSE depends on two quantities:

$$D^* = (AVE_C\{\ln Q\} - AVE_N\{\ln Q\})/SD_N\{\ln Q\}$$

$$R^* = SD_C\{\ln Q\}/ SD_N\{\ln Q\}$$

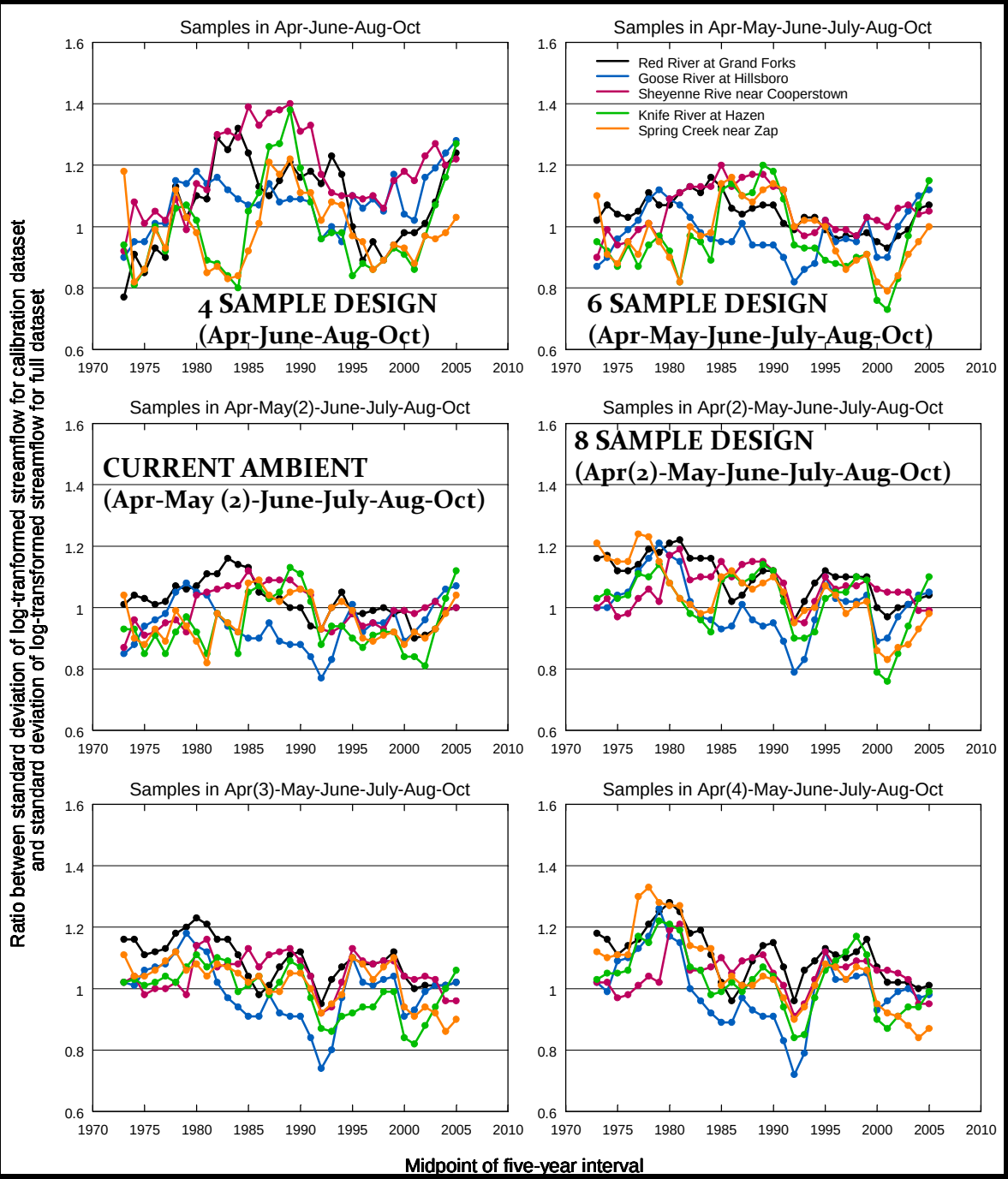
SAMPLING DESIGN
LOADS

- Five-year moving averages of daily flow used to compute D*
- Designs with D* closer to 1 more efficient for predicting loads



SAMPLING DESIGN
LOADS

- Five-year moving averages of daily flow used to compute R*
- Designs with R* greater than 1 more efficient for predicting loads



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 April and July were added to the Level 2 design:

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

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

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

Sample Design Summary

Current Sampling Networks

Sampling program	Number of sites	Sampling frequency	Total number of samples	Constituent groups
NDDH Ambient	34	8	272	Majors, trace metals, nutrients, bacteria, sediment
NDSWC High-Low	81	2	175*	Majors, Trace metals
USGS other	7	5-7	45	Majors, Trace metals, Nutrients,sediment

Total 492 samples per year

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

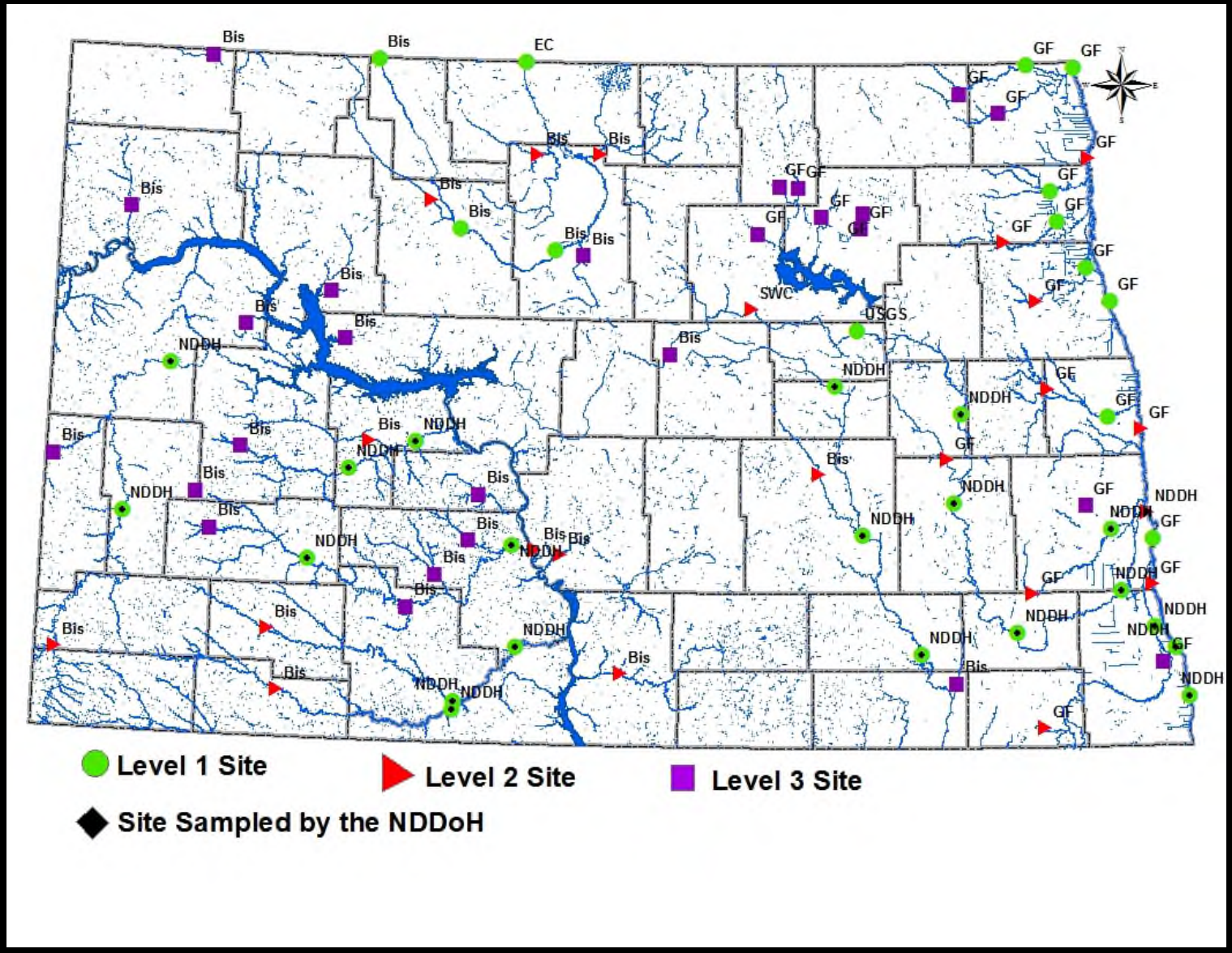
Level	J	F	M	A	M	J	J	A	S	O	N	D
1	X			2	X	X	X	X		X		
2	X			X	X	X		X		X		
3				X		X		X		X		

New sampling network design

Design level	Number of sites	Sampling frequency	Total number of samples	Constituent groups	Objective
1	34	8	272	Majors, Trace metals, Nutrients, bacteria, sediment	Trends, Loads
2	21	6	126	Majors, Trace metals, Nutrients	Fill gaps in trends network
3	26	4	104	Majors, Trace metals, Nutrients	Fill gaps in spatial coverage

Total 502 samples per year

Sampling Design - Statewide



Summary

- Three level site design
  - Level 1
    - 8 samples per year
    - Characterization, load and trend
  - Level 2
    - 6 samples per year
    - Characterization and trend
  - Level 3
    - 4 samples per year
    - Characterization
- State monitoring council facilitated the communication necessary to address deficiencies in state ambient river and stream monitoring network
- Implementation in 2013
- http://pubs.er.usgs.gov/publication/sir20125216