Trends in Major Ion and Nutrient Concentrations in the Mainstem of the Red River of the North

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In cooperation with
International Red River Board

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Objectives

- Determine trends in concentrations of selected nutrients and major dissolved ions for the Red River at Emerson, Manitoba
- Compare trends at Emerson using data from Environment Canada and from U.S. sources (USGS, NDDH, NDSWC)
- Compare trends at Emerson with trends for upstream (Halstad) site
- Discuss potential causes of the trends in relation to their time intervals, directions, and magnitudes

U.S. Portion of the Red River Basin

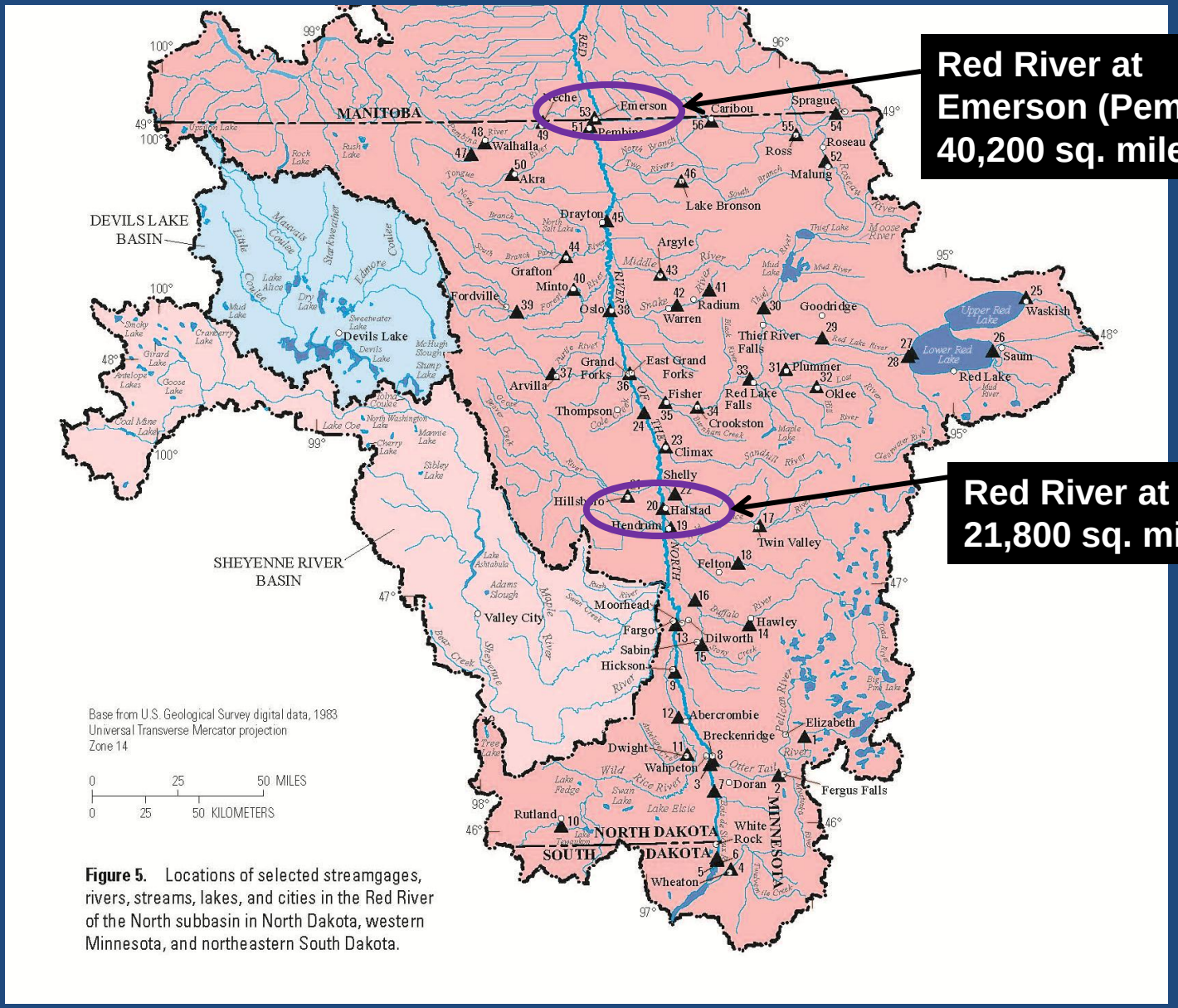


Figure 5. Locations of selected streamgages, rivers, streams, lakes, and cities in the Red River of the North subbasin in North Dakota, western Minnesota, and northeastern South Dakota.

Data used for trend analysis

Red River at Emerson

- Daily streamflow for Emerson obtained from Water Survey of Canada records
- Constituent concentrations at Emerson obtained from Environment Canada (personal communication, Minzhen Su, EC) – referred to as "Canada Data"
- Constituent concentrations for from USGS, NDDH, and NDSWC for Red River at Emerson (05102500) and Pembina (05102490) combined into single data set – referred to as "United States Data"

Red River at Halstad

- Daily streamflow data from USGS streamgage and water quality data from USGS, NDDH, and NDSWC sources

Concentration values that may have been "appreciably" affected by the Devils Lake outlet were removed (resulted in removal of some values during July-Feb of 2008-11)

Method used for trend analysis

QWTREND – time series model developed by USGS for analyzing flow-related variability and trends in constituent concentrations

Model described in detail in USGS reports:

- **Vecchia, 2000 (http://nd.water.usgs.gov/pubs/wri/wri004019/index.html)**
- **Vecchia, 2003 (http://nd.water.usgs.gov/pubs/wri/wri034094/index.html)**
- **Vecchia, 2005 (http://pubs.usgs.gov/sir/2005/5224/)**

Used in numerous other USGS studies and two Canadian studies that included Red River at Emerson:

- **Jones and Armstrong (2001) – Province of Manitoba**
- **Paquette (2011) – Univ. of Manitoba (funded by IJC)**

Basic idea behind QWTREND

Log-transformed constituent concentration represented in terms of additive components

Log(C) = Trend + FRV +SEAS + SVAR + Error

- Trend is a long-term trend that is unrelated to flow
- FRV is flow-related variability in concentration computed using current and antecedent daily streamflow
- SEAS is seasonality in concentration that is unrelated to flow
- SVAR is "systematic" variability in concentration that is serially correlated
- Error is the model error, assumed to be uncorrelated "noise"

Basic idea behind QWTREND (cont.)

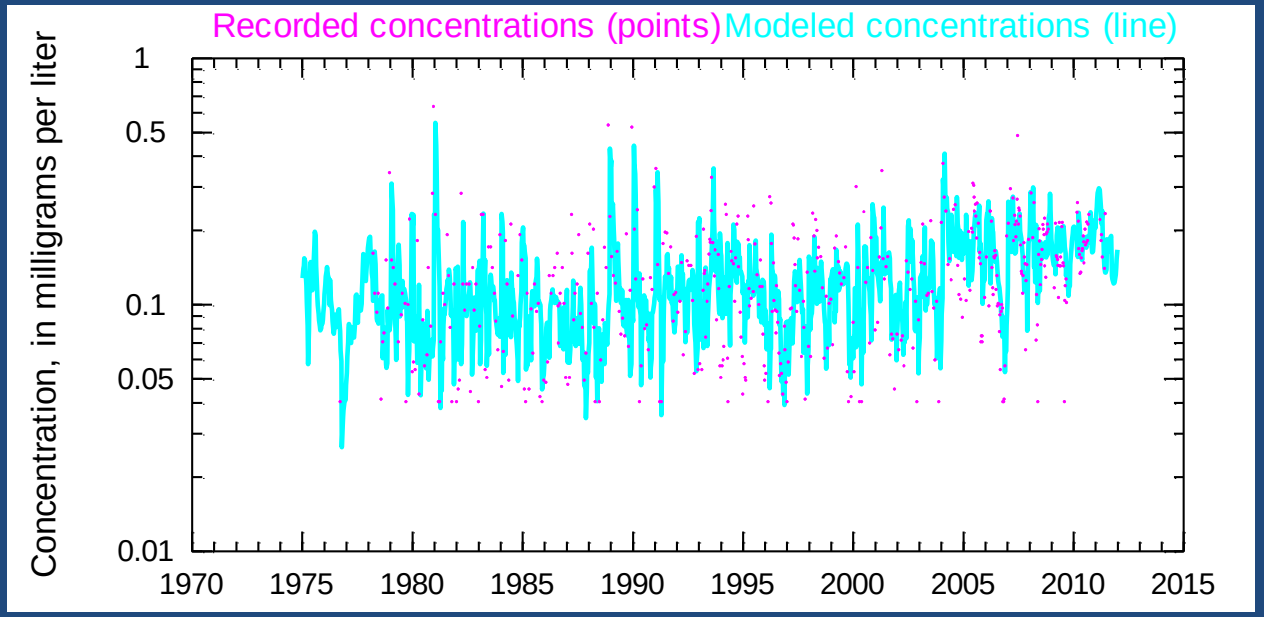
Model fitted using Gaussian maximum likelihood estimation (MLE)

MLE theory can be used to distinguish between different types of trends (time periods, directions, etc.)

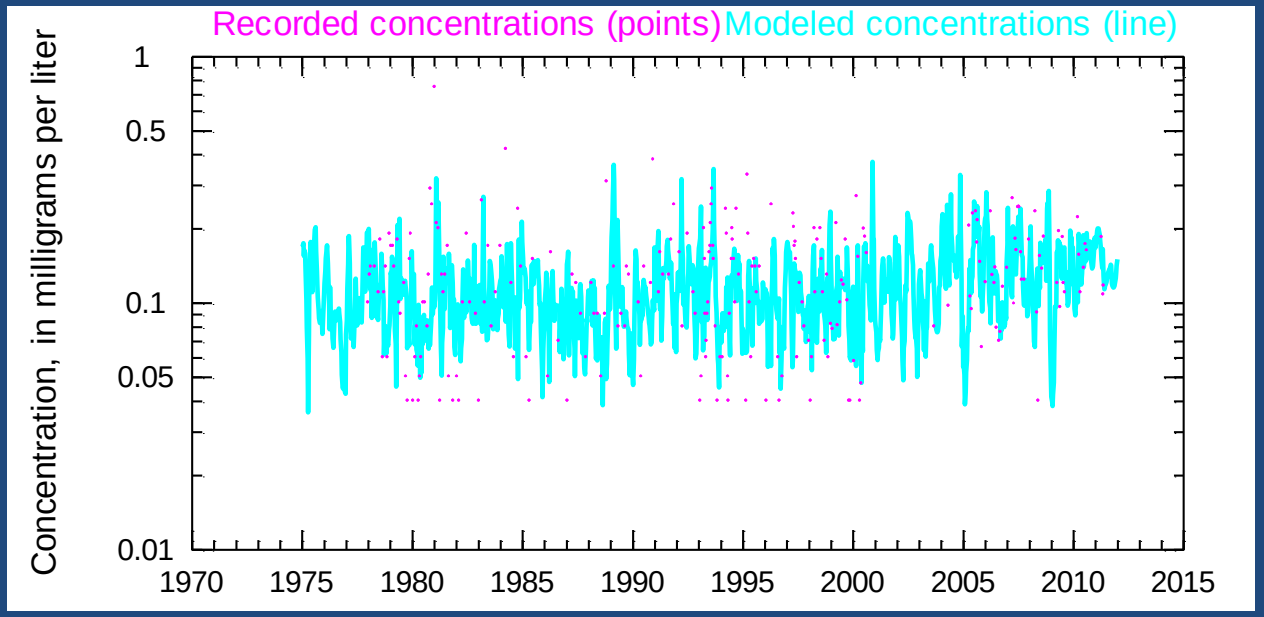
Generalized likelihood ratio tests can be used to determine the p-value of the trend. The smaller the p-value, the more significant the trend.

Red River at Emerson, Dissolved Phosphorus, 1975-2011

Canada Data →



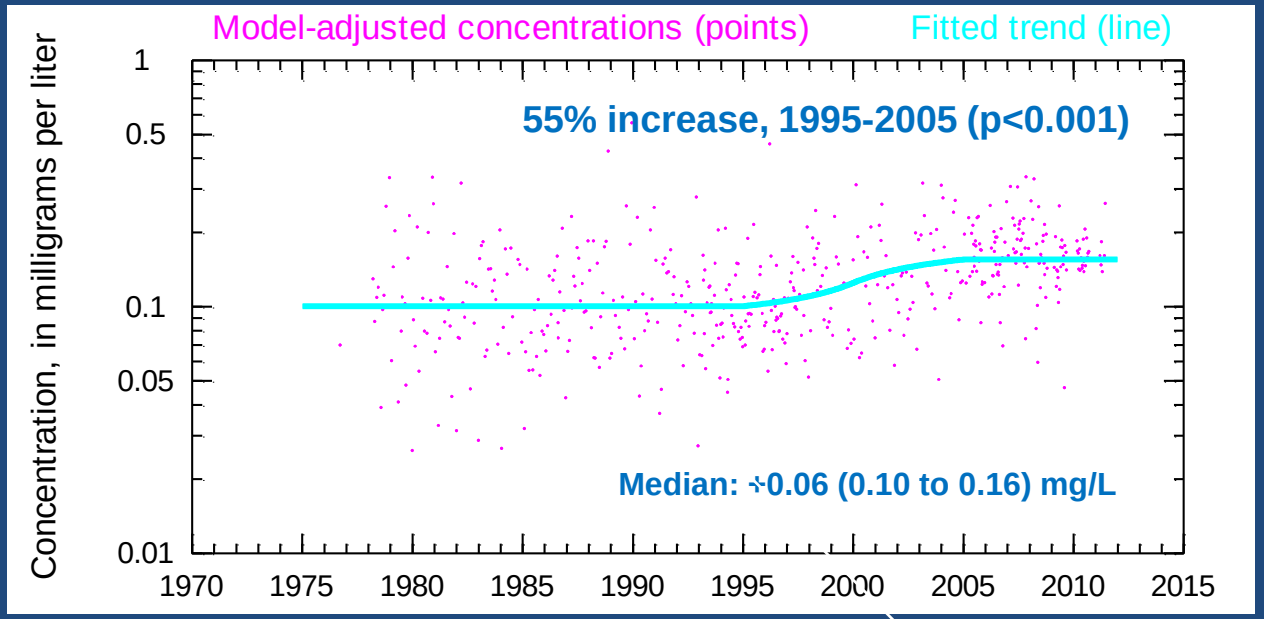
United States Data →



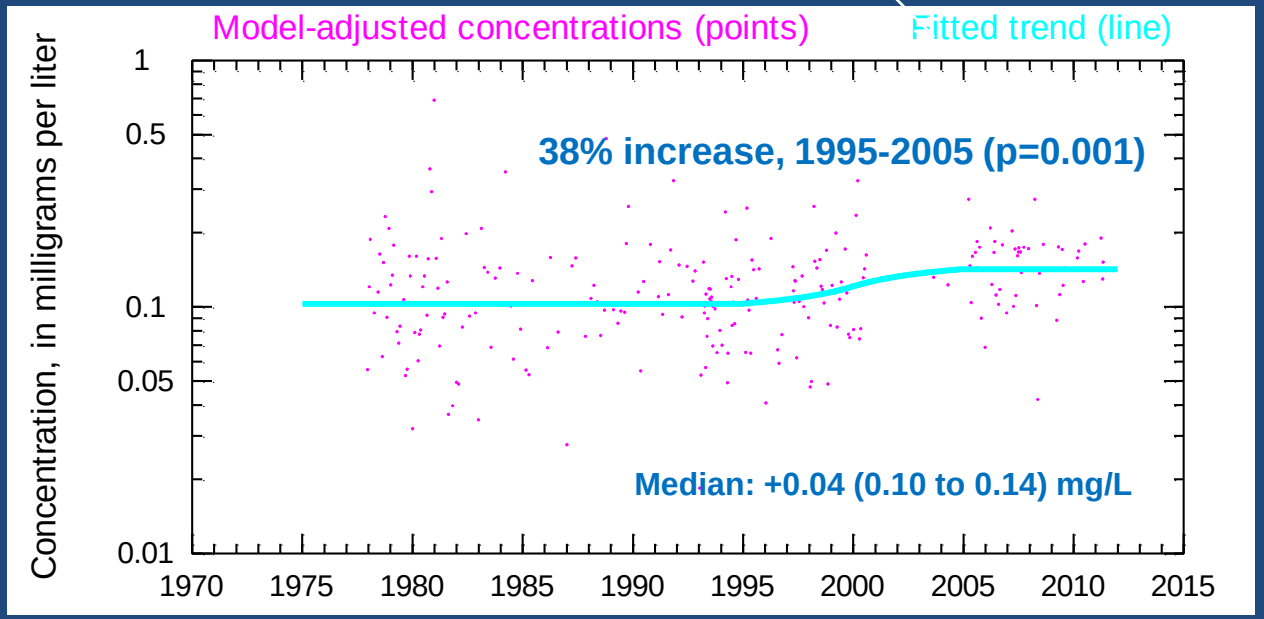
Modeled concentrations are estimated concentrations including trends and "natural" variability (eg, flow-related variability)

Red River at Emerson, Dissolved Phosphorus, 1975-2011

Canada Data →



United States Data →

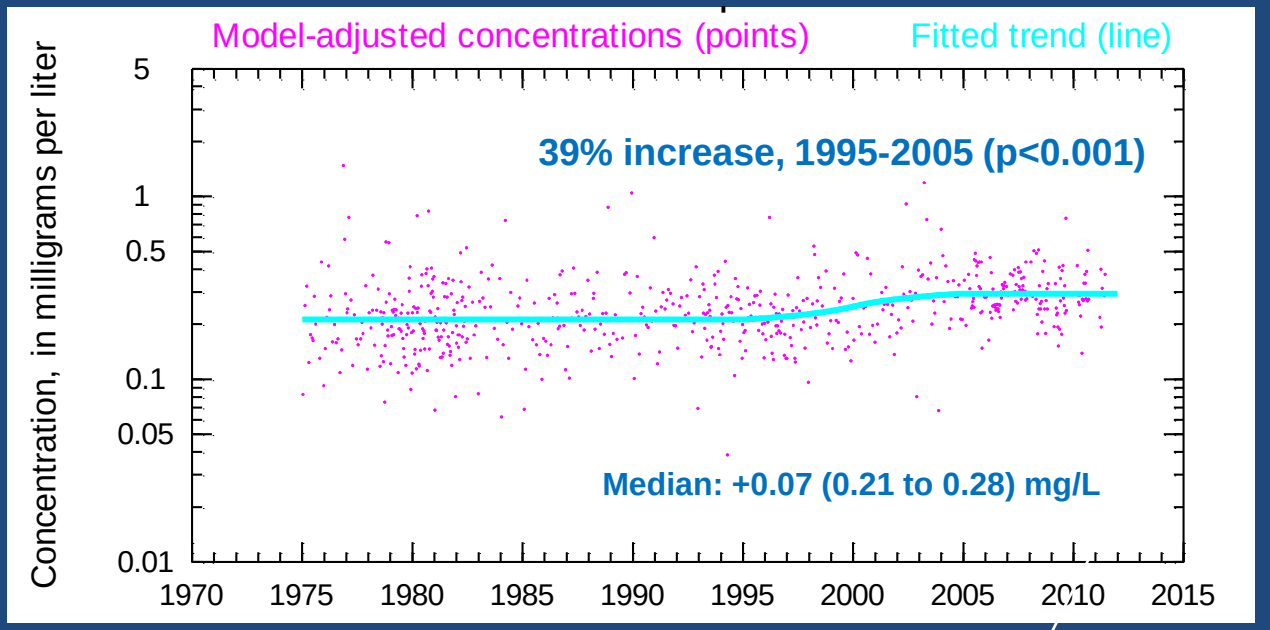


Model-adjusted concentrations have "natural" variability removed

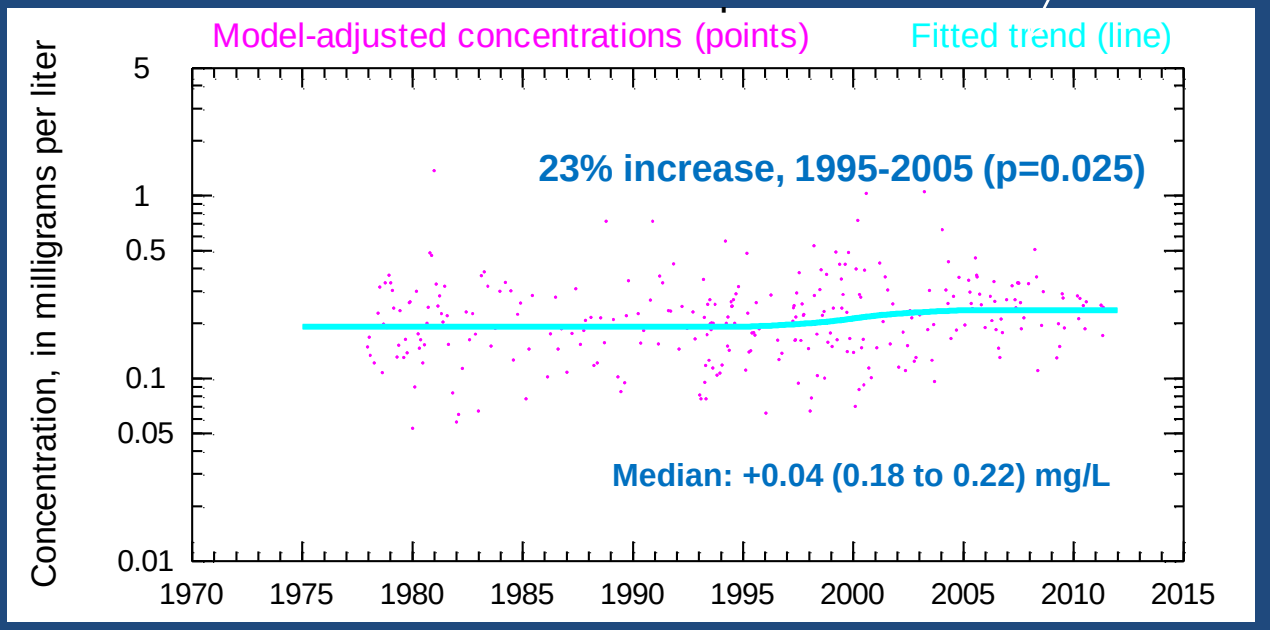
The likelihood function for both data sets indicates these trends provide a better fit than trends that extend through other periods .

Red River at Emerson, Total Phosphorus, 1975-2011

Canada Data →



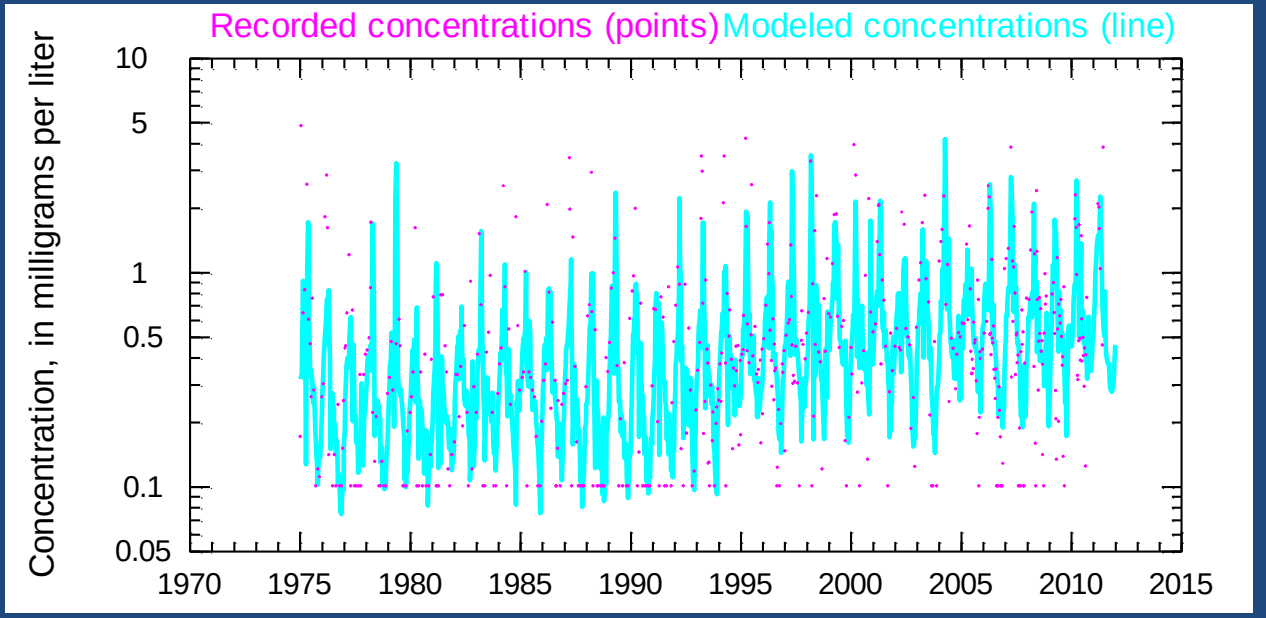
United States Data →



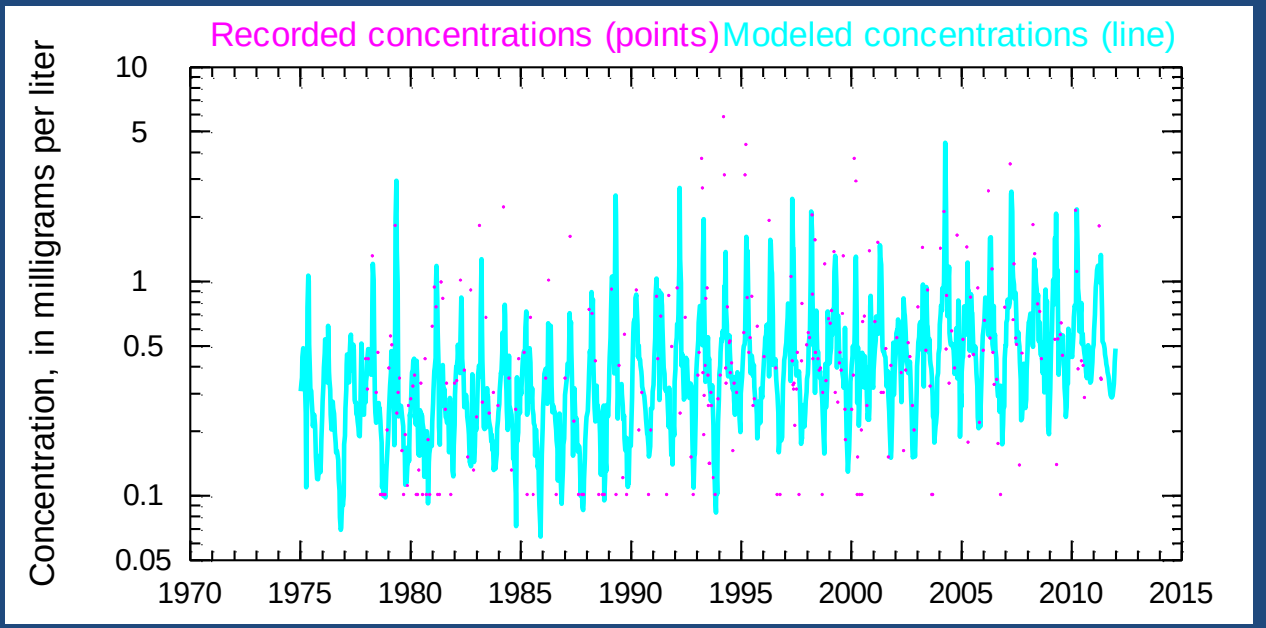
Increase in total phosphorus in mg/L essentially same as dissolved phosphorus.

Red River at Emerson, Dissolved Nitrate+Nitrite, 1975-2011

Canada Data →

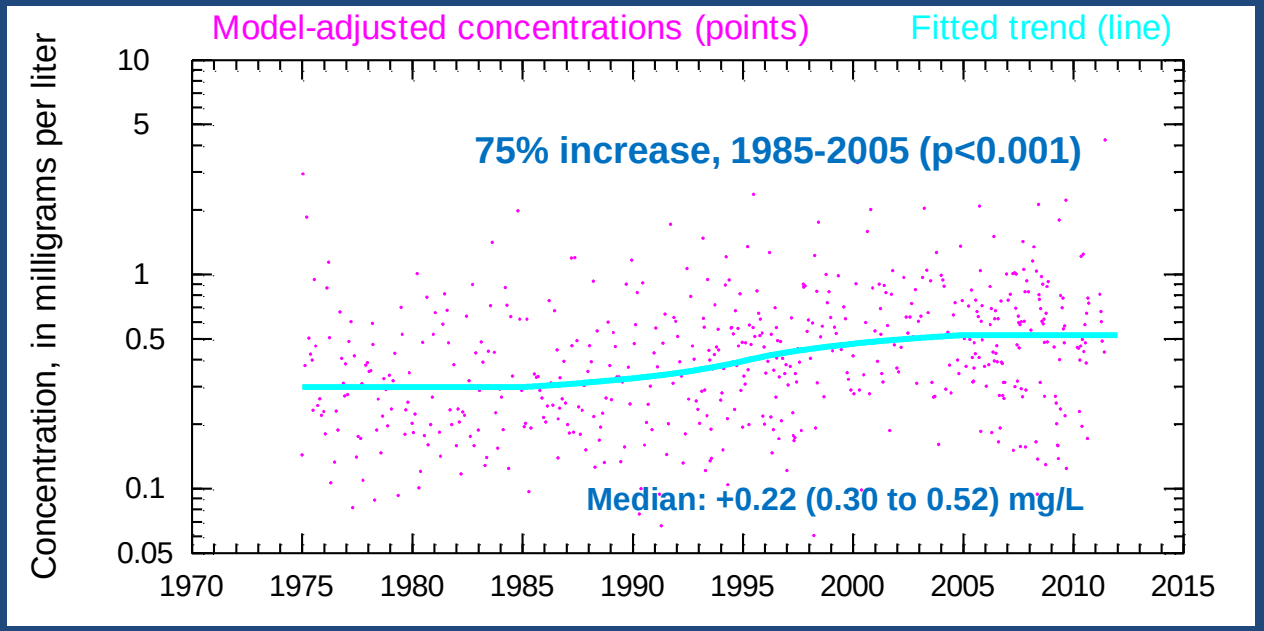


United States Data →

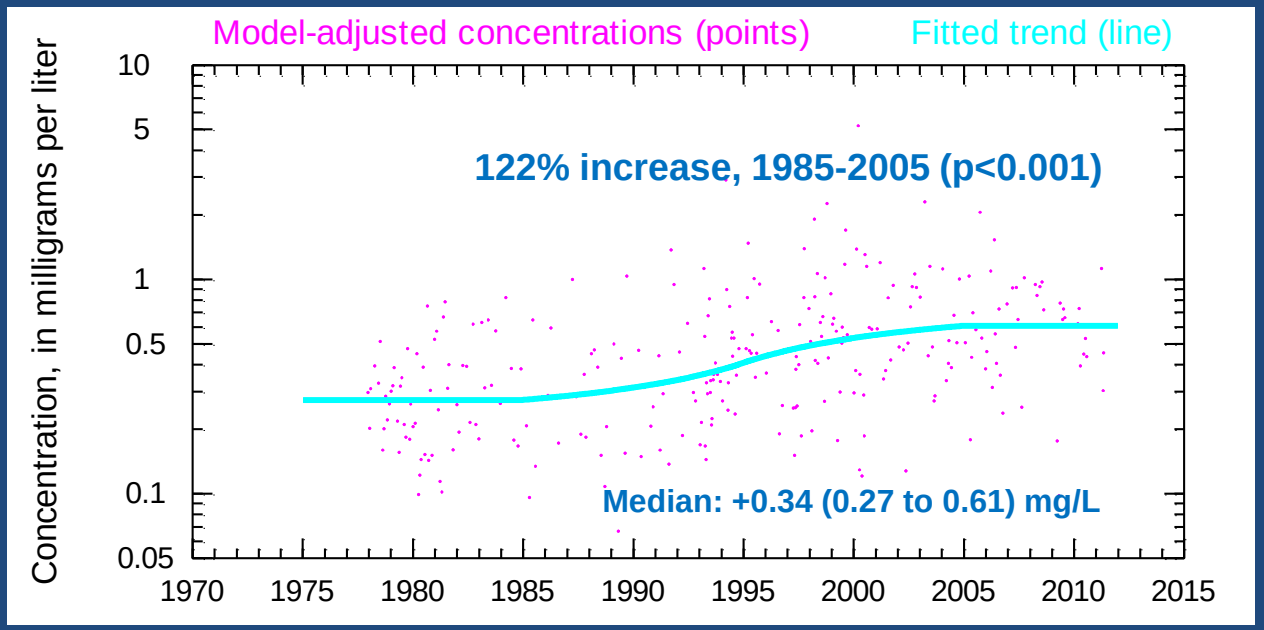


Red River at Emerson, Dissolved Nitrate+Nitrite, 1975-2011

Canada Data →

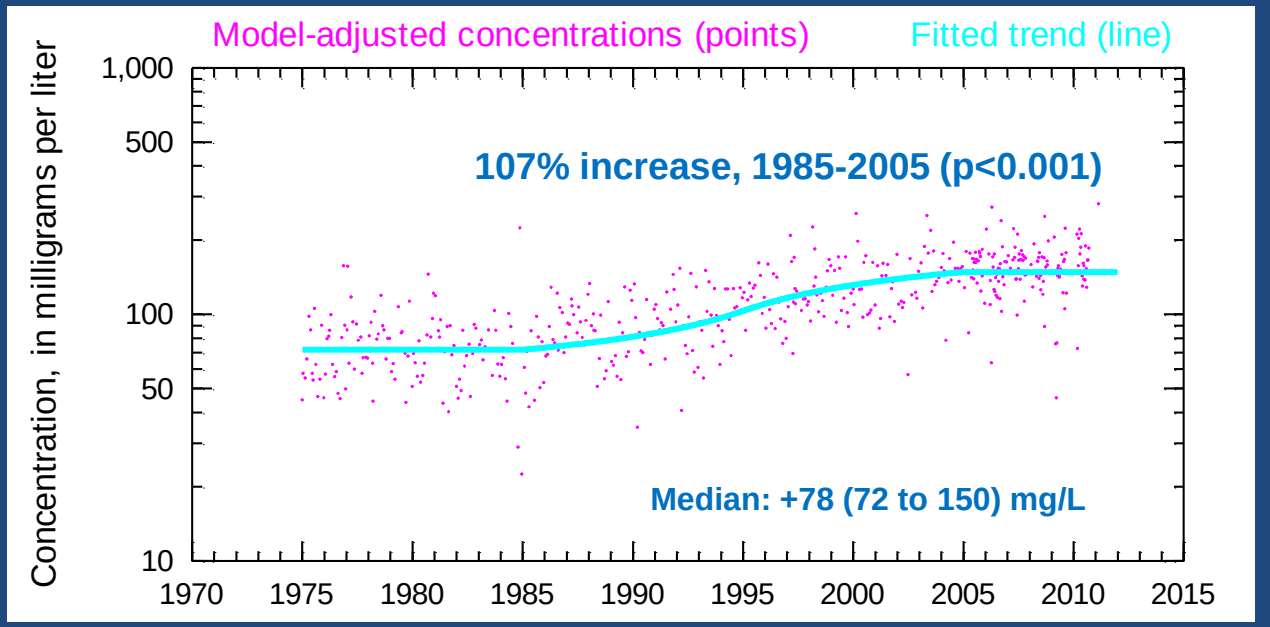


United States Data →

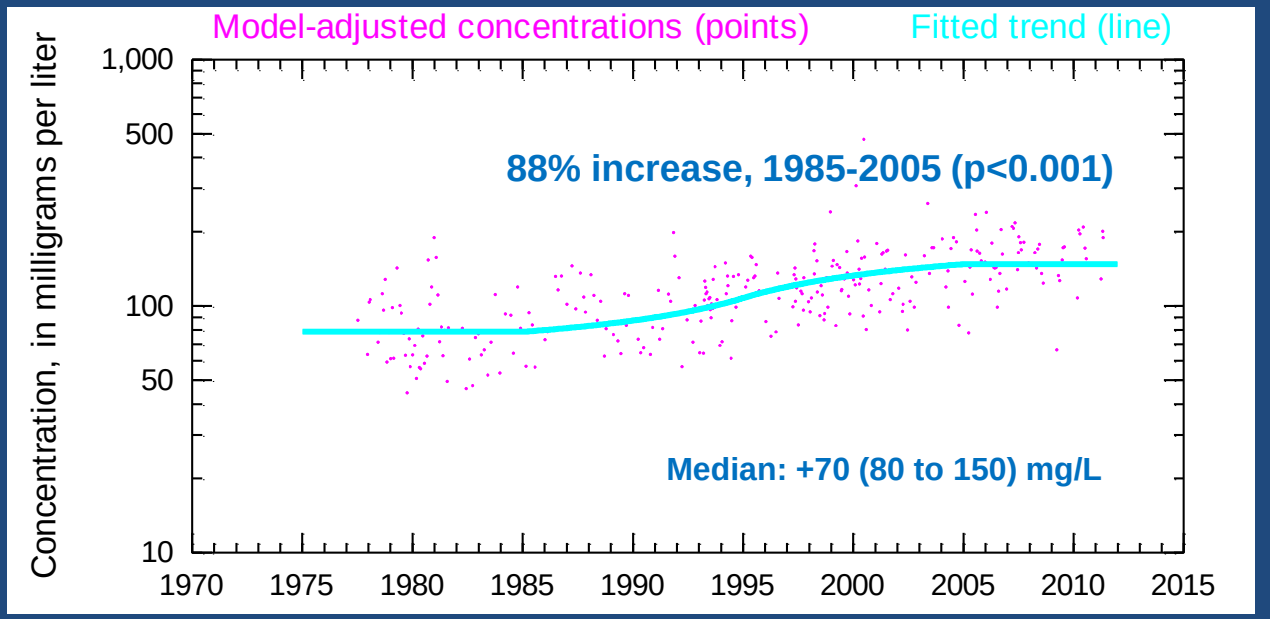


Red River at Emerson, Dissolved Sulfate, 1975-2011

Canada Data →

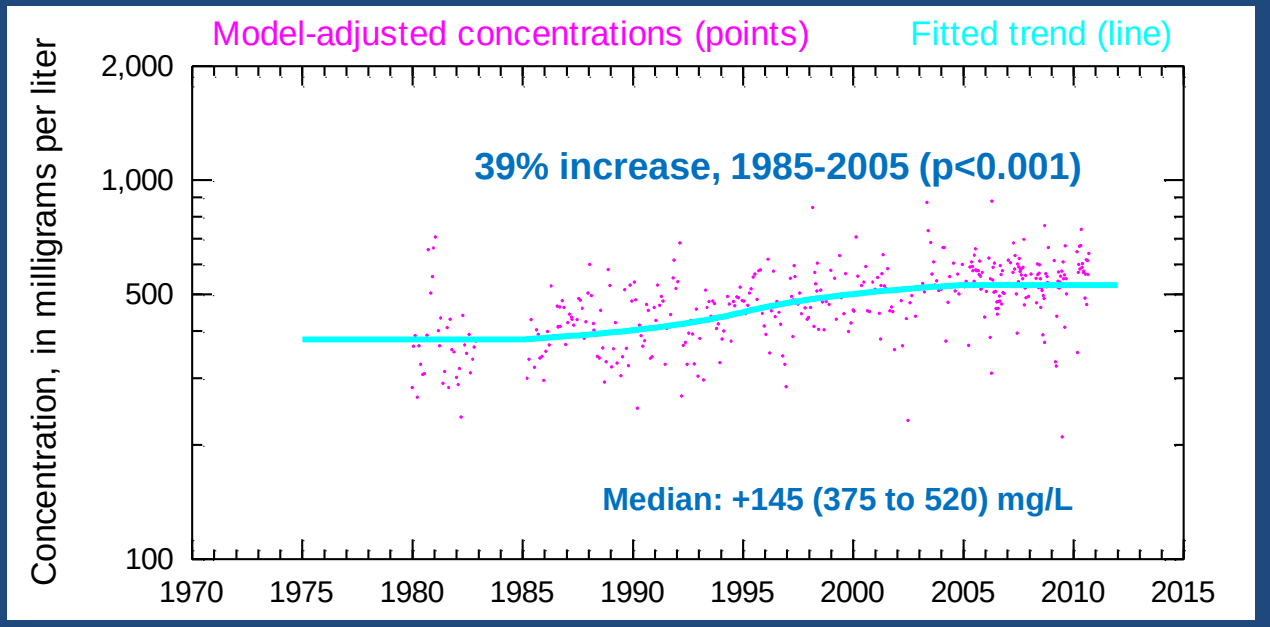


United States Data →

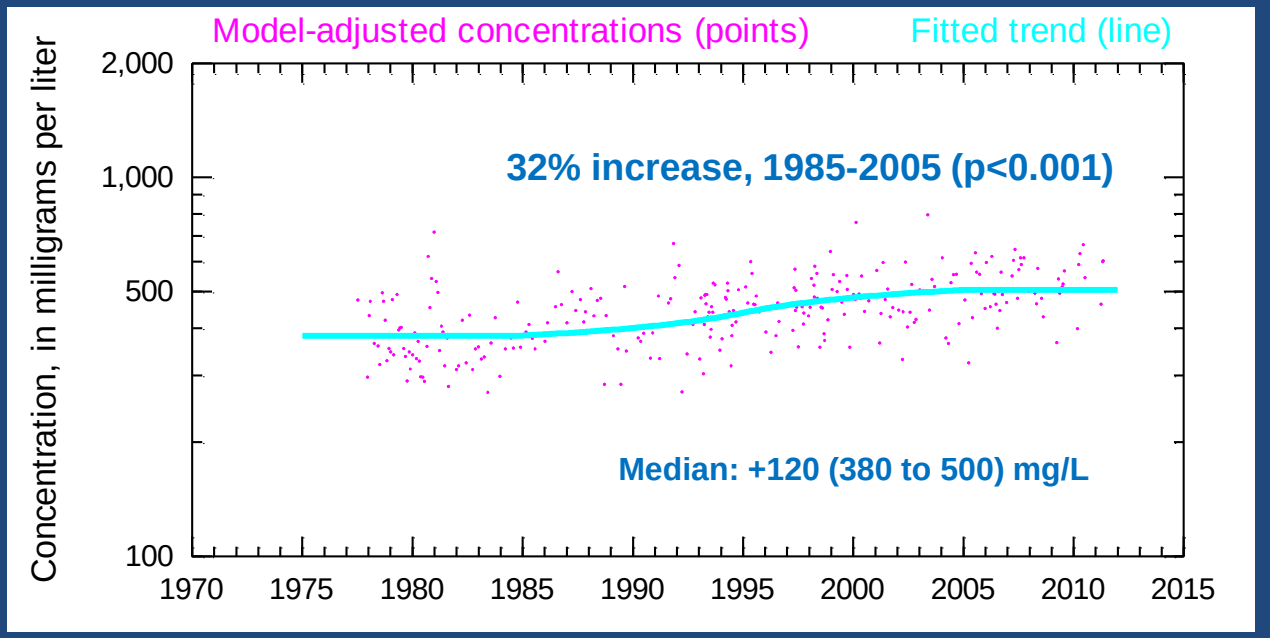


Red River at Emerson, Total Dissolved Solids, 1975-2011

Canada Data

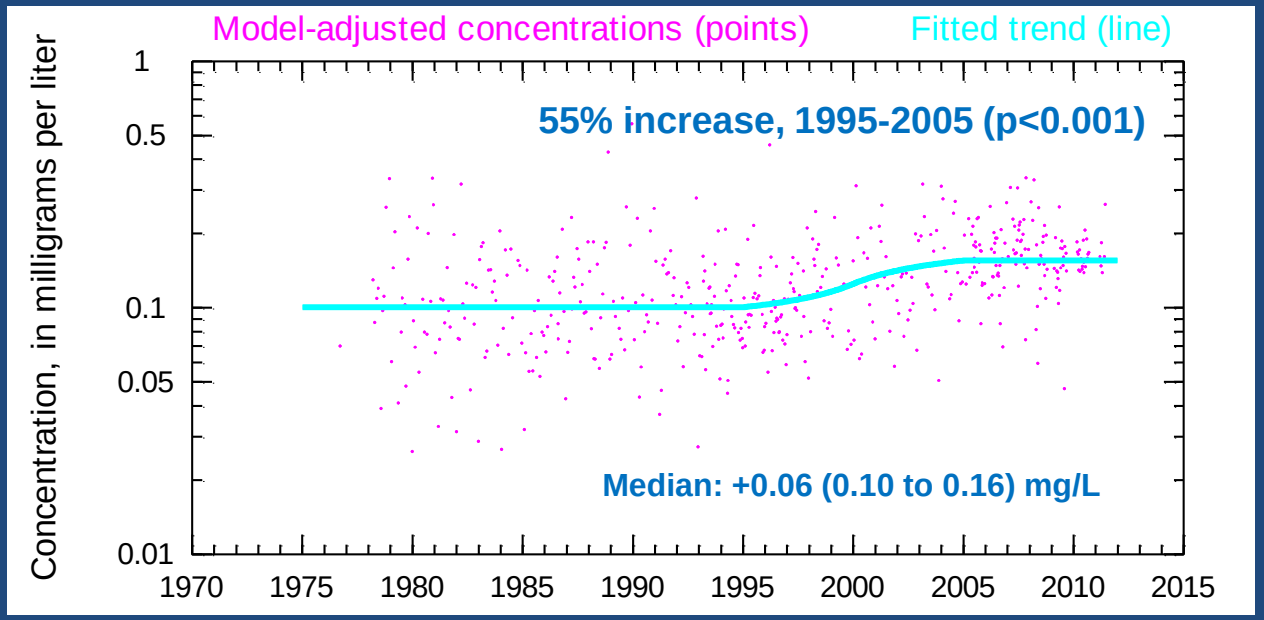


United States Data

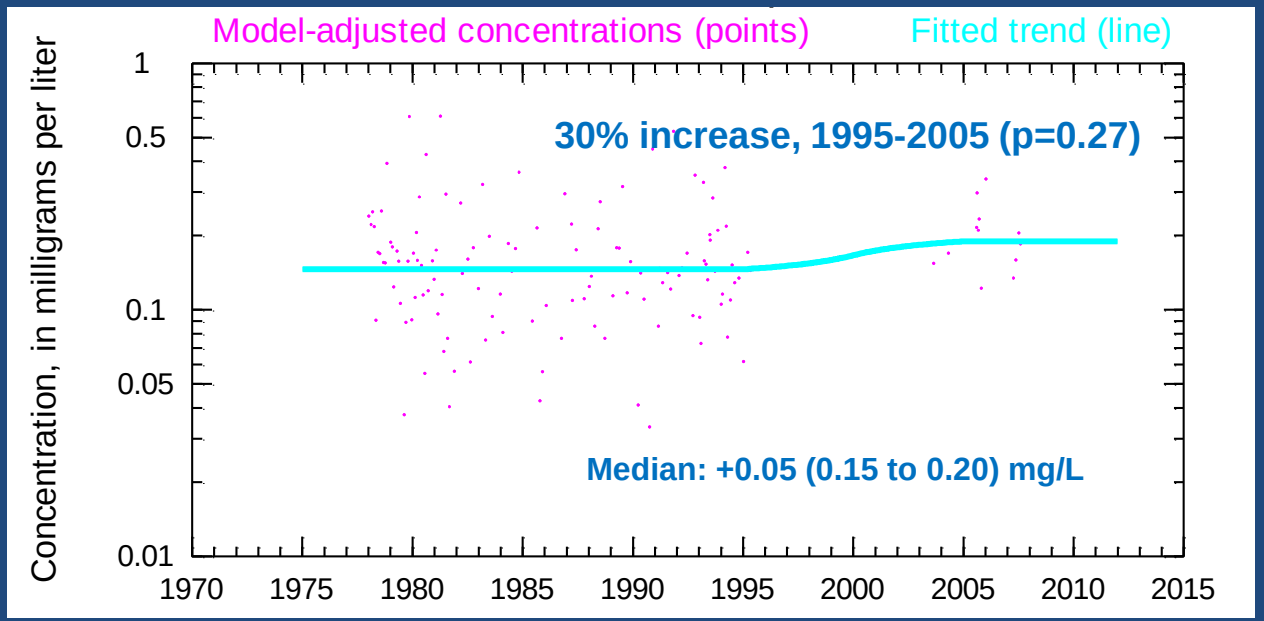


Emerson and Halstad, Dissolved Phosphorus, 1975-2011

Emerson



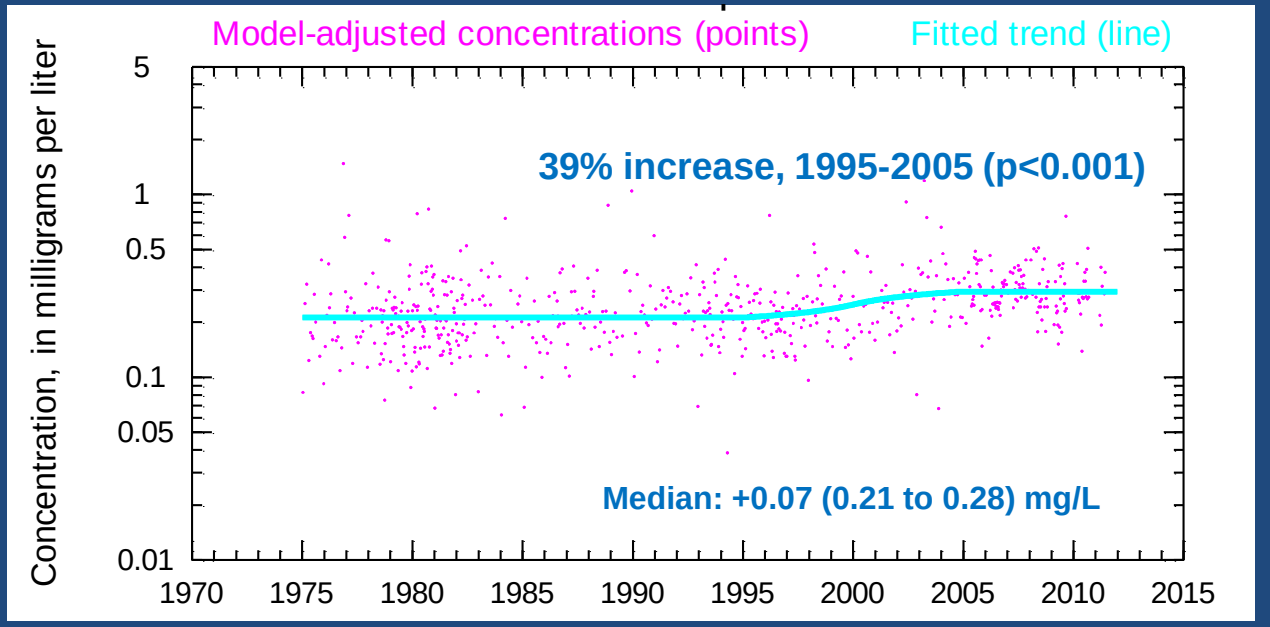
Halstad



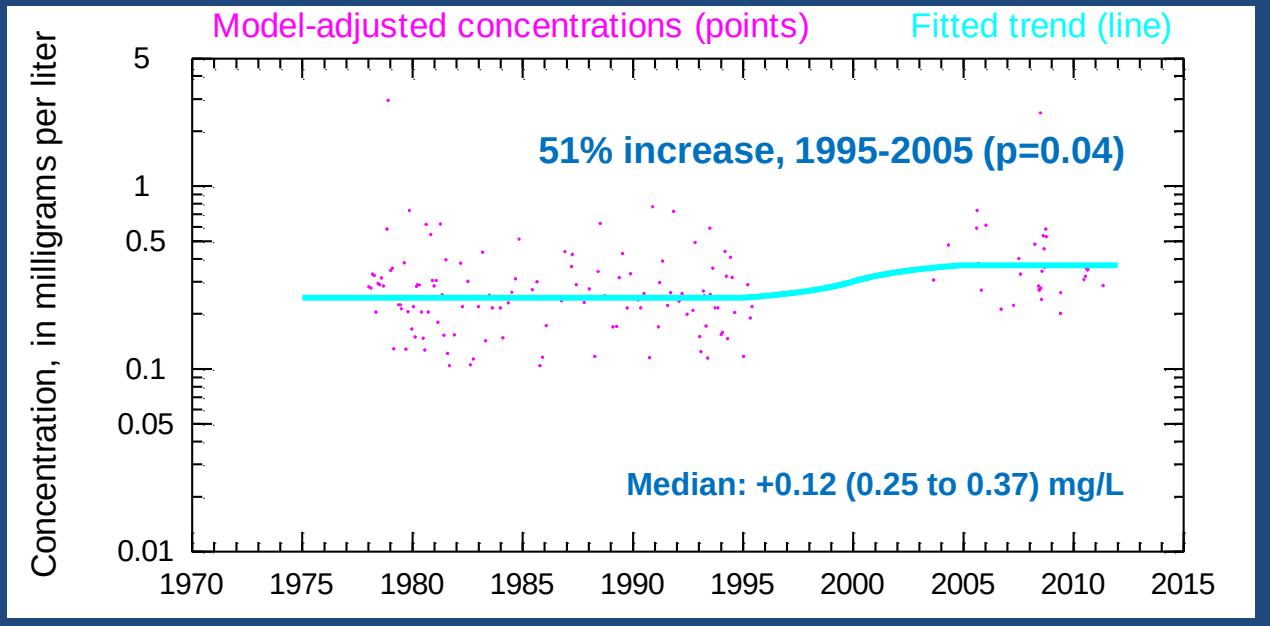
Smaller increase for Halstad, but trend uncertain and thus could be same as Emerson

Emerson and Halstad, Total Phosphorus, 1975-2011

Emerson



Halstad

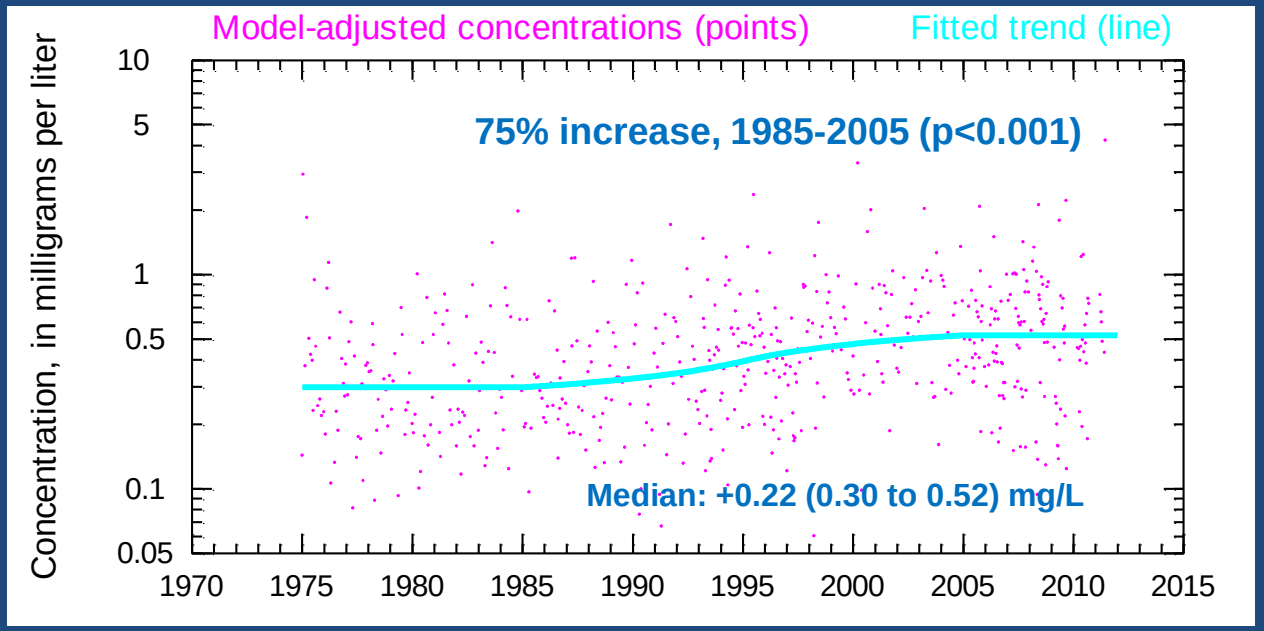


Might be more total phosphorus increase upstream of Halstad than between Halstad and Emerson

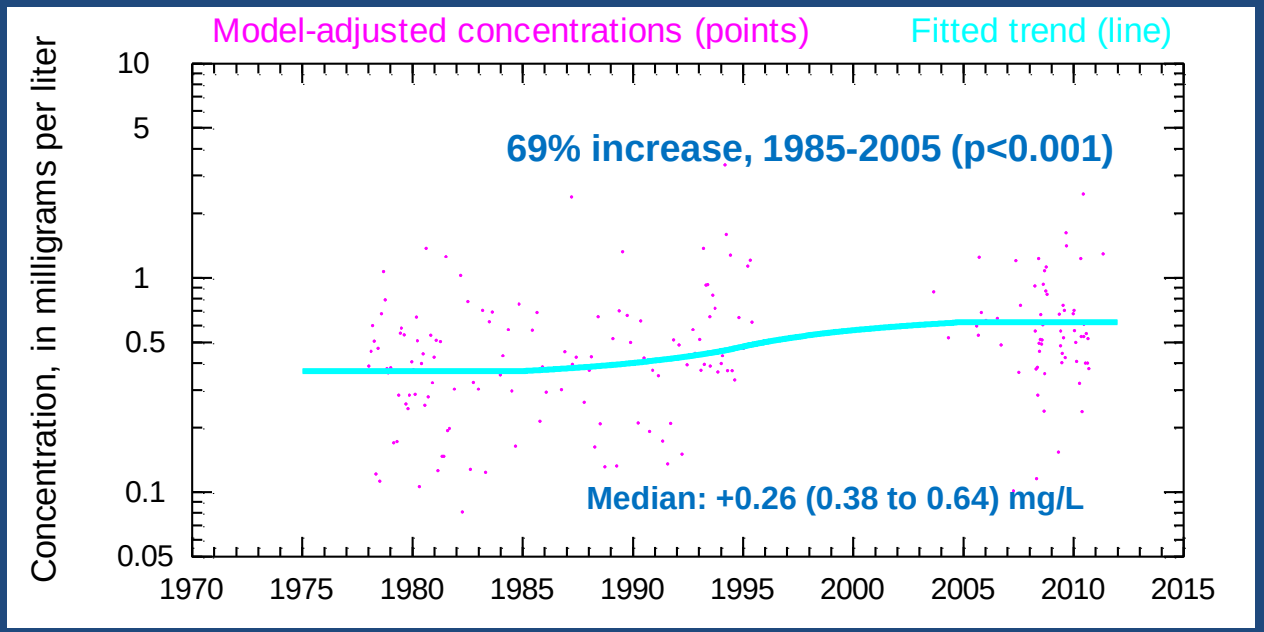
But, uncertainty in Halstad trend means it could easily be similar to Emerson

Emerson and Halstad, Dissolved Nitrate + Nitrite, 1975-2011

Emerson



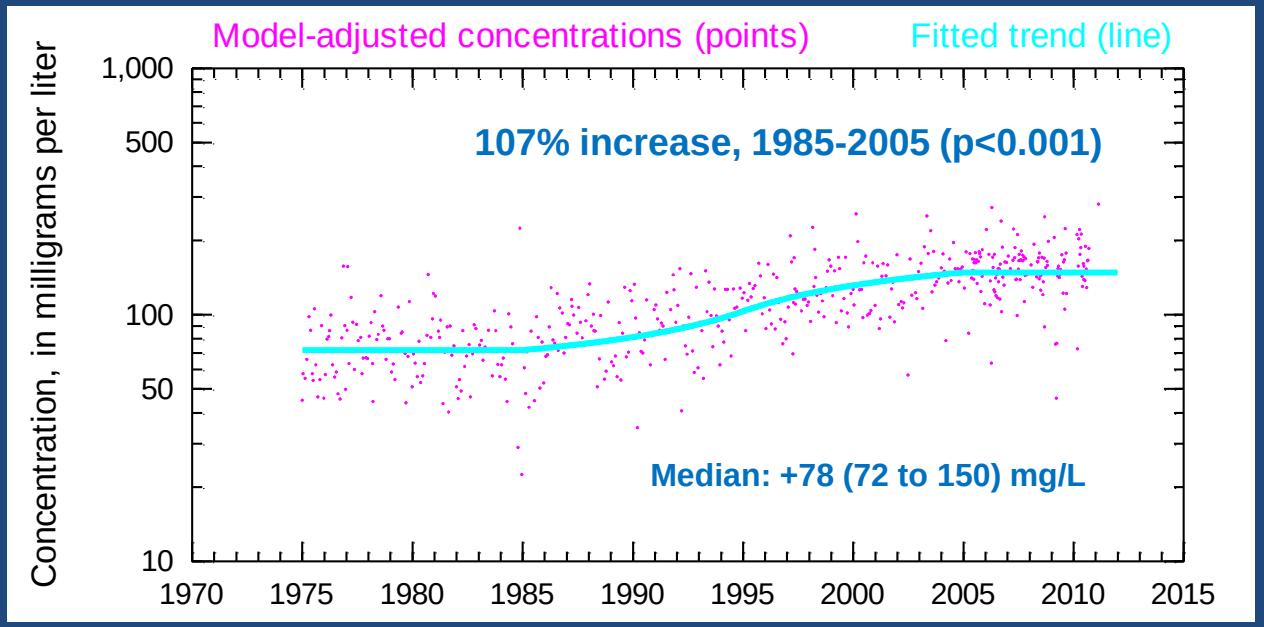
Halstad



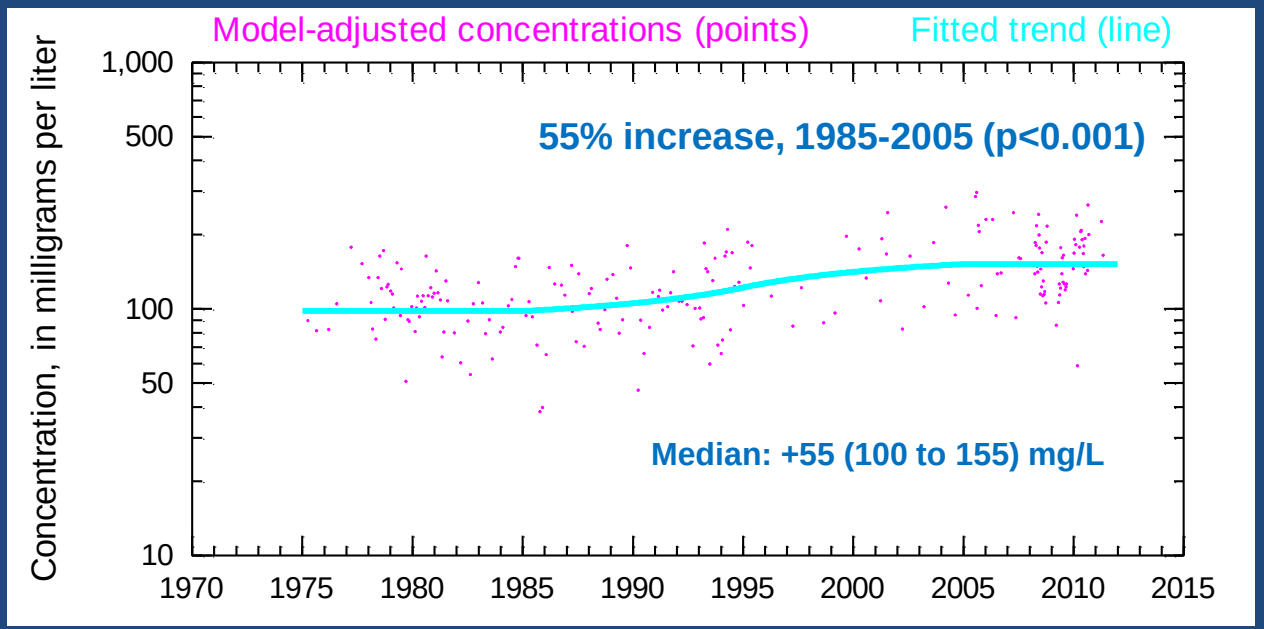
Similar increase upstream of Halstad and between Halstad and Emerson

Emerson and Halstad, Dissolved Sulfate, 1975-2011

Emerson



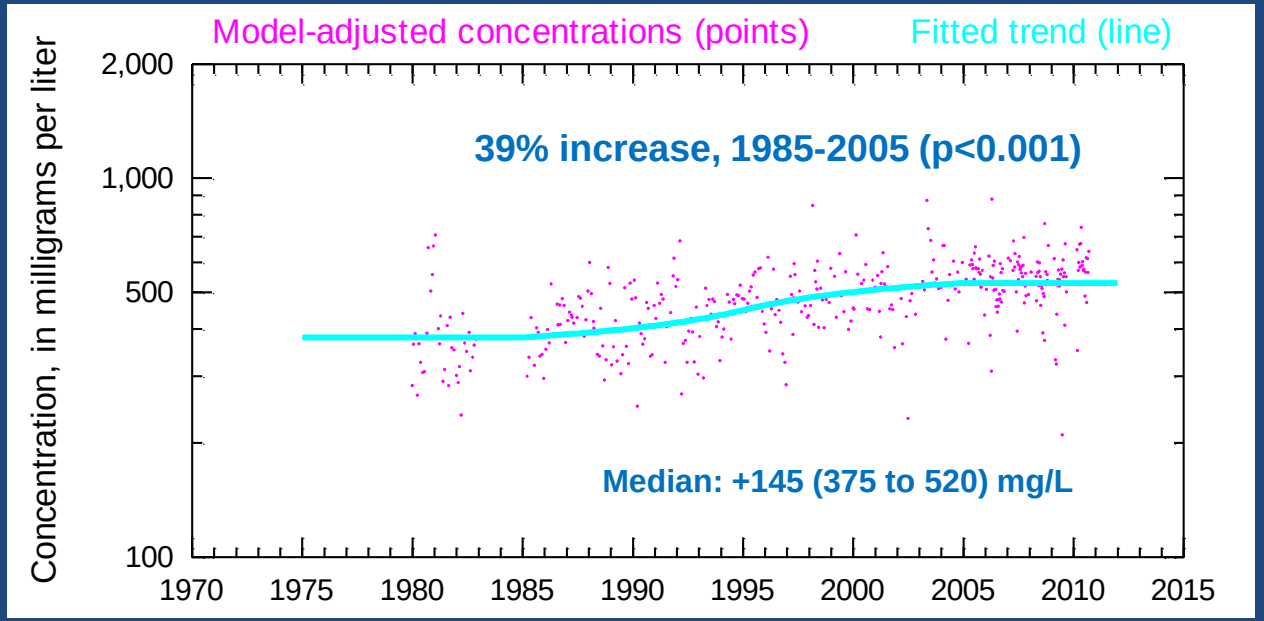
Halstad



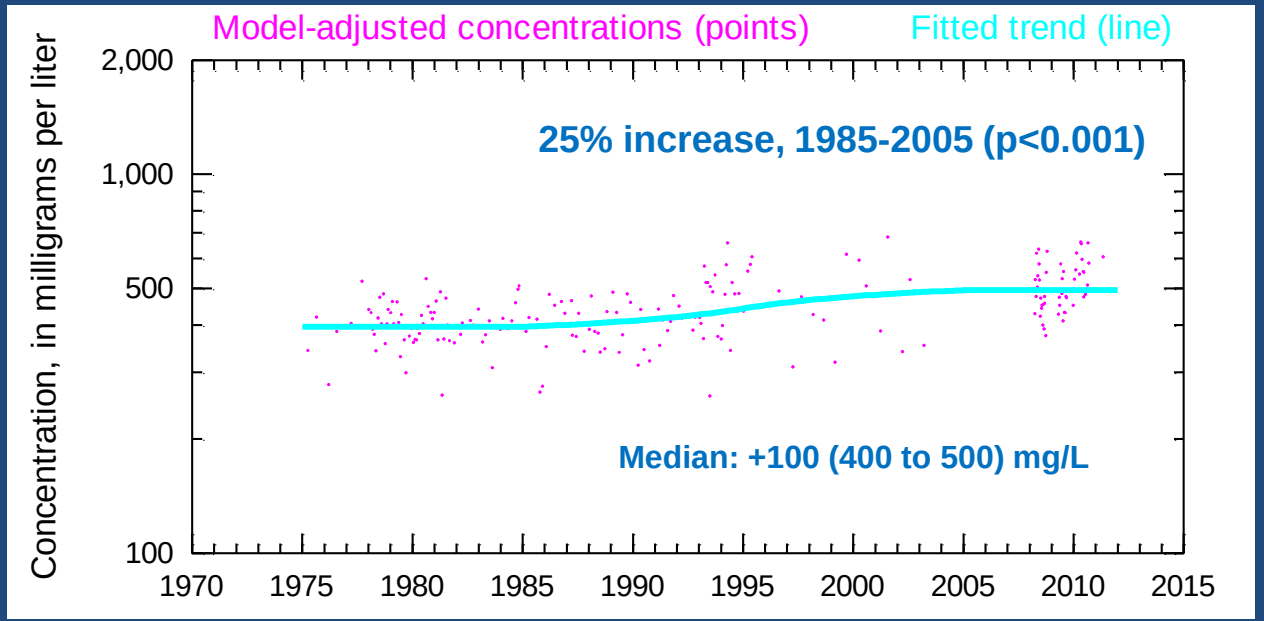
Appears to be more increase in sulfate between Halstad and Emerson than upstream of Halstad

Emerson and Halstad, Total Dissolved Solids, 1975-2011

Emerson



Halstad



Appears to be more increase in dissolved solids between Halstad and Emerson than upstream of Halstad (sulfate accounts for about half of the increase)

Summary of trends for Emerson and Halstad

- Dissolved phosphorus concentration
  - Emerson: increased 55% from 1995 to 2005.
  - Halstad: also increased, but magnitude uncertain
- Total phosphorus concentration
  - Emerson: increased 39% from 1995 to 2005. Increase appears to be mostly in dissolved (not particulate) phase
  - Halstad: also increased, but magnitude uncertain
- Dissolved nitrate + nitrite concentration
  - Emerson: increased 75% from 1985 to 2005
  - Halstad: increased 69% for same period
- Dissolved sulfate (total dissolved solids) concentration
  - Emerson: increased 107% (39%) from 1985 to 2005
  - Halstad: increased 55% (25%) for same period

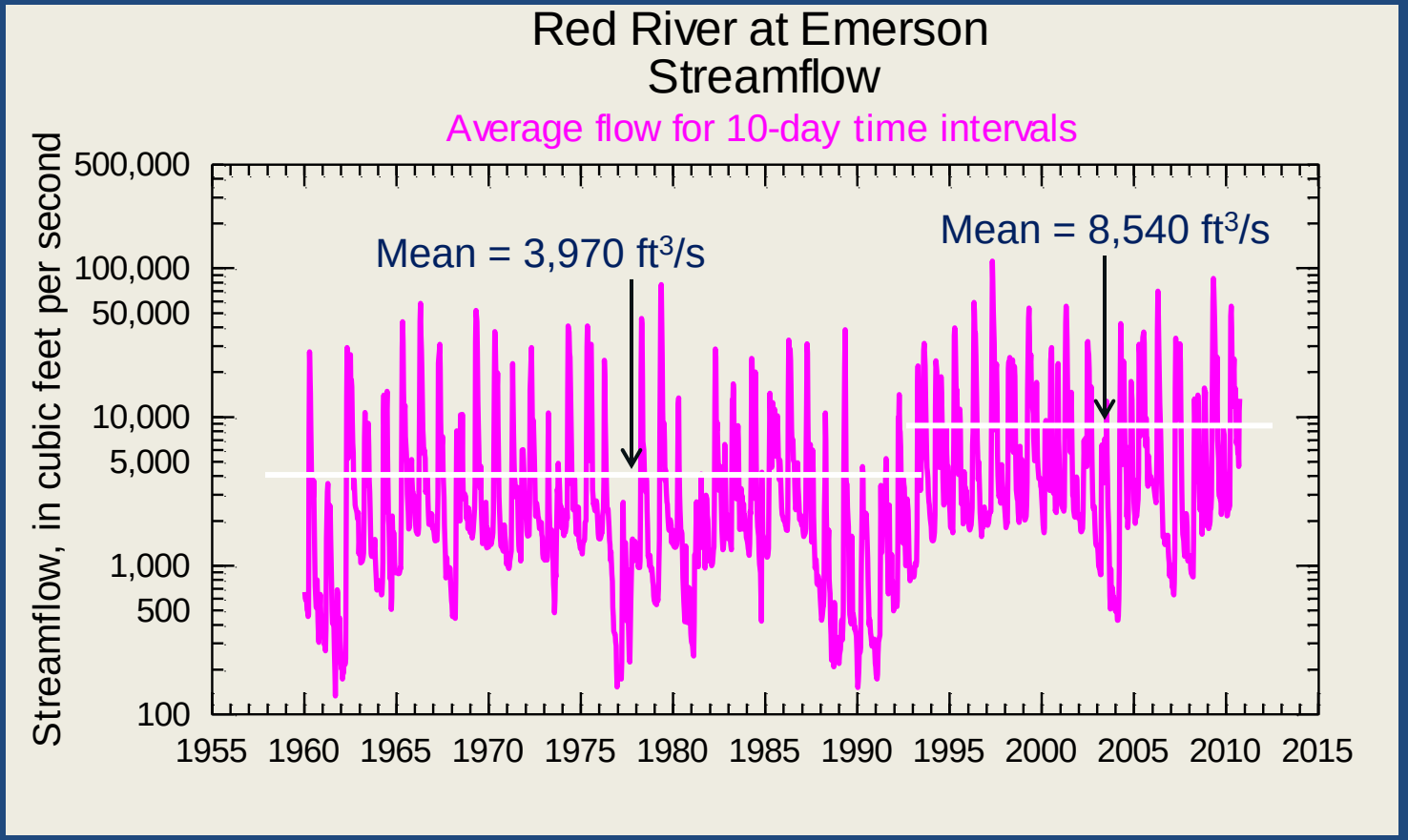
Both nutrient and major ion concentrations appear to have stabilized after 2005, but it is too early to tell if the uptrends may be reversing.

Potential causes for recent uptrends

Determining the potential cause(s) of the trends is very tricky, but there are a number of clear indications from the trend analysis that can provide some clues:

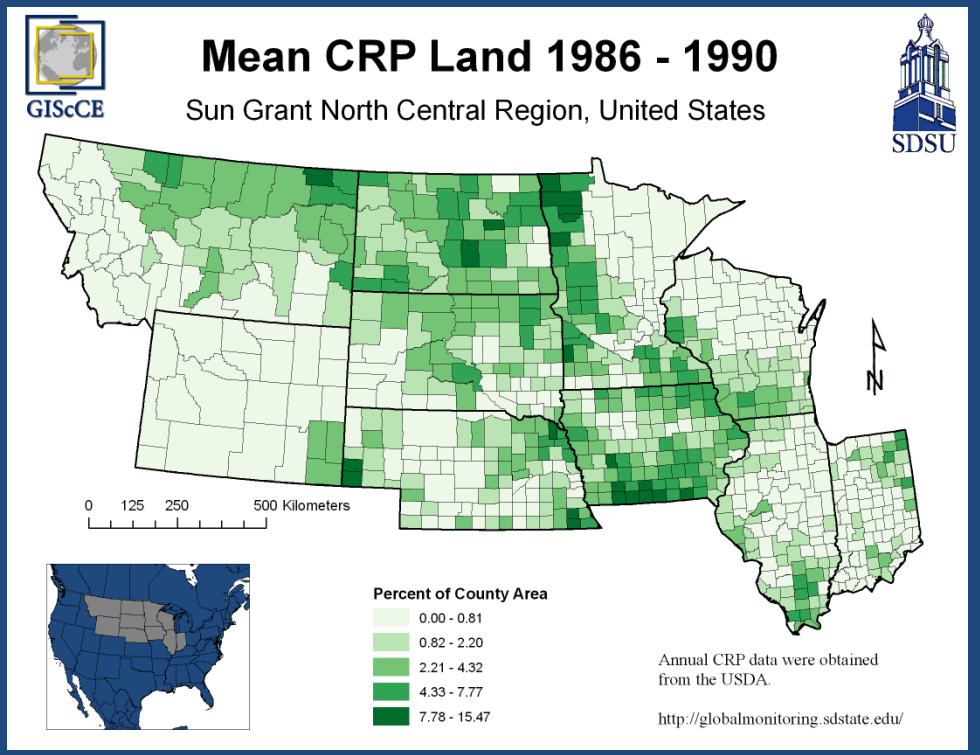
- **The trends all are relatively recent (about 1985 or later)**
- **All trends are uptrends**
- **All trends are large in magnitude (particularly when considering the mass of nutrients and dissolved solids being transported)**
- **Uptrends in nutrients (particularly dissolved nitrate) appear to be similar for the upstream (Halstad) and downstream (Halstad to Emerson) portions of the basin**
- **Uptrends in dissolved solids appear to be smaller for the upstream (Halstad) than downstream (Halstad to Emerson) portions of the basin**

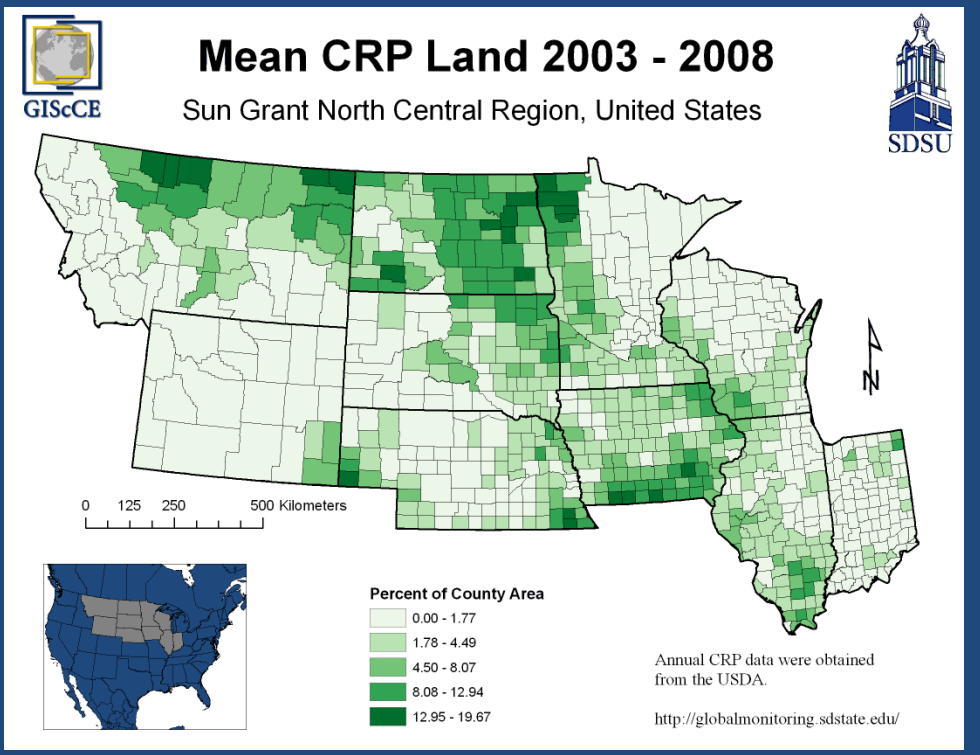
Concentration increases correspond with large streamflow increases



Mean flow more than doubled pre-1993 to post-1993
Couple that with 50 percent or larger increases in concentration
The result: Huge increases (300% or more) in the mass of dissolved nutrients and ions being transported from the basin

Example of unlikely contributor
Changes in CRP land





CRP acres increasing from 1985-2005 – should tend to improve water quality?
However, increase is small – about 4% increase mostly in western counties. Mostly grassland anyway, productive farmland not converted to CRP

Potential causes for recent uptrends (continued)

*This table is very preliminary. A much more detailed attribution study is required to pinpoint actual causes

Possible cause	Major contributor?	Comments
Point sources?	Probably not	Trends too large and consistent . Most of these sources probably trending downward due to better regulation
Tillage practices/CRP ?	Not likely	Right timing but wrong direction, affects small percentage of land
Livestock production?	Not likely	Production in Red River Basin generally decreasing during 1985-2005
Tile drainage?	Maybe?	Thought to be increasing (how much?). Something to watch closely in future years
Changes in crop patterns?	Possibly	Major change from wheat/grains to corn/soybeans during 1985-2005
Increase in GW tables and contributing drainage areas?	Possibly	Right direction and timing, affects large areas (especially ND side), might explain consistency among trends, salty soils more prevalent in northern basin, study by NDSWC indicates high water tables caused increasing sulfate in Sheyenne River

Thank you

Questions?

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