Kansas River Water Quality Model: A tool for evaluating ammonia and bacteria transport

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

Problem

- Population growth increasing WWTF effluent
- Kansas River receives most of the WWTF effluent from this population
- Kansas River is the primary water supply for the same population

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Objectives

- Characterize ambient hydrologic and water-quality conditions during **low** flow
- Compile and calibrate a numerical simulation model (CE-QUAL-W2)
- Simulate various hypothetical wastewater-treatment scenarios to evaluate effects of WWTFs on the Kansas River

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Questions

- What are the water-quality constituents of concern?
- When are these issues of greatest concern?
- How much WWTF effluent can the Kansas River receive?
- How can WWTP effluent to the Kansas River be managed so that a healthy ecosystem is sustained?

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Approach

- Analyze synoptic survey data
  - compare concentrations
  - mass balance for ammonia and FCB
- Compile model for the Kansas River
  - simulate hydrodynamics
  - simulate water quality
- Model hypothetical scenarios

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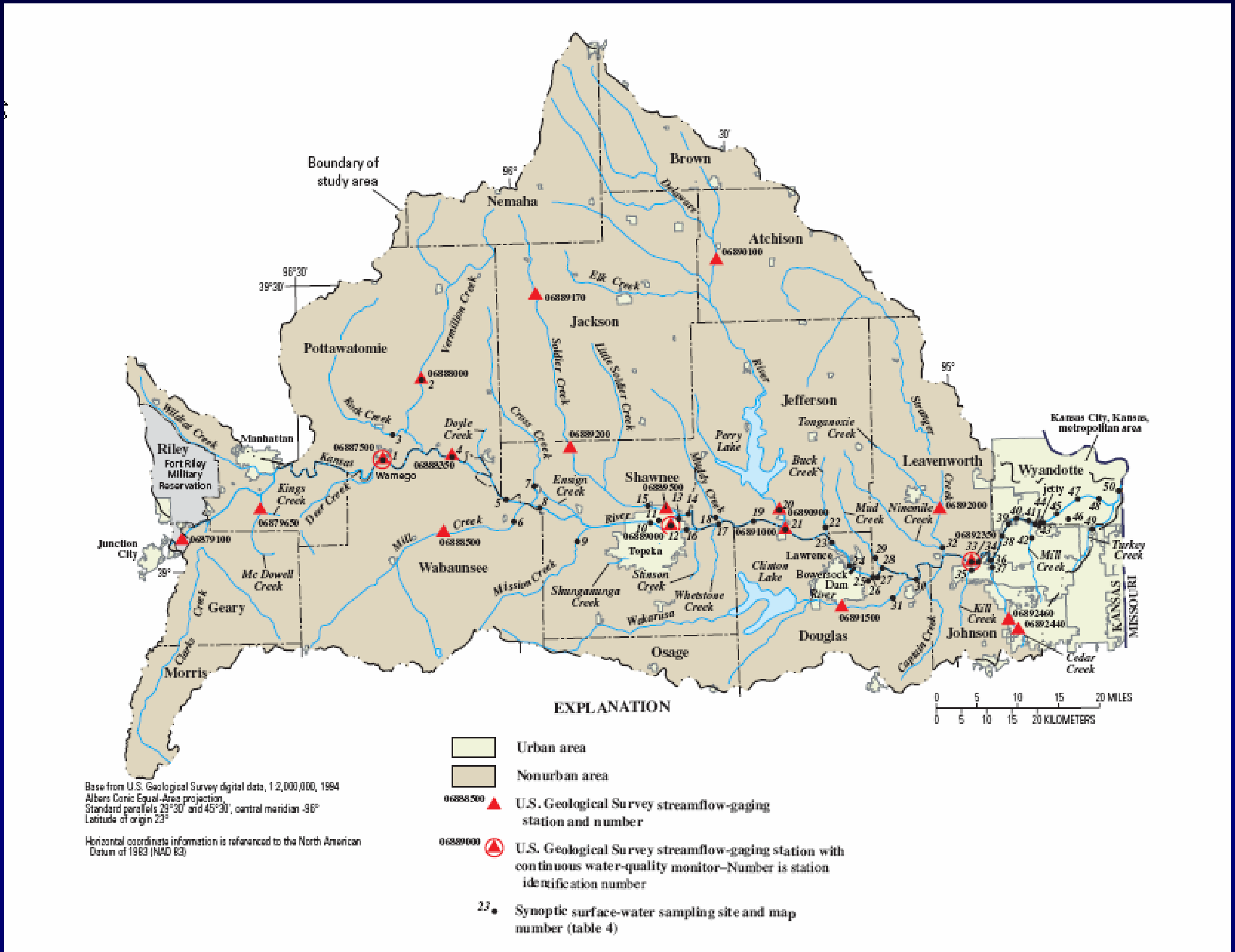

- Winter and summer low-flow synoptic surveys
  - 189 samples were collected at 50 sites
    - 25 Kansas River sites
    - 17 tributary streams
    - 8 WWTFs sites

Sampled 25 Kansas River sites

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Sampled 17 tributaries

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Sampled 8 WWTF

Constituent Concentrations Determined

- Physical properties
- Major Ions
- Nutrients
- TOC
- Bacteria
- Sediment
- BOD/CBOD
- Algal biomass

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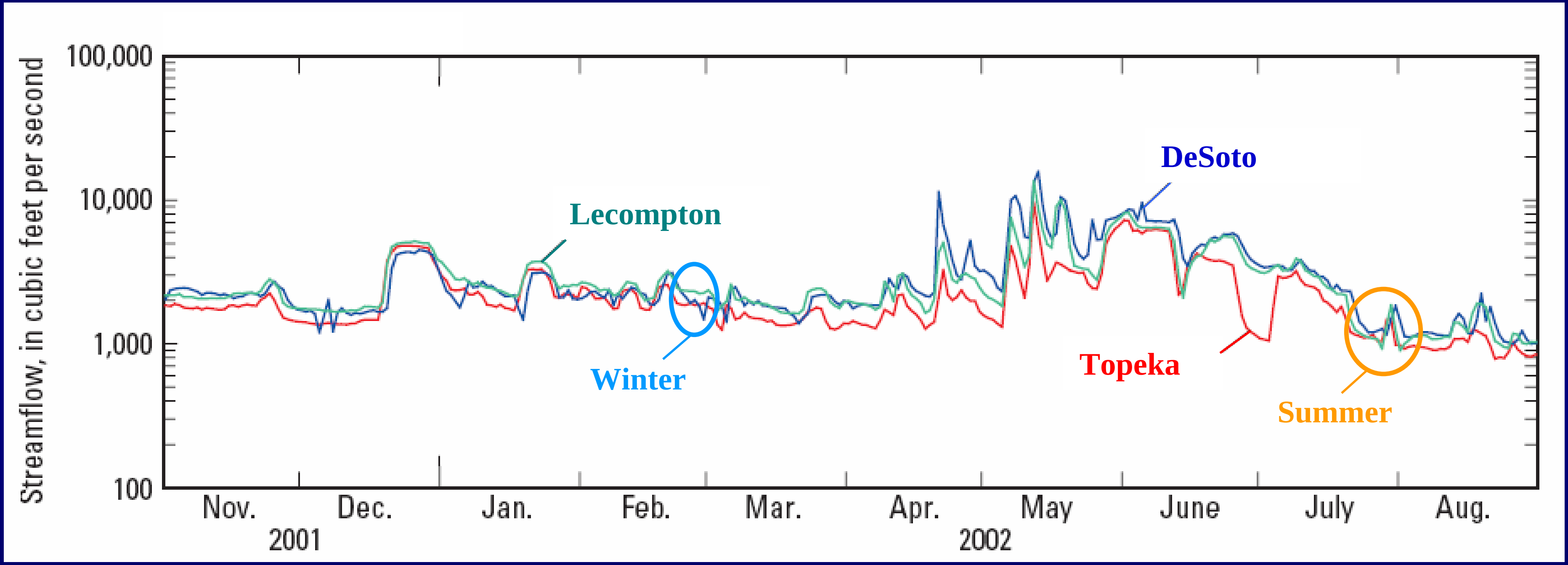
Streamflow at Topeka and DeSoto



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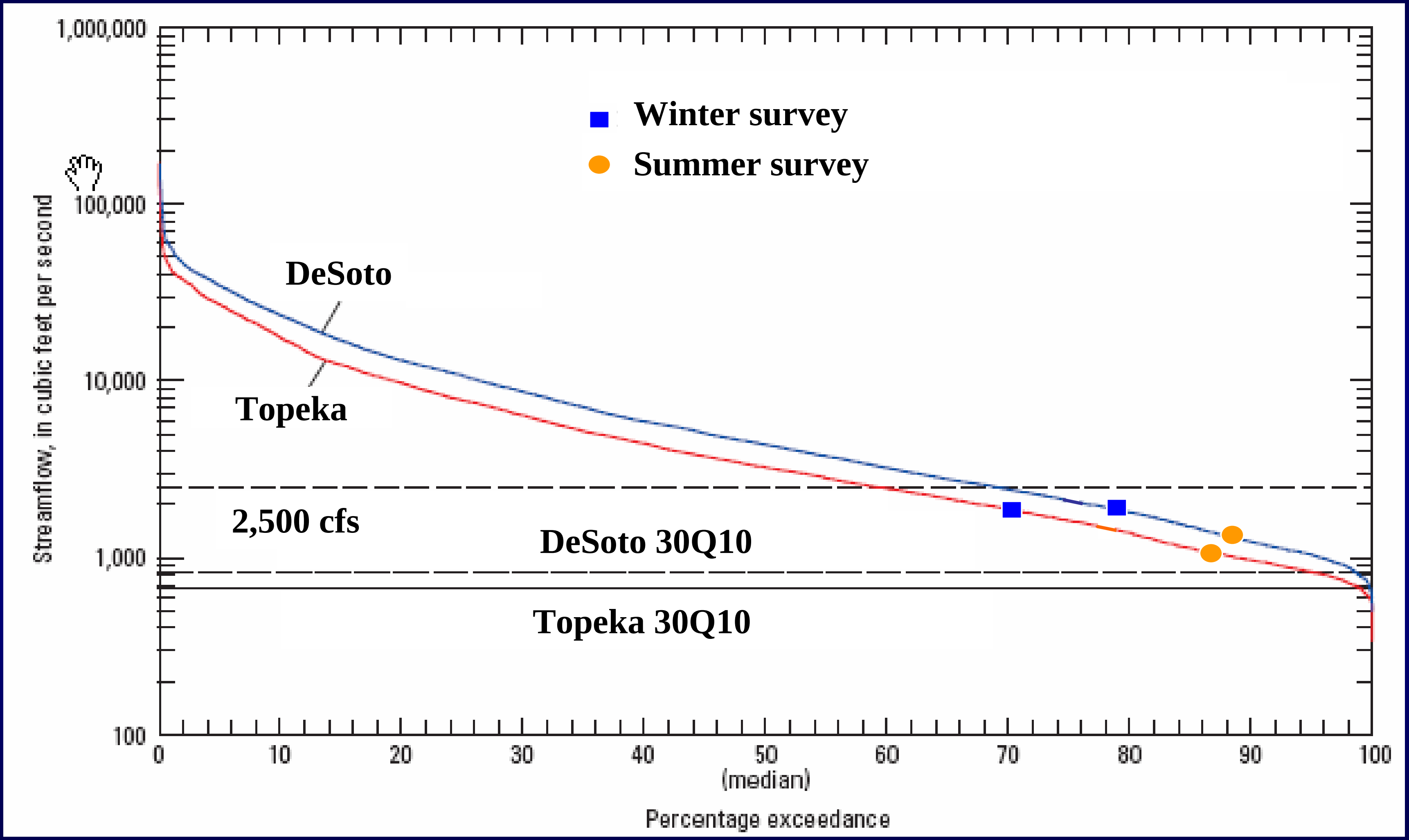
Streamflow during surveys



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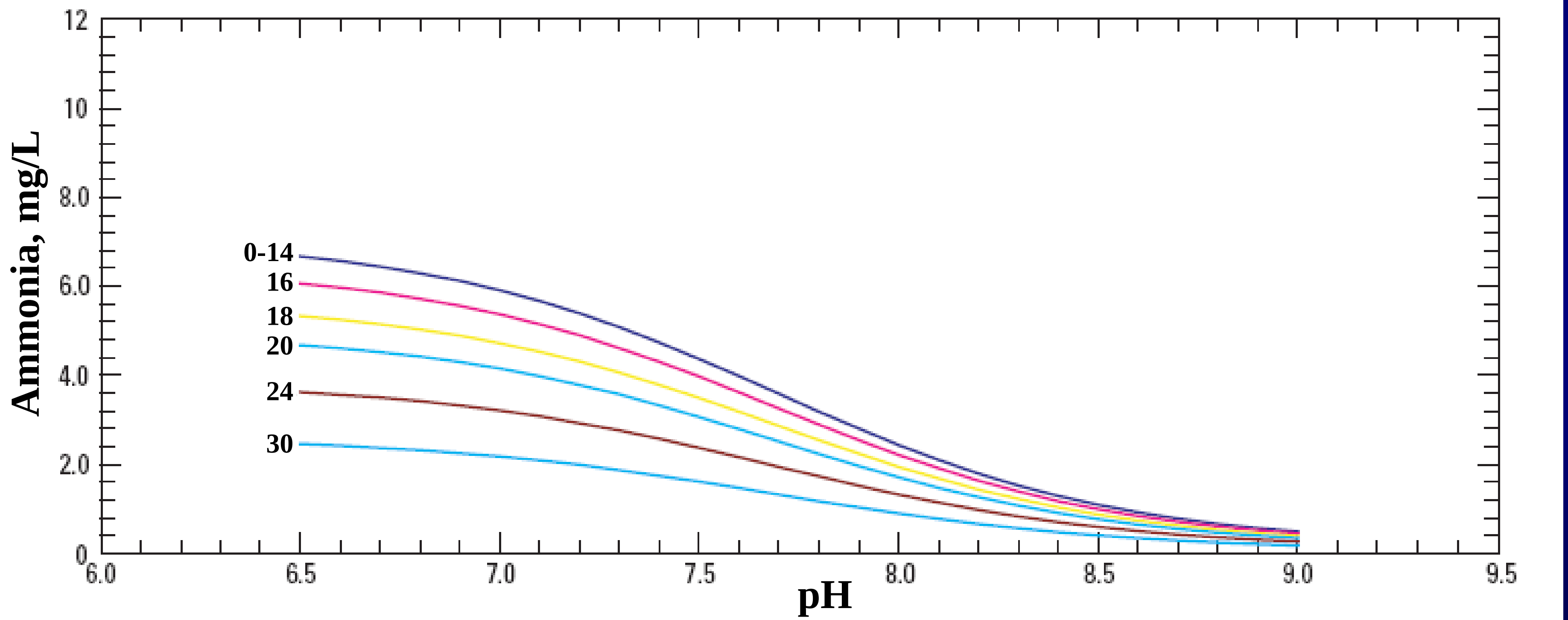
Ammonia Criteria—toxicity increases with temp and pH



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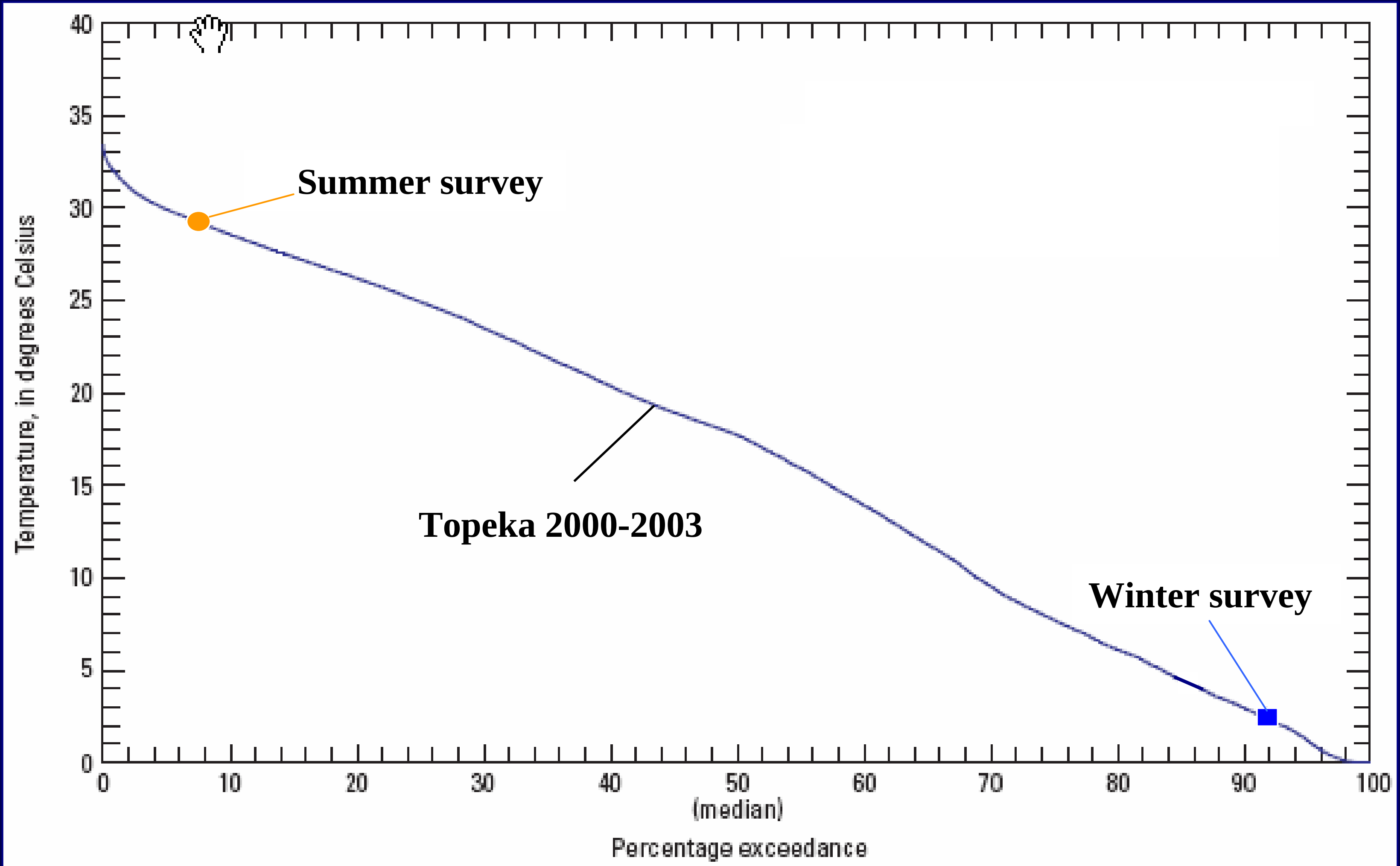
Water Temperature during surveys



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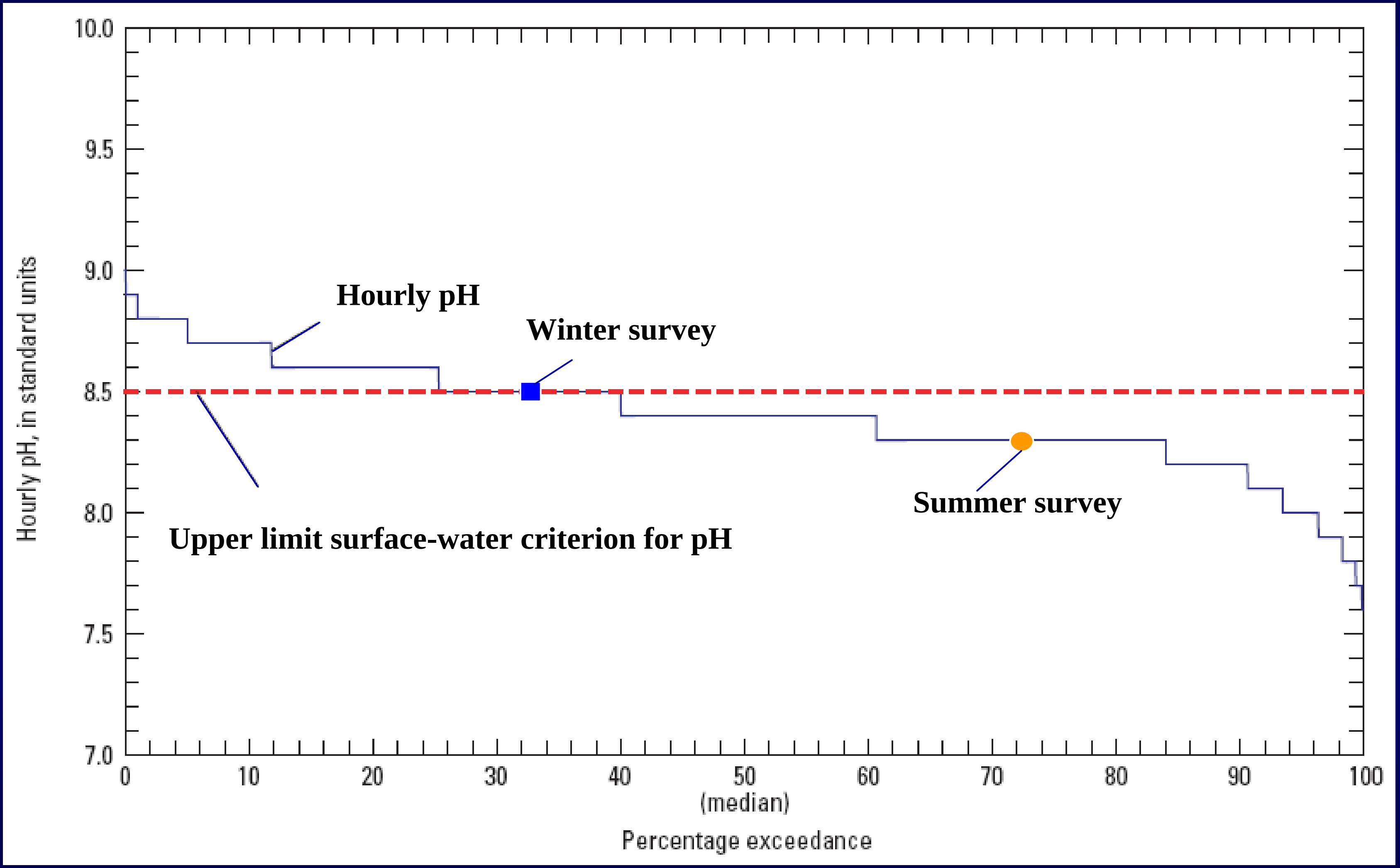
pH during surveys



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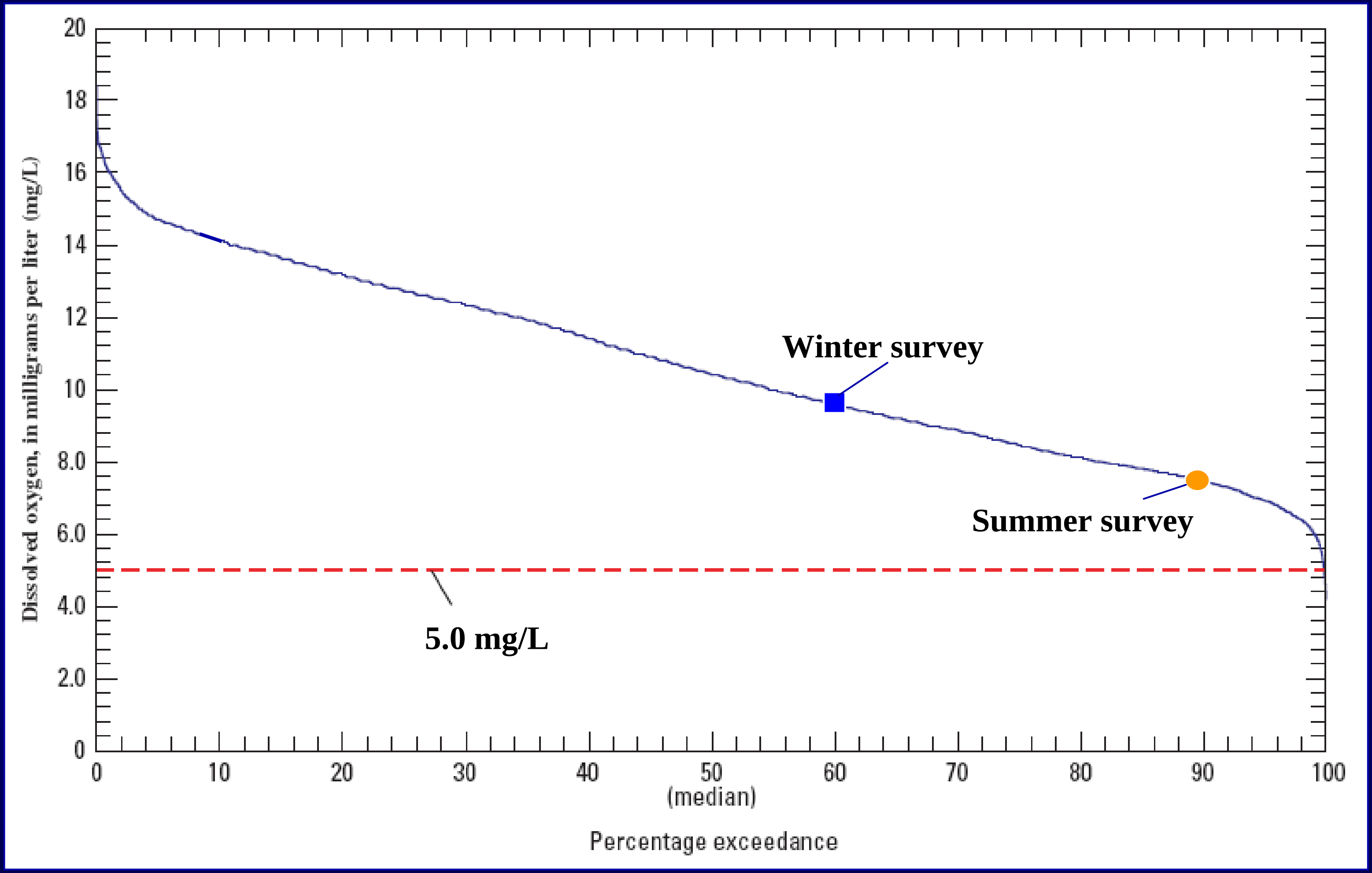
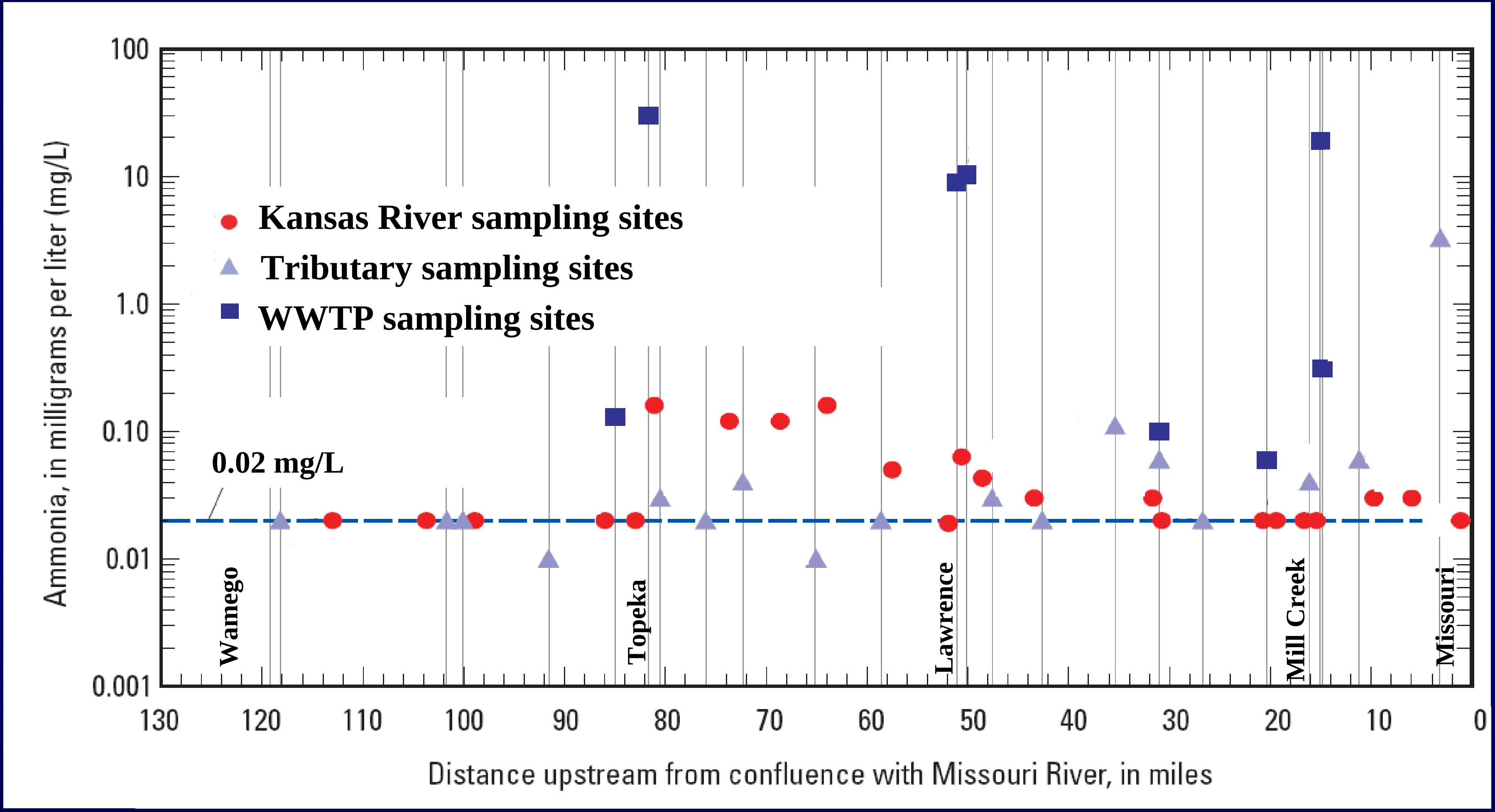
Dissolved oxygen during surveys



Ammonia Concentrations-Feb.



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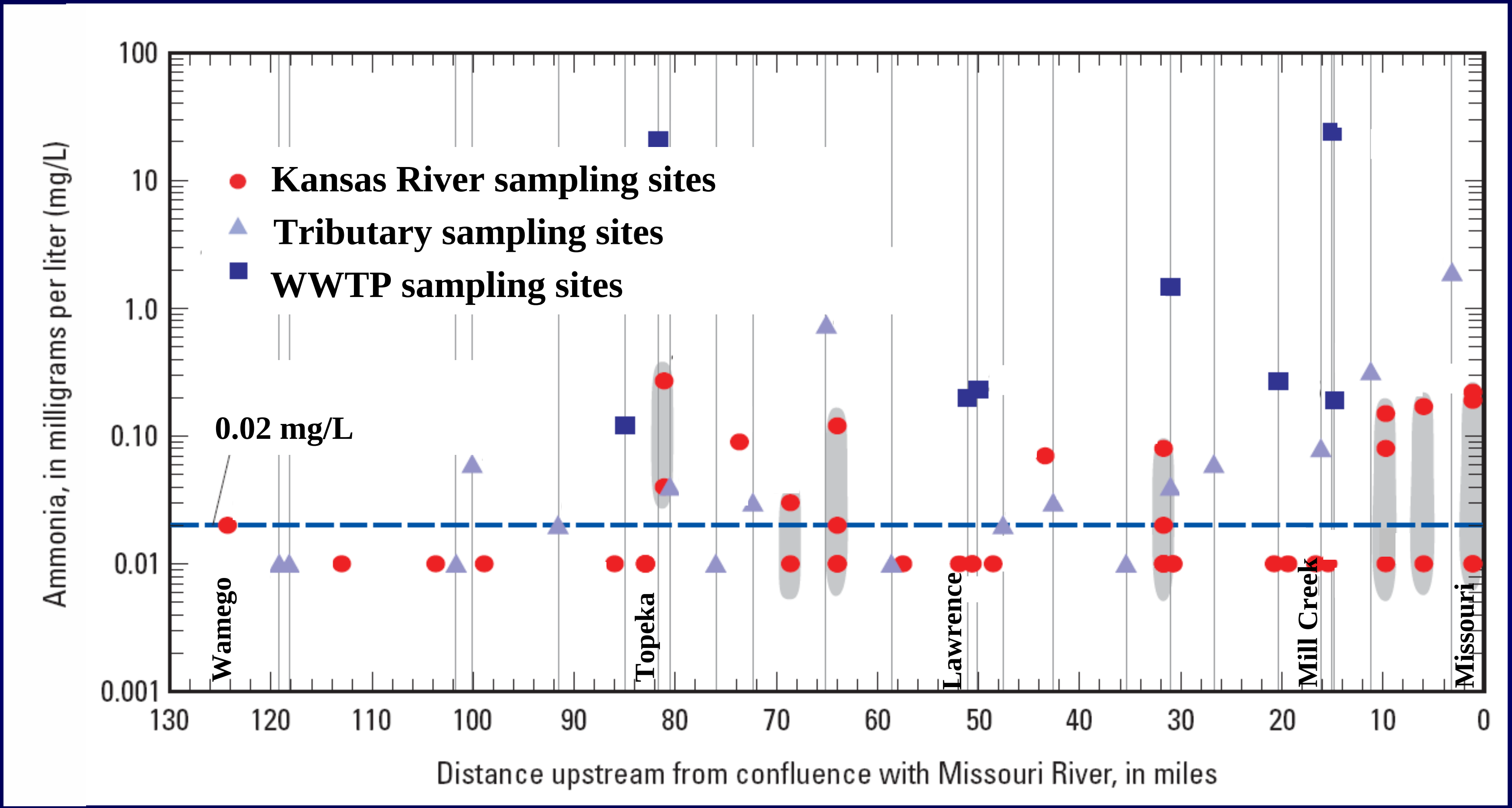
Ammonia Concentrations-July



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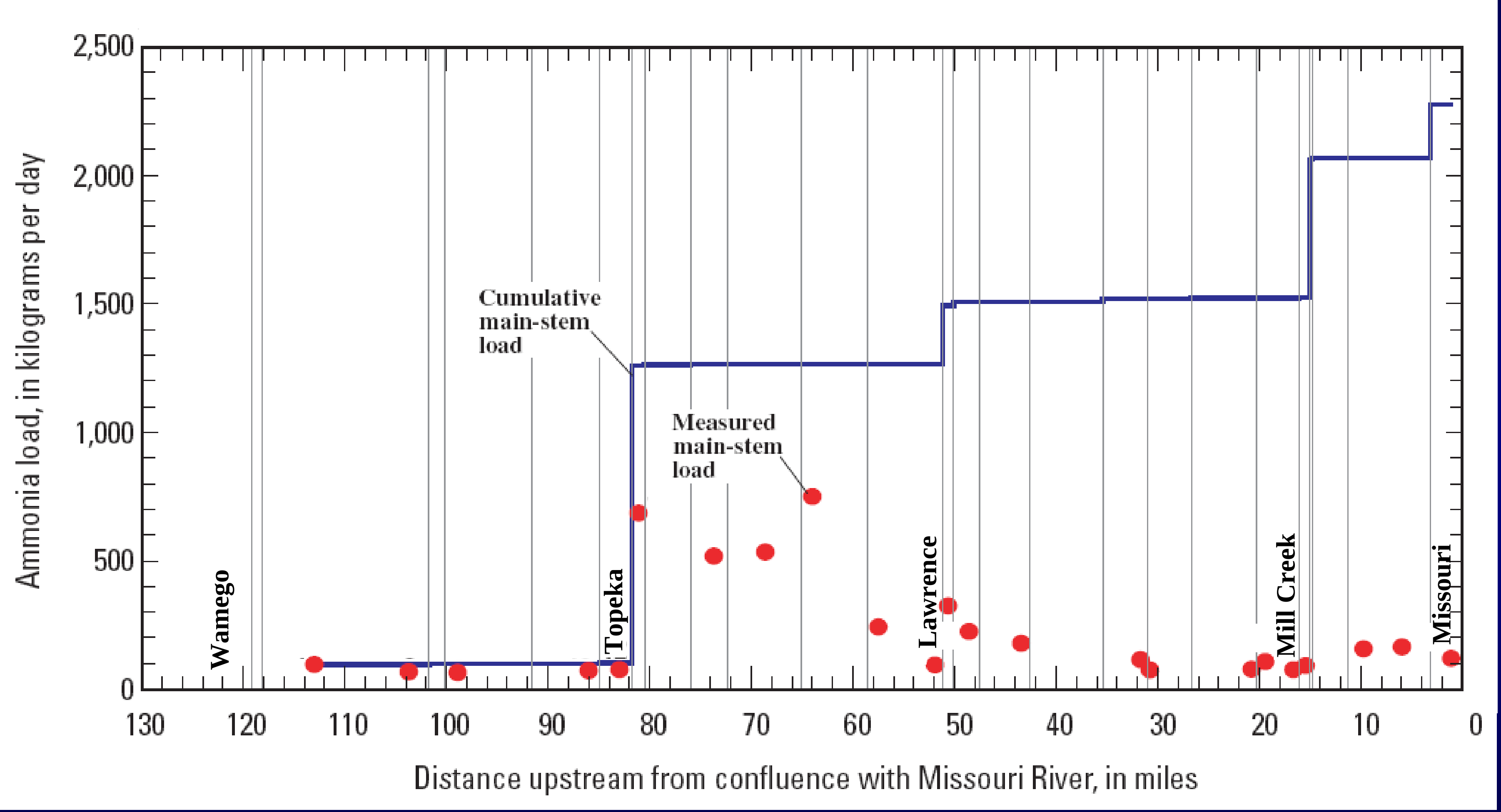
Ammonia Concentrations

- Synoptic Survey II (winter)
  - Ammonia concentration increased immediately downstream of WWTFs
  - All KSR concentration were less than criteria
- Synoptic Survey III (summer)
  - All KSR concentrations less than criteria
    - 70% of KSR less than reporting limit (0.015 mg/L)
  - Concentrations at a single site varied by as much as 20 times over the 2 week period

Ammonia Loads - Feb.



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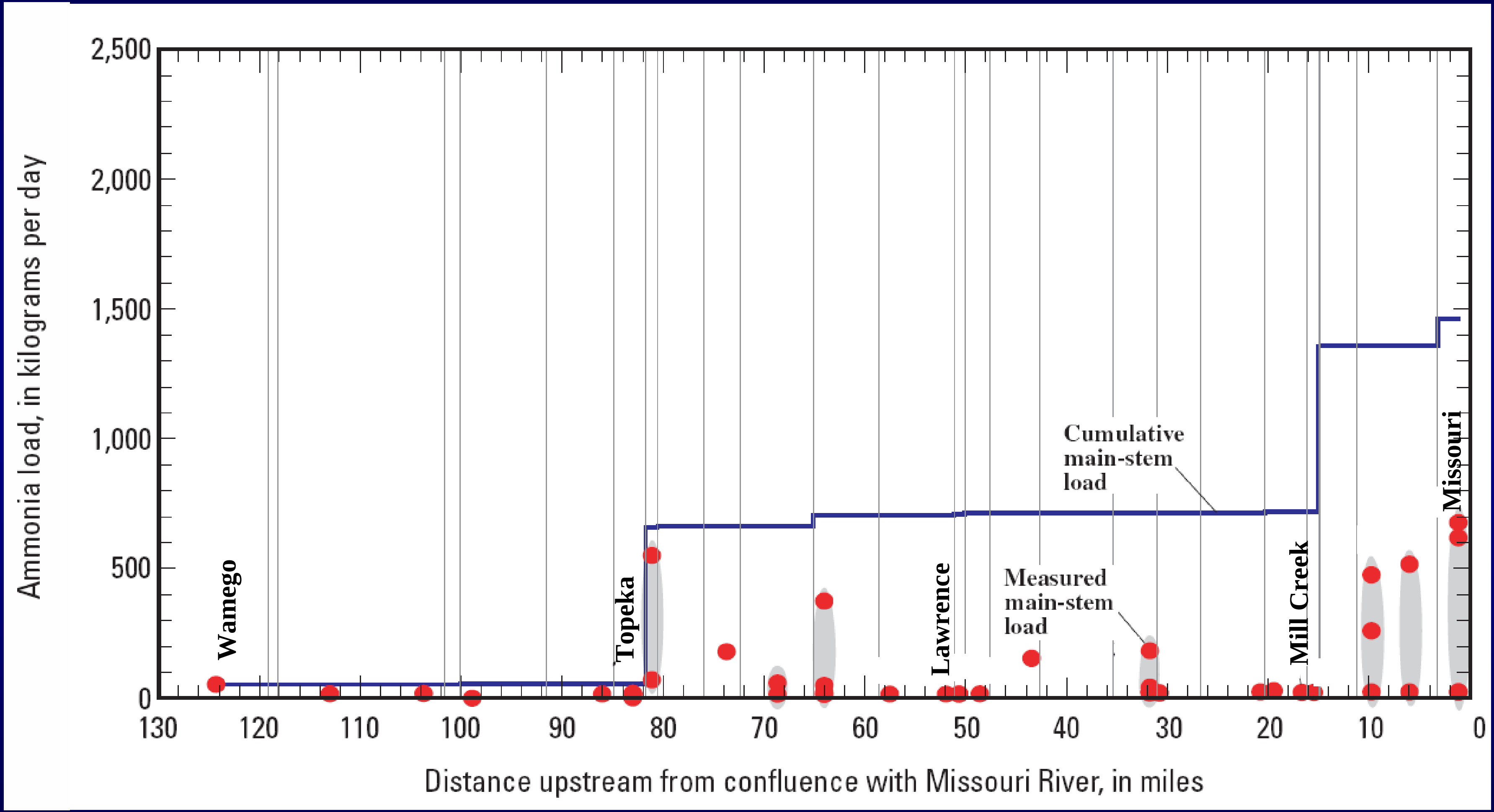
Ammonia Loads - July



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“Half Life” of Ammonia

- $C_{(t)}=C_o e^{-kt}$, $length_{1/2}=\ln(2)/k$
- 12 miles (7.8 hrs) for Topeka-Lawrence
- 20 miles (12 hrs) for Lawrence-JoCo Mill Creek WWTF
- 28 miles (17 hrs) for JoCo Mill Creek WWTF-Kansas City

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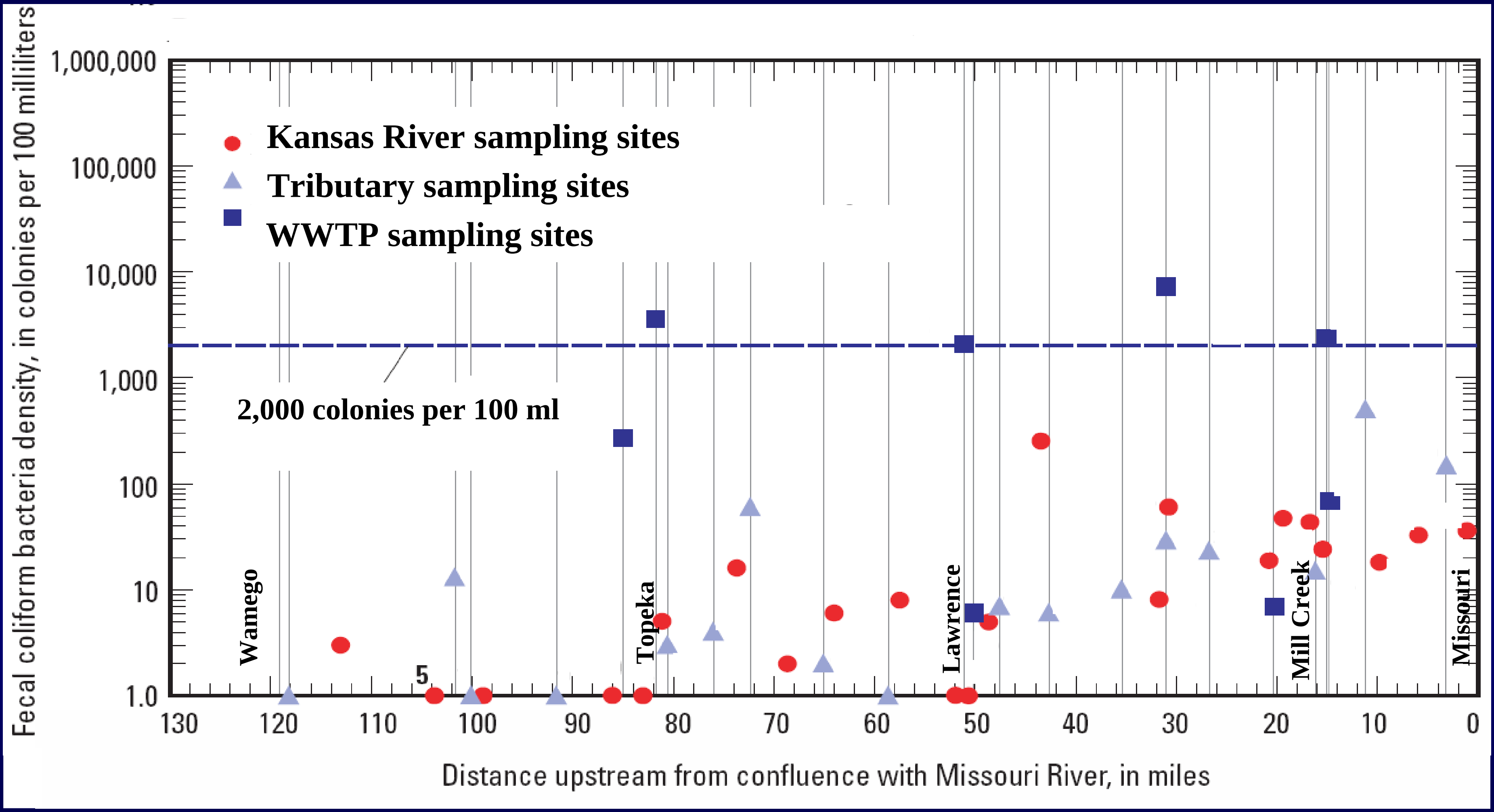
Bacteria Densities-Feb.



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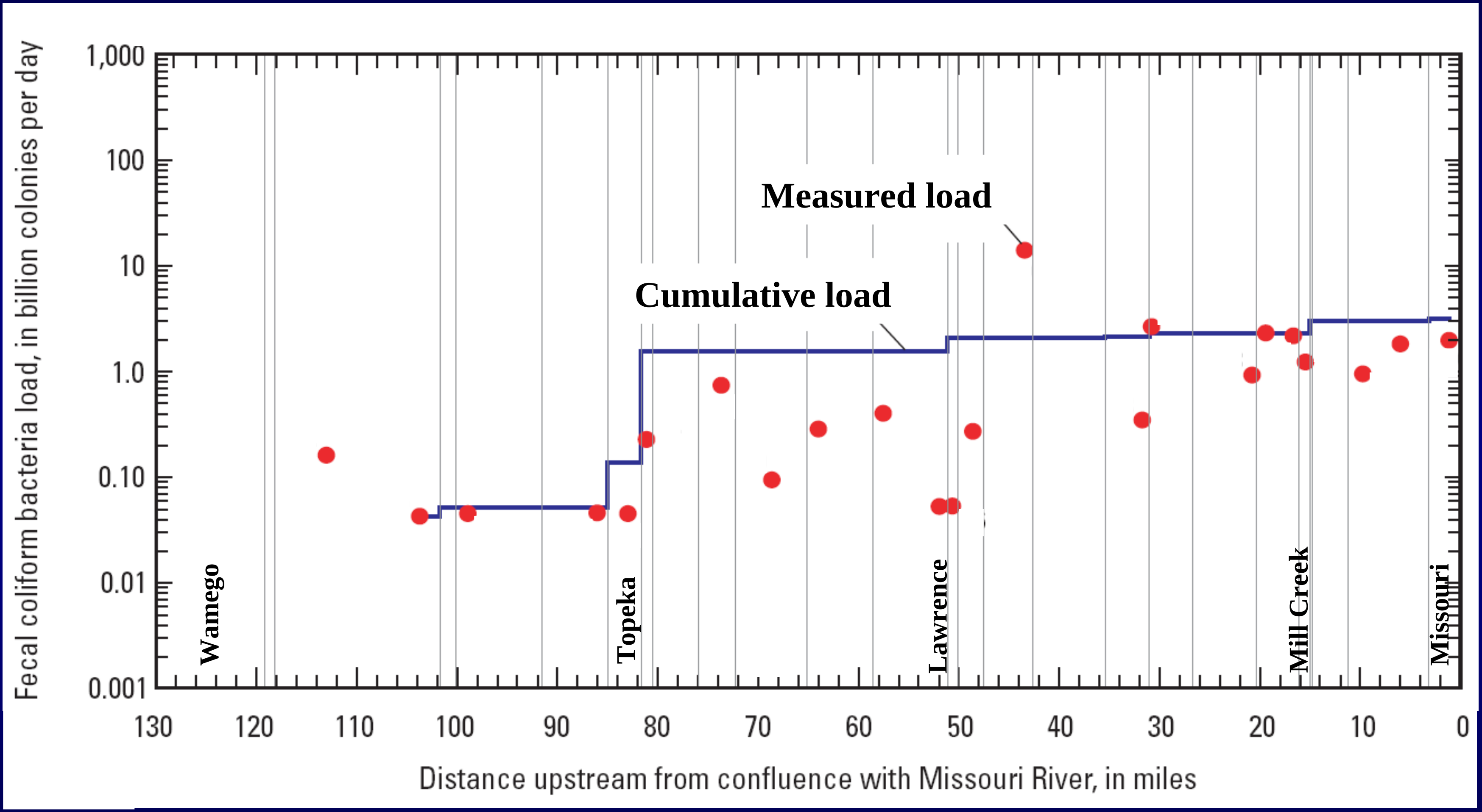
Bacteria Loads-Feb.



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Data Analysis Results

- Ammonia assimilation differs among stream segments
- Ammonia assimilation differs seasonally
- Ammonia decay rates in the Kansas River vary spatially and temporally
- Bacteria decay rates were not detected

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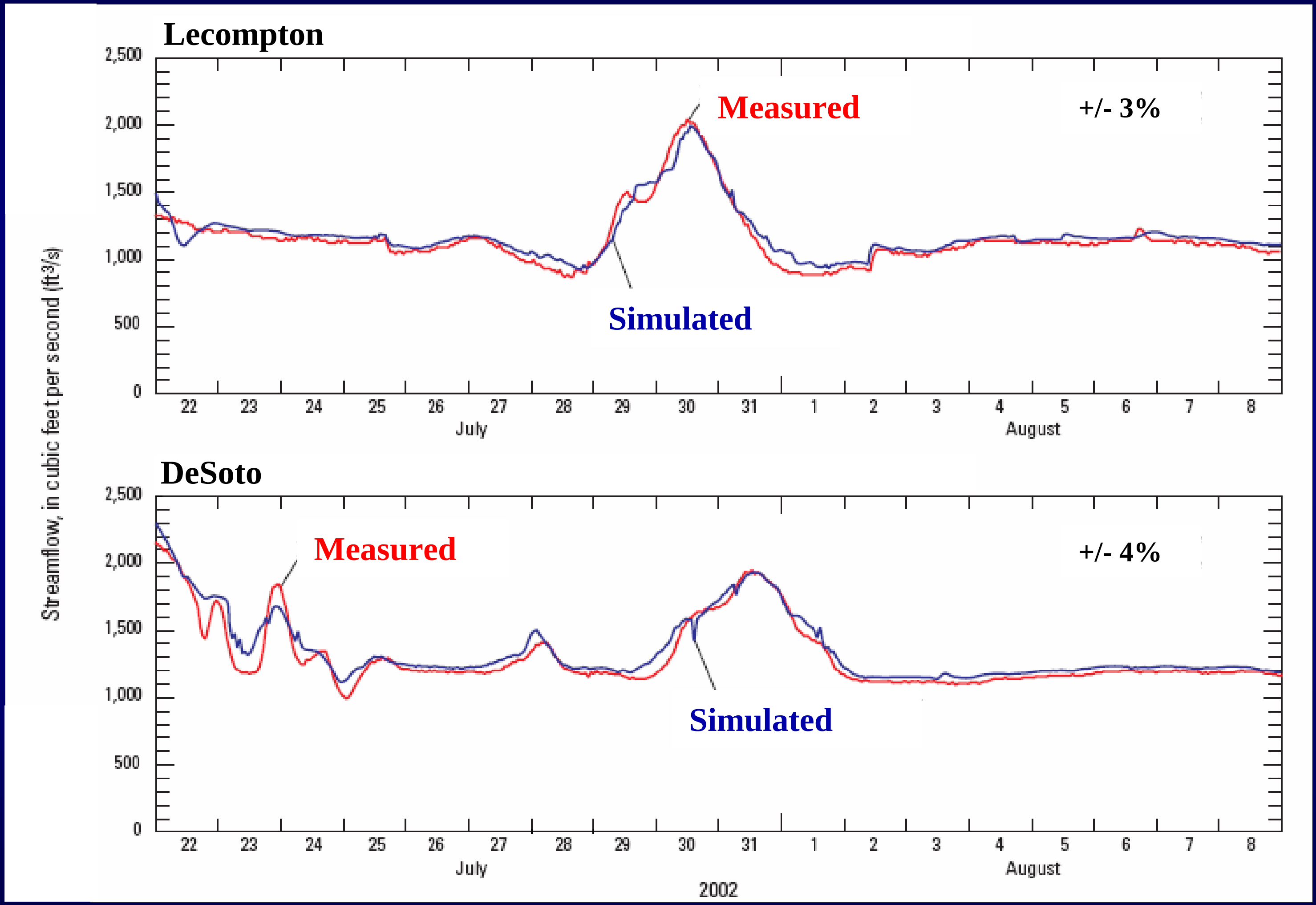
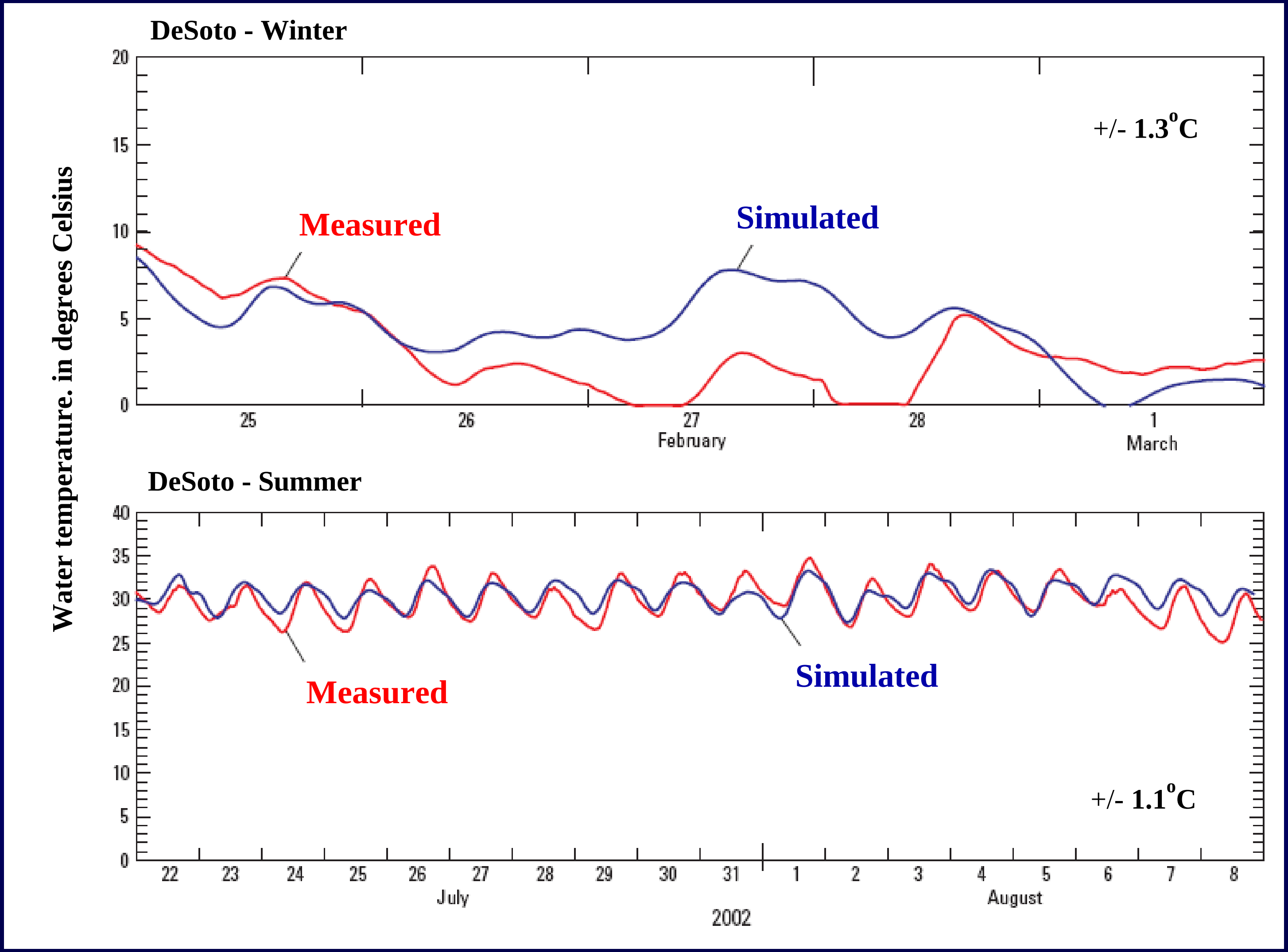
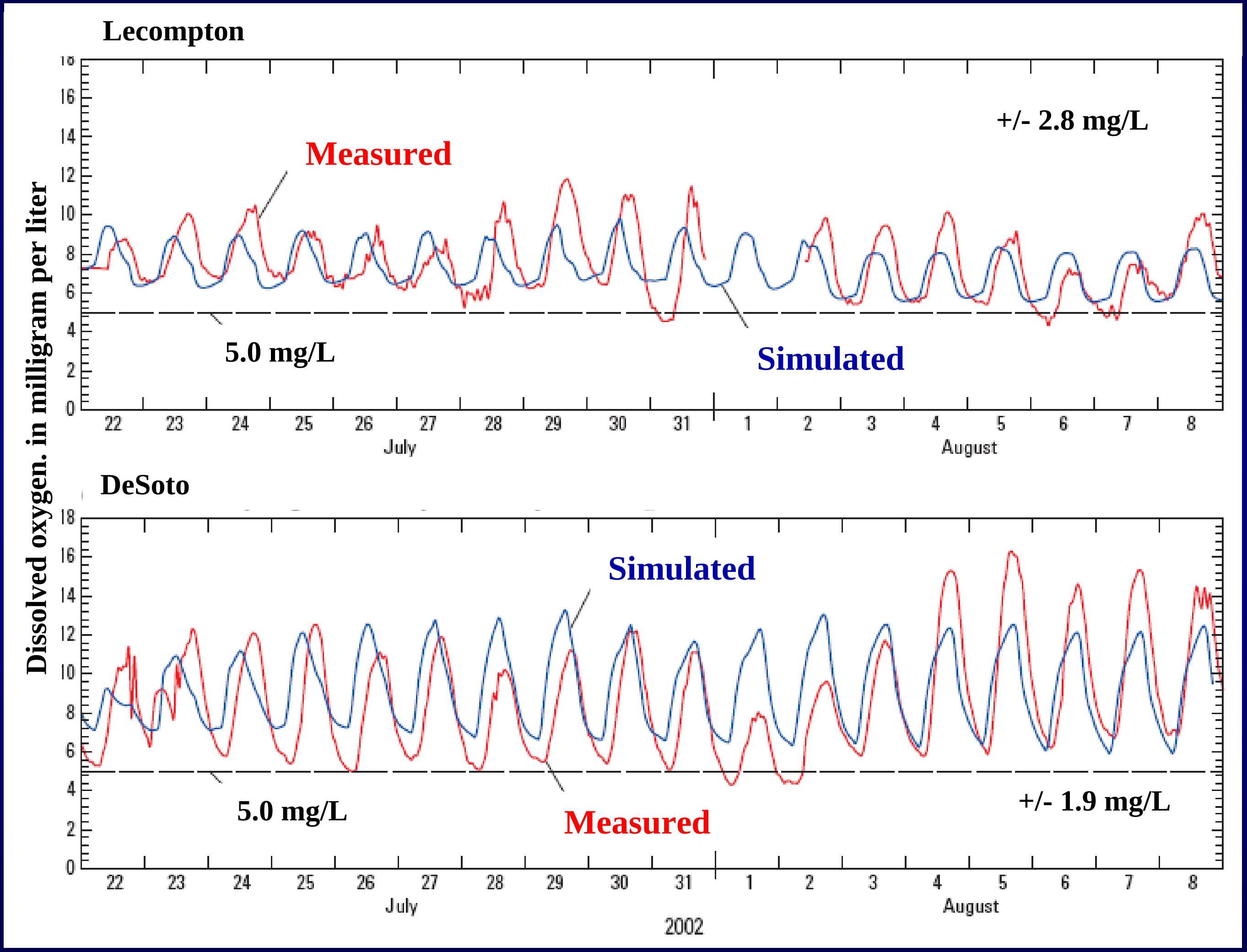
Modeling Streamflow



Modeling Water Temperature



Modeling Dissolved Oxygen



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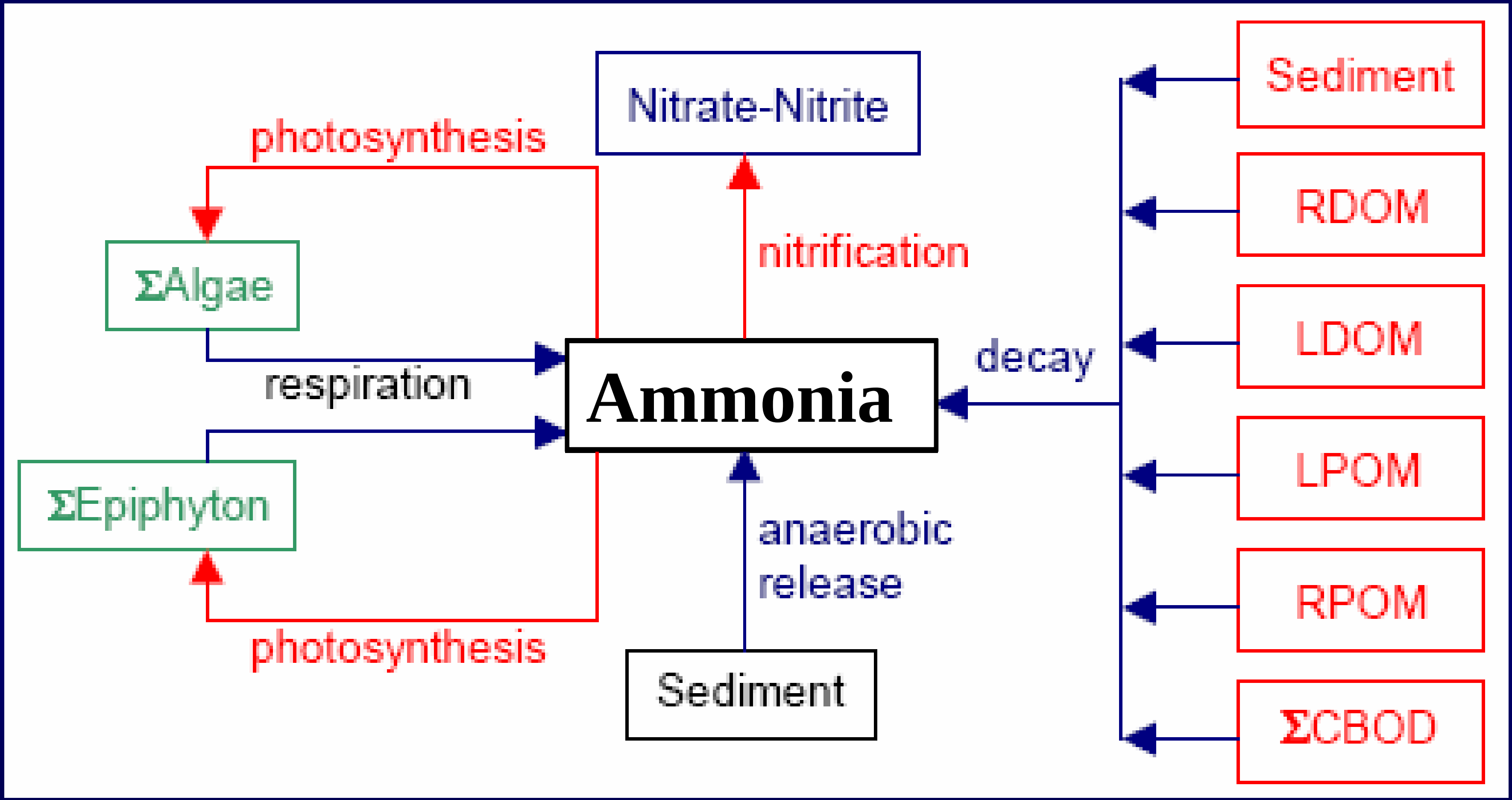
Ammonia



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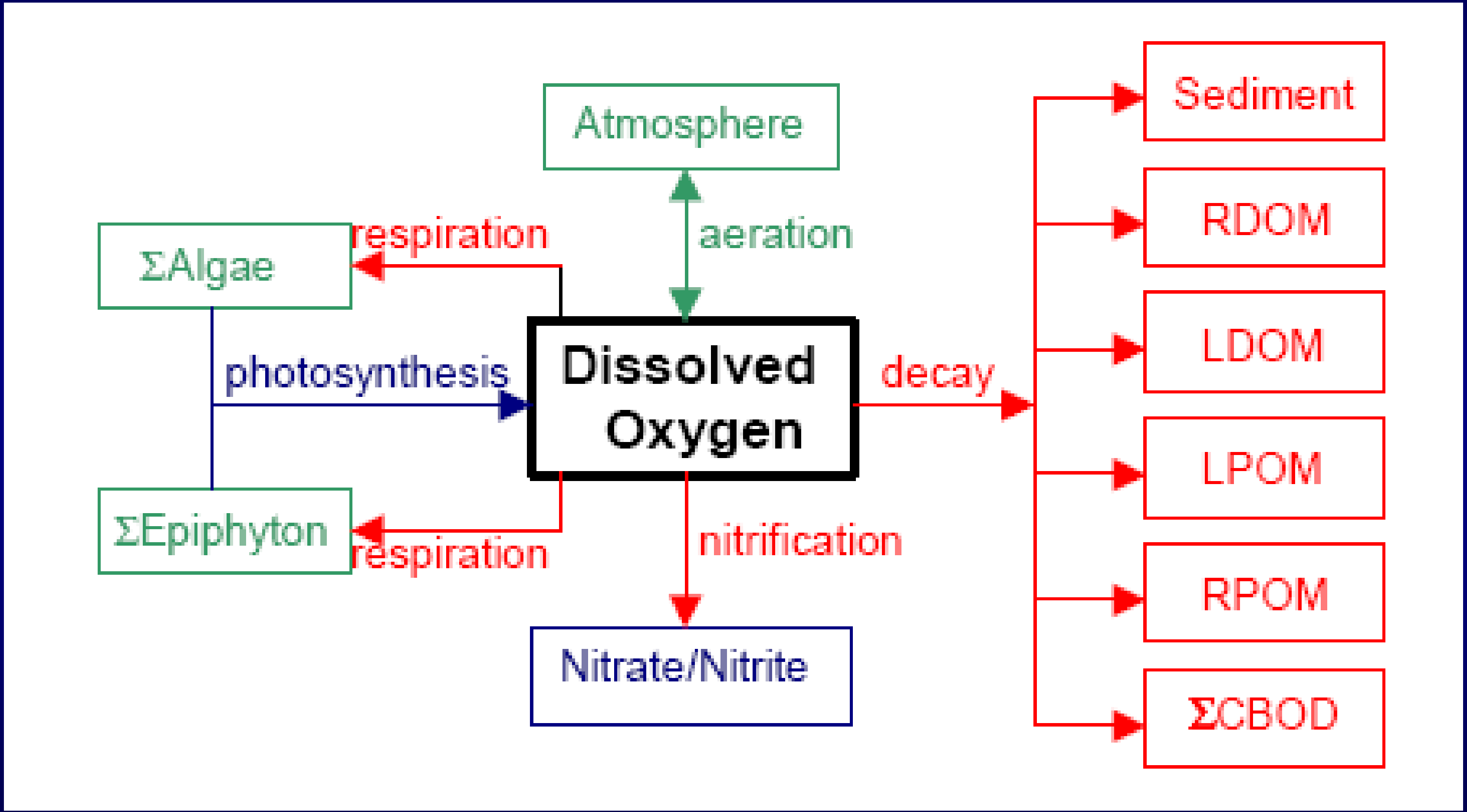
Dissolved Oxygen



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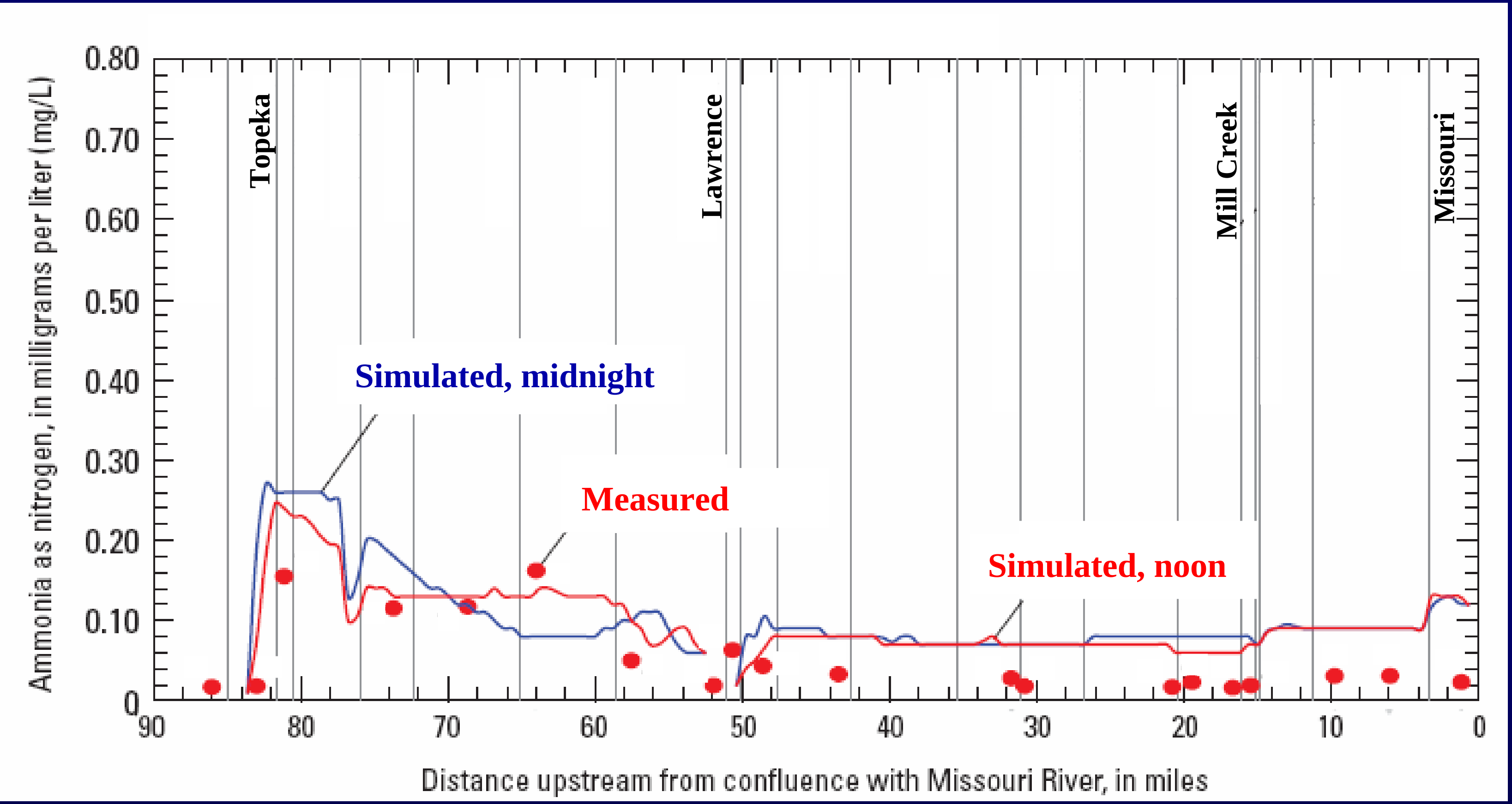
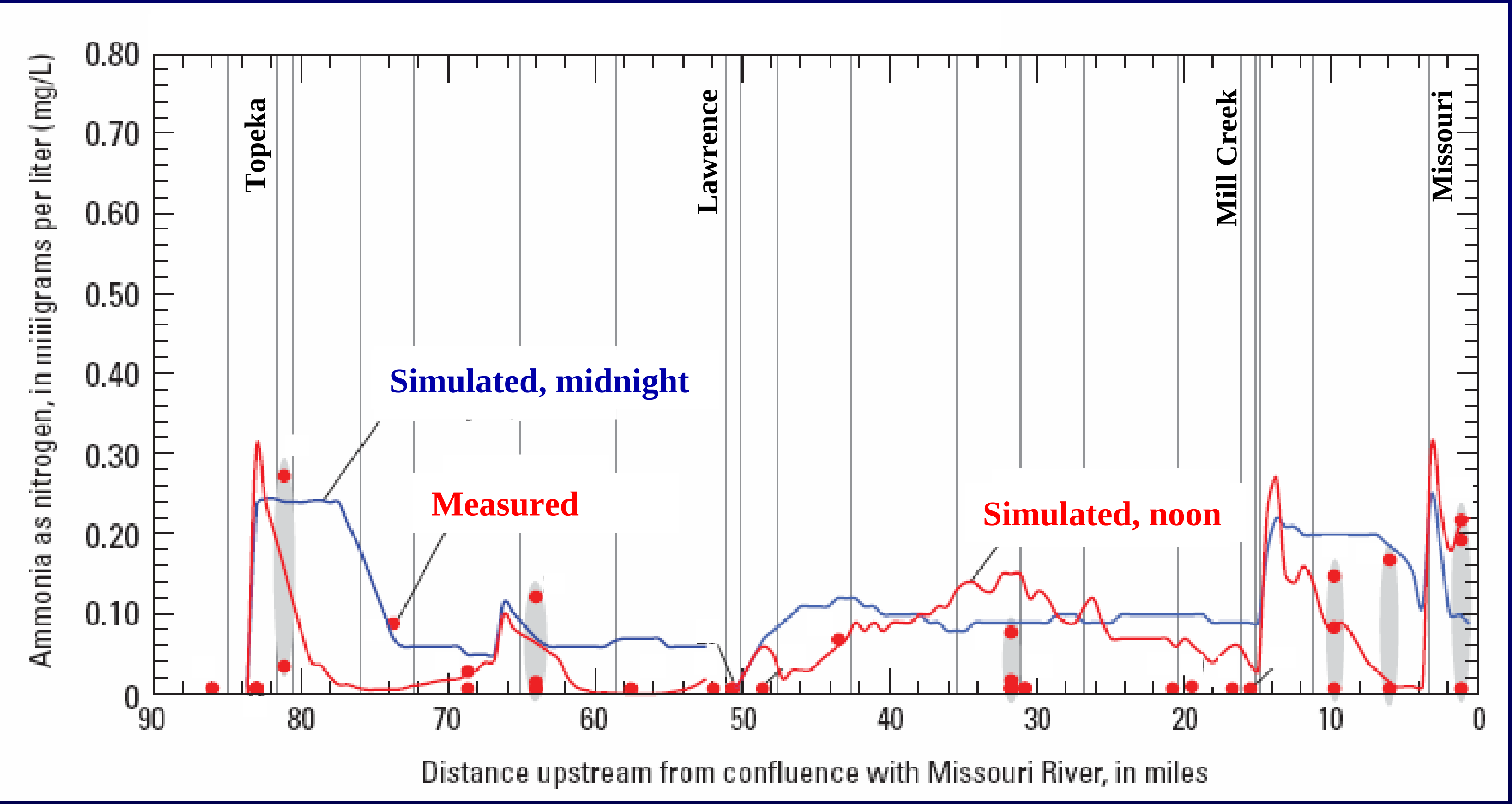
Modeling Ammonia - Winter



Modeling Ammonia - Summer



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Hypothetical Scenarios

- Reduce nutrient concentrations from the existing major WWTF to KNR plan levels
- Increase volume of effluent at major WWTF
- Add a large WWTF near DeSoto
- Reduce the Kansas River streamflow to 30Q10 level

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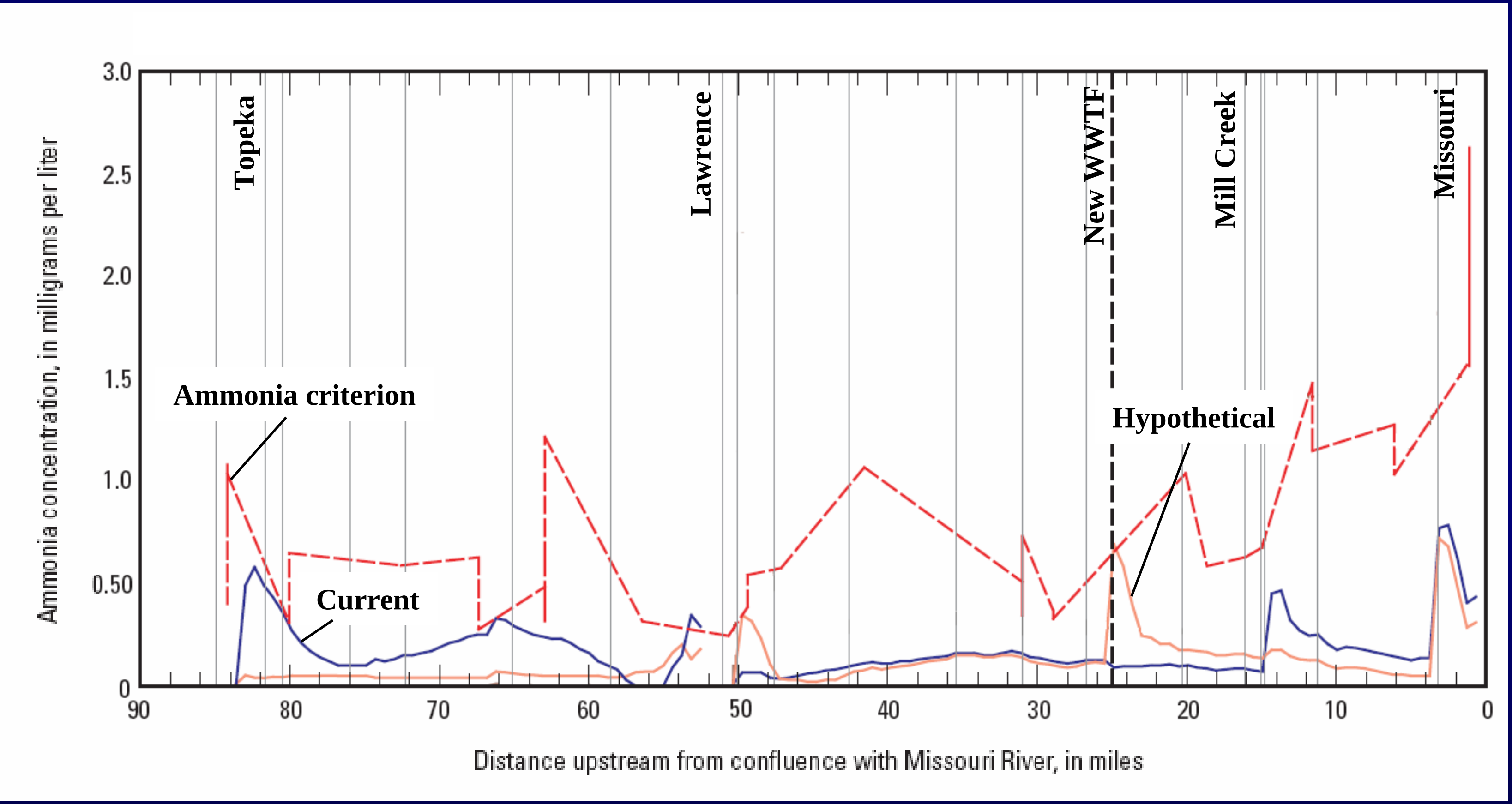
Hypothetical Ammonia Concentrations During 30Q10 Streamflow



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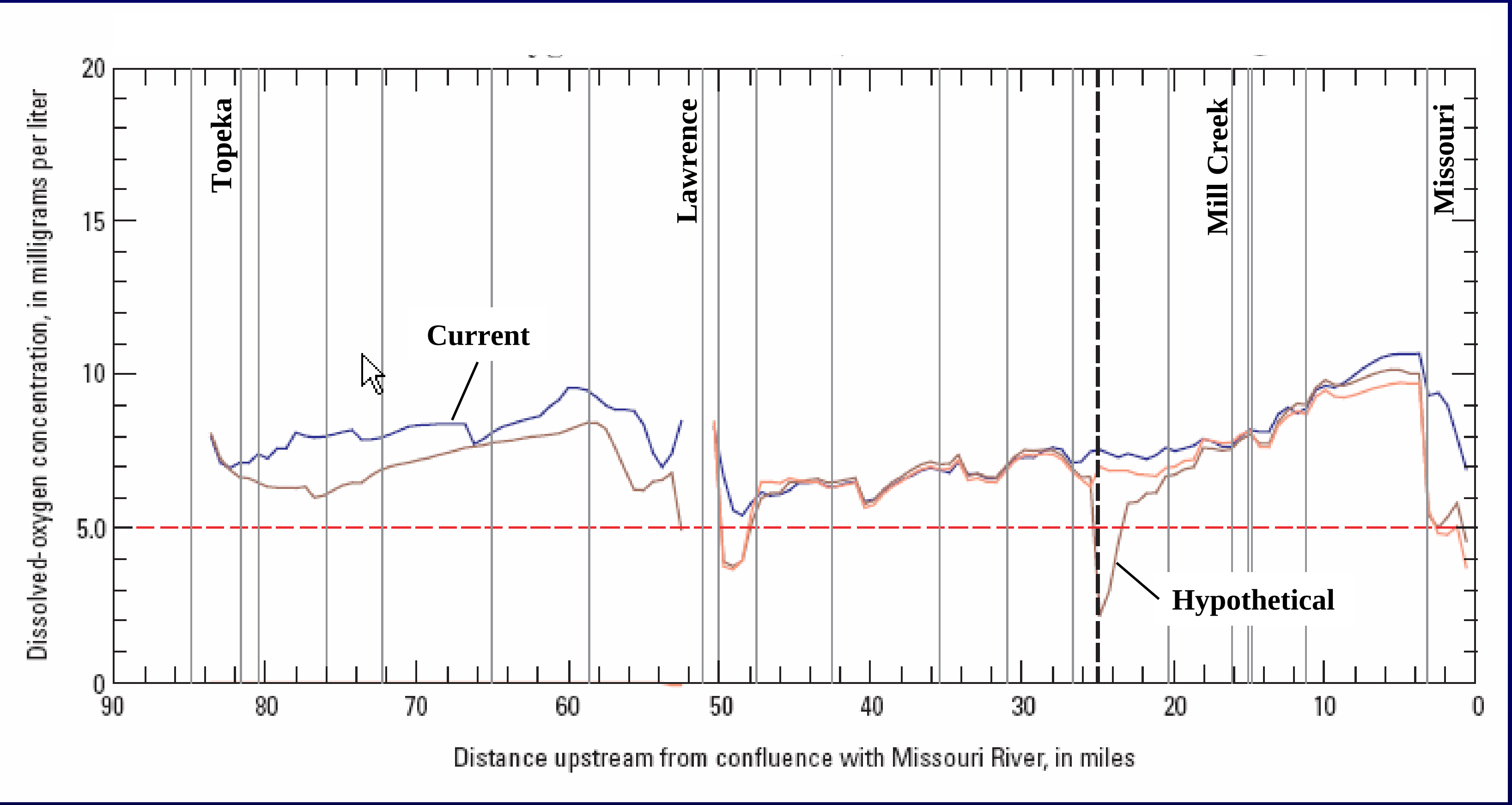
Hypothetical Dissolved Oxygen



Summary

- Ammonia detected in the Kansas River more frequently during winter – especially downstream of WWTF
- Almost none of the measured ammonia or bacteria in the Kansas River exceeded criteria
- Ammonia assimilative capacity is greater in the summer and differs among segments
- Bacteria concentrations were low and decay was not detected

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Summary - continued

- Model results indicate that the Kansas River has capacity to assimilate additional nutrients
- In immediate vicinity of point sources water-quality standards may be exceeded within the mixing zone

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More Information

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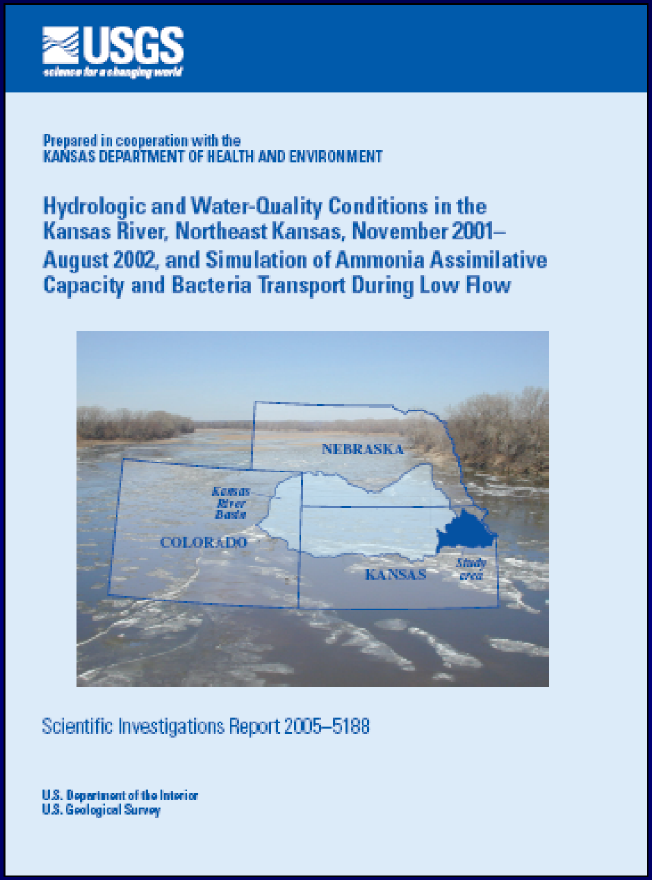

ks.water.usgs.gov/Kansas/studies/KSR.ammonia

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