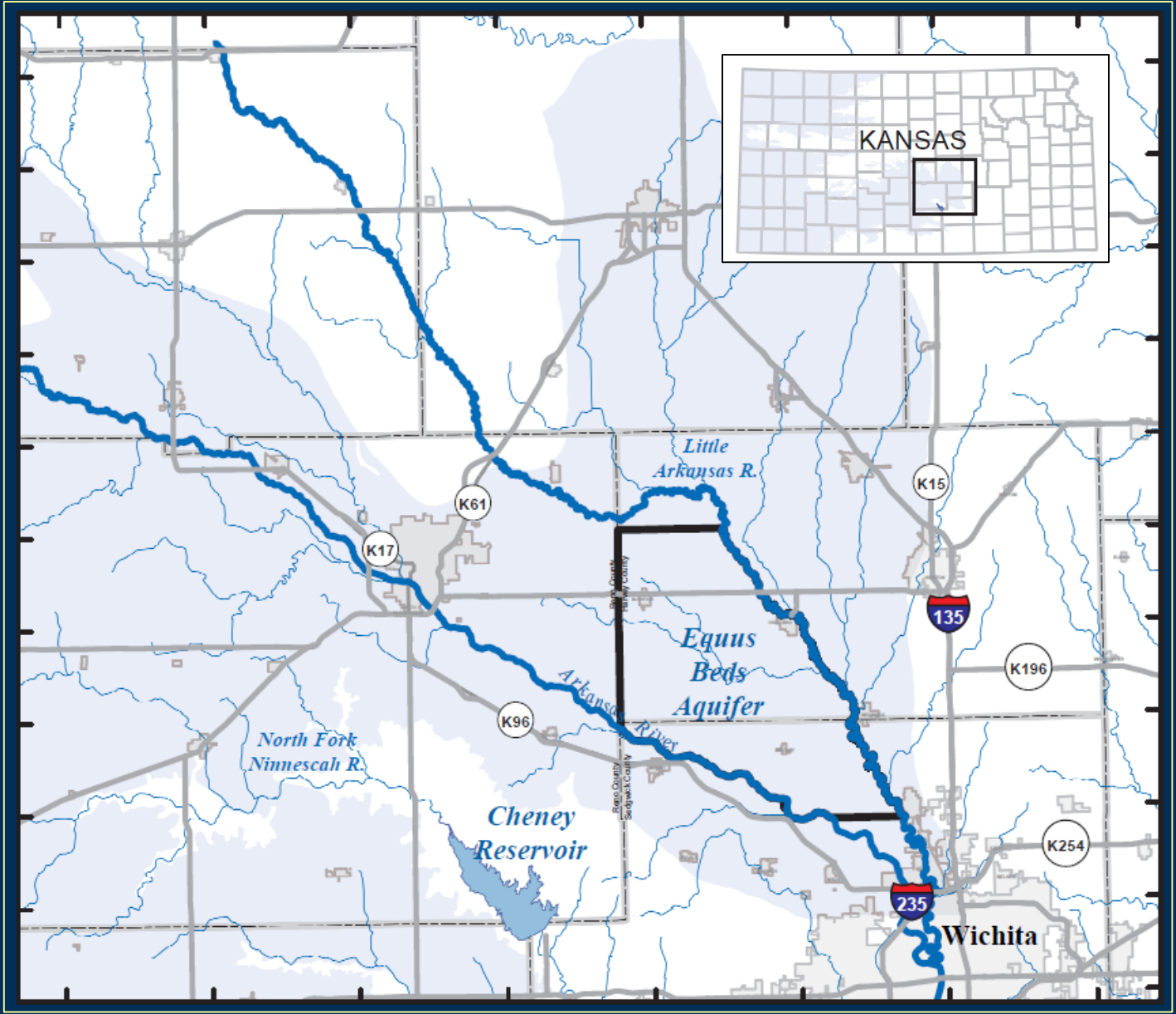
Long-Term Water-Quality Data Collection Associated with Wichita's Primary Drinking Water Sources: Cheney Reservoir & the *Equus* Beds Aquifer, South-Central Kansas, 1966–2019

Prepared in cooperation with the city of Wichita

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

M.L. Stone & A.R. Kramer
Governor's Conference on the Future of Water in Kansas
November 8, 2019

Study Areas: Cheney Reservoir & the *Equus* Beds Aquifer



Primary water sources for the City of Wichita

USGS water data collection since the 1920s; long term datasets for both projects

North Fork Ninnescah River is Cheney's major inflow

Little Arkansas River is source water for *Equus* Beds Aquifer Storage and Recovery (ASR)

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Study Area: Cheney Reservoir

Constructed in 1965

167,000 acre-ft capacity

(Kansas Biological Survey, 2010)

Area: 15.5 mi^2 or 9,940 ac

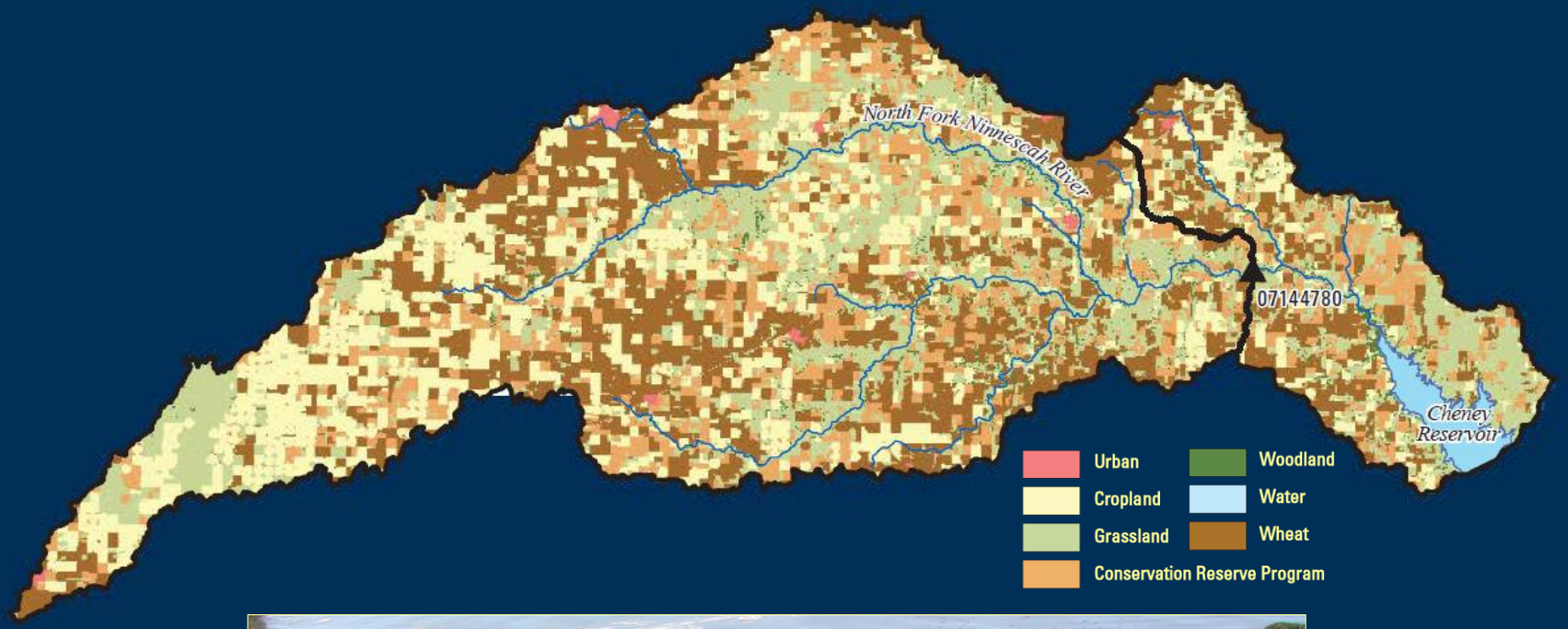
North Fork Ninnescah River is main tributary

Watershed land use predominately agricultural

Nutrients & sediment are primary pollutants (non-point)

Stratifies for short periods

Taste-and-odor issues



Harmful Algal Bloom at Cheney Reservoir Dam
September 26, 2006

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Selected Background Highlights: Cheney Reservoir

Cheney Reservoir Task Force:

- Formed in 1992 due to taste-&-odor occurrences
- Prepared a pollution management plan & established stream water-quality goals
- Concentrations during baseflow & runoff conditions have been well documented (Stone and others, 2009 & 2013)
- Long-term trends in concentrations have been more difficult to assess due to hydrologic variability & length of data collection

Sediment Loading:

- Sedimentation is reducing storage capacity
- Substantial sediment loads enter the reservoir over very short periods of time (Stone and others, 2015)

Table 1. Cheney Reservoir Task Force mean stream water-quality goals for total suspended solids, dissolved nitrate as nitrogen, and total phosphorus concentrations in Cheney Reservoir watershed streams during base flow, runoff, and long-term streamflow conditions.*

Water-quality constituent	Mean water-quality goal (milligrams per liter)		
	Base flow	Runoff	Long term
Total suspended solids	20	550	100
Dissolved nitrate as nitrogen	0.25	6.60	1.20
Total phosphorus	0.05	0.40	0.10

*Cheney Reservoir Task Force, 1994.

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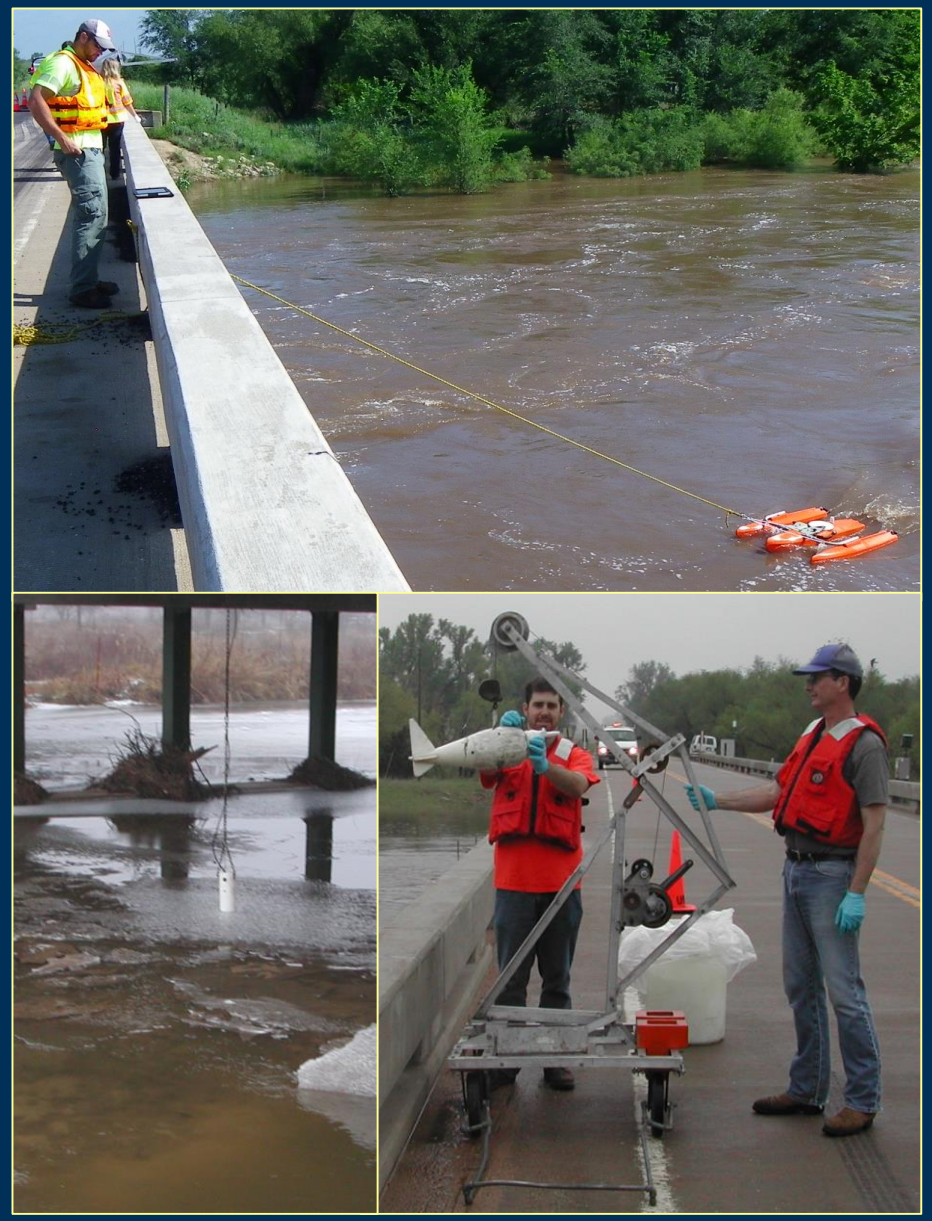
Selected Long-Term Data Collection & Analysis: Cheney Reservoir Inflow



Data Collection:

Continuous streamflow (since 1966) & water-quality (since 1999)

Discrete (since 1967) solids, sediment, nitrate, & total phosphorus

Data available at *nwis.waterdata.usgs.gov/nwis*

Data Analysis:

Long-term trend analysis

- EGRET (Exploration & Graphics of RivEr Trends)
  - Hirsch & De Cicco, 2015: *pubs.usgs.gov/tm/04/a10/*
  - WRTDS (Weighted Regressions on Time, Discharge, & Season)
    - WBT (WRTDS Bootstrap Test) – assigns trend likelihood

Surrogate model development

- National Real-Time Water Quality at *nrtwq/usgs.gov*
- Stone & others, 2013 & 2015
- Streamflow & suspended sediment → long-term loads

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Selected Long-Term Trend Results: Cheney Reservoir Inflow Nutrients 1999–2017

Total phosphorus:

Frequency that flow-normalized concentration is trending up in bootstrap replicates: 0.89

upward trend likely

1999 flow-normalized: 0.125 mg/L

2017 flow-normalized: 0.158 mg/L

Trend magnitude: 26% increase

Nitrate:

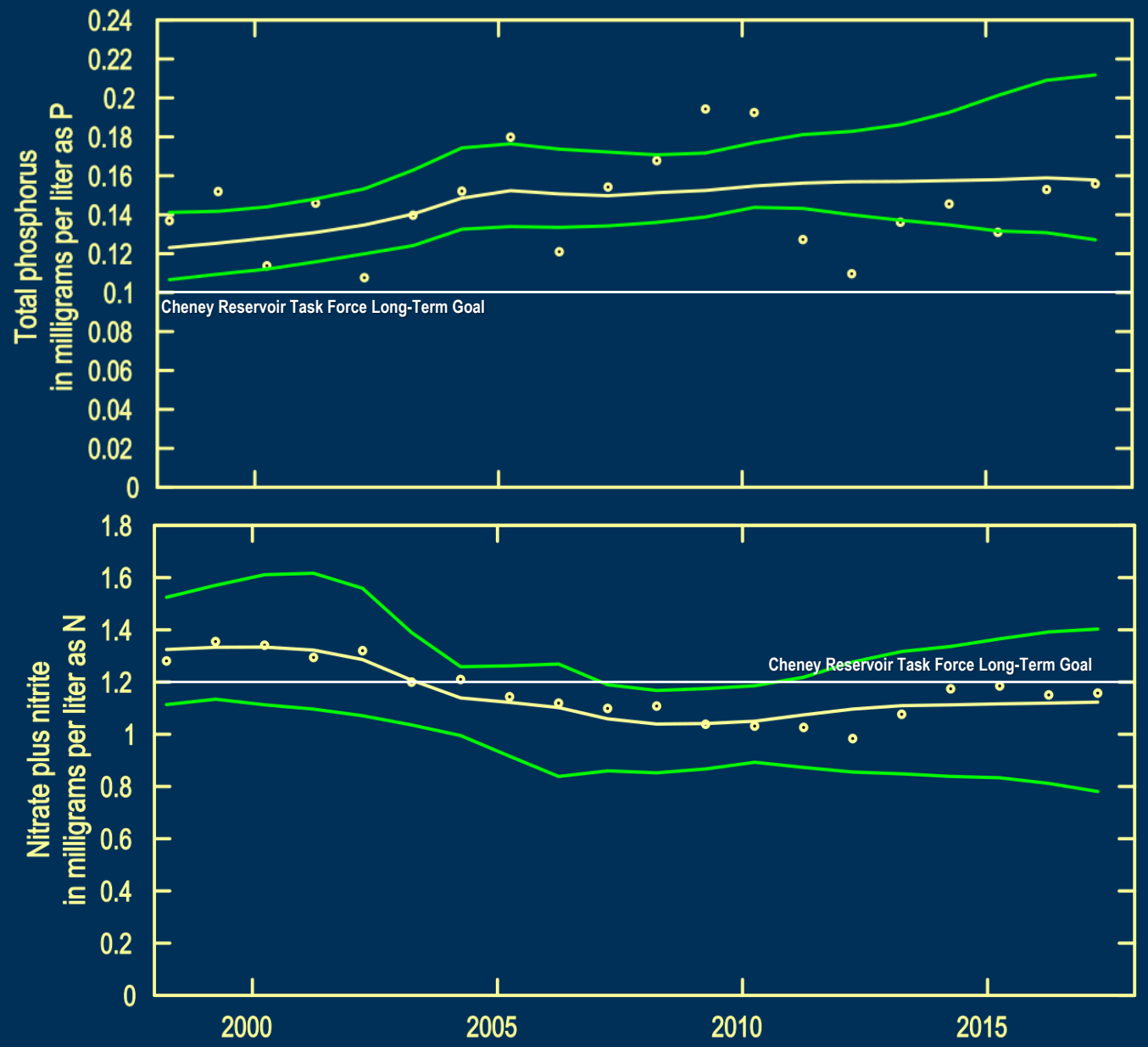
Frequency that flow-normalized concentration is trending down in bootstrap replicates: 0.86

downward trend likely

1999 flow-normalized: 1.33 mg/L

2017 flow-normalized: 1.12 mg/L

Trend magnitude: 16% decrease



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Long-Term Trend Results: Cheney Reservoir Inflow Solids & Sediment 1999–2017

Total suspended solids:

Frequency that flow-normalized concentration is trending up in bootstrap replicates: 0.84

- *upward trend likely*
- 1999 flow-normalized: 60.9 mg/L
- 2017 flow-normalized: 83.1 mg/L
- Trend magnitude: 36% increase

Suspended sediment:

Frequency that flow-normalized concentration is trending up in bootstrap replicates: 0.99

- *upward trend highly likely*
- 1999 flow-normalized: 111 mg/L
- 2017 flow-normalized: 175 mg/L
- Trend magnitude: 57% increase

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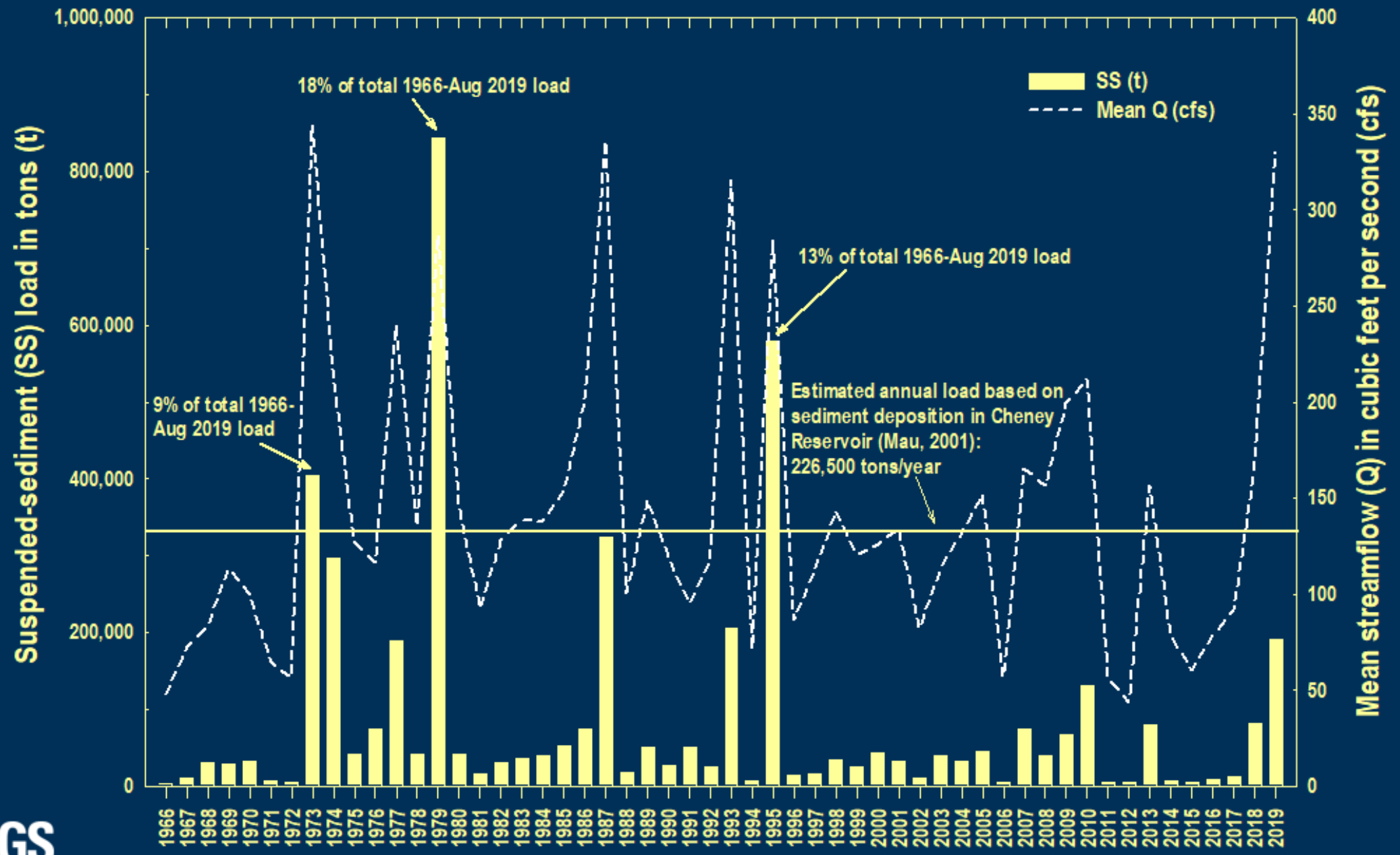
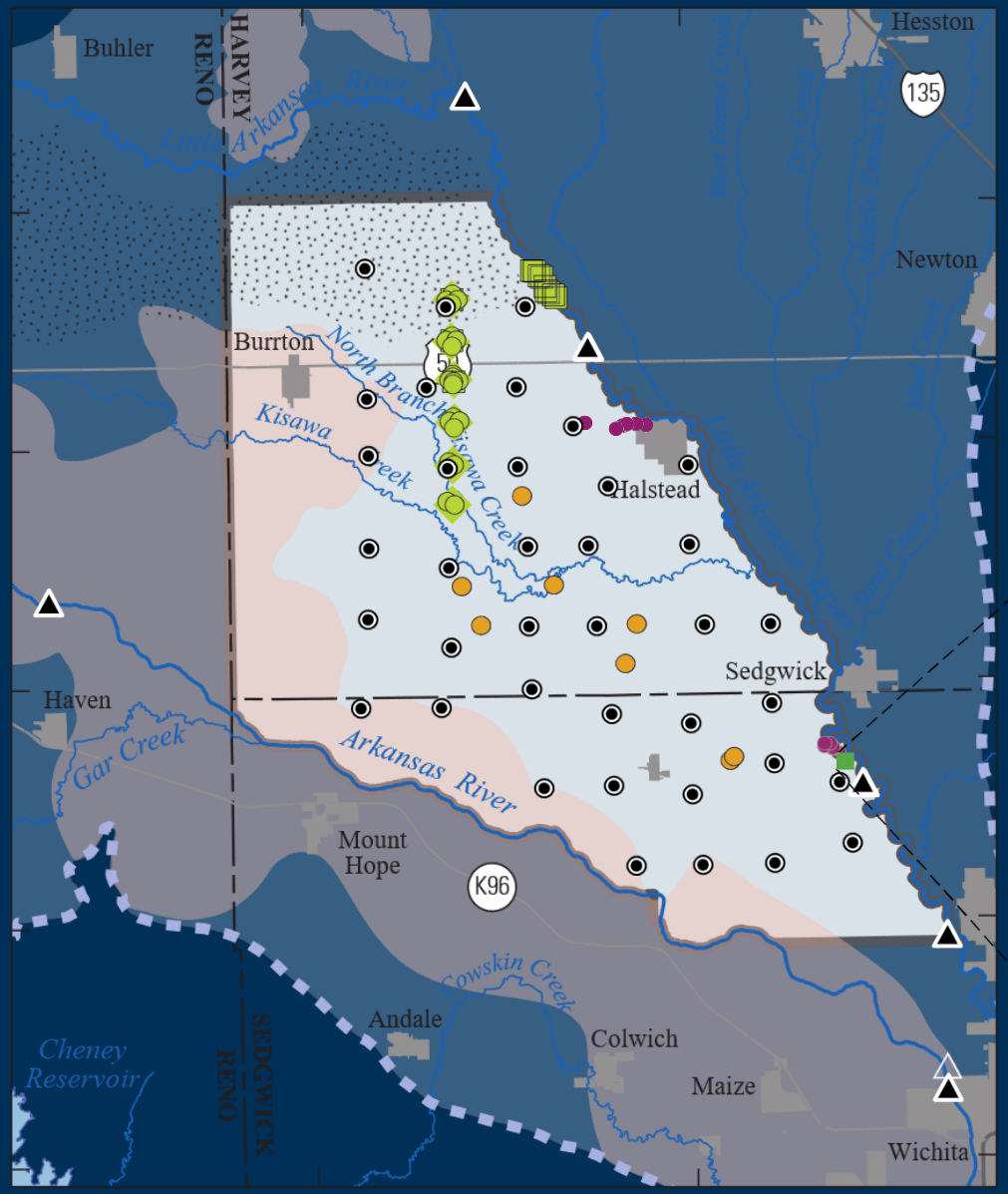
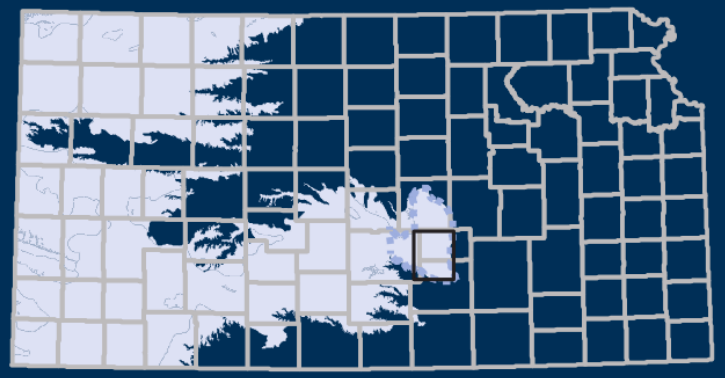
Long-Term Suspended Sediment Loads into Cheney Reservoir: 18% of Total Load in 1979



Modified from Stone and others, 2015

Study Area: *Equus* Beds Aquifer





Data Collection

- Two surface-water sites

  Source water for ASR

- 38 Index Well clusters

  Shallow (<80 feet)
  Deep (>80 feet)

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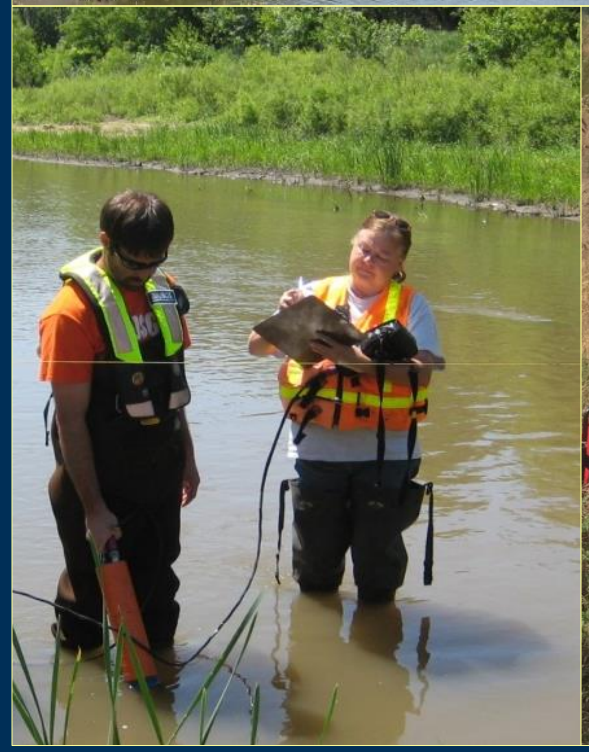
Selected Long-Term Data Collection and Analysis: Little Arkansas River & *Equus* Beds Aquifer



Data Collection:

Continuous streamflow & groundwater levels (since 1993)

Discrete (since 1967) ions, trace elements, and nutrients

Surface & groundwater continuous water-quality (since 1999)

Data available at *nwis.waterdata.usgs.gov/nwis*

Data Analysis:

Surrogate model development (Rasmussen & others, 2016)

- National Real-Time Water Quality at *nrtwq/usgs.gov*
- Turbidity & total organic carbon → long-term loads

Interpolated water-quality maps (Stone & others, 2019)

Groundwater model development (Klager & others, 2014)

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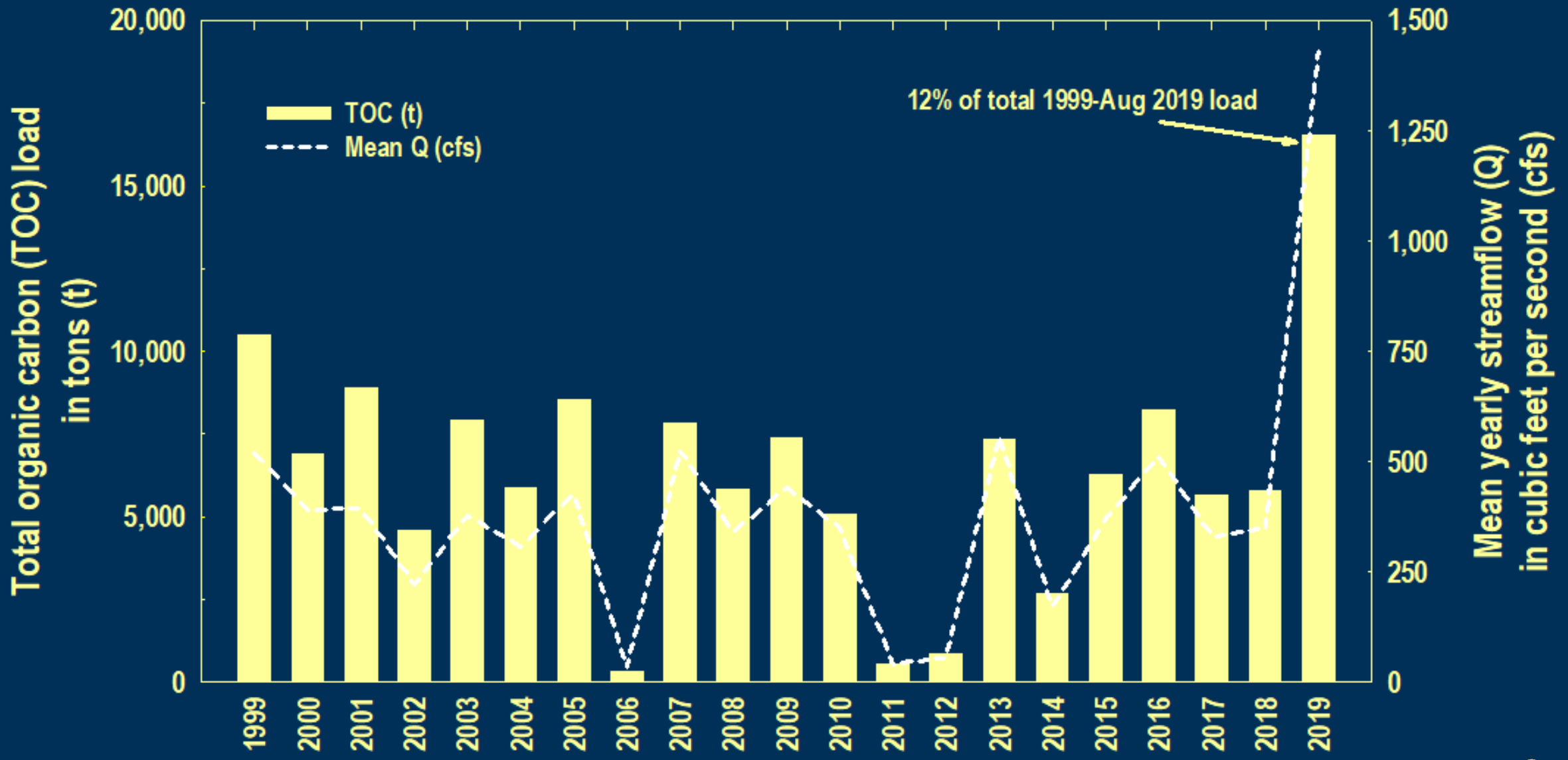
Little Arkansas River Long-Term Carbon Loads: 12% of Total Load in 2019



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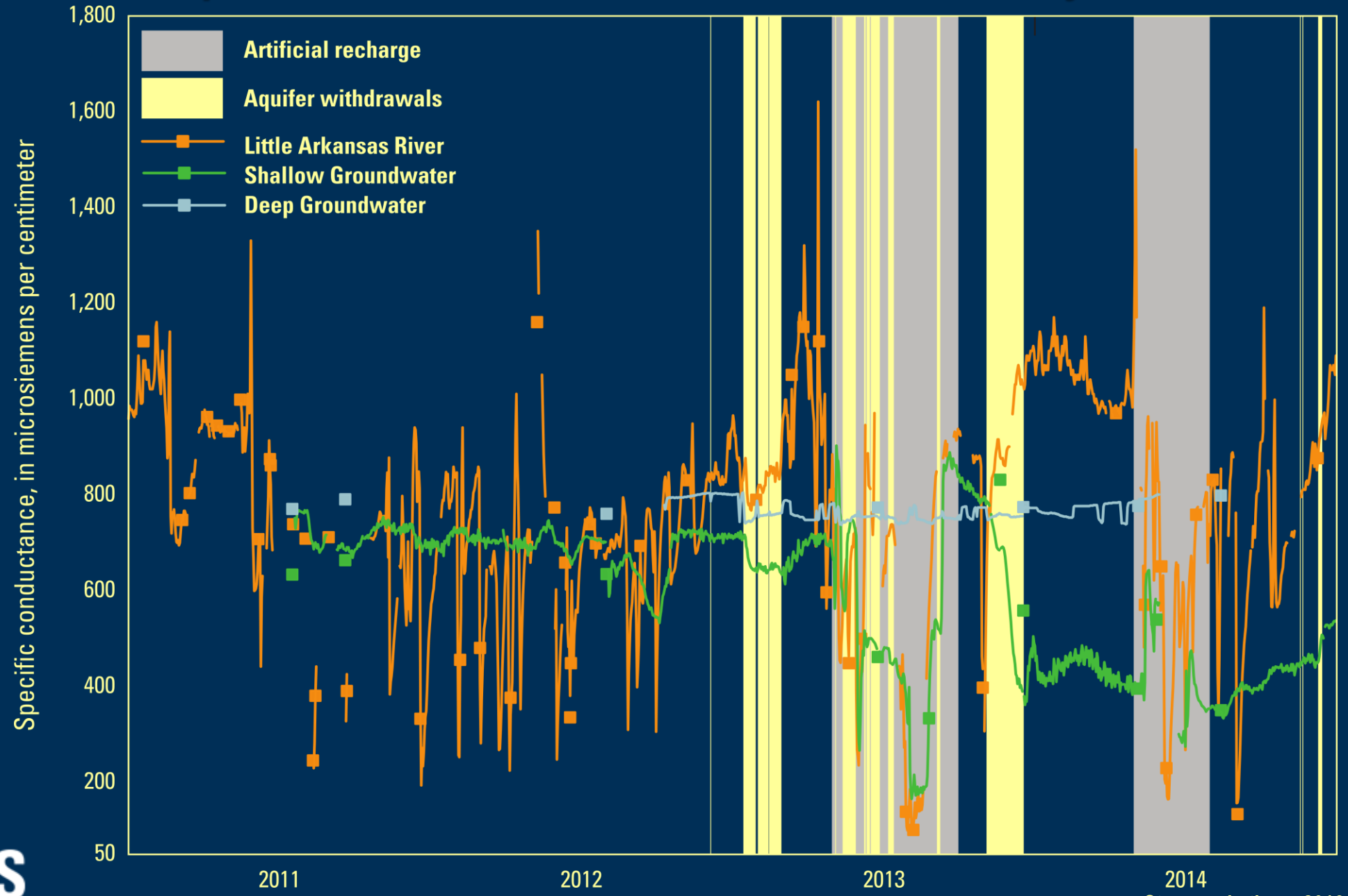
Equus Beds Continuous Groundwater Quality 2011–14



Stone and others, 2016

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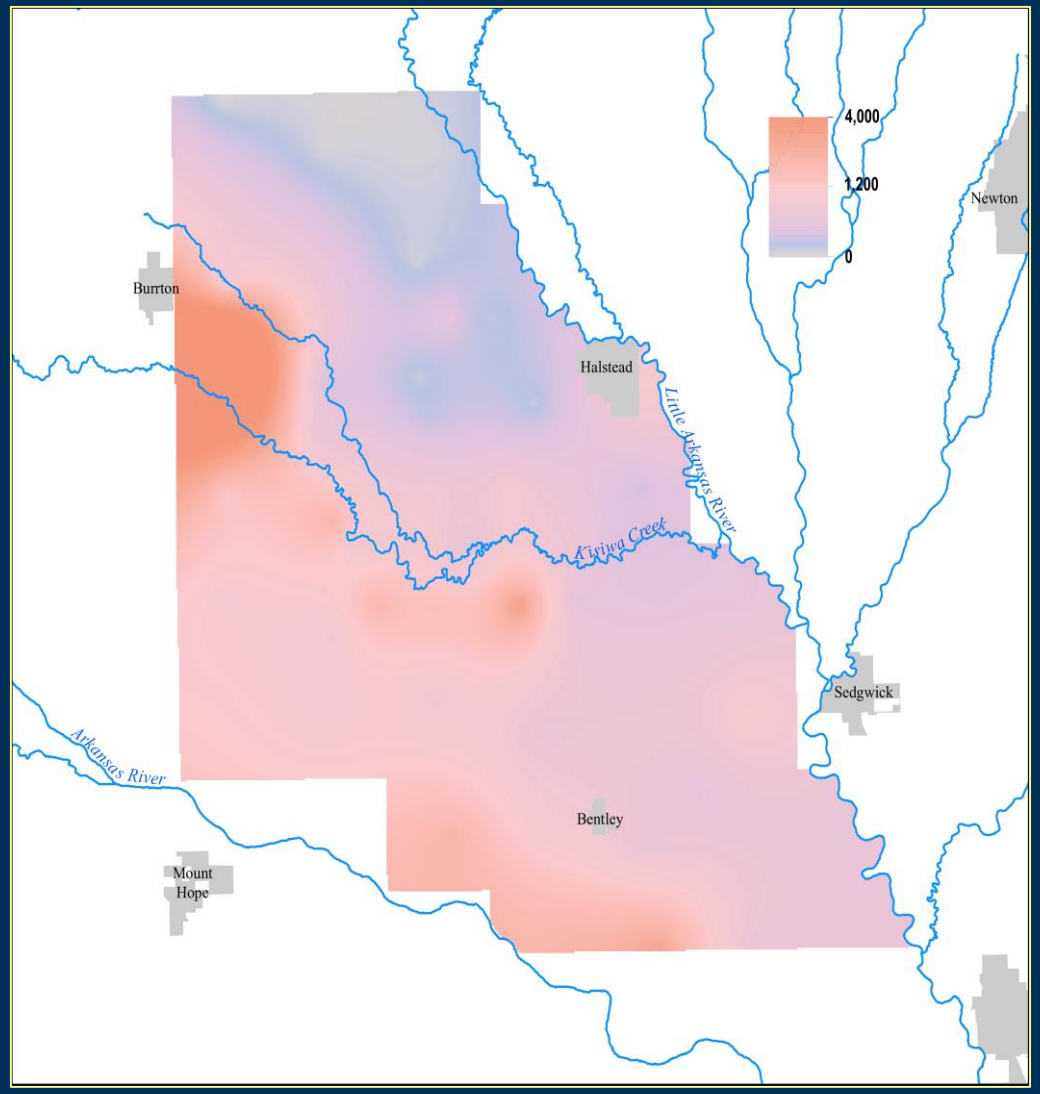
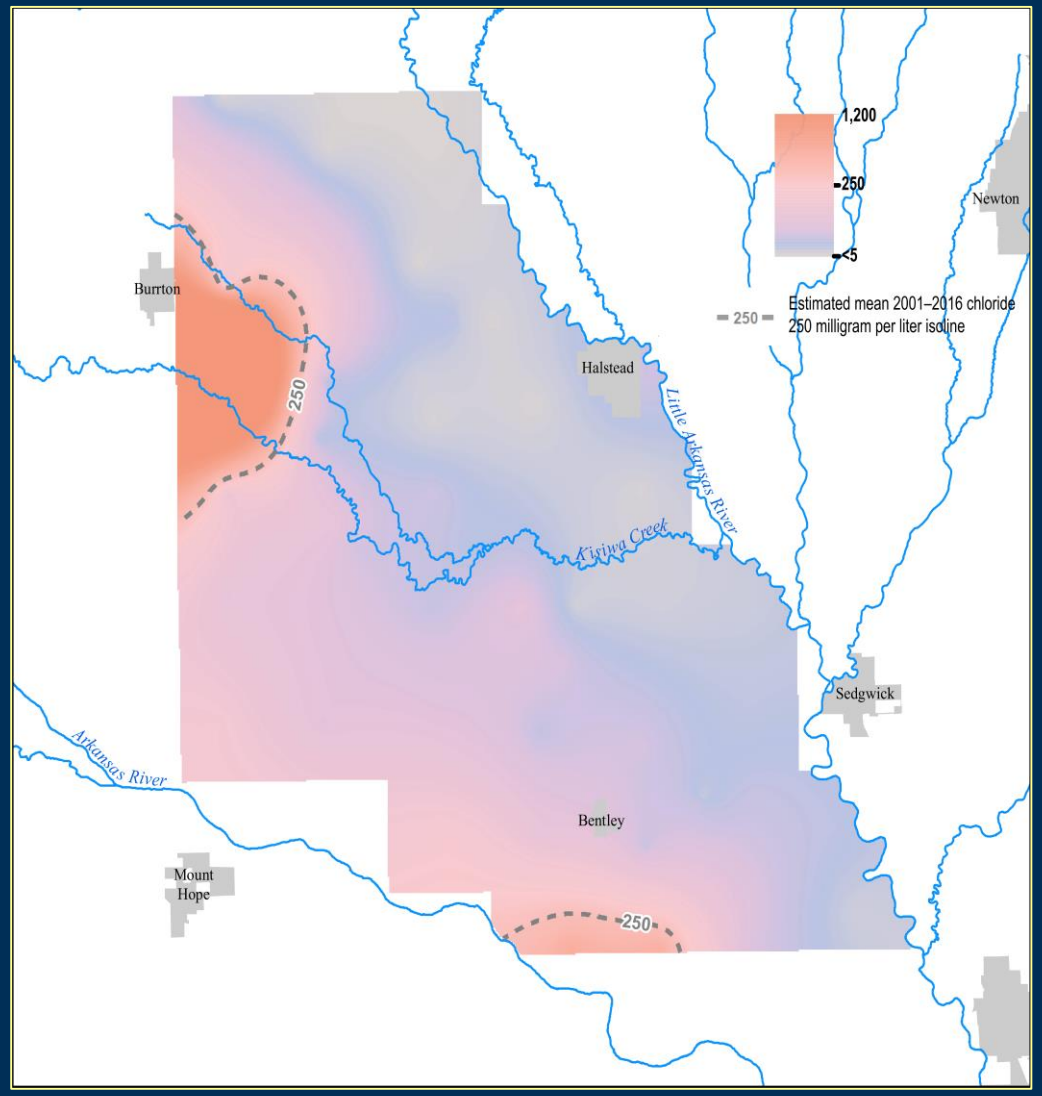
Long-Term *Equus* Beds Water Quality: Specific Conductance & Chloride 2001–16

Mean (deep) specific conductance (µS/cm)



Mean (deep) chloride (mg/L)



Stone and others, 2019

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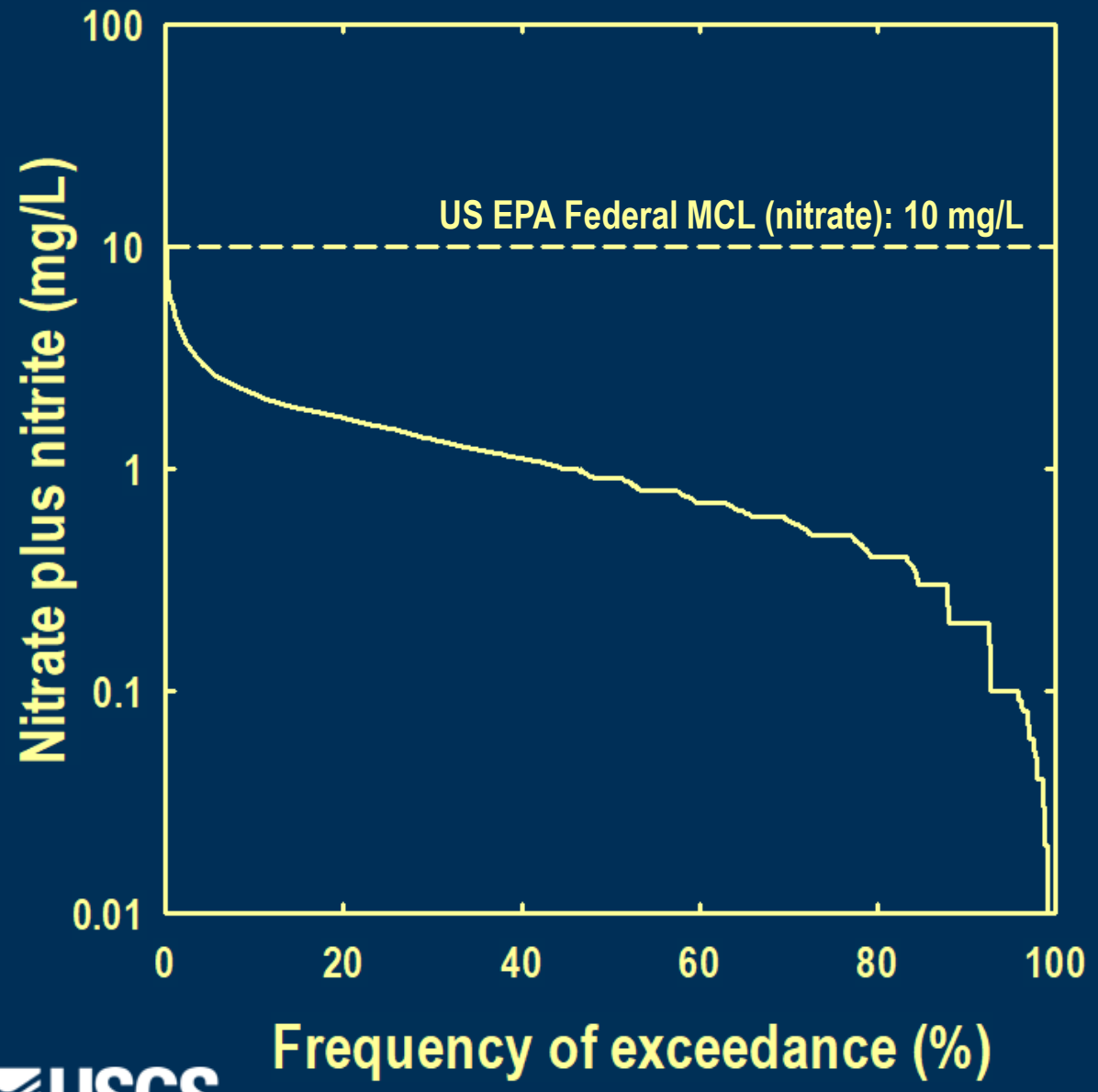
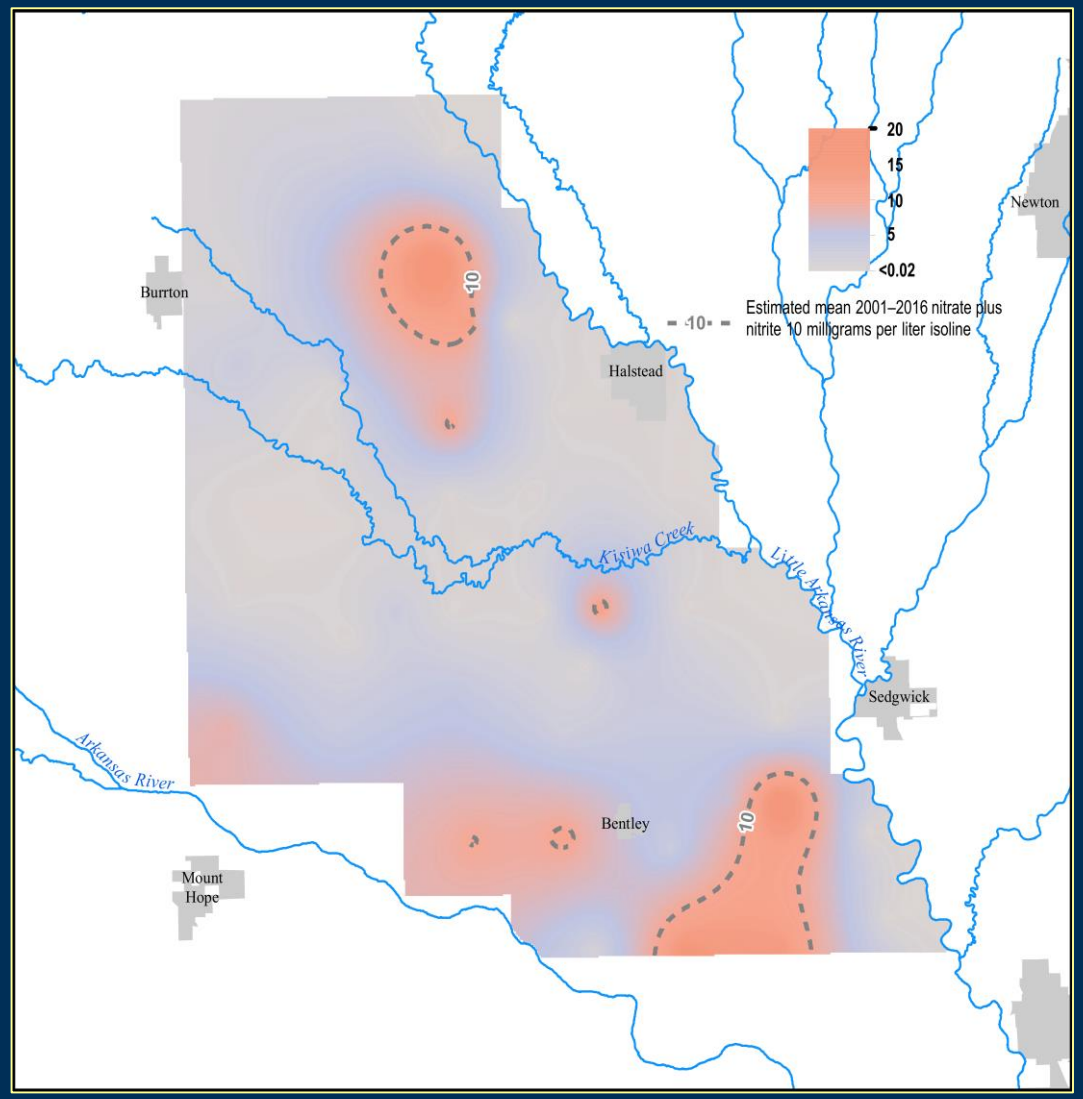
Long-Term Little Arkansas River & *Equus* Beds Water Quality: Nitrate 2001–16



Mean (shallow) nitrate plus nitrite (mg/L)



Stone and others, 2019

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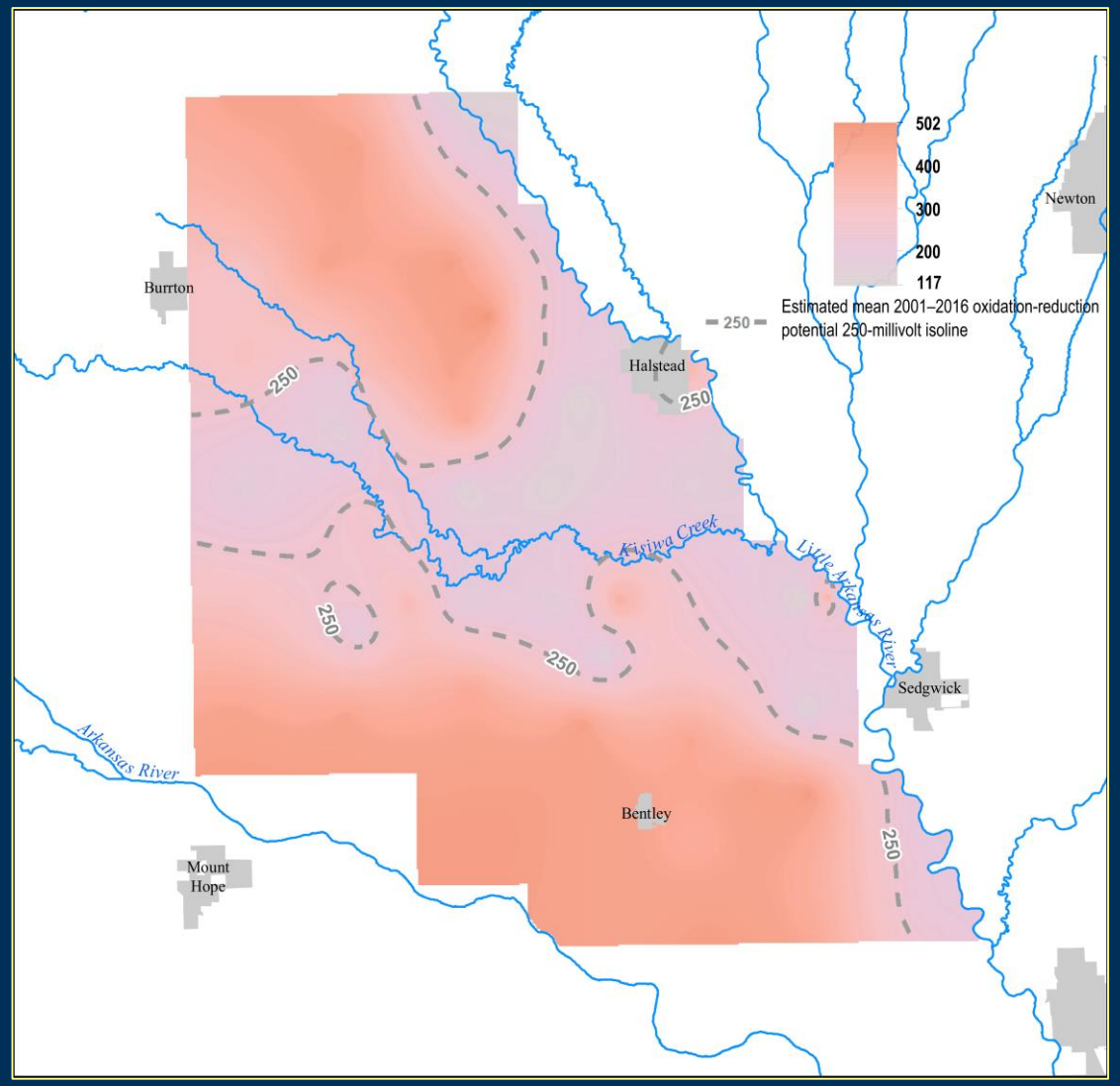
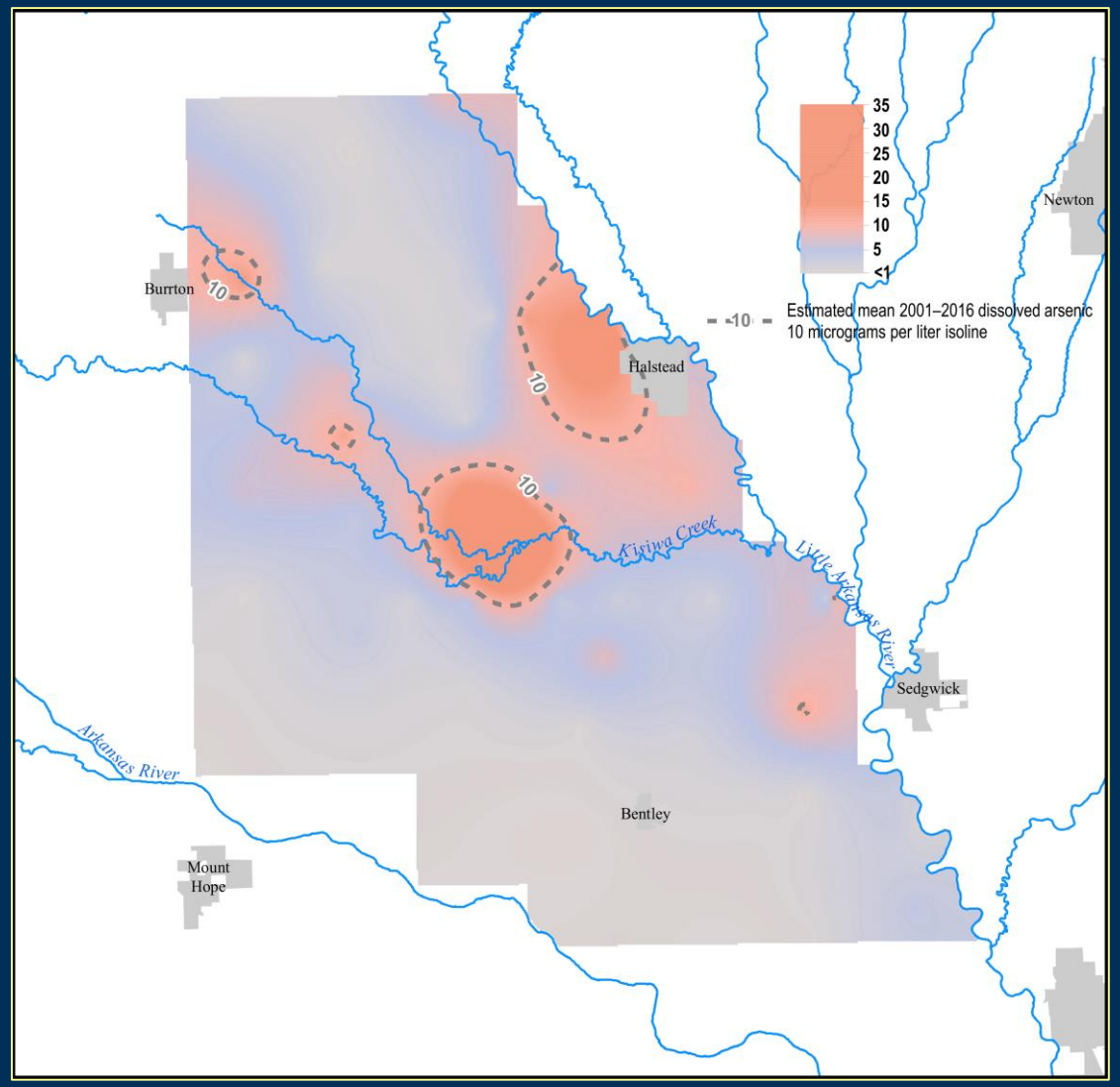
Long-Term *Equus* Beds Water Quality: Oxidation-Reduction Potential & Arsenic 2001–16

Mean (shallow) oxidation-reduction potential (µg/L)



Mean (shallow) arsenic (µg/L)



Stone and others, 2019

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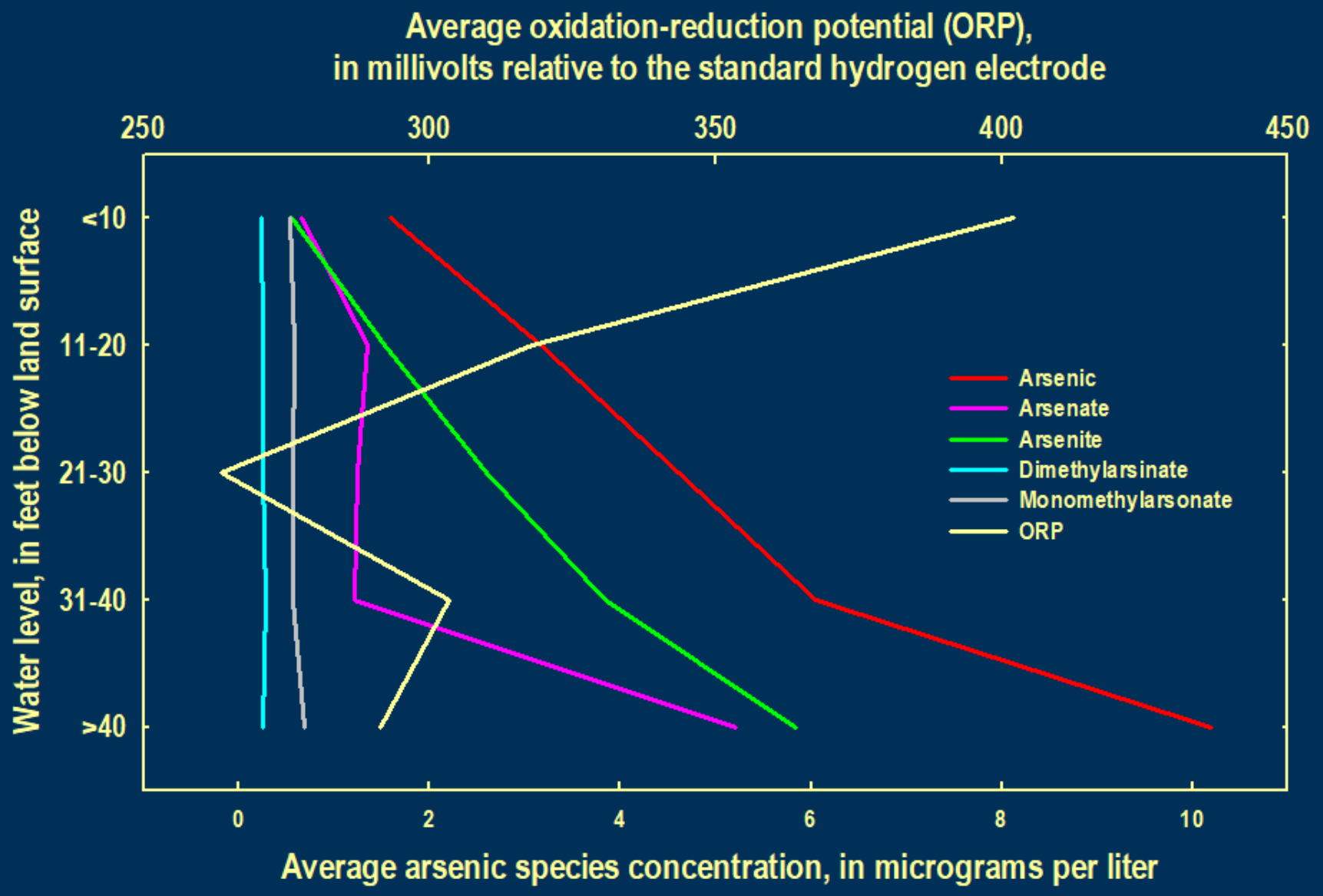
Equus Beds Water Quality: Arsenic, ORP, & Water Levels 2001–16
As concentrations increase with increased depth to water and decreased ORP



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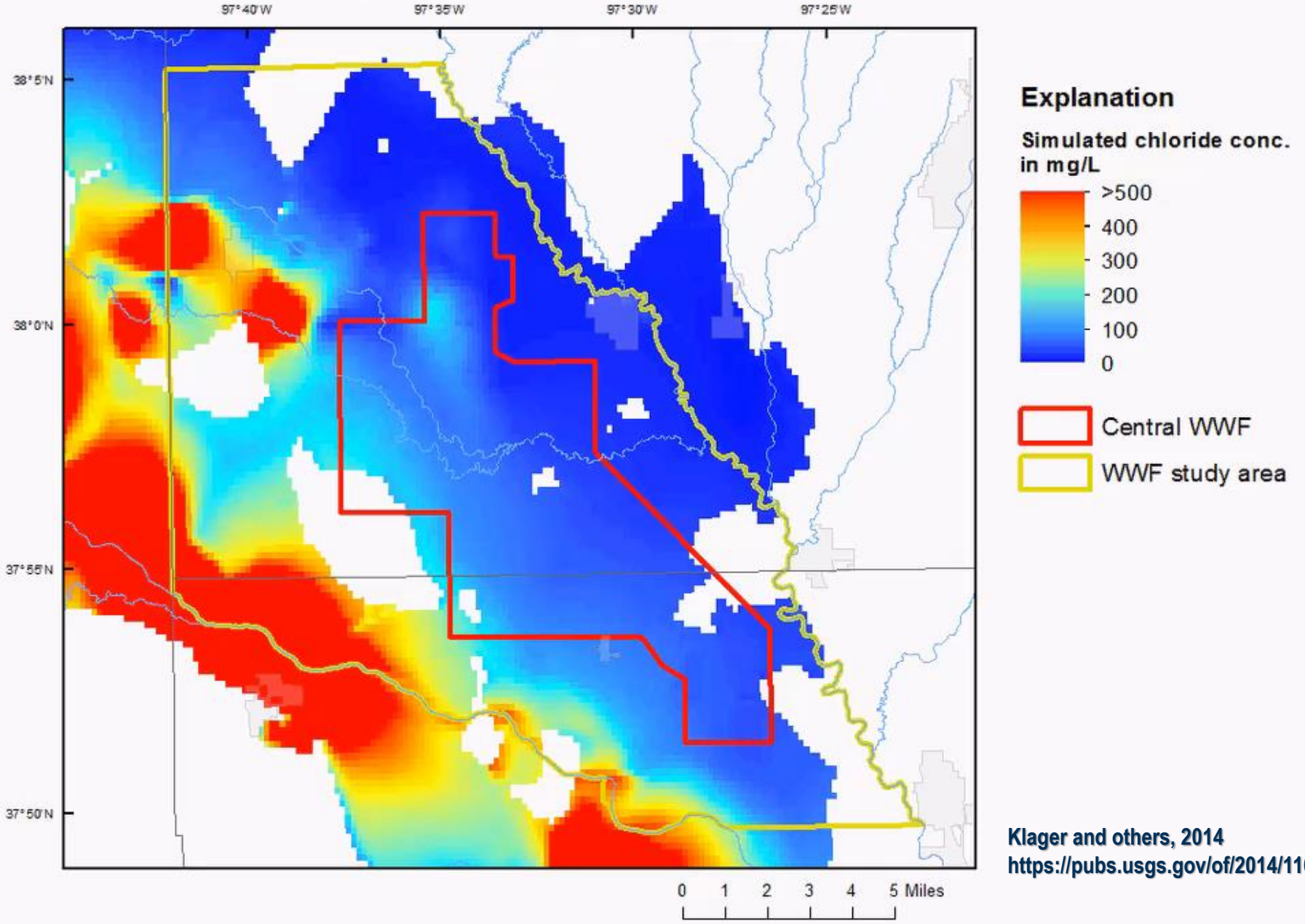
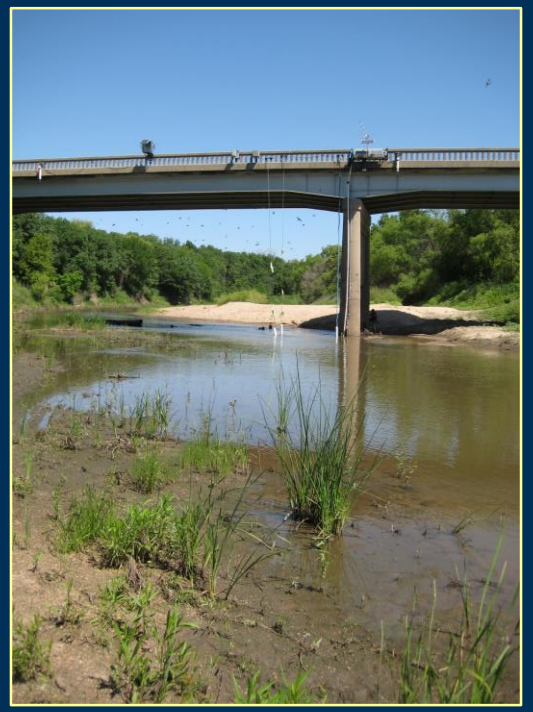
Equus Beds aquifer simulated chloride concentration, Layer 3, 1990



Klager and others, 2014
https://pubs.usgs.gov/of/2014/1162/

Summary and Conclusions: Long-Term Data Collection



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https://www.usgs.gov/centers/kswsc/science

Cheney Reservoir Inflow:

- Long-term trend analysis indicates total suspended solids & total phosphorus are likely increasing, sediment is highly likely increasing, & nitrate is likely decreasing
- Large sediment loads delivered in substantially small periods of time

Little Arkansas River & *Equus* Beds Aquifer:

- River organic carbon loads largest in 2019
- Few water-quality constituents of interest exceeded historical ranges
- Nitrate concentrations were larger in the shallow part of the aquifer while chloride, & arsenic concentrations were larger in the deep part of the aquifer; all commonly exceeded criteria
- Aquifer chloride plume is moving about 1 foot per day

→ *Long-term data collection critical to understanding trends & processes*

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