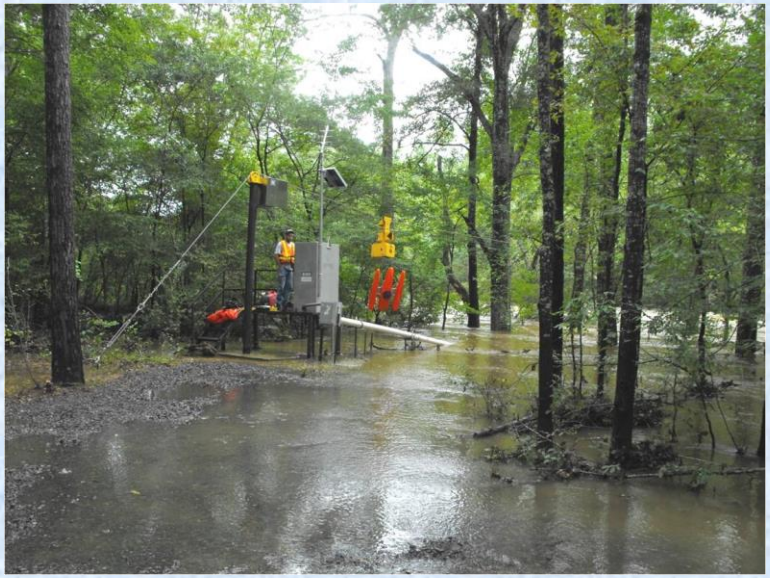
An Evaluation of Continuous Monitoring Data for Assessing Dissolved-Oxygen in the Boston Mountains



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USGS (Science) Mission Areas

- Water
- Ecosystems
- Energy and Minerals
- Natural Hazards
- Climate and Land Use Change
- Core Science Systems
- Environmental Health

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USGS Water Resources Mission Statement

To provide reliable, impartial, timely information needed to understand the Nation's water resources……..

- Protect and enhance water resources for human health, aquatic health, and environmental quality.

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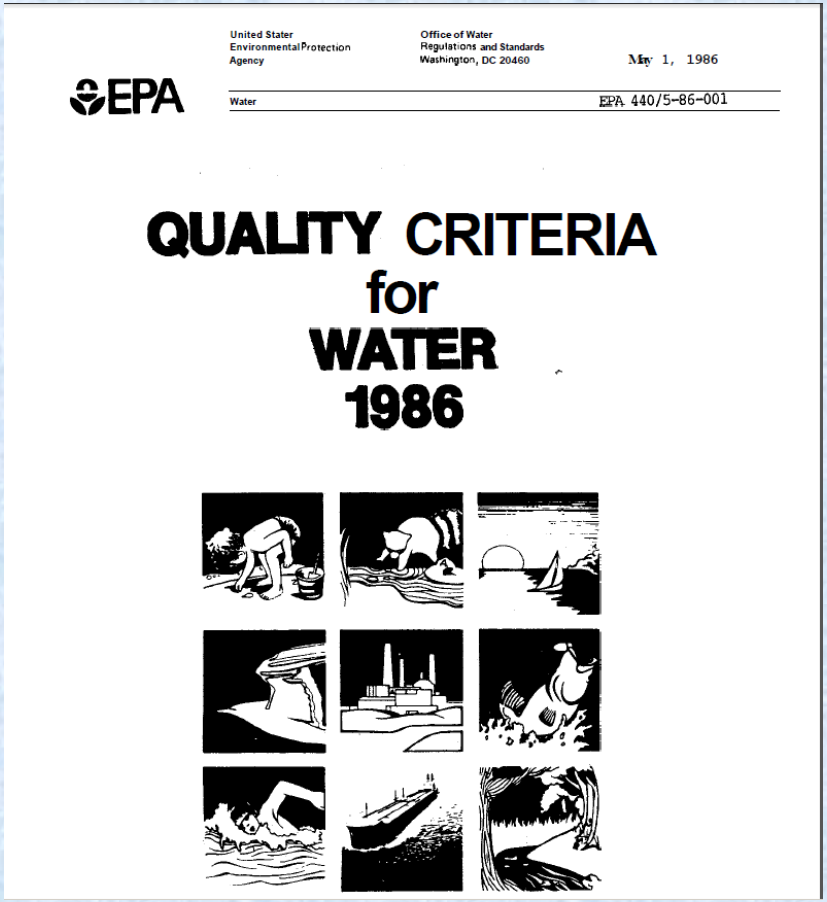
Water-Quality Standards: Almost 45 years after passing the Clean Water Act (CWA), the established national standards have only a general application and are not specific to different types of waterbodies and ecoregions.

EPA: Gold Book



United Stater
Environmental Protection
Agency

Office of Water
Regulations and Standards
Washington, DC 20460

May 1, 1986

EPA

Water

EPA 440/5-86-001

QUALITY CRITERIA for WATER 1986

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Current Arkansas Dissolved Oxygen (DO) Standards

Arkansas DO standards for 3 Ecoregions

Watershed size	Primary (November-April)	Critical (May-October)
	mg/L	mg/L
Ozark Highlands		
<10-mi^2	6	2
10- to 100-mi^2	6	5
>100-mi^2	6	6
Boston Mountains		
<10-mi^2	6	2
>10-mi^2	6	6
Arkansas River Valley		
<10-mi^2	5	2
10- to 150-mi^2	5	3
151-400 mi^2	5	4
>400 mi2	5	5

*Concentrations are in milligrams per liter (mg/L).

- Primary season < 22 °C
- Critical season > 22 °C
- Data collected during discrete samples
- Short-term continuous data (e.g. 72 hours)

“Stream and river monitoring segments will be listed as non-support when more than 10 percent of the total samples for primary or critical season within the period of record fail to meet the minimum applicable dissolved oxygen standard listed in APC&EC Reg. 2.505”

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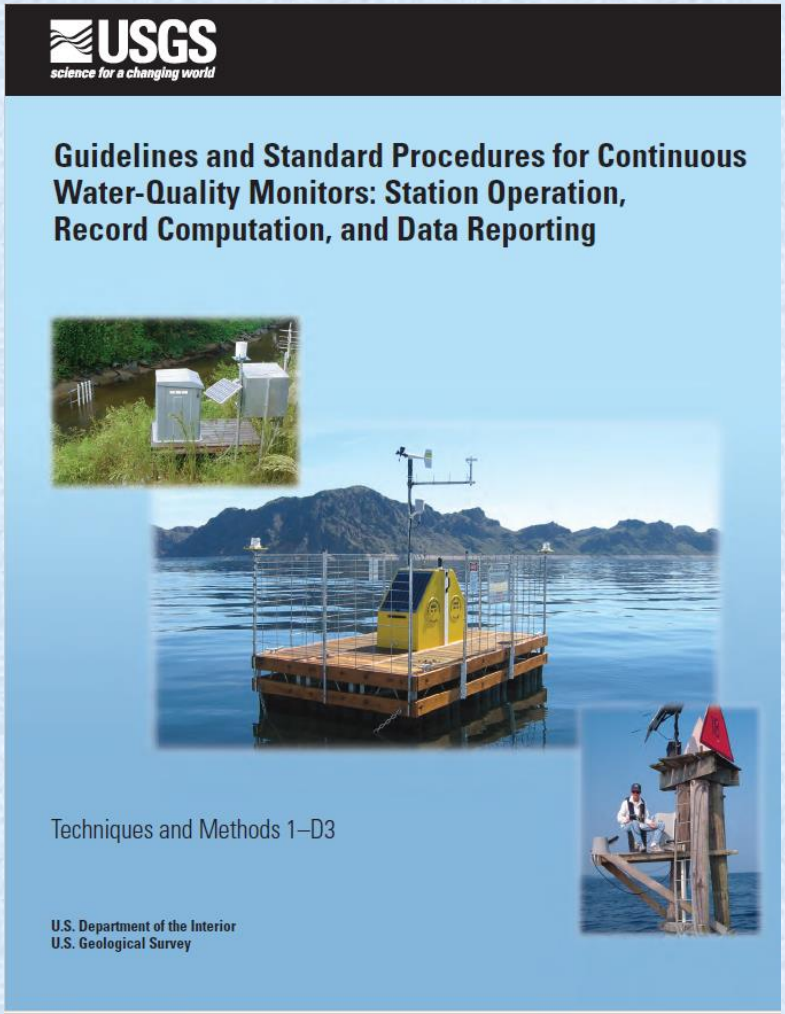
Discrete sample data – collected manually or with automatic samplers

Continuous data records - Electronic field monitors are capable of measuring DO and other field parameters almost continuously



Preliminary information – subject to revision.
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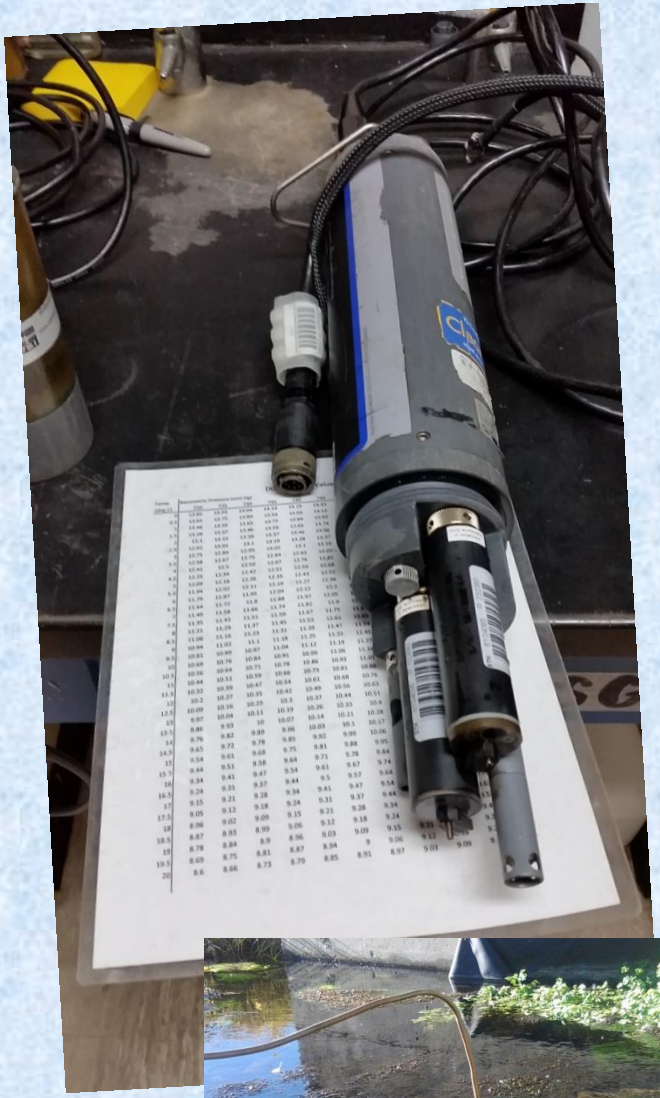

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Problem

- An increasing amount of continuous DO data has resulted in the need for Arkansas to appropriately assess those data to better meet requirements defined in the Clean Water Act

- There is no guidance for how States should assess continuous DO data

- States who use continuously monitored DO data for regulatory purposes are challenged to determine the amount of DO variability that can be expected across space (e.g. a range of stream disturbance) and time (e.g. diurnally, seasonally)

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Study Objectives

(1) To compare DO variability at least-disturbed (best available) and disturbed (non-reference quality) streams in the Boston Mountains for the critical season

(2) To evaluate the current DO standard and determine if the exceedance value used in the current assessment methodology is appropriate

(3) To evaluate the degree of DO variability that may be explained by other constituents (e.g. pH, specific conductivity, and water temperature).

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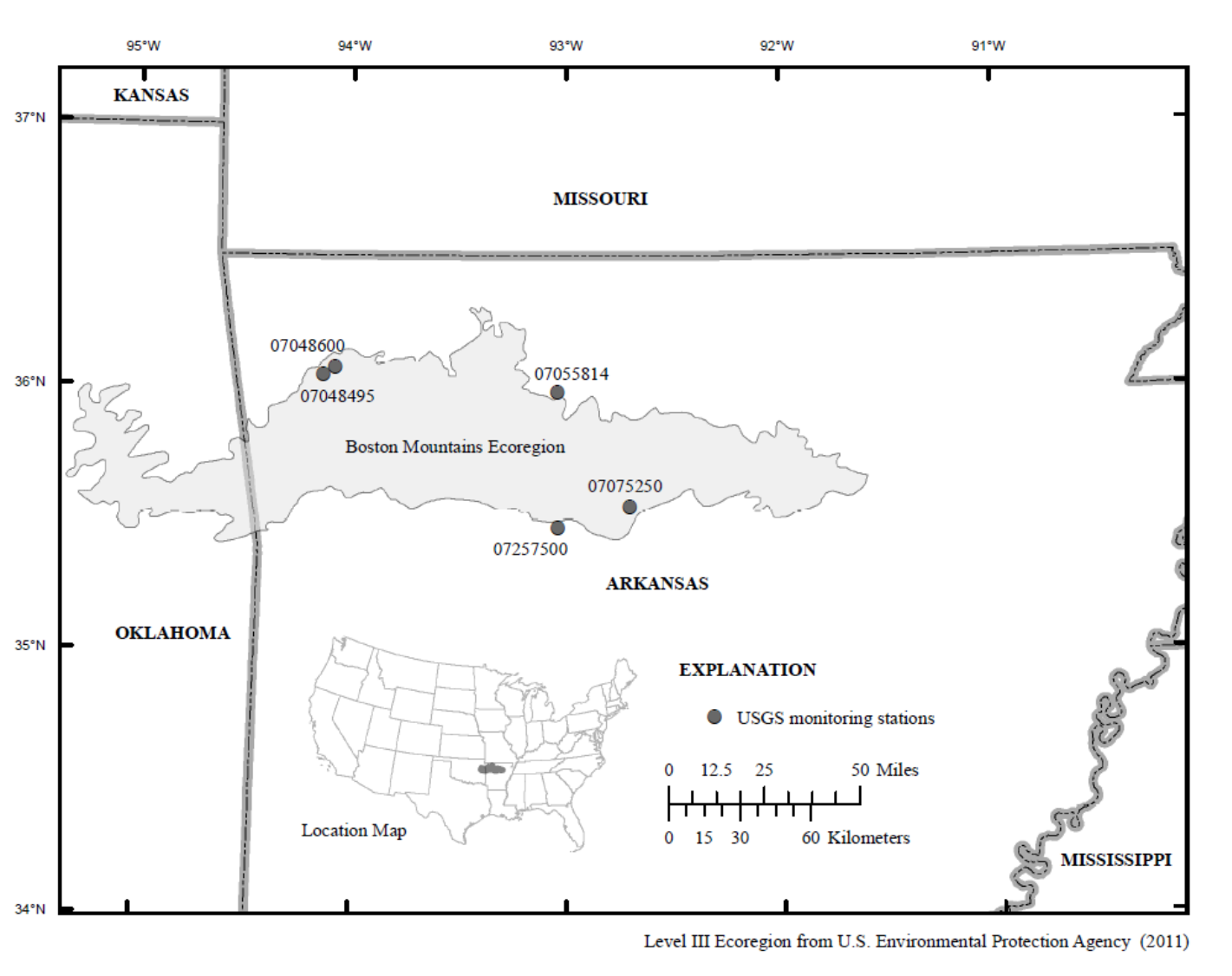
Locations of 5 continuous monitoring locations in the Boston Mountains, Arkansas



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Sample Characteristics for DO data for Critical Temperature Days (water temperatures were > 22°C)

Stream name	Site no.	Drainage area (mi^2)	Start of period	End of period	Critical temp. days	No. of unit values
South Fork Little Red River	07075250	47.6	2013-06-12	2015-09-30	313	21,715
Illinois Bayou	07257500	241	2013-05-14	2015-09-30	323	27,986
Big Creek	07055814	89.9	2014-06-02	2015-09-30	202	14,623
White River	07048600	400	2014-05-03	2015-09-30	127	11,007
Town Branch	07048495	30	2015-06-17	2015-09-30	96	7,488

Characteristics of the 5 sites

- Watersheds >10 mi^2
- Gradient of land use and nutrient concentrations

Preliminary information – subject to revision.
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Relations among Dissolved Oxygen, Nutrients, and Land Use

Intensified land use can increase stream nutrient concentrations….

Increasing stream nutrient concentrations can stimulate aquatic plant productivity (i.e. benthic algae, phytoplankton, and macrophytes)

Increasing plant productivity results in a higher rate of photosynthesis and respiration that can result in greater variability in DO concentrations over time

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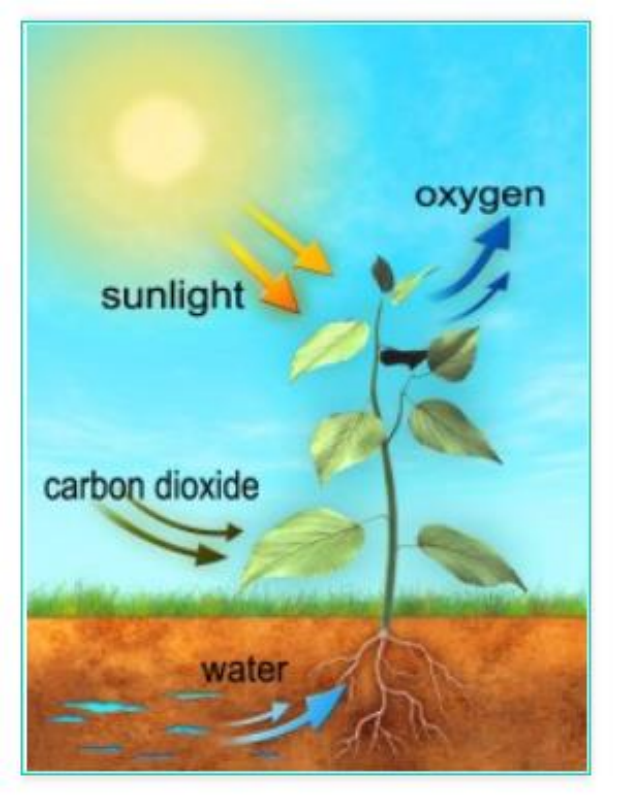
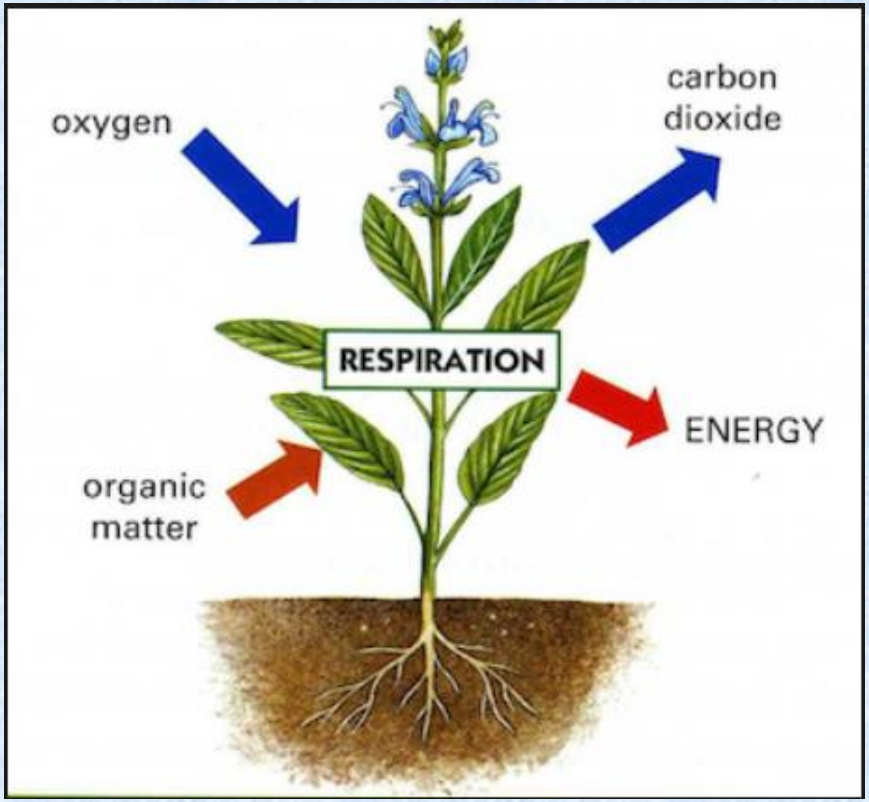
Understanding processes related to photosynthesis and respiration ……





If plant productivity is high, diurnal variability of DO generally increases

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Study Design Considerations

- *A priori* designation

- Gross divisions in nutrients and land use were used to classify sites into three impairment classes
  (Least, Moderate, and Most-disturbed)

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Study Design Considerations (continued)

- The 5 Sites were ranked based on discrete nitrate and total phosphorus data (collected for past projects)

	Nitrate						Total Phosphorus						Nutrient Index	
	Baseflow			Stormflow			Baseflow			Stormflow				
Stream name	No. of samples	Mean (mg/l)	Rank	No. of samples	Mean (mg/l)	Rank	No. of samples	Mean (mg/l)	Rank	No. of samples	Mean (mg/l)	Rank	Sum of Ranks	Final Rank
South Fork Little Red River	24	0.057	1	26	0.096	1	24	0.015	2	26	0.081	1	5	1
Illinois Bayou	9	0.086	2	17	0.202	2	9	0.013	1	17	0.242	2	7	2
Big Creek	5	0.171	3	9	0.242	3	4	0.016	3	10	0.254	3	12	3
White River	23	0.309	4	12	0.399	4	23	0.032	4	12	0.255	4	16	4
Town Branch	8	0.513	5	9	0.472	5	8	0.036	5	9	0.623	5	20	5

Study Design Considerations (continued)

- The 5 sites were also ranked based on 7 land-use metrics

Pasture (%)
Forest (%)
Evergreen forest (%)
Urban (%)
Unpaved Roads (miles/sq.miles)
All Roads (miles/sq.miles)
Confined animal feeding operations (no./sq.mi)

Stream name	Rank	Assigned Rank
South Fork Little Red River	2	Least disturbed
Illinois Bayou	1	Least disturbed
Big Creek	3	Moderately disturbed
West Fork White River	4	Most disturbed
Town Branch	4	Most disturbed

Other Important Constituents (Surrogate Relations)

Specific conductance and water temperature *often can be surrogates for groundwater influence on water-quality in a stream……*

- during low-flow periods (baseflow), large parts of the flow in a stream are contributed by groundwater

- USGS studies indicate that specific conductance in groundwater (GW) can be twice that of surface water (SW)

- Reduced atmospheric exposure results in lower DO concentrations in GW compared to SW

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Other Important Constituents **(Surrogate Relations cont….)**

Significance of pH - ***CO_2 and water form a weak acid***

Photosynthesis

carbon dioxide + water (+ energy) → glucose + oxygen

- when CO_2 is removed during photosynthesis, pH generally increases

Respiration

glucose + oxygen → carbon dioxide + water (+ energy)

- when CO_2 is added during respiration, pH generally decreases

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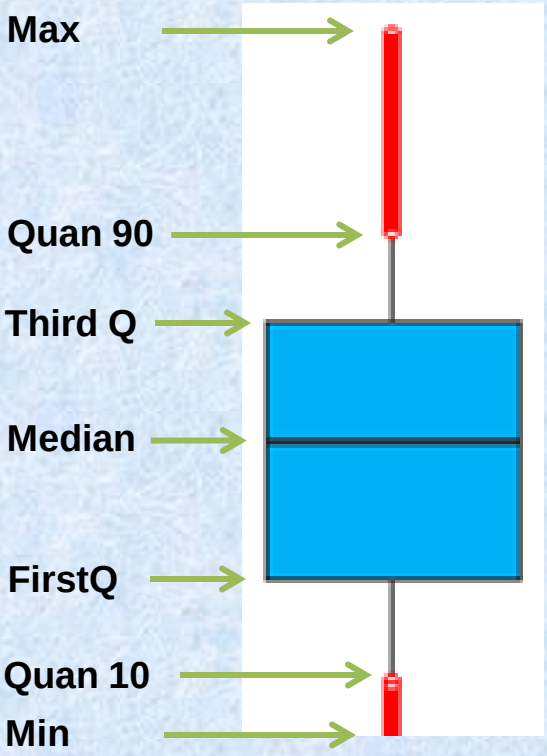
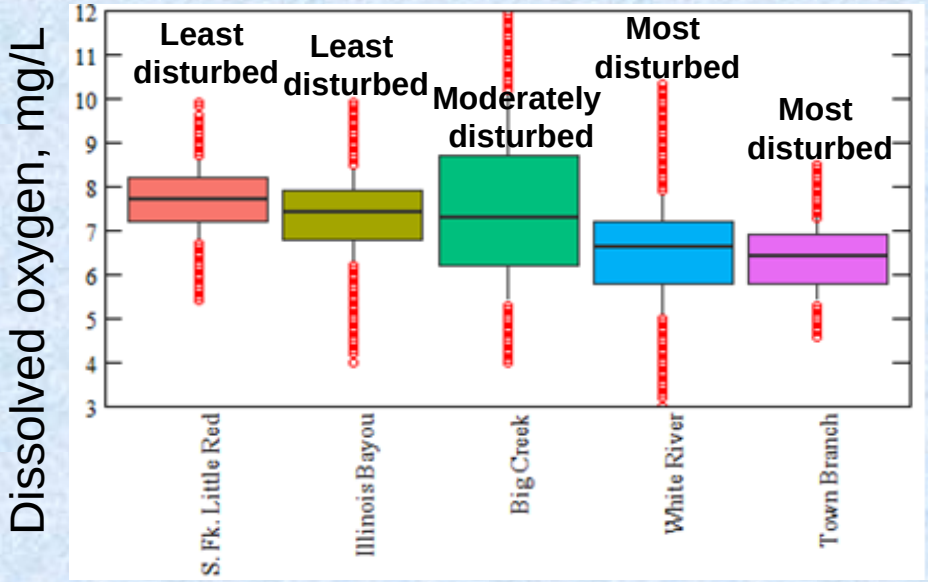
Box Plot Description

Table 4a. Descriptive statistics for DO data (concentrations are in milligram per liter)

Stream name	site_no	min	quan10	firstQ	med	mean	thirdQ	quan90	max
South Fork Little Red River	07075250	5.4	6.8	7.2	7.7	7.7	8.2	8.6	9.9
Illinois Bayou	07257500	4	6.3	6.8	7.4	7.4	7.9	8.4	9.9
Big Creek	07055814	4	5.4	6.2	7.3	7.5	8.7	10.1	12.2
White River	07048600	3	5.1	5.8	6.6	6.5	7.2	7.8	10.3
Town Branch	07048495	4.6	5.4	5.8	6.4	6.4	6.9	7.3	8.5



Continuous DO statistics indicated a strong connection between the nutrient and land-use indices and DO concentrations



Stream name	Site no.	No. of unit values	No. of unit values < 6 mg/L	Percent of unit values < 6 mg/L
South Fork Little Red River	07075250	21,715	75	0.03
Illinois Bayou	07257500	27,986	1,046	3.7
Big Creek	07055814	14,623	2,992	20.5
White River	07048600	11,007	2,976	27.0
Town Branch	07048495	7,488	2,494	33.0

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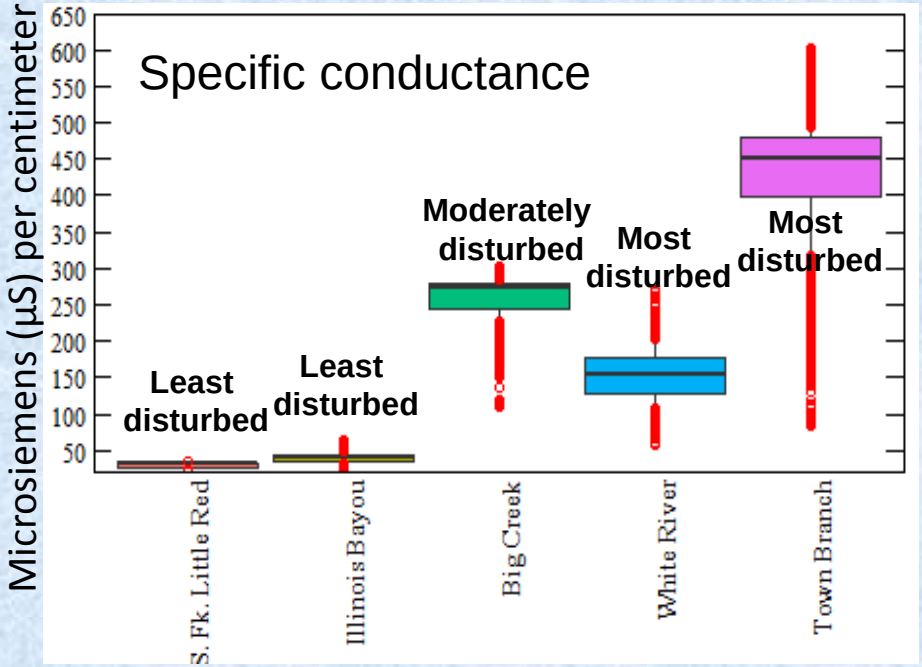
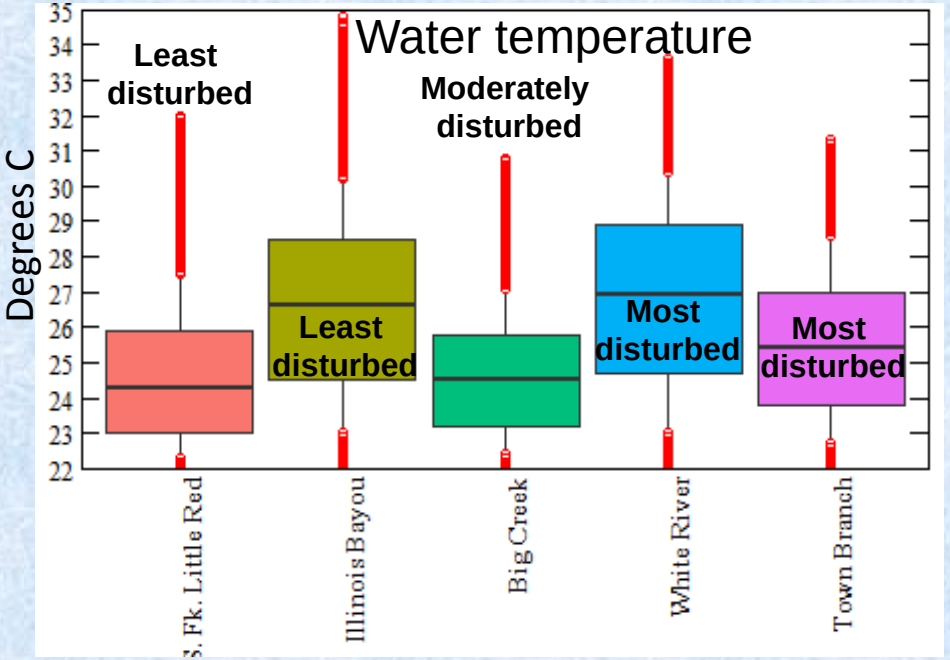
Specific conductance and water temperature generally indicated some degree of GW influence at two of the three sites that were most disturbed





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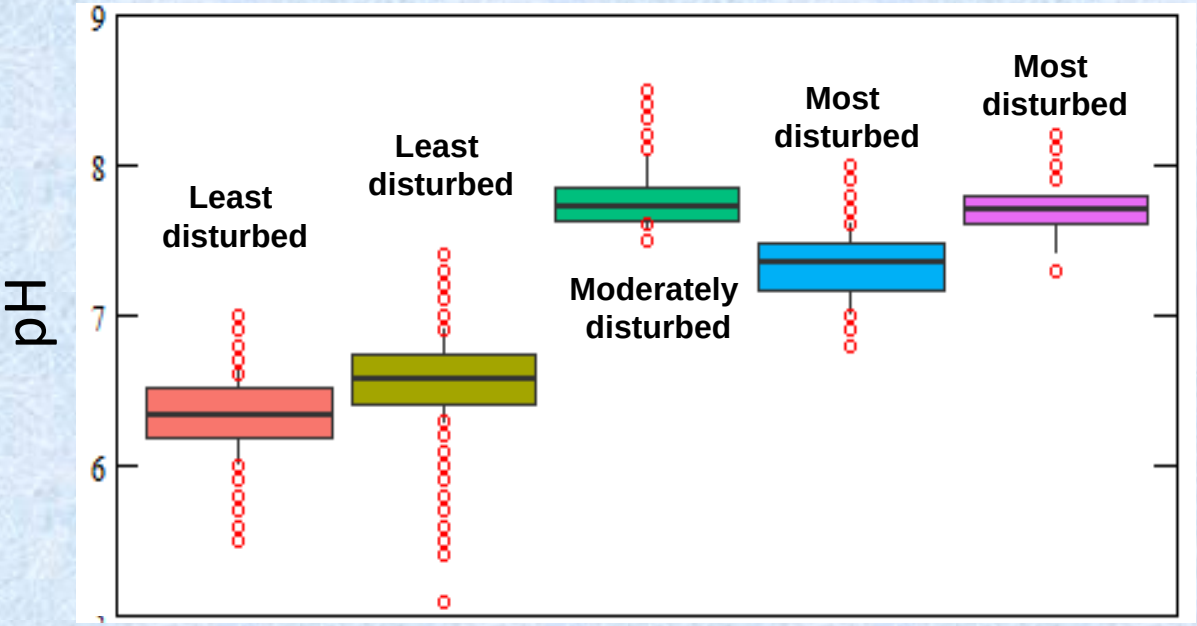
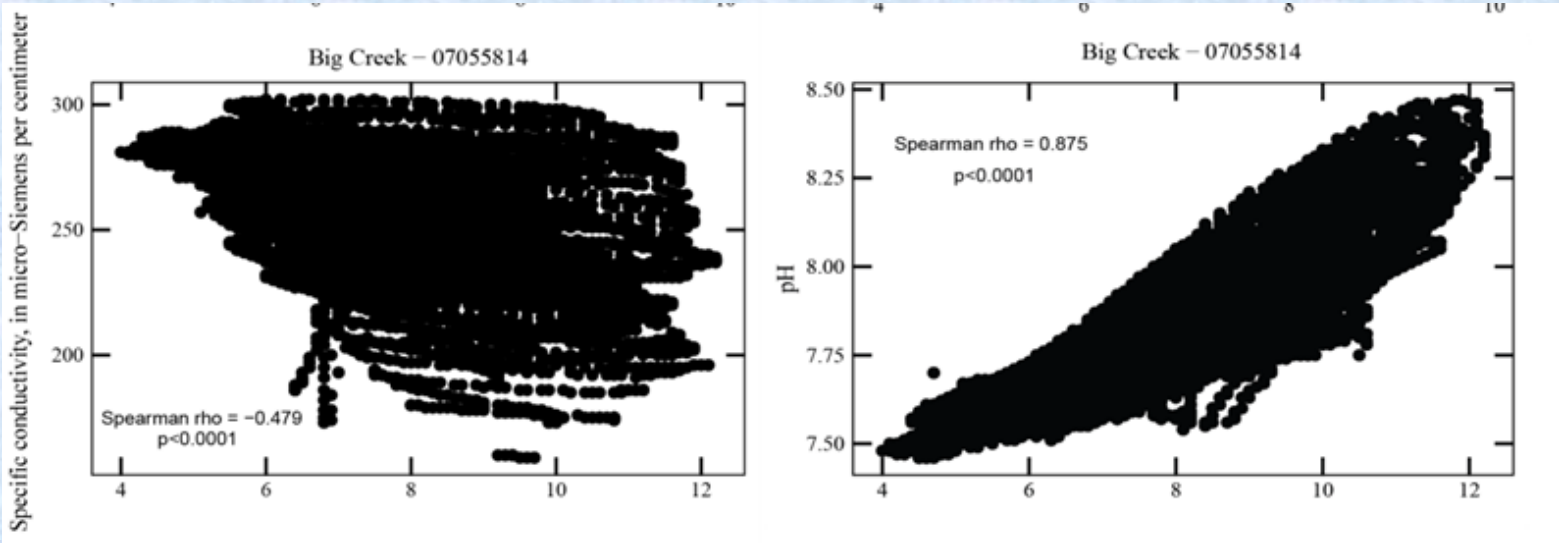
pH was much lower at the two least-disturbed sites compared to sites that were more disturbed



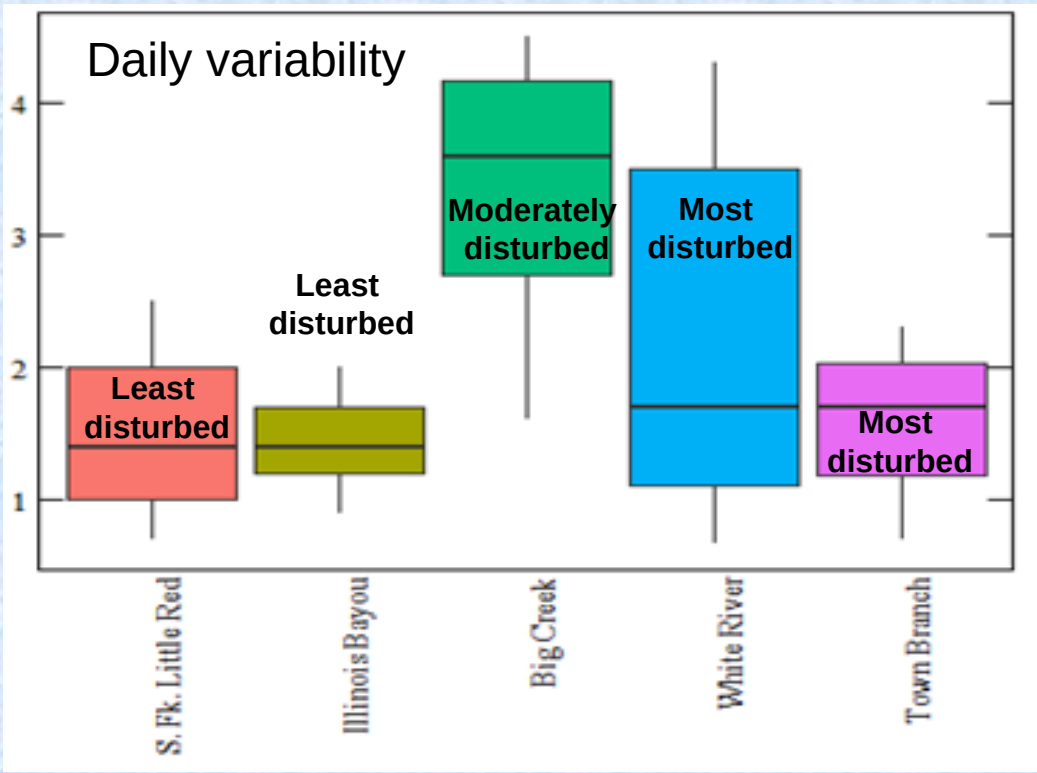
DO was negatively correlated to specific conductance and positively correlated to pH

Stream name	Site no.	Dissolved oxygen x Specific conductance	Dissolved oxygen x pH
South Fork Little Red River	07075250	-0.26	0.13
Illinois Bayou	07257500	-0.33	0.19
Big Creek	07055814	-0.48	0.87
White River	07048600	-0.20	0.50
Town Branch	07048495	-0.17	0.41

An indication of high productivity



Even though some low-end variability can be explained by GW influence, sites with the highest amount of DO variability generally had highest nutrient concentrations and more intense land use



Preliminary Conclusions

- DO concentrations at the two least-disturbed sites exceeded the Arkansas standard of 6 mg/L for less than 4% of the unit values indicating

  1) that the current standard is obtainable (i.e. not too high), and

  2) that continuous DO data (e.g 15-minute unit values) can be used appropriately with the current assessment methodology (10% allowable exceedance of the 6 mg/L standard)

- Some of the DO variability at the low end of the data range (near the 6 mg/L standard) for some sites in the Boston Mountains may be explained by GW influence; however, a high degree of variability at the upper end of the range indicates a relation with nutrient concentrations

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Future Directions

- Developing R code and scripts
  - streamlining the data evaluation process so that the Arkansas Department of Environmental Quality (ADEQ) can access and use USGS continuous data

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We would like to acknowledge:

Brian Breaker (USGS, for data retrieval)

Tate Wentz and Jessie Green (Arkansas Department of Environmental Quality - for review comments and partial funding)

Questions???

USGS