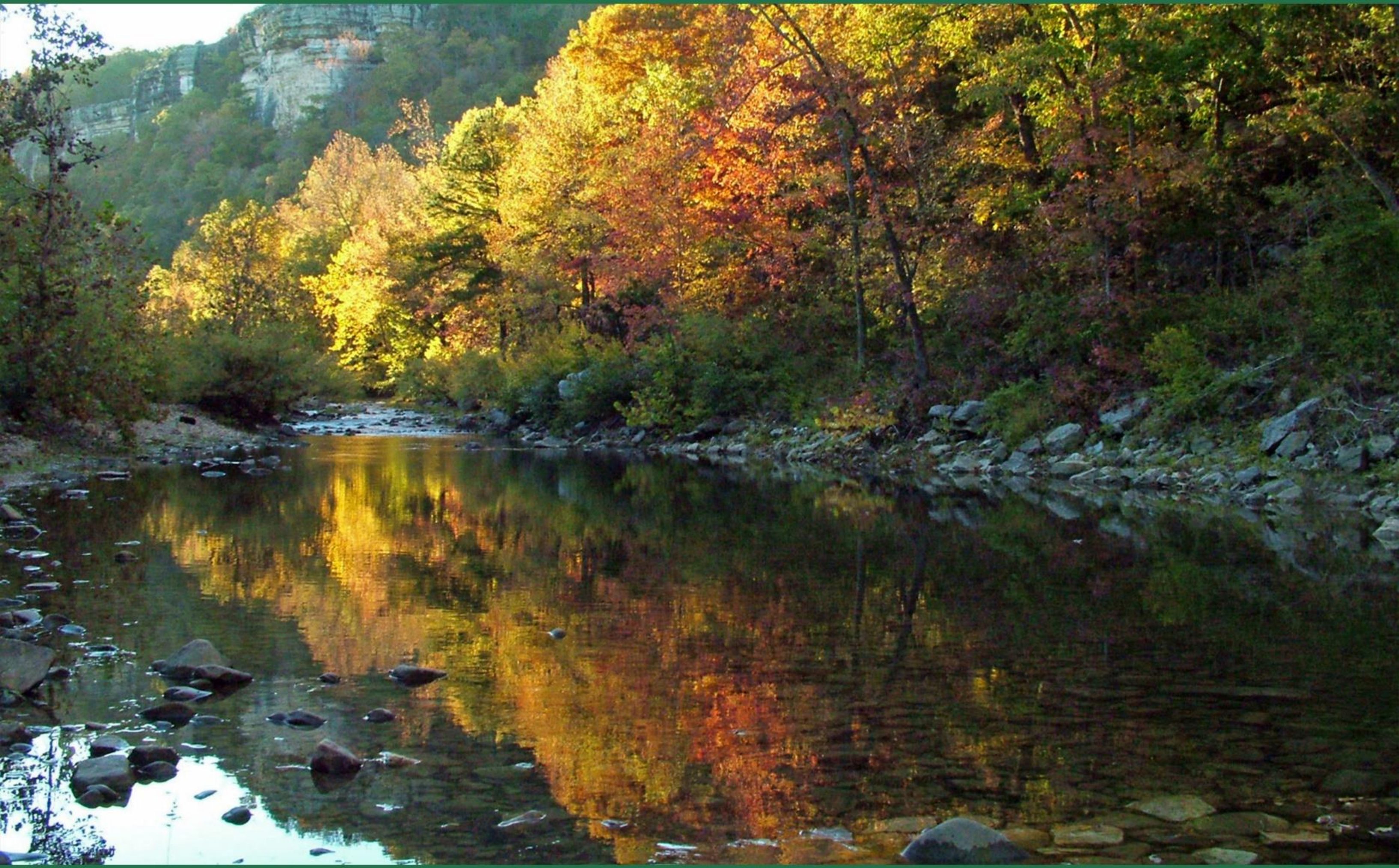
EPA/600/R-22/215.

Background Specific Conductivity and Associated Five Percent Extirpation Estimates in Arkansas



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The views expressed in this report are those of the authors and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency.

ABSTRACT

This report describes the analyses and models used in a weight of evidence for characterizing background specific conductivity (SC) in Arkansas. The ionic composition of waters in the state are described. Formulae for converting total dissolved solids (TDS) to SC are provided for each ecoregion. Stream background was estimated using observed and empirically modeled data by choosing among three options, the objective being to identify the best available estimate of minimally affected background for estimating 5% extirpation. The lowest of three values is recommended for estimating background: the median observed SC at the station, the median of stations within 5 km, or the estimated default background for the ecoregion. In the Mississippi Alluvial Plain, Mississippi Valley Loess Plains, Ouachita Mountains, Ozark Highlands, or South Central Plains, the default background is the stream segment empirically modeled background. In the Boston Mountains and Arkansas Valley, the default background is the station background or the ecoregional 75th centile. The ecoregional estimate is recommended rather than the predicted stream segment estimate because the empirical model consistently over-predicts background in these two ecoregions. These methods, data, and models may be used to assess the protectiveness of site-specific water quality criteria proposed by third parties.

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ABBREVIATIONS

Abbreviation	Definition
µS/cm	Microsiemens per Centimeter
ADEQ	Arkansas Department of Environmental Quality
ANCOVA	Analysis of Co-Variance
B-C model	Background-to-Criterion Model
Ca^{2+}	Calcium Cation
CFD	Cumulative Frequency Distribution
Cl^{-}	Chloride Anion
e. g.	Exempli Gratia, For Example
GAM	Generalized Additive Models
HCO_3^{-}	Bicarbonate Anion
K^{+}	Potassium Ions
MAE	Mean Absolute Error
Mg^{2+}	Magnesium Ions
N	Number of Stations
n	Number of Samples
NA	Not Available or Not Applicable
Na^{+}	Sodium Ions
NSE	Nash-Sutcliffe Error
SC	Specific Conductivity
SO_4^{2-}	Sulfate Anion
TDS	Total Dissolved Solids
UAA	Use Attainability Analysis
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
XC95	Extirpation Concentration
XCD	Extirpation Concentration Distribution
XCD05	5th Centile of an Extirpation Concentration Distribution

1 Executive Summary

This report describes the methods to process and curate stream data to estimate background specific conductivity (SC) in Arkansas. The report is organized into two major sections: background SC estimates and 5% extirpation estimates. USEPA ORD conducted analyses as technical support to USEPA Region 6 and the state of Arkansas. The report includes:

1. Characterization of the data set used in the report:
2. Conversion formulae for total dissolved solids (TDS) to SC (linear regression models),
3. Estimation of ecoregional least disturbed background from observed stream measurements (method: Cormier et al., 2018c),
4. Estimation of stream segment least disturbed background using an empirical random forest regression model based on geological, climate, and soils and other data (method: Olson and Cormier, 2019), and
5. A flowchart for selecting recommended background values to estimate 5% extirpation of benthic invertebrates (Cormier et al., 2018c; USEPA, 2017).

In this report, minimally affected conditions are the physical, chemical, and biological habitats found in the absence of recognizable human disturbance. Least disturbed conditions are the best available physical, chemical, and biological habitat conditions given the present degree of disturbance of the landscape or habitat type (Stoddard et al., 2006). In this report, the term least disturbed is used when referring to stations designated as “high quality” in the Arkansas data set because these stations appear to be a mix of minimally affected and least disturbed conditions.

Relationship between TDS and SC: TDS and SC are highly correlated but differ slightly among ecoregions; therefore, different regression equations were generated to convert TDS to SC for each ecoregion (Table 1).

Table 1. Summary of regression models for converting TDS (*x*) mg/l to Conductivity (*y*) (µS/cm) by Ecoregion.

Ecoregion	Equation
Arkansas Valley	$y = -26.46 + 1.82x$
Boston Mountains	$y = -14.89 + 1.8x$
Mississippi Alluvial Plain	$y = -42.62 + 1.86x$
Mississippi Valley Loess Plains	$y = -69.92 + 1.8x$
Ouachita Mountains	$y = -13.11 + 1.67x$, *breakpoint* 141.75 mg/l, $y = 157.6 + 0.94x$
Ozark Highlands	$y = 12.63 + 1.69x$
South Central Plains	$y = -38.49 + 1.7x$

Observed Least Disturbed Ecoregional Background: The background levels of dissolved ions in streams in Arkansas are among the lowest in the country (Cormier et al., 2018c; Cormier et al., 2021; Griffith, 2014). Streams often have dissolved ion levels of less than 50 µS/cm. On average, ecoregional background estimates based on the 75th centile of least disturbed station medians are: 63 µS/cm in the Arkansas Valley, 92 µS/cm in the Boston Mountains, 105 µS/cm in the Ouachita Mountains, and 134 µS/cm in the South Central Plains. The 75th centile of least disturbed background SC was higher in the Ozark Highlands (381 µS/cm) and Mississippi Alluvial Plain (329 µS/cm) and background based on the 25th centile of all stations oddly is much less, 248 and 116 µS/cm, respectively. The difference between all stations and least disturbed estimated background suggests that the stations identified as least disturbed include disturbed stations or that the range of least disturbed conditions is broader than half the sampled locations. A provisional background estimate for the Mississippi Valley Loess Plains (69 µS/cm) is based on the 25th centile of the ecoregion in and outside of Arkansas from an EPA probability data set because there was only one sample in Arkansas.

Predicted Least Disturbed Background for Stream Segments: Comparison of Arkansas's least disturbed stations with predicted least disturbed background levels suggests that estimates were over-predicted in the Boston Mountains and Arkansas Valley. SC levels were higher than predicted and may be due to an anthropogenically shifting baseline in the Spring River in the Ozark Highlands.

Flowchart for Selecting Recommended Background Values Weight of Evidence for Least Disturbed Background Selection: A weight-of-evidence approach was used to select the scale, data set, and assessment statistic to estimate background for each ecoregion and for site-specific estimates (Cormier et al., 2018c; USEPA, 2017). Minimally affected background is the preferred estimate. Where such data or conditions are unavailable, the next most relevant estimated background is one from one or more nearby, minimally affected locations. Where neither of these options is available, values recommended for use are shown in Table 2. In the Mississippi Alluvial Plain, Mississippi Valley Loess Plains, Ouachita Mountains, Ozark Highlands, or South Central Plains, the default recommended background is the stream segment background predicted from the empirical model. In the unlikely case that minimally affected background cannot be estimated for the Boston Mountains and Arkansas Valley, the default recommended background is the observed ecoregional 75th centile because the model consistently over-predicts background in these two ecoregions. In all ecoregions, where station SC is less than the values recommended in Table 2, the station SC takes precedence. These methods, data, and models may be used to assess the protectiveness of proposed site-specific water quality criteria proposed by third parties.

5% Extirpation Levels Based on National Extirpation Model: The SC levels expected to extirpate 5% of benthic invertebrates (XCD05) were estimated from a linear regression extirpation model (B-C model). The log-log linear model was developed from 24 ecoregions within the contiguous United States for which XCD05 values had been regressed against the 25th centile of observed SC values in each ecoregion (Cormier et al., 2018a). Where available, minimally disturbed background SC estimates are recommended as the independent variable to estimate XCD05 values at the smallest scale deemed reliable. When site-specific minimally disturbed background is not known and cannot be ascertained, XCD05 values may be estimated, as described above, using the B-C model and the empirically predicted least disturbed background or observed SC as recommended in Table 2 and the flowchart (Figure 8).

In sum, for any station where minimally affected stations are available for comparison or where the observed SC is less than an estimated recommended background SC, the observed background is most relevant and likely more accurate. Therefore, wherever it is possible to directly measure minimally affected SC background with confidence, that observed background is more reliable, relevant, and defensible. Anthropogenic background (i.e., least disturbed background) is a useful metric, but it suffers from the effect of a shifting baseline and can contribute to worsening water quality (Pauly, 1995; Campbell et al., 2009; Gillon et al., 2016; Kaushal et al., 2018).

Table 2. Estimated specific conductivity (µS/cm) background and value above which 5% extirpation is expected.

Ecoregion	**Geomean of predicted stream segments [range]**		**75th centile of observed ecoregional least disturbed stations [range]**	
	Background	5% extirpation	Background	5% extirpation
Arkansas Valley[a]			63 [18.5 – 423[c]]	180 [80 – 629[c]]
Boston Mountains[a]			92 [18 - 259]	231 [79 - 456]
Mississippi Alluvial Plain	125 [55 - 350]	283 [164 - 556]		
Mississippi Valley Loess Plains[b]	270 [55 - 363]	469 [164 - 569]		
Ouachita Mountains	100 [54 - 350]	244 [162 - 556]		
Ozark Highlands	301 [86 - 409]	503 [221 - 615]		
South Central Plains	90 [48 - 375]	228 [150 - 582]		

[a]Predicted values were overestimated, therefore XCD05 calculated from 75th centile of ecoregional least disturbed stations is likely to be more accurate.
[b]Background and 5% extirpation levels are provisional.
[c]Although identified in data set as least disturbed, these maxima may represent an anthropogenically altered background.

2 Background Estimates

This section describes factors influencing natural background SC and then describes analyses used to develop and recommend least disturbed background estimates.

Stress from elevated ionic concentration, measured as SC, causes adverse effects on a range of freshwater ecosystems (e.g., Cañedo-Argüelles, et al., 2016; Kaushal et al., 2018; USEPA, 2011a). The sources of ions in surface waters may be anthropogenic or natural, reflecting the level of alteration of soils and geology. Nationally, the two most common background anionic mixtures in streams are those dominated by either chloride anions (Cl^-) or bicarbonate (HCO_3^-) plus sulfate (SO_4^{2-}) anions based on mass (Hem, 1985; Griffith, 2014). Calcium (Ca^{2+}) is the most common cation nationally.

Different mixtures of ions that increase SC are associated with multiple anthropogenic sources, including discharges from wastewater treatment facilities, ground water recharge, surface and underground mining, oil and gas exploration, runoff from urban areas, and discharges of agricultural irrigation return waters, among others (USEPA, 2016). Different ionic mixtures have been shown to have different toxicities in laboratory tests (Mount et al., 2016; Erickson et al., 2017; Erickson et al., 2022a, b; Hills et al., 2022) and field studies (Mooney et al., 2020). However, at low SC-effect levels, SC or a sum of all ions demonstrate only marginally different toxicities.

To our knowledge, map layers based on stream SC or ionic concentrations have not been delineated. However, background stream SC is known to be “rock dominant” and affected by soils, air deposition, precipitation, evapotranspiration, relative ground and surface water contribution, and other factors (Hem, 1985; Olson and Cormier, 2019). And given that geology and soil parameters were used to develop national ecoregions (Omernik, 1987, 1995), groups of streams were sorted by USEPA ecoregions or two groups of combined ecoregions for some analyses (USEPA, 2013). We found that the different ecoregions of Arkansas have different natural background SC partly owing to their unique natural geological characteristics. In Arkansas, the most abundant sediments are sand, clay, silt, gravel, and marl. The most abundant sedimentary rocks are shale, sandstone, dolostone, limestone, and chert (AGS, 2022). Ionic sources arise from the dissolution of minerals in rock. For example, sandstone grains of quartz are resistant but the cement that holds the particles together is not and weathering of exposed surfaces releases calcium and carbonates.

Arkansas can be divided into a highland area in the northwest and a lowland region in the south and east. Sedimentary rocks in the highlands are marine. In the southern and eastern parts of the state, the sedimentary deposits are predominantly fluvial, arising from fresh-water processes. Rocks in the Ozark Highlands, Boston Mountains, and Ouachita Mountains are dominated by well-lithified sandstones, shales, limestones, and dolostones. The Arkansas Valley and other valley floors are associated with the streams and rivers having alluvium deposits of unconsolidated clays, sands, and gravel formed by freshwater erosional processes and also have strata of coal. The sedimentary deposits of the lowlands are varied including clay, sand, gravel silt, limestone, and lignite, marl, and chalk (Haley B.R. and Arkansas Geological Commission staff, 1993). Additional details for each ecoregion are included in Appendix A-1.

2.1 Data Sets

2.1.1 Ecoregional Groups

Most analyses were performed by ecoregion (Figure 1). However, for one analysis, ecoregions were combined to form two groups to allow comparison with a previous EPA report (USEPA, 2016). Ecoregion Group 1 consists of the Arkansas Valley, Boston Mountains, Ouachita Mountains, and South Central Plains. Ecoregion Group 2 consists of the Ozark Highlands, Mississippi Alluvial Plain, and Mississippi Valley Loess Plains (Figure 1).

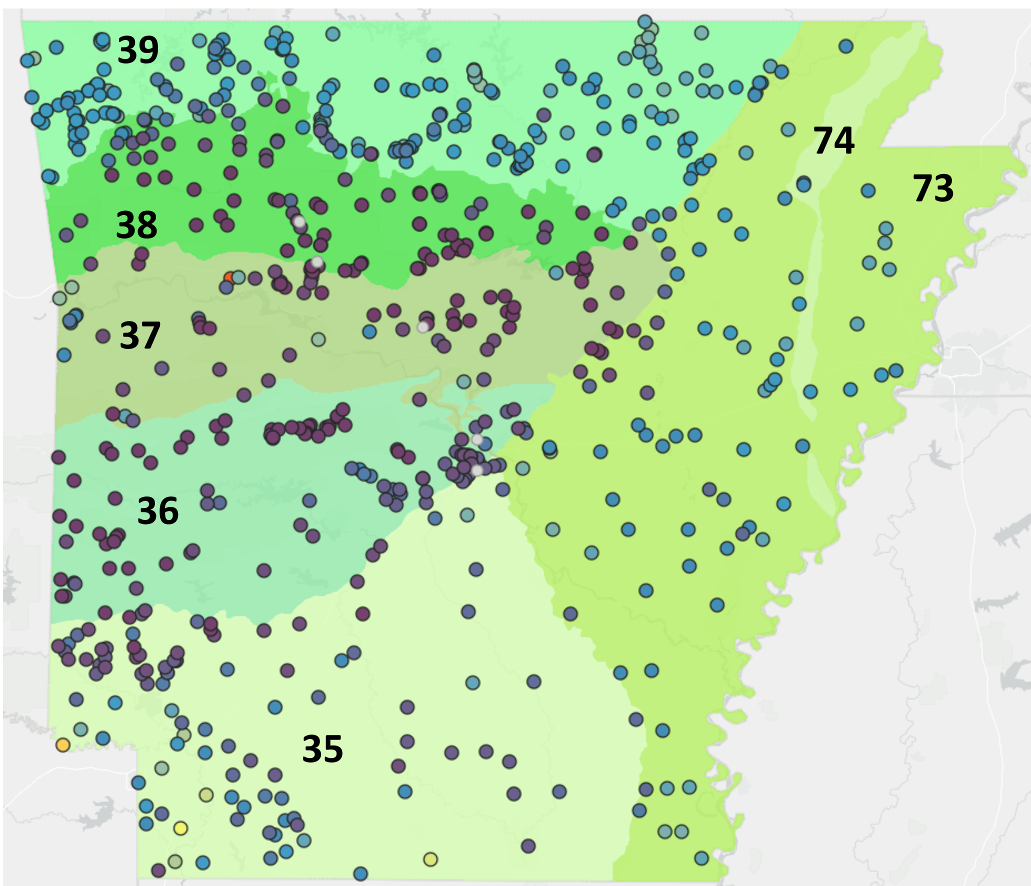

Figure 1. Arkansas data sampling stations sampled (circles) within the seven USEPA Ecoregions.
TDS records were converted to SC and combined with SC to produce this map. Cooler colored circles indicate lower SC (e.g., violet and blue); warmer colors indicate higher SC (e.g., yellow to red); gray circles are <10 or > 5000 µS/cm. Group 1: (35) South Central Plains, (36) Ouachita

Mountains, (37) Arkansas Valley, (38) Boston Mountains. Group 2: (39) Ozark Highlands, (73) Mississippi Alluvial Plain, (74) Mississippi Valley Loess Plains.

2.1.2 Observational Data Sets

Descriptive statistics (e.g., centiles, minima, maxima, means) were estimated for Arkansas stream observations to characterize chloride, sulfate, TDS, SC, and relative ionic composition (Appendix A.2.1-14). Data were obtained directly from the Arkansas Department of Environmental Quality (ADEQ) for the years 1990-2021 but are also available from the EPA Water Quality Portal (https://www.waterqualitydata.us). Data processing and links to R-scripts are available from the authors. Of the 16,745 records, 21 records designated as not available (NA) were removed as were 6 with values ≤ 1 µS/cm which were assumed to be data management errors or measures of rainwater. TDS values below detection limits were removed (TDS ≤ 5 mg/l). For maps, TDS records were converted to SC and combined with SC. For characterizing SC, only SC measurements were used.

For analyses of ecoregional predicted SC, a stream segment that crossed an ecoregional boundary was included in both ecoregional estimates. Therefore, the sum of ecoregional stream segments exceeds the total number of stream segments in Arkansas.

2.1.2.1 Arkansas Data set (1990-2021)

The frequency and period of sampling varies greatly among the stream stations. Some stations (ambient stations) were sampled monthly from the early 1990s to the present, while other sites were sampled intermittently (roving stations) or to address a particular concern (e.g., special survey, toxicological survey, or use attainability analysis (UAA)). For most of the analysis in this report, concentrations are based on station medians for a given water quality parameter so that all stations are given equivalent weight regardless of sampling intensity. Parameters included SC, individual ions, TDS, pH, and genus level occurrences.

2.1.2.2 Arkansas Least Disturbed Stations (1990-2021)

The Arkansas least disturbed stations data set is a subset of the Arkansas data set. For this analysis, rivers and streams classified by ADEQ as high-quality resource waterbodies were treated as least disturbed stations. ADEQ identifies high-quality stations based on best professional judgment including confirmation of no (or very few) point source discharges and no substantial areas of nonpoint source disturbances; land use data and other factors (Green, 2014; ADPCE, 1987a, b). A complete list of station names, station descriptions, and where applicable, the corresponding least disturbed stream classifications is available from the authors.

2.2 Ionic Composition and SC Analytics

In the Boston Mountains, Mississippi Alluvial Plain, and Ozark Highlands ecoregions, the relative proportion of divalent cations, $[Ca^{2+}] + [Mg^{2+}]$ is greater than monovalent cations, $[Na^{+}] + [K^{+}]$ based on mass. In the Ouachita Mountains, Arkansas Valley, and South Central Plains ecoregions, $[Na^{+}] + [K^{+}]$ is dominant at 5%, 33% and 58% of least disturbed stations, respectively (Table A.2.5). Although the possible cause was not investigated, oil and gas wells predominately occur in these two ecoregions (Map A.6.1). This suggests that the higher Na^+ levels may be influenced by anthropogenic causes rather than minimally affected ion composition. In single species tests, $Na^+ + K^+$ are more toxic than $Ca^{2+} + Mg^{2+}$ on a mass-basis (e.g., Mount et al., 2016; Erickson et al., 2022a, 2022b; Hills et al., 2022).

The anionic composition was characterized using measured alkalinity, pH, sulfate, and chloride from each station (Tables A.2.1 to A.2.4). For all ecoregions except the South Central Plains (96%), 100% of the least disturbed stations were dominated by conditions of bicarbonate (HCO_3^-) plus (SO_4^{2-}) being greater than chloride (Cl^-), often by factors >10 (Table A.2.6). Of the 28 least disturbed stations identified by ADEQ in the South Central Plains, only one station appeared to be chloride-dominated. It is unclear if the station was misclassified as least disturbed conditions or is an anomalous station. HCO_3^- and SO_4^{2-} dominance is consistent with Hem (1985) and Griffith (2014). Therefore, where chloride is the dominant ion, then the natural ionic mixture is likely due to anthropogenic inputs exhibiting altered relative amounts and concentrations of ions. Exceptions may occur at natural salt springs, but they were not among the least disturbed stations included in this analysis and not typical of water in Arkansas streams. Sodium and bicarbonate are the dominant ions in Arkansas hot springs in the Ouachita Mountains. (Kresse and Hays, 2009).

2.3 Observed Least Disturbed Level III Ecoregional Background

The background levels of dissolved ions in streams in Arkansas are among the lowest in the country (Cormier et al., 2018c; Cormier et al., 2021; Griffith, 2014), a testament to the natural characteristics of the region and little or moderate anthropogenic alteration in many areas. Streams in Arkansas are often below 50 µS/cm (Tables A.2.1 to A.2.4). Based on the 75^{th} centile of least disturbed station medians, ecoregional background values are: 63 µS/cm (Arkansas Valley), 92 µS/cm (Boston Mountains), 105 µS/cm (Ouachita Mountains), and 134 µS/cm (South Central Plains). Background SC was higher in the Ozark Highlands (381 µS/cm) and Mississippi Alluvial Plain (328 µS/cm) (Table 3).

Table 3. Summary median statistics for SC (µS/cm) by Ecoregion, least disturbed stations. Individual values represent the median of all measurements for a given parameter at that site.

	Arkansas Valley	Boston Mountains	Mississippi Alluvial Plain	Ouachita Mountains	Ozark Highlands	South Central Plains
Minimum	18.5	18	57	3	5	6
10^{th} centile	30	31	110	29	148	38
25^{th} centile	35	44	152	38	201	57
50^{th} centile	45	67.5	239	58	279	92
75^{th} centile	63	92	329	105	381	134

Geo Mean	49	64	224	61	263	91
Maximum	423	259	891	472	568	1150
***n* (samples)**	13	26	5	32	55	22
***N* (stations)**	593	400	253	1203	1847	841
St. Dev.	31.39	43.08	146.05	46.95	105.22	114.07

2.4 Relationship between TDS and SC

TDS and SC are two common measurement endpoints for characterizing the total ionic strength or salinity of a water body. In freshwater systems, TDS, usually expressed as mg/l, is a measure of the total mineral content of water typically determined by the weight of the evaporates. SC is expressed as µS/cm. It measures dissolved mineral concentration from the relationship in which the conductance of the flow of electrical current increases as the concentration of dissolved ions increases. In the past, total ionic concentration was often measured by the ADEQ as TDS but more recently as SC. In this section, the development of ecoregional models is described for converting TDS (mg/l) to SC (µS/cm).

Linear regression models of TDS and SC were calculated for each ecoregion using the Arkansas data set. Prior to analysis, values of ≤5 mg/l TDS were removed and assumed to be below the detection limit. Values of ≤1 µS/cm conductivity were also removed as likely below detection limit.

Visual inspection of linear regression models suggested that the slope of the Ouachita Mountains was different from the other ecoregions and appeared to have at least two distinct slopes. The cause of the distinct slopes was not investigated. However, anthropogenic inputs different from freshwater ionic composition may be reflected in the less steep slope, which occurs at higher SC. A broken-stick regression analysis revealed an inflection at 141.75 mg/l TDS (Figure 3). Note that there are two regression models with different range limits for Ecoregion 36 that are used to convert TDS to SC, but the single r^2-value relates to the combined performance of both regression models.

Overall, TDS and SC are highly correlated with r^2 values ranging from 0.86-0.99. An analysis of co-variance (ANCOVA) showed that the slopes and intercepts of each ecoregional regression model (Ecoregions 35, 37, 38, 39, 73, and 74, excluding Ouachita Mountains, Ecoregion 36) are significantly different from one another. Also, the r^2-values of individual regression models are stronger than the combined data of these six ecoregions (Figure 3). Therefore, conversions from TDS to SC are expected to be more accurate using regression models tailored to each ecoregion (Figure 4, Table 4). These models were used for maps to convert TDS to SC.

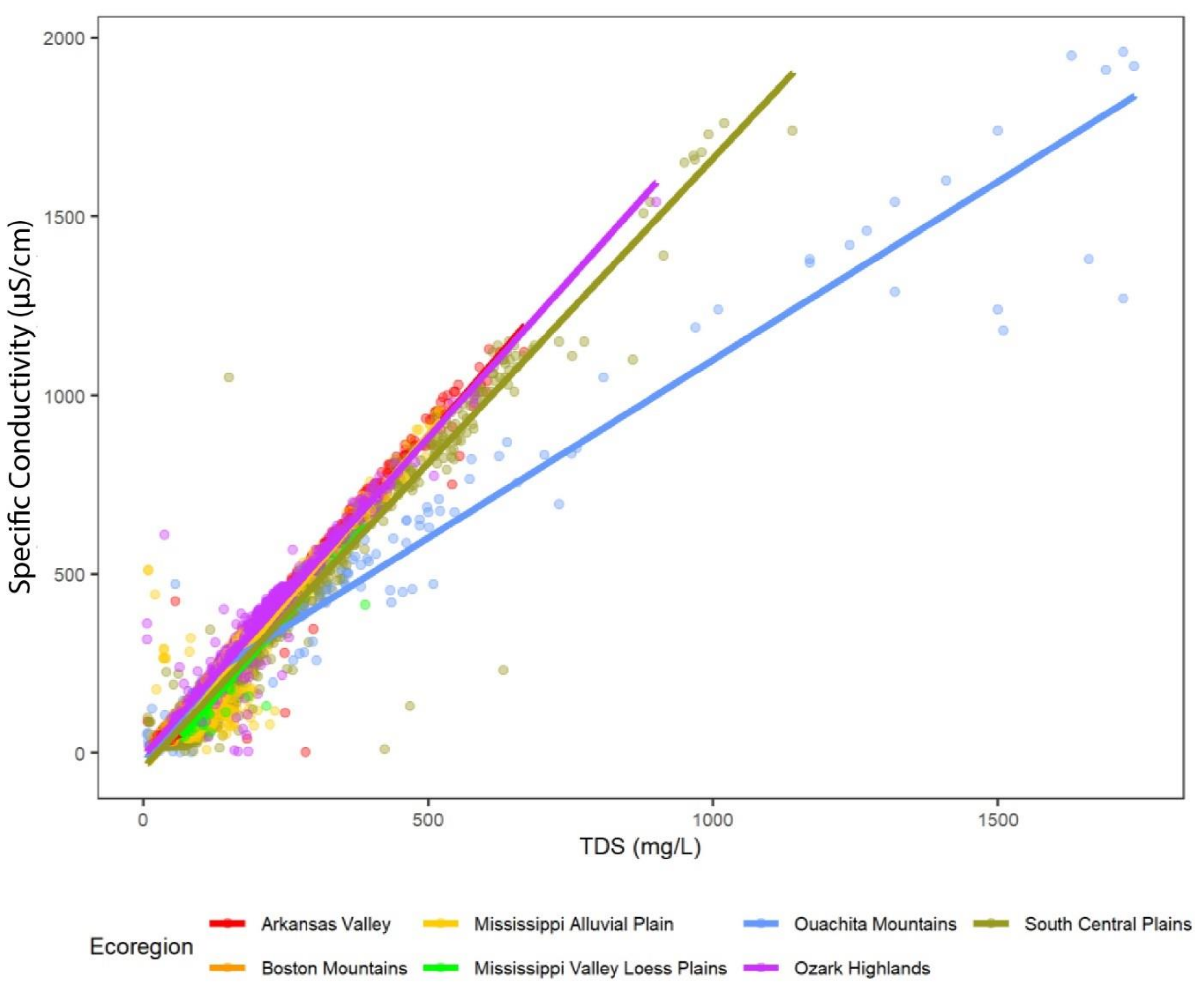

Figure 2. Relationship between TDS and SC for Arkansas data set by ecoregion. Ouachita Mountain has a markedly different slope.

Values less than or equal to 5 mg/l TDS and 1 µS/cm were removed prior to analysis.

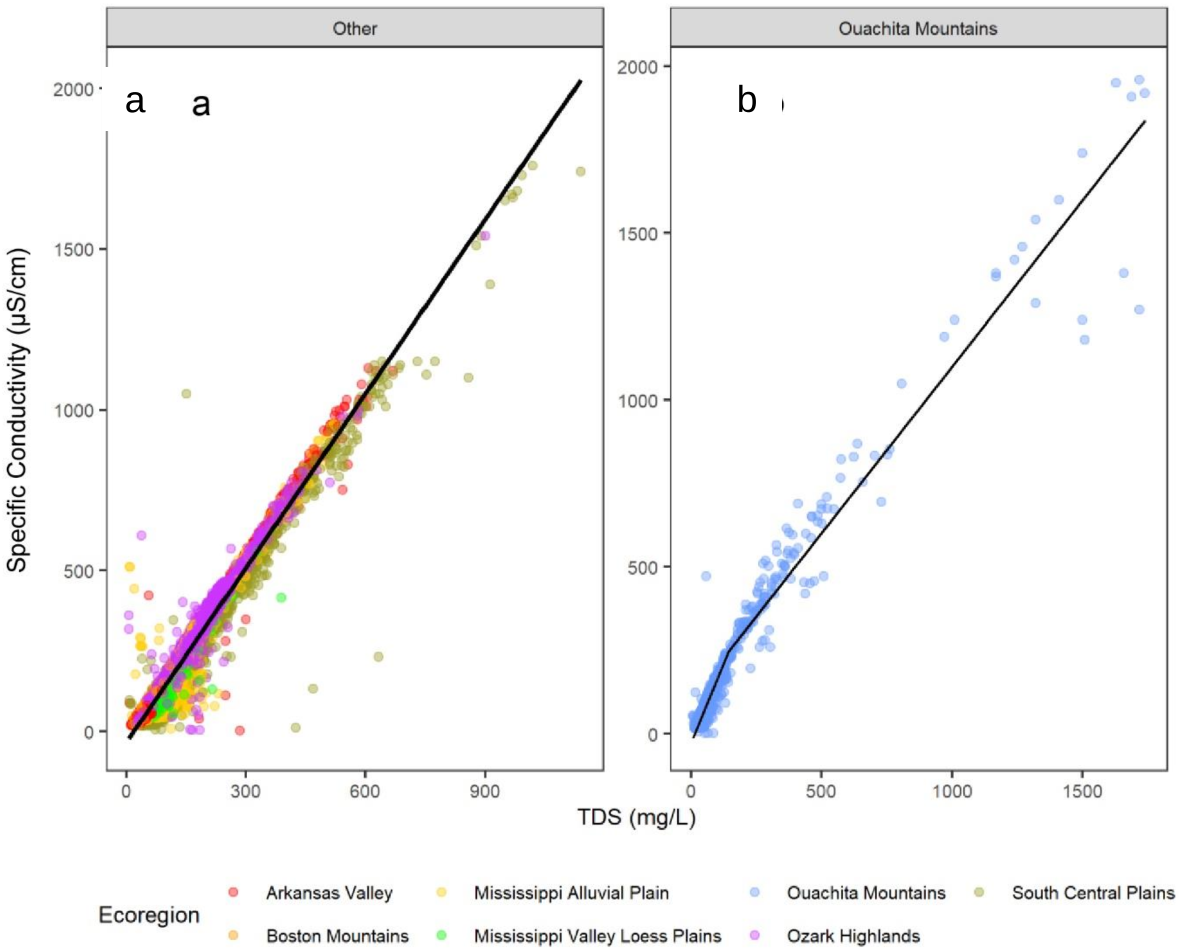

Figure 3. Relationship between TDS and SC for Arkansas
(a) All ecoregions except Ouachita Mountains and (b) Ouachita Mountains. Broken stick regression at 141,75 mg/l TDS is characterized by steeper slope at low SC. Values less than or equal to 5 mg/l TDS and 1 µS/cm were removed prior to analysis.

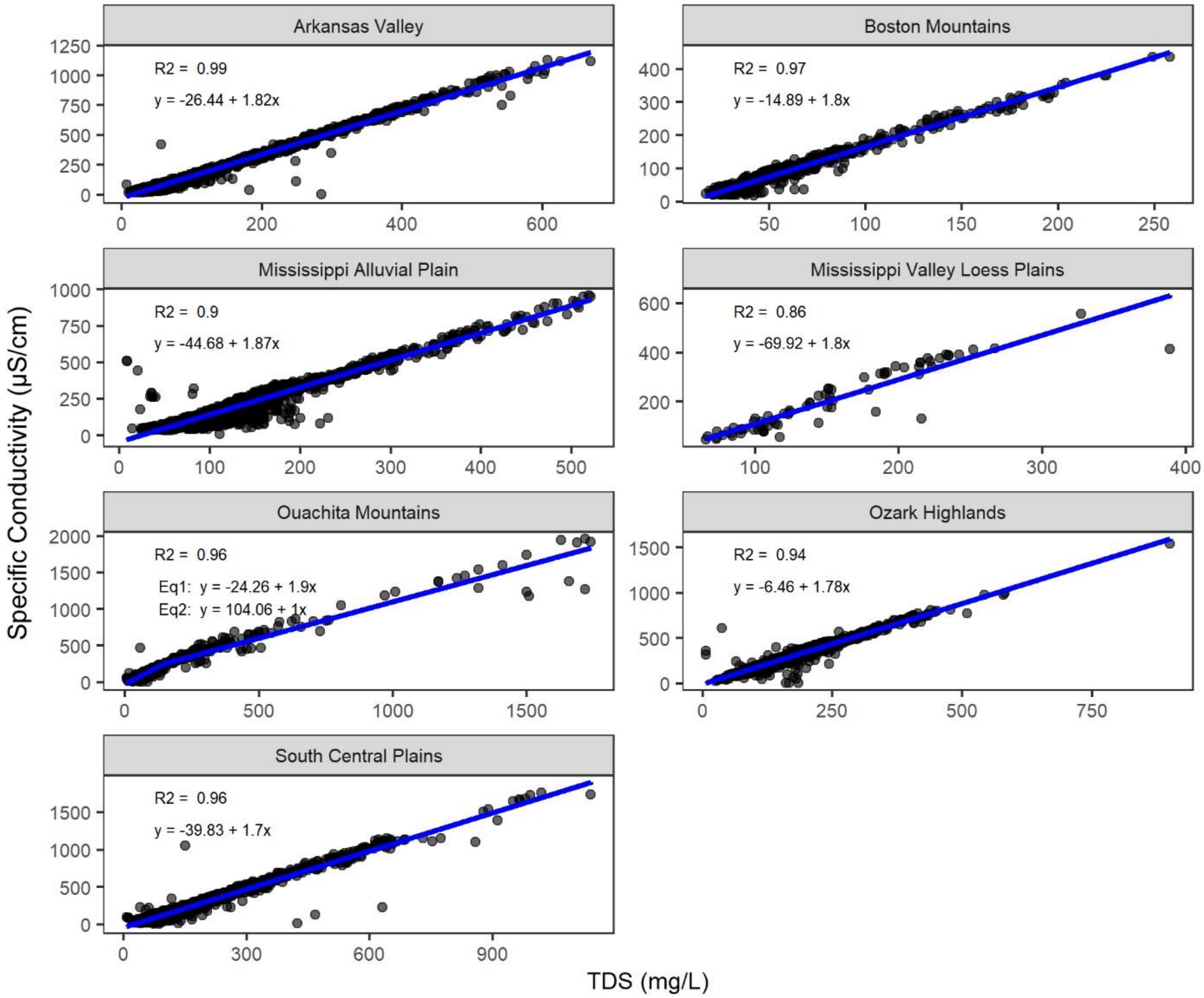

Figure 4. Relationship between TDS and SC for Arkansas data set by ecoregion.
Ouachita Mountain has two equations with a breakpoint at 141.75 mg/l TDS. Values less than or equal to 5 mg/l TDS and 1 µS/cm were removed prior to analysis.

Table 4. Summary of regression models and r^2 values for converting TDS (*x*) mg/l to conductivity (*y*) (µS/cm) by ecoregion based on the Arkansas data set from 1990-2021.

	Ecoregion	*N*	r^2	Eq1	Eq2
36	Ouachita Mountains	3046	0.96	$y = -24.26 + 1.9x$	$y = 104.06 + 1x$ (breakpoint: 141.75 mg/l)
39	Ozark Highlands	3085	89	$y = 6.46 + 1.78x$	NA
38	Boston Mountains	600	0.97	$y = -14.89 + 1.8x$	NA
37	Arkansas Valley	2066	0.99	$y = -26.44 + 1.82x$	NA
74	Mississippi Alluvial Plain	1743	0.90	$y = -44.68 + 1.87x$	NA
35	South Central Plains	4298	0.96	$y = -38.83 + 1.7x$	NA
73	Mississippi Valley Loess Plains	73	0.86	$y = -69.92 + 1.8x$	NA

2.5 Predicted Least Disturbed Background for Stream Segments

The mean least-disturbed predicted background SC was empirically estimated for stream segments throughout Arkansas using an empirical random forest regression model of geophysical attributes and ecoregional background (Olson and Cormier, 2019). Descriptive statistics are shown in Table 5. Because the predicted background is based on least disturbed stations, these predicted values may be useful for evaluating whether observed SC has been altered by anthropogenic activity (Cormier et al., 2018c). Stations identified as least disturbed may be the best in an area, but that area may be anthropogenically altered and quite different from a stream that is minimally affected by people. For example, whereas elsewhere in the Ozark Highlands the predicted background SC values are within 100 µS/cm of observed values, the observed SC near Spring River is greater than 100 µS/cm of the predicted SC and may indicate an anthropogenically shifting baseline. Least disturbed background is a useful metric, but it suffers from the effect of a shifting baseline and can contribute to worsening water quality over time (Pauly, 1995; Campbell et al., 2009; Gillon et al., 2016; Kaushal et al., 2018).

In contrast, in the Boston Mountains, observed SC is consistently less than the empirically modeled least disturbed background. The lower observed SC is a better estimate of minimally affected background than a model of least disturbed stations. Therefore, where observed SC is less than the predicted background SC, then the observed SC is a more relevant and accurate measure of minimally affected conditions than modeled estimates.

Table 5. Descriptive statistics of the predicted background SC and centiles estimated from an empirical random forest model.

		Centiles							
Ecoregion	**Min**	**10th**	**25th**	**50th**	**75th**	**Max**	**Mean**	**GeoMean**	***N***
Arkansas Valley	57	96	108	122	144	449	142	133	11975
Boston Mountains	69	134	176	237	295	464	235	222	6382
Mississippi Alluvial Plain	55	103	115	125	230	350	165	150	20718
Mississippi Valley Loess Plains	55	97	117	270	319	363	233	208	1576
Ouachita Mountains	54	69	89	100	114	350	110	104	9605
Ozark Highlands	86	242	267	301	315	409	290	288	12620
South Central Plains	48	69	73	90	126	375	116	104	26265
Arkansas	48	74	97	124	249	464	166	145	82679

The total number of stream segments from all ecoregions (summing all the values in the *N* column from row 1 to row 7) will be larger than the total number of the entire Arkansas data set. This is because a segment crossing the boundary of two ecoregions is included in each ecoregion, but only once for the state estimate.

2.5.1 Validation of the predicted background model for Arkansas ecoregions

The performance of the predicted background model for Arkansas ecoregions was evaluated by comparing predicted background SC with observed SC at least disturbed stations from the Arkansas data set. A map of the absolute difference between observed SC and predicted background SC shows that the predictive background model overestimates SC in the Boston Mountains and Arkansas Valley (Figure 5) and underestimates in the northeastern Ozark Highlands in parts of the Spring River drainage. The same patterns were observed with values in the non-reference Arkansas data set (Figure 6). In both analyses, the model underestimated SC in parts of the Ozark Highlands and Mississippi Alluvial Plain, suggesting a greater level of altered SC in these two ecoregions (green circles) (Figures 5 and 6).

A scatter plot of the absolute difference between observed SC and predicted background SC shows that the observed values at Boston Mountain and Arkansas Valley stations consistently fall below the 1/1 line, indicating that the predicted values are overestimated (Figure 7). For the least disturbed Arkansas data set excluding the Boston Mountains and Arkansas Valley, 62.5% of observed SC values were within 61 µS/cm and 81.2% were within 100 µS/cm of predicted background SC values. Stations in the Ozark Highlands varied greatly and observed values in the Spring River drainage were often slightly more than 100 µS/cm than predicted by the random forest model, suggesting that baseline SC for the river may be shifting toward more mineralized conditions or that there are unusual natural factors not considered by the empirical model at these stations. A site-specific assessment would be needed to identify probable causes.

Statistical metrics for predictive performance were calculated after removing the Boston Mountain and Arkansas Valley. To compensate for bias from repeat sampling, stations with the same geographical location (samples with the same catchment identified for the ComID, where ComID is a unique stream segment identifier in NHDPlus) were pooled and the medians of unique stations were calculated. For the least disturbed Arkansas data set, the model explained most of the variation in SC and produced fairly accurate predictions for the least disturbed Arkansas data (Mean Absolute Error (MAE) = 61 µS/cm, Nash-Sutcliffe Error (NSE) = 0.62, and r^2 = 0.64, percent bias 6.3%).

Due to the over-estimation of background SC in the Arkansas Valley and Boston Mountains, we attempted to calibrate the predicted values using long term SC observations collected at gaging stations by the United States Geological Survey (USGS) (Appendix A-2). Although the temporal patterns were qualitatively similar, rising and falling at the same time for observed and predicted background SC, a consistent difference in average magnitude was not discernable and so calibration was not done.

The percentage of sites greater than the predicted background was estimated for all stations in the Arkansas data set (Figure 6 and Figure 7). For the Arkansas data set excluding the Boston Mountains and Arkansas Valley, 53.5% of observed SC values are within 61 µS/cm and 75% are within 100 µS/cm of predicted background SC values. This indicates that more than half of the monitored streams in the state are within the MAE of the predicted background model's estimate.

Because the predictive model consistently overestimated background SC for the Boston Mountains and Arkansas Valley compared to observed SC, that poses a risk for under-protecting the aquatic life in those two ecoregions. Because observed background in freshwater is substantially lower than the modeled predicted background, the ecoregional 75^{th} centile of least disturbed stations is recommended in lieu of the predicted background for the Boston Mountains and the Arkansas Valley, where an ecoregional estimate is needed.

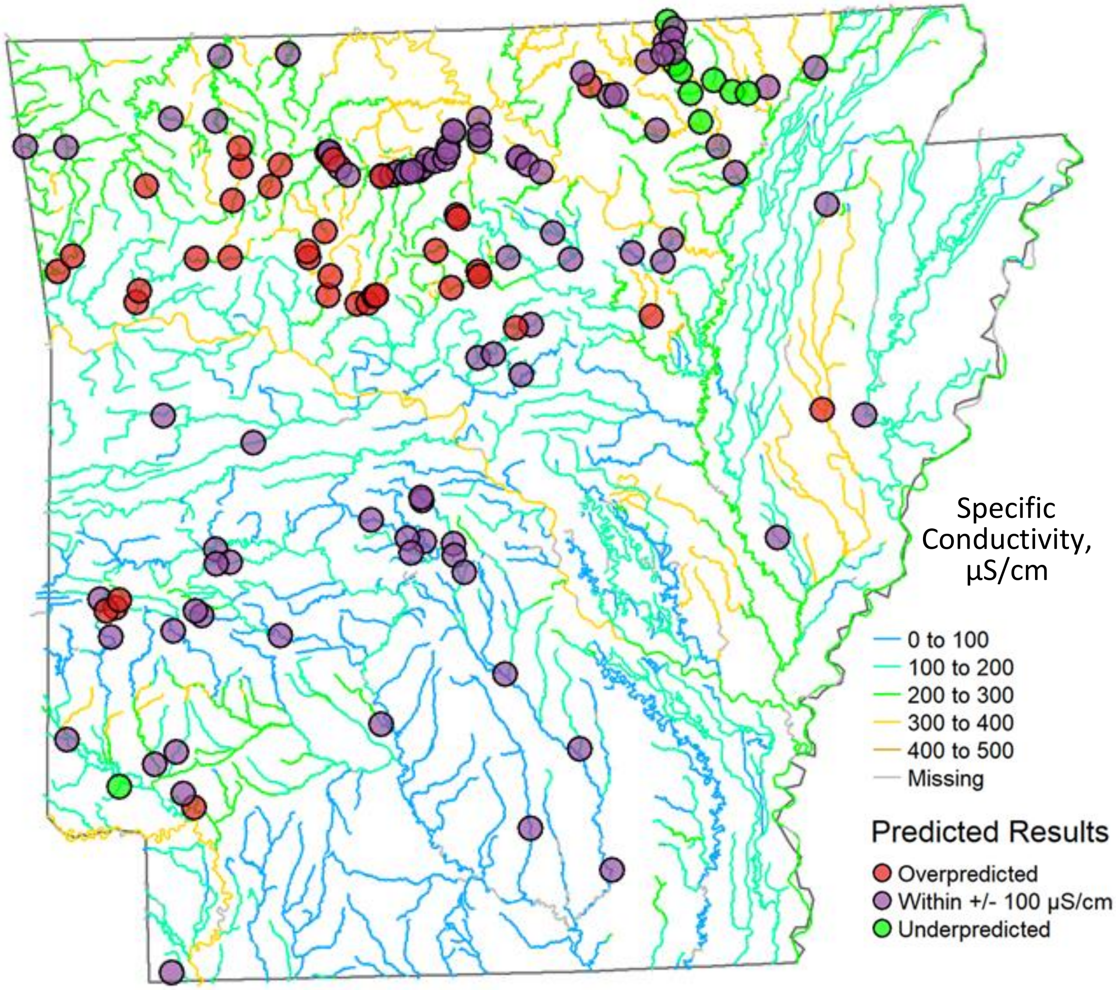

Figure 5. Comparison of absolute difference between median predicted background SC and median observed SC in Arkansas least disturbed stations (*N*=135).
Predicted background levels are overestimated in the Boston Mountains and Arkansas Valley. SC is underestimated in the Ozark Highlands near Spring River and may be due to anthropogenic alteration or unusual natural sources. No least disturbed stations were identified for the Mississippi Valley Loess Plains.

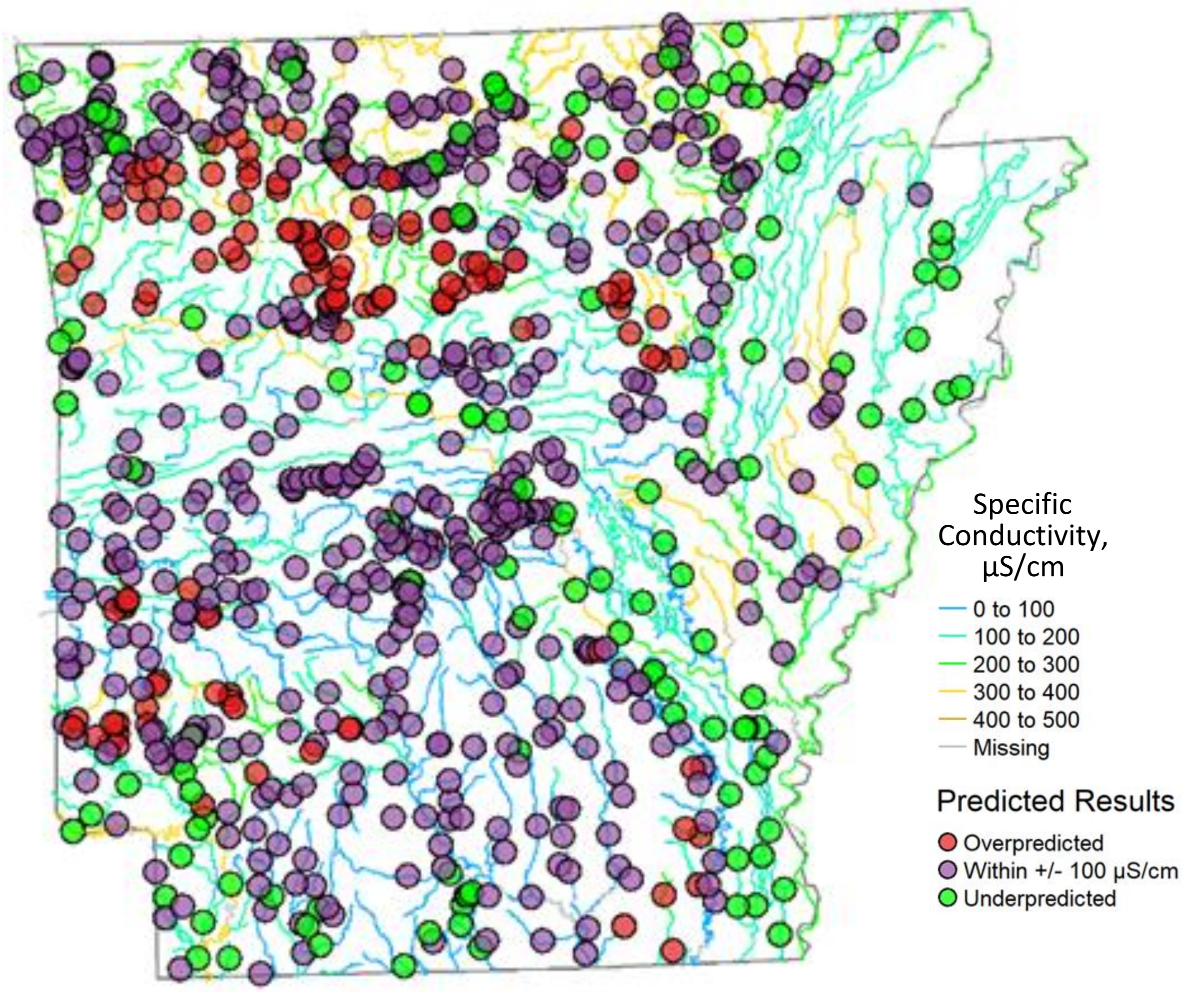

Figure 6. Comparison of absolute difference between predicted median background SC and median observed SC with Arkansas data set for all stations.

Observed values in the Arkansas data set (*N*=811) confirm the bias for over-estimation in the Boston Mountains and Arkansas Valley (red circles). The model underpredicted in parts of the Mississippi Alluvial Plain and Western portion of the South Central Plain, indicative of altered SC regimes (green circles).

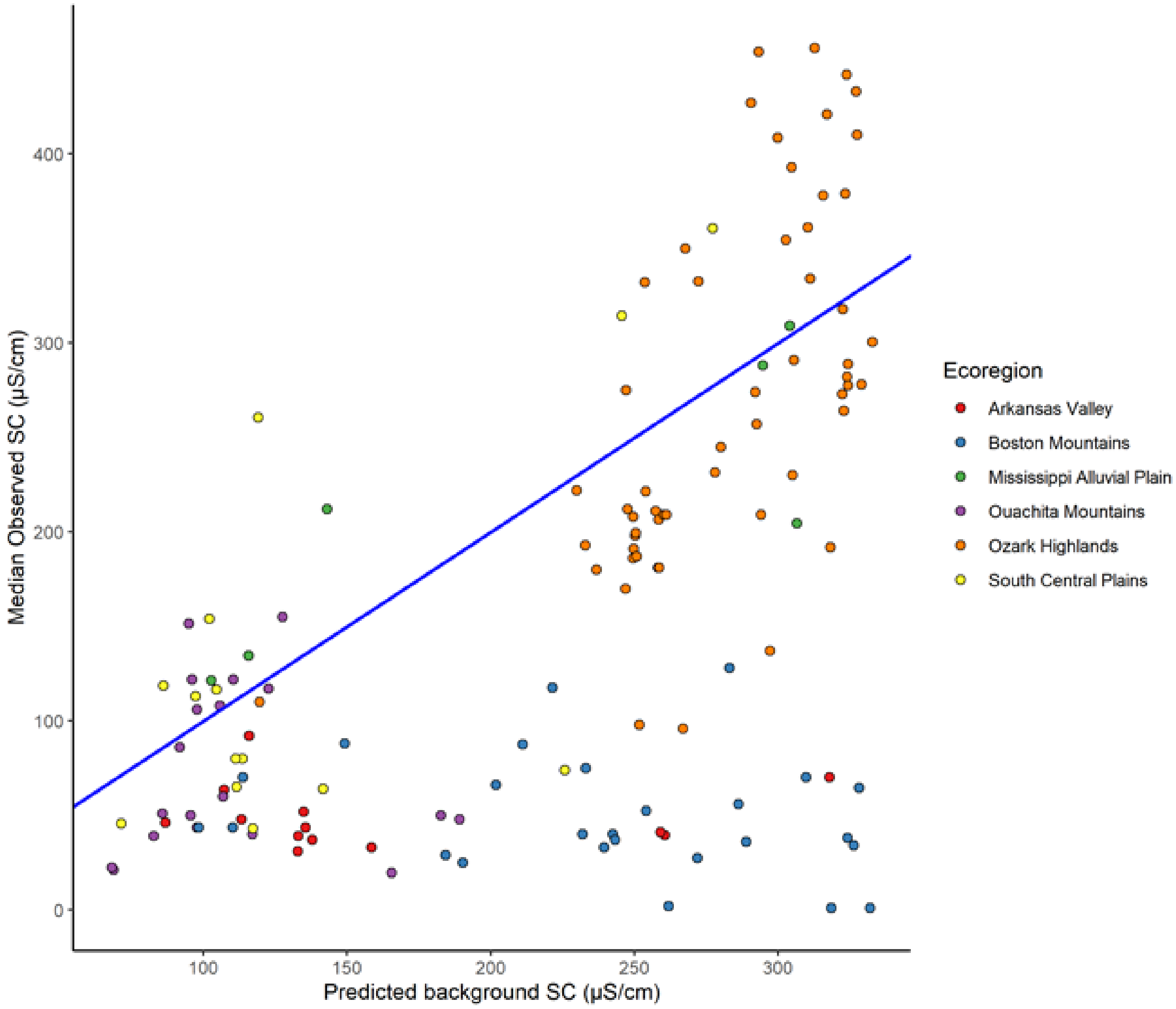

Figure 7. Scatter plot of Arkansas least disturbed stations.
Oblique line is 1:1 line. Background SC values in the Boston Mountains (blue circles) and Arkansas Valley (red circles) are overestimated and indicate that the model is unreliable for this ecoregion. Three Boston Mountain stations are questionably low with observed SC near zero and are either below detection limit or indicative of data management errors. No least disturbed stations were identified for the Mississippi Valley Loess Plain.

2.6 Development of Flow Chart to Select Background SC

2.6.1 Weight of Evidence Used to Select Background SC Estimates

A weight-of-evidence approach was used to select the scale, data set, and assessment statistic to estimate background for each ecoregion and site-specific estimate (Cormier et al., 2018c; USEPA, 2017). Comparing available and relevant evidence provides greater confidence than one line of evidence and increases transparency in the decision process. Relevance and reliability were scored using symbols indicating support (+) or weakening (—) of the option for selecting a data set, the statistic for background, and appropriate spatial scale (Table 6). Based on the weight of evidence, least disturbed Arkansas ecoregional background estimates were calculated (Table 7). A flow chart was developed that depicts considerations for selecting background SC in Arkansas streams based on location, comparisons, and available data (Figure 8).

Minimally affected background is more relevant and therefore the preferred estimate. Where such data or conditions are unavailable, the next most relevant estimated background is one from one or more nearby, minimally affected location. Where neither of these options is available, values recommended for use are shown in Table 7. In the Mississippi Alluvial Plain, Mississippi Valley Loess Plains, Ouachita Mountains, Ozark Highlands, or South Central Plains, the recommended background is the stream segment empirically modeled background. In the unlikely situation that minimally affected background cannot be estimated from observed SC for the Boston Mountains and Arkansas Valley, the recommended background is the ecoregional 75th centile because the model consistently over-predicts background in these two ecoregions. These methods, data, and models may be used to assess the protectiveness of site-specific water quality criteria proposed by third parties.

Ouachita Mountains, Ozark Highlands, and South Central Plains: The predictive model appears to reliably and realistically estimate background for stream segments in the Ouachita Mountains, Ozark Highlands, and South Central Plains with an error less than 100µS/cm. Therefore, the stream segment predicted background is a reasonable default for estimating background SC where observed measures are greater than the predicted background, or the background is known to be altered from minimally affected conditions.

Mississippi Alluvial Plain: The predicted background of the Mississippi Alluvial Plain (125 µS/cm) was within 20 µS/cm of the 25th centile of all stations in the Arkansas data set (116 µS/cm) and of the stations in the ecoregion wide probability data set (132 µS/cm). Although the background for least disturbed stations should be lower than an estimate of all stations, the estimated background at the 75th centile is about double the 25th centile of all Arkansas stations (*N*=36) and ecoregion-wide stations (*N*=27), and the 75th centile was greater than half of all stations in the ecoregion in Arkansas. This may be attributed to the paucity of least disturbed stations (*N*=5) in the Mississippi Alluvial Plain Arkansas data set. Owing to the few least disturbed stations and the disparity between the resulting 75th centile of least disturbed stations and other metrics, the predicted background was judged to be a better estimate than one based on five least disturbed stations in the Mississippi Alluvial Plain. Therefore, the stream segment predicted background is recommended for estimating background SC where observed measures are greater than the predicted background.

Mississippi Valley Loess Plains: There is insufficient data to estimate background for the Mississippi Valley Loess Plains based on the Arkansas data set, and there is a large discrepancy between the observed EPA ecoregion-wide probability stations from the entire ecoregion (69 µS/cm, *N*=26) compared to the predicted background median (270 µS/cm, range 55-363 µS/cm)—which may be reflecting altered vegetative cover that is almost entirely agricultural rather than native forest. The background for this ecoregion is uncertain and no one approach is strongly recommended at this time. As a practical provisional default estimate, the empirically modeled background is recommended in the absence of least disturbed stations for comparison.

Boston Mountains and Arkansas Valley: The predictive model consistently overestimates background for the Boston Mountains and Arkansas Valley. This may be due to the high proportion of intact ecosystems in this ecoregion in Arkansas and the challenge of modeling in a left censored data set bounded by zero. For this reason, the predicted background is not recommended. Instead, either observed SC at the station less than the 75th centile or the 75th centile for ecoregional least disturbed stations is recommended to estimate 5% extirpation levels, whichever is the lower estimate.

2.6.2 Recommended process for estimating background from predicted and observed data

For any station where nearby minimally affected stations are available for comparison, the observed background is most relevant and likely more accurate. Minimally affected conditions are the physical, chemical, and biological habitat found in the absence of significant human disturbance (Stoddard et al., 2006). Therefore, wherever it is possible to directly measure minimally affected SC background, *not least disturbed background*, with confidence, that observed background is the more reliable, relevant, protective, and scientifically defensible estimate.

Anthropogenic background or least disturbed conditions are the best available physical, chemical, and biological habitat conditions given the present degree of disturbance of the landscape or habitat type (Stoddard et al., 2006). Least disturbed background is a useful metric, but it suffers from the effect of a shifting baseline and can contribute to worsening water quality (Pauly, 1995; Campbell et al., 2009; Gillon et al., 2016; Kaushal et al., 2018).

Where it is necessary to estimate background SC in the absence of minimally affected stations, predicted background SC is recommended for the Mississippi Alluvial Plain, Mississippi Valley Loess Plains, Ouachita Mountains, Ozark Highlands, and South Central Plains or the observed SC, whichever is less. The Arkansas Level 3 ecoregional estimates are recommended as a default estimate for the Boston Mountains and Arkansas Valley or the observed SC, whichever is less. A flow diagram depicts the process (Figure 8).

Table 6. Weight of evidence used to select scale, data set, statistic, and method for estimating background SC.

	Relevance		Reliability and Justification	
Scale	Scores: supports (+), weakens (—), not applicable (*NA*)			
Level 3 ecoregions	The objective is to estimate site-specific background, so this scale is likely to be less relevant than at state scale.	+	Reliability is less at greater scales because natural variations are expected to increase with scale. However, sample size is larger than when constrained to Arkansas which increases confidence, especially for Ecoregion 74.	+
Level 3 ecoregions within Arkansas	More relevant because scale is smaller than entire level 3 ecoregion and is within Arkansas.	++	This is an intermediate scale and reliability is also intermediate for estimating at a stream reach.	+
			Ecoregion 74 is very small within Arkansas and number of samples are also few in number, so an estimate would be unreliable.	–
Stream segment (e.g., predicted, comparison stations)	Stream segment is very relevant to the application of site-specific benchmarks.	+++	This is among the smallest scales and can be reliable depending on available data and predictive performance of a model.	+
Stream station (e.g., observed)	Stream station is most relevant to the application of site-specific benchmarks.	+++	This is the smallest scale and can be reliable depending on availability of comparison stations and rigor of ground-truthing.	+
Summary	Stream segment or station is most relevant to the application of site-specific benchmarks. However, depending on data sets, larger scales may be more reliable estimates when there is a paucity of localized data or model predictions are weak.			
Data set: Source of Estimate				
Predicted	The data used in the model screens for anthropogenic disturbance, which makes it more relevant, but excludes local natural sources.	+	At the regional scale, validation indicated predicted background was estimated with reasonable accuracy. For Arkansas least disturbed stations excluding the Boston Mountains and Arkansas Valley, 81.2% were within 100	+

	Relevance		Reliability and Justification	
			μS/cm of predicted background SC values.	
			The Boston Mountains and Arkansas Valley were consistently overestimated.	−
Observed Arkansas stations	Ecoregion metric: Measurements are inherently relevant to current conditions but include various levels of anthropogenically disturbed waters.	−	Ecoregion metric: Data set was quality assured, but records of ≤1 μS/cm suggest not all values are valid and may affect the 25th centile estimate.	+
	Stream station or segment: Many streams in Arkansas have low background SC even though they have not been designated as least disturbed and therefore may be relevant for comparison.	+	Stream station or segment: Data quality must be reviewed on a case-by-case basis. Not reliable on its own, but where it is less than other metrics it is justifiably the best estimate of background.	+
Observed Arkansas least disturbed	Measures of least disturbed stations are most relevant, because they represent the type of stream condition of interest, and the samples are from Arkansas. However, stations may represent best available (least disturbed) rather than natural background condition (minimally affected).	++	Data set was quality assured, but records of ≤1 μS/cm suggest not all values are valid but influence on the 75th centile is likely to be negligible. Ground truthing by state agencies strengthens the designation of least disturbed status for this data set.	+
Summary	Predicted estimates are relevant, accurate, and minimally influenced by anthropogenic alteration but less reliable for the Boston Mountains and Arkansas Valley. Observed data from least disturbed stations are more relevant but may include stations with anthropogenic influences. The Arkansas least disturbed station data set is more relevant than other data sets but is not available for all stream segments and there are none in the Mississippi Valley Loess Plains.			
Background statistic				
10th	The small difference between 10th and 25th centiles suggest that the 10th centile may be too conservative for all ecoregions, especially for Ecoregions 39 and 74.	−	Low centile sites are more likely to characterize background but may be conservative because there were many sites with low SC across the state. Also, the 10th centile is less reliable than a central tendency or larger centile especially with a small number of available of stations.	+

	Relevance		Reliability and Justification	
25th	The 25th centile of a mixed probability data set may be comparable to the 75th centile of best available, least disturbed stations (USEPA, 2011), but others have disputed appropriateness of using a fixed centile (Herlihy and Sifneos, 2008).	+	The small SC increase from 10th to 25th centile suggests that the 25th is a reasonable background estimate in this non-randomized Arkansas data set and is less influenced by potential errors among low values.	+
75th	The 75th centile of best available, least disturbed stations may be comparable to the 25th centile of a mixed probability data set (USEPA, 2011), but others have disputed the practice of using a fixed centile (Herlihy and Sifneos, 2008).	+	The 75th centile of least disturbed stations tended to be greater than other estimates, but this may be due to the overall higher percentage of high-quality streams in the state. Alternatively, the higher value may be due to the inclusion of non-reference stations in the data set. The 50th centile of all stations was often similar to 75th centile of least disturbed stations (Table 7)	++
Central tendency	For the model prediction, geomean or median is relevant because the model predicts an annual estimate of least disturbed stations.	+	Central tendencies are the most robust statistic because they represent all the data.	++
Summary	Depending on the data set, any statistic may be appropriate to estimate background in Arkansas except the 10th centile.			
Weight-of-Evidence Summary	For any station where nearby minimally affected stations are available for comparison or where the observed SC is less than an estimated background SC, the observed background is most relevant and likely more accurate. Where it is necessary to estimate background SC: • Mississippi Alluvial Plain, Mississippi Valley Loess Plains, Ouachita Mountains, Ozark Highlands, South Central Plains—the mean predicted background SC is recommended because the model is reliable and the need is for local predictions. • Arkansas Valley and Boston Mountains—the 75th centile of Arkansas ecoregional least disturbed stations is recommended because the ecoregion is the smallest reliable scale and because the predictive model overestimates background.			

Note: Scores: supports (+), weakens (−), not applicable (NA)

Table 7. Conductivity background estimates (μS/cm) obtained from different data sets. Number of stations in the data set in parentheses, range in brackets. Cells in green were identified by weight of evidence as the more reliable estimate.

	Predicted ecoregion Arkansas stream segments geomean[b]	Observed Arkansas least disturbed, 75th centile[c]	Observed Arkansas station medians, 25th centile	Observed Arkansas station medians, 50th centile	Observed Ecoregion-wide EPA probability samples, 25th centile[a]
Arkansas Valley	122 (11975) [56.82 - 449.45]	63 (13)	38 (43)	61 (43)	32 (47)
Boston Mountains	237 (6382) [68.74 - 464.36]	92 (26)	53 (39)	91 (39)	23 (26)
Mississippi Alluvial Plain	125 (20718) [54.62 - 349.58]	329 (5)	116 (36)	215 (36)	132 (27)
Mississippi Valley Loess Plains[a]	270 (1576) [54.62 - 362.58]	NA	89 (1)	164 (1)	69 (26)
Ouachita Mountains	100 (9605) [54.26 - 350.47]	105 (32)	38 (85)	56 (85)	22 (50)
Ozark Highlands	301 (12620) [86.24 - 409.06]	381 (55)	248 (128)	318 (128)	362 (54)
South Central Plains	90 (26265) [48.18 - 375.34]	134 (22)	60 (129)	94 (129)	51 (60)

[a]*Disparity between Ecoregion-wide and only one observed station in Arkansas suggests a conservative provisional estimate.*

[b] *Sources: Cormier, S.M., Zheng, L., Hill, R.A., Novak, R.M. and Flaherty, C.M. 2018c. A flow-chart for developing water quality criteria from two field-based methods. Science of The Total Environment, 633: 1647-1656.*

[c] *Cormier, S., Wharton, C., and Olson, J. 2021. USEPA Freshwater Explorer. V: 0.1. U.S. Environmental Protection Agency.* https://arcg.is/KHb9S

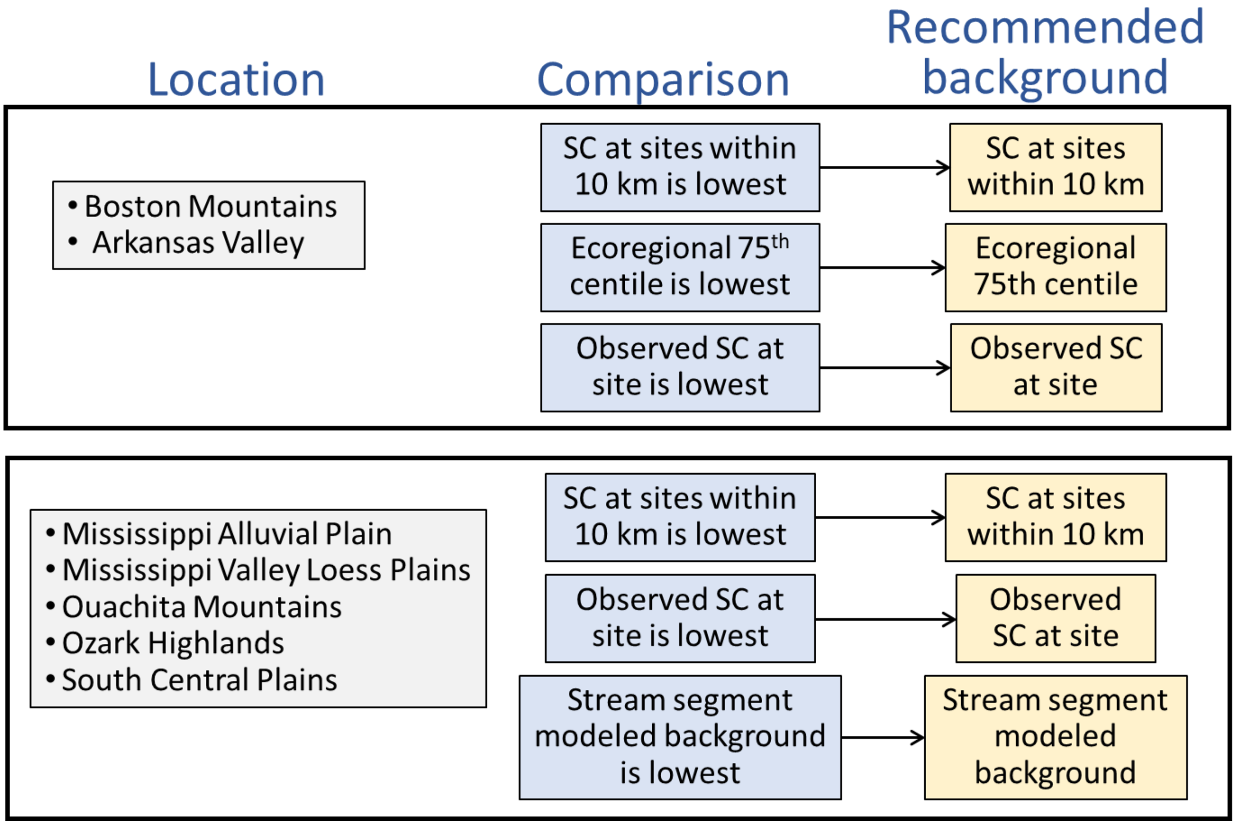

Figure 8. Flow chart depicting considerations for selecting background SC in Arkansas streams.

3 Calculation and Assessment of Extirpation Estimates

Field observational data have been successfully used for developing exposure-effect models and risk levels associated with salts (USEPA, 2011; Cormier et al., 2020; Humphrey and Chandler, 2018; MPCA, 2020). Although EPA released a method for deriving benchmarks for SC based on the extirpation of benthic invertebrates using large regional data sets with paired biology and chemistry data, these types of data are not always available or of sufficient size. ORD developed an approach requiring no biological data. The approach uses local background SC to predict the 5th centile from distribution of extirpation concentration (XCD05) using a national SC benthic invertebrate extirpation model (B-C model) (Cormier et al., 2018a).

The method using the B-C model was also selected because it measures the diversity of vulnerable species' responses, species interactions, autecology, and routes and dynamics of exposure (Gerritsen et al., 2015) rather than using SC alone to set an environmental threshold. The results are ecoregional estimates that reflect localized conditions, allowing XCD05 values to be estimated at the stream reach spatial scale.

3.1 Extirpation Based on National B-C Model and Arkansas Background Estimates

The underlying basis for the model is the SC range that is occupied by different benthic macroinvertebrate species. Natural conditions limit where species can thrive. The lowest SC niches are not necessarily filled by the same species at each location. Where a niche is absent due to natural factors affecting background, species specialized for that absent niche are also absent. In other words, species specialized for niches less than natural background in a region are unable to compete and survive because conditions are not suitable for their survival. As a result, biological communities differ from place to place, but the lowest tolerance limit cannot be lower than the lowest SC niche. So, as background SC increases, the tolerance values of the most sensitive species are greater and likewise, the 5th centile of those tolerance values also increases. This translates into a positive mathematical relationship between increasing background and increasing minima of niches.

This basic ecological relationship was mathematically modeled using species sensitivity distributions from many data sets with different background SC regimes and therefore different ionic-niche structures. The model was constructed using 24 data sets with XCD05 paired with the 25th centile SC for the data set. The 25th centile does not necessarily reflect minimally affected or least disturbed conditions; rather, it is an estimate of the background of the dataset experienced by the biota in that dataset. The resulting model is a linear $\log_{10}$-$\log_{10}$ least square regression model that can be used to estimate the SC likely to cause 5% extirpation with just the input of background SC (Figure 9) (Cormier et al., 2018a). The formula for the mean model prediction (Eq. 1) is shown below with an example calculation.

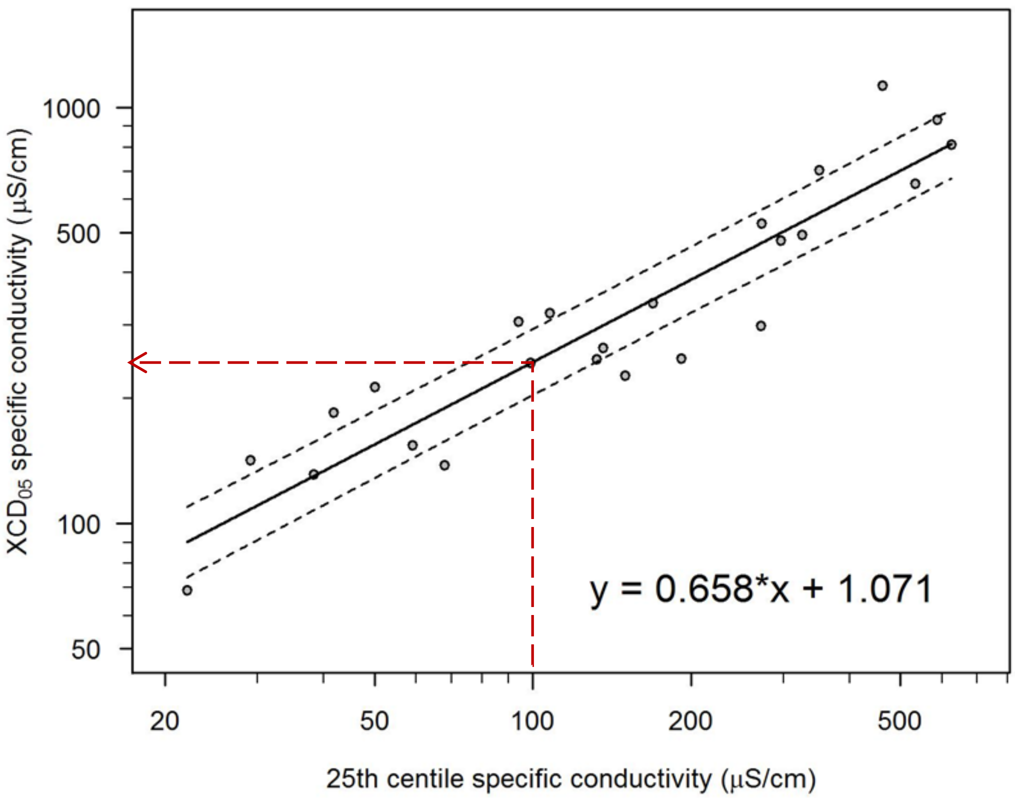

Figure 9. Background-to-criterion model (Cormier et al., 2018a).
Circles represent 24 ecoregions. In the formulae, *y*- and *x*-values are expressed as $\log_{10}$. The formula is $\log_{10}y = 0.658 * \log_{10}x + 1.071$. The solid oblique line is the least squares regression model, with 90% confidence limits shown as dashed lines. An example background value was inserted into the model as the independent *x* variable to yield the SC value likely to cause extirpation of 5% of benthic invertebrates (XCD05). The example calculation shows the vertical dashed line at 100 µS/cm intercepts the mean regression line at 244 µS/cm.

Using the background SC estimates in Table 7, example XCD05 values were calculated for each ecoregion in Arkansas using the B-C extirpation model. For each stream segment, the SC predicted from the empirical model was used as the independent variable to estimate an XCD05 (Table 8) except for the Boston Mountains and Arkansas Valley Ecoregions. For these two ecoregions, the observed least disturbed background for each ecoregion was used as the example.

An example calculation using background SC to estimate an XCD05 from a stream segment or ecoregion is shown below (Eq 1.). SC least disturbed background is the independent variable used in the 5% extirpation model to estimate dissolved ion levels likely to extirpate 5% of aquatic life. As an example, an estimated background SC of 100 µS/cm was used as the independent variable (*x*) in the B-C model to generate the SC level expected to extirpate 5% of aquatic life (XCD05)(*y*) in Eq 1.

25th centile Specific Conductivity (µS/cm)

$$\log_{10} y = 0.658 * \log_{10} x + 1.071 \qquad \text{Eq. 1}$$

$$\log_{10} y = 0.658 * \log_{10}(100\ \mu S/cm) + 1.071$$

$$y = XCD05 = 244\ \mu S/cm$$

As an example, the SC 5% extirpation level from Eq. 1 (244 µS/cm) was converted to TDS using the SC-TDS regression generated from the Arkansas data set for Ecoregion 35, South Central Plains (Table 4, Figure. 4). The XCD05 from Eq. 1 was used as the independent variable (*x*) to predict TDS XCD05 (*y*). An example is shown in Eq. 2.

$$y\ (244\ \mu S/cm) = -38.83 + 1.7 * x \text{ mg/l} \qquad \text{Eq. 2}$$

$$244\ \mu S/cm + 39 = 1.7\ x \text{ mg/l}$$

$$282.83/1.7 = x \text{ mg/l} = 166.37 \text{ mg/l}$$

$$\text{TDS XCD05} = 166 \text{ mg/l}$$

Table 8. Ecoregional XCD05 (µS/cm) values for SC (µS/cm) based on the 5% extirpation model.
Green cells are recommended XCD05 values.

	Median geomeans of predicted stream segments and [range]		**75th centile of median ecoregional least disturbed stations and [range]**	
Ecoregion	Background	5% extirpation	Background	5% extirpation
Arkansas Valley[a]	122 [57 - 449]	278	63 [18.5 - 423[c]]	180 [80 - 629[c]]
Boston Mountains[a]	237 [69 – 464]	430	92 [18 - 259]	231 [79 - 456]
Mississippi Alluvial Plain	125 [55 - 350]	283 [164 - 556]	328 [57 - 891[c]]	533
Mississippi Valley Loess Plains[b]	270 [55 - 363]	469 [164 - 569]	NA	NA
Ouachita Mountains	100 [54 - 350]	244 [162 - 556]	105 [3 – 472[c]]	252
Ozark Highlands	301 [86 - 409]	503 [221 - 615]	279 [5 - 568[c]]	479
South Central Plains	90 [48 - 375]	228 [150 - 582]	134 [6 – 1150]	296

[a] *Predicted values were overestimated, therefore XCD05 calculated from 75th centile of ecoregional least disturbed stations is more accurate than predicted.*
[b] *Observation at only one station in Mississippi Valley Loess Plains.*
[c] *Although identified in data set as least disturbed, these maxima may represent an anthropogenically altered background.*

4 General Conclusions

These analyses demonstrate that many streams in Arkansas have SC at nearly natural background levels and thus are a national treasure. The ionic compositions of these natural waters are primarily due to rock dominance and are thus well suited for estimating their SC levels from a random forest model that relies heavily on geological parameters (Olson and Cormier, 2019). However, the model does not perform well in the Boston Mountains and Arkansas Valley ecoregions and estimates based on observational data are recommended. These stream segment and ecoregional estimates of background SC may be useful for estimating site specific benchmarks or criteria that take into account not only the water chemistry but also how freshwater organisms are expected to respond to changes in SC (Cormier et al., 2018a).

A weight of evidence was used to assess the choice of scale, data sets that would be used for the background estimate, and the statistic used to characterize background (Table 6). Considerations were weighted based on relevance and reliability with justifications for each score.

A key objective is to provide information to inform assessments of third-party site-specific aquatic life criteria. Therefore, the stream segment or station scale is the most relevant background scale. However, depending on data sets, larger scales may provide more reliable estimates when there is a paucity of localized data or model predictions are weak within a particular area. Consequently, a flow chart was developed that recommends scale based on information about the location (Figure 8).

Similarly, the relevance and reliability of the source of SC values is influenced by location. In most of the state, SC estimated from an empirical model was reliable and offered the advantage of being scaled to the stream segment. However, based on a comparison of SC of high-quality stations identified by ADEQ and SC estimated from an empirical model, modeled least disturbed SC is less reliable in the Boston Mountains and Arkansas Valley (Figure 7). Therefore, observed SC is recommended in combination with a comparison with other possible background estimates in these two ecoregions (Figure 8).

In minimally affected fresh water, the lowest observed SC is the background for a defined temporal period, typically 1-year, but seasonal backgrounds can also be characterized and can be important in arid regions where deep groundwater has a greater seasonal influence (Clark and Davidson, 2009; Olson and Cormier, 2019). In general, where observed SC is less than predicted, the observed SC is a more relevant and reliable estimate of background conditions. Where observed SC is greater than predicted SC, the observed SC is likely affected by anthropogenic sources. The unknown true minimally affected background SC may be less than the predicted SC, but the predicted SC is the more protective estimate than an altered background.

The 10^{th}, 25^{th}, 75^{th}, and central tendencies were evaluated as possible choices for estimating background: (USEPA, 2011; Herlihy and Sifneos, 2008; Stoddard et al., 2006; Cormier et al., 2018c). Depending on the data set, any of these statistics may be appropriate to estimate background in Arkansas except the 10th centile. Low centile sites are more likely to characterize background but may be too conservative because there are many sites with low SC across the state. Also, the 10th centile is less reliable than a central tendency or larger centile, especially with the small number available of least disturbed stations.

In summary, for any station where nearby minimally affected stations are available for comparison or where the observed SC is less than predicted background SC, the observed background is most relevant and likely more accurate. Where it is necessary to estimate background SC in the absence of verified minimally affected SC background, the selection process differs by ecoregion. In the Mississippi Alluvial Plain, Mississippi Valley Loess Plains, Ouachita Mountains, Ozark Highlands, and South Central Plains, the mean predicted background SC is recommended because the model is reliable in these ecoregions and there is need for local predictions. In the Arkansas Valley and Boston Mountains, the 75th centile of Arkansas ecoregional least disturbed stations is recommended because the predictive model overestimates background and because the ecoregion is the smallest reliable scale. However, because there are many low SC observations in these two ecoregions, nearby stations may inform background estimates at a finer spatial resolution than the ecoregion scale.

The development of a robust data set has enabled these analyses and may provide a valuable resource for future research. For example, the data set may enable characterization of ionic signatures for commonly encountered sources that may be helpful for stressor and source identification. As new data are added to the database, the analyses can be revisited. One opportunity for improving confidence in the findings of this report and the database is the development of an explicit process for selection of high-quality stations. Currently, documentation relies on technology and guidance from more than 30 years ago (ADPCE, 1987a, b). There is also a research opportunity to perform similar analyses using data augmented with data from outside Arkansas but from within an ecoregion. Also, these data may be analyzed in time series to monitor salinization of fresh water in the state, a condition that that has become an international problem (Cañedo-Argüelles et al., 2016; Kaushal et al., 2018; USEPA, 2011a).

5 Quality Assurance and Supplementary Data

Data, metadata, R-codes, and quality assurance procedures are contained in Wang, Y-C., Wharton, C., Cormier, S. M. 2022. Data sets: Background Specific Conductivity and Associated 5% Extirpation Estimates in Arkansas. United States Environmental Protection Agency, Office of Research or can be obtained from the authors at cormier.susan@epa.gov.

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7 Citations

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8 Appendices

Appendix A-1. Ecoregion Level 3 Descriptions

The South Central Plains region (Ecoregion 35) is at the western edge of the southern coniferous forest belt, much of which is now used for pine plantations. Two-thirds of Ecoregion 35 is forest and woodland and a sixth is cropland. The dominant economic activities are timber or oil and gas related. The surface geology of this area is characterized by unconsolidated deposits of sand, gravel, silt, and clay from the ocean bottom, beaches, and estuaries that have eroded (USEPA, 2013).

The Ouachita Mountains region (Ecoregion 36) is defined by east-west trending ridges of tilted strata of eroding sedimentary rock formations. Sandstone and shale were formed from deep marine sediments. Natural vegetation is oak-hickory-pine forest but most of the region is now dominated by pine forest, and the major land use activity is commercial logging (USEPA, 2013).

The Arkansas Valley (Ecoregion 37) is primarily forested valleys and ridges. Located north of the Ouachita Mountains, one-fourth of the region is grazed and one-tenth is in cropland. The area of the Arkansas River Valley warped downward into a trough that repeatedly filled and eroded as the Ouachita Mountains formed by folding upwards. Swamps of river deltas accumulated clay, and plant remains were buried under later sediments and transformed into coal and natural gas. Additional alluvia became layered above these strata (USEPA, 2013).

The Boston Mountain (Ecoregion 38) is defined by a deeply dissected sandstone, shale, and limestone plateau, covered originally by oak-hickory forests, which continue to dominate the sparsely populated ecoregion. The principal land use is recreation (USEPA, 2013).

The Ozark Highlands (Ecoregion 39) has irregular physiography and soils derived from cherty carbonate rocks. The dominant bedrock in the interior region is dolomite and sandstone while the western outer region bedrock is dominated by limestone. Karst features are common. Ecoregion 39 is forested by oak and mixed oak-pine stands. Less than one-fourth of the interior of the ecoregion has been cleared for agricultural uses. The outer half of the periphery is pasture and cropland (USEPA, 2013).

The Mississippi Alluvial Plain (Ecoregion 73) is a broad, flat alluvial plain of sand, silt, and clay with fine textured soils though some areas have coarser, better drained soils. Bottomland deciduous forest covered the region before most of it was cleared for agricultural purposes in the north and central sections of the ecoregion (USEPA, 2013).

The Mississippi Valley Loess Plains (Ecoregion 74) are characterized by thick loess deposits with deep steep, silty and erosive soils (USEPA 2013).

Appendix A.2. Data set descriptive statistics

Table A.2.1. Summary station median statistics for least disturbed stations.

Ecoregion	Parameter	Unit	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Arkansas Valley	Alkalinity, total	mg/l $CaCO_3$	0.050	3.00	7.20	11.80	18.30	117.18	14.70	10.67	12.41	1017	18
Arkansas Valley	Bicarbonate	mg/l	0.063	3.77	8.92	14.81	22.79	147.17	18.40	13.30	15.69	982	18
Arkansas Valley	Chloride	mg/l	0.190	1.49	2.19	3.33	4.54	112.00	3.76	3.13	4.18	1473	18
Arkansas Valley	Hardness, Ca, Mg	mg/l	4.000	9.00	11.00	13.30	19.00	95.00	16.52	14.72	9.46	751	18
Arkansas Valley	Sulfate	mg/l	0.020	2.14	2.72	3.63	5.81	71.60	4.89	3.93	4.77	1471	18
Arkansas Valley	Calcium	mg/l	1.200	1.90	2.27	2.81	3.72	26.80	3.33	2.99	2.09	755	18
Arkansas Valley	Total Recoverable Calcium	mg/l	1.330	2.00	2.33	2.93	3.88	28.30	3.41	3.10	2.01	348	12
Arkansas Valley	Sodium	mg/l	0.020	1.30	1.80	2.70	4.30	167.00	3.63	2.71	6.42	755	18
Arkansas Valley	Potassium	mg/l	0.010	0.63	0.95	1.45	2.20	11.00	1.77	1.43	1.20	755	18
Arkansas Valley	Magnesium	mg/l	0.212	0.90	1.12	1.59	2.41	7.30	1.99	1.70	1.24	755	18
Arkansas Valley	Specific Conductivity	µS/cm	18.500	29.92	34.70	45.30	63.10	423.00	54.13	48.67	31.39	593	13
Arkansas Valley	Total dissolved solids	mg/l	8.000	27.50	33.00	44.00	58.63	387.00	48.04	44.35	22.75	1472	18
Arkansas Valley	Aluminum	mg/l	0.008	0.01	0.02	0.05	0.06	0.93	0.07	0.04	0.09	755	18
Arkansas Valley	Total Recoverable Aluminum	mg/l	0.020	0.05	0.08	0.19	0.43	2.14	0.30	0.19	0.31	348	12
Arkansas Valley	Iron	mg/l	0.008	0.05	0.09	0.18	0.30	2.16	0.25	0.17	0.27	755	18

Ecoregion	Parameter	Unit	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Arkansas Valley	Total Recoverable Iron	mg/l	0.103	0.22	0.31	0.52	0.86	3.27	0.67	0.52	0.51	348	12
Arkansas Valley	Ammonia-nitrogen	mg/l	0.002	0.02	0.02	0.02	0.04	3.44	0.04	0.02	0.11	1466	18
Arkansas Valley	Nitrite + Nitrate as Nitrogen	mg/l	0.005	0.03	0.06	0.15	0.28	3.01	0.21	0.12	0.23	1473	18
Arkansas Valley	Total Kjeldahl nitrogen	mg/l	0.025	0.10	0.18	0.31	0.53	3.88	0.39	0.29	0.32	1238	18
Arkansas Valley	Total Phosphorus	mg/l	0.002	0.01	0.02	0.04	0.07	1.17	0.06	0.04	0.07	1450	18
Arkansas Valley	Orthophosphate	mg/l	0.003	0.01	0.01	0.01	0.02	0.45	0.02	0.01	0.03	1469	18
Arkansas Valley	Total suspended solids	mg/l	0.500	0.50	1.50	4.00	9.89	392.50	10.13	4.09	22.90	1472	18
Arkansas Valley	pH	NA	4.000	6.22	6.50	6.75	7.06	8.82	6.78	6.76	0.51	1451	18
Arkansas Valley	Temperature	°C	1.000	6.81	10.50	17.50	25.00	36.30	17.75	15.53	8.07	1491	18
Boston Mountains	Alkalinity, total	mg/l $CaCO_3$	0.299	8.30	13.80	24.25	35.58	164.00	27.93	21.25	20.89	854	35
Boston Mountains	Bicarbonate	mg/l	0.376	10.43	17.43	30.78	44.63	204.47	35.23	26.79	26.29	829	35
Boston Mountains	Chloride	mg/l	0.250	1.19	1.50	1.95	2.46	239.00	2.58	1.98	7.88	1310	36
Boston Mountains	Hardness, Ca, Mg	mg/l	1.000	9.07	13.00	23.00	35.38	231.00	27.25	21.83	21.31	762	34
Boston Mountains	Sulfate	mg/l	0.500	2.38	3.03	4.03	5.60	82.60	4.79	4.16	3.65	1313	36
Boston Mountains	Calcium	mg/l	0.100	2.30	3.40	6.87	11.50	83.20	8.52	6.31	7.42	763	34
Boston Mountains	Total Recoverable Calcium	mg/l	1.110	2.19	3.13	6.47	11.50	42.00	7.92	5.99	6.11	293	28
Boston Mountains	Sodium	mg/l	0.020	0.97	1.25	1.62	2.20	161.00	2.52	1.69	7.08	764	34

Ecoregion	Parameter	Unit	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Boston Mountains	Potassium	mg/l	0.200	0.50	0.70	0.92	1.22	6.12	1.04	0.92	0.58	764	34
Boston Mountains	Magnesium	mg/l	0.200	0.84	1.04	1.30	1.70	24.70	1.46	1.33	1.04	764	34
Boston Mountains	Specific Conductivity	µS/cm	18.000	31.00	44.00	67.50	92.00	259.00	74.46	64.15	43.08	400	26
Boston Mountains	Total dissolved solids	mg/l	14.500	28.00	35.00	46.00	57.50	519.00	49.70	45.75	26.73	1099	35
Boston Mountains	Aluminum	mg/l	0.008	0.01	0.01	0.02	0.06	1.28	0.05	0.03	0.07	764	34
Boston Mountains	Total Recoverable Aluminum	mg/l	0.010	0.04	0.06	0.11	0.26	3.57	0.25	0.13	0.41	293	28
Boston Mountains	Iron	mg/l	0.006	0.01	0.02	0.04	0.06	0.94	0.05	0.03	0.06	764	34
Boston Mountains	Total Recoverable Iron	mg/l	0.021	0.06	0.11	0.16	0.24	2.84	0.23	0.17	0.30	293	28
Boston Mountains	Ammonia-nitrogen	mg/l	0.002	0.01	0.02	0.02	0.03	0.27	0.02	0.02	0.02	1312	36
Boston Mountains	Nitrite + Nitrate as Nitrogen	mg/l	0.005	0.01	0.02	0.06	0.15	2.08	0.13	0.06	0.19	1311	36
Boston Mountains	Total Kjeldahl nitrogen	mg/l	0.025	0.04	0.07	0.14	0.24	1.42	0.18	0.13	0.16	911	34
Boston Mountains	Total Phosphorus	mg/l	0.005	0.01	0.01	0.02	0.04	4.81	0.04	0.02	0.17	1119	35
Boston Mountains	Orthophosphate	mg/l	0.003	0.01	0.01	0.01	0.02	1.51	0.02	0.01	0.08	1313	36
Boston Mountains	Total suspended solids	mg/l	0.500	0.50	0.50	1.50	3.85	462.00	5.62	1.82	22.35	1097	35
Boston Mountains	pH	NA	4.780	6.39	6.77	7.16	7.56	10.50	7.16	7.13	0.62	1240	36
Boston Mountains	Temperature	°C	0.800	7.00	10.18	16.05	23.40	33.80	16.74	14.73	7.57	1279	36
Mississippi Alluvial Plain	Alkalinity, total	mg/l $CaCO_3$	2.500	36.15	55.90	99.00	153.00	263.00	105.10	87.78	55.12	680	7

Ecoregion	Parameter	Unit	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Mississippi Alluvial Plain	Bicarbonate	mg/l	3.384	45.03	69.71	122.70	190.70	329.95	130.36	108.88	68.53	674	7
Mississippi Alluvial Plain	Chloride	mg/l	1.010	2.44	3.07	6.02	11.46	124.00	11.58	6.76	16.06	1186	7
Mississippi Alluvial Plain	Hardness, Ca, Mg	mg/l	4.000	40.12	62.88	120.00	163.00	772.00	119.27	100.50	66.67	548	7
Mississippi Alluvial Plain	Sulfate	mg/l	0.020	3.00	4.04	6.12	11.23	113.00	8.68	6.64	7.51	1193	7
Mississippi Alluvial Plain	Calcium	mg/l	1.000	10.38	16.80	28.70	36.40	284.00	28.75	24.48	17.83	549	7
Mississippi Alluvial Plain	Total Recoverable Calcium	mg/l	2.310	11.12	17.00	26.30	36.80	258.00	28.43	23.85	21.55	193	5
Mississippi Alluvial Plain	Sodium	mg/l	0.020	1.62	2.26	4.50	8.95	297.00	8.41	4.53	20.70	549	7
Mississippi Alluvial Plain	Potassium	mg/l	0.230	0.90	1.50	3.10	4.65	13.10	3.43	2.65	2.31	549	7
Mississippi Alluvial Plain	Magnesium	mg/l	0.434	3.37	5.38	10.80	17.20	31.60	11.58	9.38	6.74	549	7
Mississippi Alluvial Plain	Specific Conductivity	µS/cm	57.400	110.40	152.00	239.00	329.00	891.00	259.08	224.37	146.05	253	5
Mississippi Alluvial Plain	Total dissolved solids	mg/l	48.000	97.00	129.00	159.25	188.38	717.00	167.94	156.55	67.66	1194	7
Mississippi Alluvial Plain	Aluminum	mg/l	0.008	0.01	0.01	0.05	0.15	2.14	0.11	0.04	0.20	549	7
Mississippi Alluvial Plain	Total Recoverable Aluminum	mg/l	0.005	0.05	0.10	0.27	0.68	5.38	0.54	0.25	0.73	193	5
Mississippi Alluvial Plain	Iron	mg/l	0.001	0.01	0.02	0.05	0.14	2.37	0.13	0.06	0.23	548	7
Mississippi Alluvial Plain	Total Recoverable Iron	mg/l	0.039	0.15	0.24	0.57	1.01	6.76	0.81	0.52	0.86	193	5
Mississippi Alluvial Plain	Ammonia-nitrogen	mg/l	0.003	0.01	0.02	0.02	0.04	0.76	0.04	0.02	0.05	1183	7
Mississippi Alluvial Plain	Nitrite + Nitrate as Nitrogen	mg/l	0.005	0.01	0.03	0.09	0.22	1.57	0.15	0.07	0.17	1188	7

Ecoregion	Parameter	Unit	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Mississippi Alluvial Plain	Total Kjeldahl nitrogen	mg/l	0.025	0.14	0.40	0.63	0.83	2.51	0.63	0.50	0.35	857	7
Mississippi Alluvial Plain	Total Phosphorus	mg/l	0.006	0.03	0.07	0.14	0.21	1.05	0.15	0.11	0.11	1167	7
Mississippi Alluvial Plain	Orthophosphate	mg/l	0.003	0.01	0.02	0.07	0.10	0.60	0.08	0.05	0.06	1190	7
Mississippi Alluvial Plain	Total suspended solids	mg/l	0.500	2.00	4.50	10.00	24.50	492.00	22.69	10.46	37.43	1185	7
Mississippi Alluvial Plain	pH	NA	3.420	6.73	7.09	7.49	7.91	10.40	7.46	7.43	0.62	1169	7
Mississippi Alluvial Plain	Temperature	°C	0.400	7.30	11.00	18.00	24.30	34.00	17.69	15.52	7.65	1170	7
Ouachita Mountains	Alkalinity, total	mg/l $CaCO_3$	0.050	5.59	10.30	20.40	42.28	115.00	27.78	19.07	22.04	2178	39
Ouachita Mountains	Bicarbonate	mg/l	0.026	6.94	12.81	24.87	52.25	144.29	34.36	23.55	27.45	2104	39
Ouachita Mountains	Chloride	mg/l	0.250	1.37	1.58	1.94	2.43	37.40	2.20	2.01	1.60	3048	41
Ouachita Mountains	Hardness, Ca, Mg	mg/l	0.500	8.81	13.00	23.00	47.08	406.00	31.75	23.78	25.08	1686	40
Ouachita Mountains	Sulfate	mg/l	0.350	2.74	3.41	4.52	6.11	458.00	5.61	4.68	9.10	3041	41
Ouachita Mountains	Calcium	mg/l	0.010	1.83	3.09	6.50	14.30	115.00	9.34	6.32	8.04	1693	40
Ouachita Mountains	Total Recoverable Calcium	mg/l	0.279	1.83	2.86	6.44	14.50	40.90	9.13	6.13	7.48	1036	38
Ouachita Mountains	Sodium	mg/l	0.010	1.10	1.48	1.87	2.40	160.00	2.26	1.79	4.34	1686	40
Ouachita Mountains	Potassium	mg/l	0.010	0.45	0.57	0.75	1.07	5.76	0.87	0.77	0.49	1693	40
Ouachita Mountains	Magnesium	mg/l	0.010	0.89	1.15	1.60	2.50	28.90	2.03	1.72	1.38	1693	40
Ouachita Mountains	Specific Conductivity	µS/cm	2.960	29.00	38.00	58.00	105.00	472.00	73.43	60.92	46.95	1203	32

Ecoregion	Parameter	Unit	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Ouachita Mountains	Total dissolved solids	mg/l	12.000	28.00	34.50	45.00	63.00	712.00	51.21	46.68	25.89	3037	41
Ouachita Mountains	Aluminum	mg/l	0.008	0.01	0.01	0.02	0.06	0.59	0.04	0.03	0.05	1693	40
Ouachita Mountains	Total Recoverable Aluminum	mg/l	0.005	0.01	0.02	0.04	0.11	2.11	0.09	0.05	0.16	1036	38
Ouachita Mountains	Iron	mg/l	0.007	0.01	0.03	0.04	0.08	0.59	0.06	0.04	0.06	1693	40
Ouachita Mountains	Total Recoverable Iron	mg/l	0.010	0.03	0.03	0.08	0.16	2.90	0.13	0.07	0.20	1036	38
Ouachita Mountains	Ammonia-nitrogen	mg/l	0.003	0.02	0.02	0.02	0.03	0.64	0.02	0.02	0.03	3031	41
Ouachita Mountains	Nitrite + Nitrate as Nitrogen	mg/l	0.003	0.01	0.03	0.05	0.14	13.30	0.12	0.05	0.36	3031	41
Ouachita Mountains	Total Kjeldahl nitrogen	mg/l	0.015	0.05	0.09	0.16	0.26	4.68	0.20	0.15	0.20	2468	40
Ouachita Mountains	Total Phosphorus	mg/l	0.005	0.01	0.01	0.02	0.04	2.03	0.04	0.02	0.08	2986	41
Ouachita Mountains	Orthophosphate	mg/l	0.003	0.01	0.01	0.01	0.02	1.50	0.02	0.01	0.06	3041	41
Ouachita Mountains	Total suspended solids	mg/l	0.500	0.50	0.50	1.50	3.25	868.00	4.36	1.69	21.01	3036	41
Ouachita Mountains	pH	NA	4.010	6.41	6.79	7.11	7.37	13.20	7.05	7.03	0.51	2957	42
Ouachita Mountains	Temperature	°C	1.000	7.80	11.70	17.90	24.00	34.00	17.69	15.86	7.23	2997	42
Ozark Highlands	Alkalinity, total	mg/l $CaCO_3$	1.800	69.48	100.51	133.00	199.00	428.00	144.39	130.47	58.98	3725	65
Ozark Highlands	Bicarbonate	mg/l	2.245	86.82	125.20	166.19	247.79	527.42	179.70	162.48	73.02	3630	64
Ozark Highlands	Chloride	mg/l	0.250	2.06	2.65	3.39	5.30	62.60	5.65	4.10	6.15	6446	71
Ozark Highlands	Hardness, Ca, Mg	mg/l	1.000	79.00	113.00	145.00	211.00	2160.00	162.43	144.38	100.75	2403	70

Ecoregion	Parameter	Unit	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Ozark Highlands	Sulfate	mg/l	0.020	3.21	3.98	5.35	7.84	75.00	7.08	5.87	5.46	6454	71
Ozark Highlands	Calcium	mg/l	0.025	25.90	35.00	42.30	47.90	452.00	43.42	39.60	29.94	2430	70
Ozark Highlands	Total Recoverable Calcium	mg/l	5.120	25.68	34.80	42.75	48.80	468.00	48.10	41.00	48.74	860	45
Ozark Highlands	Sodium	mg/l	0.020	1.18	1.60	2.10	5.26	210.00	5.28	2.68	9.06	2425	70
Ozark Highlands	Potassium	mg/l	0.045	0.80	1.19	1.60	2.50	25.10	2.11	1.70	1.72	2430	70
Ozark Highlands	Magnesium	mg/l	0.065	1.80	2.19	7.38	24.90	253.00	13.16	7.14	13.25	2430	70
Ozark Highlands	Specific Conductivity	µS/cm	4.570	148.00	200.75	279.00	381.00	568.00	285.37	262.58	105.22	1847	55
Ozark Highlands	Total dissolved solids	mg/l	6.000	108.00	145.00	191.00	224.00	477.00	182.87	174.34	51.02	5027	68
Ozark Highlands	Aluminum	mg/l	0.008	0.01	0.01	0.02	0.13	1.03	0.08	0.03	0.10	2430	70
Ozark Highlands	Total Recoverable Aluminum	mg/l	0.005	0.02	0.05	0.07	0.13	8.40	0.18	0.08	0.53	860	45
Ozark Highlands	Iron	mg/l	0.001	0.01	0.01	0.02	0.04	0.88	0.03	0.02	0.04	2430	70
Ozark Highlands	Total Recoverable Iron	mg/l	0.010	0.03	0.05	0.08	0.15	10.20	0.18	0.09	0.56	860	45
Ozark Highlands	Ammonia-nitrogen	mg/l	0.000	0.01	0.02	0.02	0.03	1.50	0.02	0.02	0.03	6449	71
Ozark Highlands	Nitrite + Nitrate as Nitrogen	mg/l	0.001	0.03	0.12	0.41	1.04	24.80	0.78	0.32	1.02	6401	71
Ozark Highlands	Total Kjeldahl nitrogen	mg/l	0.005	0.05	0.12	0.19	0.30	44.00	0.26	0.18	0.76	3757	57
Ozark Highlands	Total Phosphorus	mg/l	0.005	0.01	0.02	0.04	0.08	4.86	0.09	0.05	0.20	5148	68
Ozark Highlands	Orthophosphate	mg/l	0.002	0.01	0.01	0.02	0.04	4.39	0.06	0.02	0.18	6444	71

Ecoregion	Parameter	Unit	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Ozark Highlands	Total suspended solids	mg/l	0.500	1.00	2.00	4.00	8.00	1130.00	11.79	3.97	46.14	5024	68
Ozark Highlands	pH	NA	4.580	7.26	7.62	7.91	8.15	10.23	7.85	7.84	0.45	6188	78
Ozark Highlands	Temperature	°C	0.460	7.50	11.00	15.70	22.00	34.00	16.41	14.76	6.88	6365	78
South Central Plains	Alkalinity, total	mg/l $CaCO_3$	0.050	3.00	8.29	20.40	40.95	342.00	28.40	16.65	30.82	1802	28
South Central Plains	Bicarbonate	mg/l	0.063	3.77	10.43	25.50	51.76	428.52	35.69	20.90	38.93	1753	28
South Central Plains	Chloride	mg/l	0.190	2.29	3.07	4.13	5.60	165.00	5.35	4.33	6.29	2914	28
South Central Plains	Hardness, Ca, Mg	mg/l	0.025	10.00	16.00	29.00	44.00	1710.00	36.40	26.20	65.93	1468	28
South Central Plains	Sulfate	mg/l	0.250	3.43	5.27	10.50	20.60	255.00	15.68	10.44	15.83	2921	28
South Central Plains	Calcium	mg/l	0.010	2.48	4.17	7.50	11.95	680.00	10.38	6.90	25.40	1483	28
South Central Plains	Total Recoverable Calcium	mg/l	0.909	2.03	3.69	6.89	11.10	627.00	12.28	6.78	35.26	746	28
South Central Plains	Sodium	mg/l	0.010	1.98	3.30	6.05	10.20	187.00	8.36	5.55	9.84	1482	28
South Central Plains	Potassium	mg/l	0.010	0.80	1.15	1.56	2.20	16.50	1.82	1.52	1.24	1483	28
South Central Plains	Magnesium	mg/l	0.010	0.80	1.30	2.31	3.40	33.00	2.52	2.01	1.94	1483	28
South Central Plains	Specific Conductivity	µS/cm	5.940	37.90	56.80	92.00	134.00	1150.00	118.97	90.62	114.07	841	22
South Central Plains	Total dissolved solids	mg/l	12.000	56.00	69.00	83.00	99.75	642.00	90.25	83.90	42.94	2923	28
South Central Plains	Aluminum	mg/l	0.008	0.02	0.04	0.06	0.14	1.09	0.11	0.07	0.12	1483	28
South Central Plains	Total Recoverable Aluminum	mg/l	0.020	0.11	0.19	0.37	0.66	4.39	0.50	0.35	0.48	746	28

Ecoregion	Parameter	Unit	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
South Central Plains	Iron	mg/l	0.005	0.07	0.14	0.30	0.53	2.79	0.38	0.26	0.34	1483	28
South Central Plains	Total Recoverable Iron	mg/l	0.050	0.29	0.59	0.94	1.47	6.25	1.16	0.88	0.90	746	28
South Central Plains	Ammonia-nitrogen	mg/l	0.003	0.02	0.02	0.03	0.04	10.20	0.04	0.02	0.20	2911	28
South Central Plains	Nitrite + Nitrate as Nitrogen	mg/l	0.001	0.01	0.03	0.10	0.18	7.75	0.15	0.08	0.31	2916	28
South Central Plains	Total Kjeldahl nitrogen	mg/l	0.025	0.22	0.30	0.43	0.63	11.10	0.49	0.42	0.36	2307	28
South Central Plains	Total Phosphorus	mg/l	0.005	0.02	0.04	0.06	0.09	3.87	0.08	0.06	0.16	2871	28
South Central Plains	Orthophosphate	mg/l	0.003	0.01	0.01	0.02	0.03	2.94	0.04	0.02	0.13	2909	28
South Central Plains	Total suspended solids	mg/l	0.500	2.50	4.50	7.50	12.50	414.00	11.63	7.42	17.77	2922	28
South Central Plains	pH	NA	4.300	6.00	6.41	6.83	7.17	9.39	6.77	6.74	0.62	2875	28
South Central Plains	Temperature	°C	1.000	8.00	12.00	18.00	25.00	36.60	18.23	16.36	7.56	2879	28

Table A.2.2. Summary station median statistics for all stations.

Ecoregion	Parameter	Unit	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Arkansas Valley	Alkalinity, total	mg/l $CaCO_3$	0.050	3.00	10.60	24.50	75.90	418.00	43.09	24.27	41.48	4324	72
Arkansas Valley	Bicarbonate	mg/l	0.063	3.77	13.07	30.61	94.74	321.33	53.69	30.17	51.38	4177	72
Arkansas Valley	Chloride	mg/l	0.035	1.65	2.84	5.70	45.90	1890.00	31.01	9.83	56.24	6795	86
Arkansas Valley	Hardness, Ca, Mg	mg/l	0.500	10.00	13.00	24.00	92.35	1050.00	54.43	32.00	62.65	3307	85
Arkansas Valley	Sulfate	mg/l	0.020	2.51	3.42	10.30	38.11	338.00	23.91	11.47	29.30	6812	86
Arkansas Valley	Calcium	mg/l	0.066	2.00	2.70	5.10	23.05	406.00	14.10	7.15	19.98	3319	85
Arkansas Valley	Total Recoverable Calcium	mg/l	1.040	2.04	2.72	4.94	21.60	413.00	14.55	7.08	26.18	1387	48
Arkansas Valley	Sodium	mg/l	0.020	1.41	2.43	6.29	36.40	679.30	24.80	8.44	39.77	3319	85
Arkansas Valley	Potassium	mg/l	0.010	0.70	1.20	2.28	3.80	46.00	3.28	2.15	4.53	3319	85
Arkansas Valley	Magnesium	mg/l	0.010	1.02	1.48	2.90	7.00	58.90	4.66	3.12	4.47	3319	85
Arkansas Valley	Specific Conductivity	µS/cm	2.380	29.00	38.43	61.15	262.75	1300.00	184.10	95.02	228.93	2098	43
Arkansas Valley	Total dissolved solids	mg/l	7.000	30.50	41.00	77.00	248.00	5020.00	154.48	96.82	166.56	6836	86
Arkansas Valley	Aluminum	mg/l	0.008	0.01	0.02	0.05	0.07	1.21	0.08	0.04	0.10	3319	85
Arkansas Valley	Total Recoverable Aluminum	mg/l	0.010	0.07	0.12	0.25	0.48	4.47	0.37	0.24	0.39	1387	48
Arkansas Valley	Iron	mg/l	0.001	0.02	0.05	0.11	0.21	7.65	0.17	0.09	0.25	3319	85
Arkansas Valley	Total Recoverable Iron	mg/l	0.025	0.17	0.26	0.44	0.78	6.88	0.59	0.44	0.50	1387	48
Arkansas Valley	Ammonia-nitrogen	mg/l	0.001	0.02	0.02	0.03	0.06	19.00	0.21	0.03	1.15	6760	86
Arkansas Valley	Nitrite + Nitrate as Nitrogen	mg/l	0.005	0.02	0.06	0.21	0.45	51.50	0.67	0.17	2.13	6786	86
Arkansas Valley	Total Kjeldahl nitrogen	mg/l	0.025	0.11	0.24	0.46	0.65	25.80	0.72	0.39	1.55	5645	86
Arkansas Valley	Total Phosphorus	mg/l	0.001	0.02	0.03	0.07	0.12	25.76	0.26	0.07	1.07	6701	86
Arkansas Valley	Orthophosphate	mg/l	0.003	0.01	0.01	0.02	0.06	17.80	0.20	0.03	0.95	6778	86
Arkansas Valley	Total suspended solids	mg/l	0.250	1.00	2.50	6.30	13.00	960.00	11.95	5.58	24.47	6845	86

Ecoregion	Parameter	Unit	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Arkansas Valley	pH	NA	4.000	6.35	6.68	7.05	7.50	9.91	7.08	7.05	0.63	6570	86
Arkansas Valley	Temperature	°C	0.200	7.00	10.90	17.80	25.00	36.30	17.87	15.60	8.16	6794	86
Boston Mountains	Alkalinity, total	mg/l $CaCO_3$	0.299	10.10	19.80	35.00	56.00	178.00	43.64	31.86	33.36	1649	63
Boston Mountains	Bicarbonate	mg/l	0.376	12.63	24.99	43.80	70.21	219.82	54.69	39.90	41.77	1593	63
Boston Mountains	Chloride	mg/l	0.250	1.27	1.75	2.45	3.52	239.00	3.85	2.66	8.33	2723	90
Boston Mountains	Hardness, Ca, Mg	mg/l	1.000	10.30	17.00	35.80	57.00	622.00	45.05	32.65	39.87	1413	68
Boston Mountains	Sulfate	mg/l	0.020	2.62	3.66	5.87	10.90	110.48	10.22	6.75	12.08	2724	89
Boston Mountains	Calcium	mg/l	0.100	2.52	4.72	11.60	19.00	243.00	14.67	9.87	14.15	1419	68
Boston Mountains	Total Recoverable Calcium	mg/l	1.110	2.39	4.08	11.00	17.30	234.00	13.06	8.88	14.27	477	37
Boston Mountains	Sodium	mg/l	0.020	1.03	1.42	2.04	3.56	161.00	4.00	2.36	8.28	1421	68
Boston Mountains	Potassium	mg/l	0.100	0.60	0.80	1.12	1.60	21.50	1.40	1.13	1.25	1421	68
Boston Mountains	Magnesium	mg/l	0.200	0.90	1.20	1.67	2.40	24.70	2.07	1.76	1.44	1421	68
Boston Mountains	Specific Conductivity	µS/cm	18.000	34.20	52.80	91.00	144.00	437.00	112.52	89.06	79.47	723	39
Boston Mountains	Total dissolved solids	mg/l	13.000	32.00	43.38	62.00	92.00	564.00	77.92	65.47	52.79	2312	80
Boston Mountains	Aluminum	mg/l	0.008	0.01	0.01	0.02	0.06	1.28	0.05	0.03	0.08	1421	68
Boston Mountains	Total Recoverable Aluminum	mg/l	0.010	0.04	0.06	0.13	0.27	14.70	0.29	0.13	0.79	477	37
Boston Mountains	Iron	mg/l	0.001	0.01	0.01	0.03	0.05	0.94	0.04	0.03	0.05	1421	68
Boston Mountains	Total Recoverable Iron	mg/l	0.021	0.06	0.10	0.18	0.29	20.80	0.31	0.18	1.02	477	37
Boston Mountains	Ammonia-nitrogen	mg/l	0.002	0.01	0.02	0.02	0.03	0.39	0.02	0.02	0.03	2739	90
Boston Mountains	Nitrite + Nitrate as Nitrogen	mg/l	0.005	0.02	0.04	0.12	0.39	4.86	0.29	0.11	0.45	2723	90
Boston Mountains	Total Kjeldahl nitrogen	mg/l	0.025	0.05	0.09	0.18	0.32	2.94	0.25	0.17	0.24	1893	67
Boston Mountains	Total Phosphorus	mg/l	0.004	0.01	0.02	0.03	0.05	4.81	0.05	0.03	0.13	2331	78
Boston Mountains	Orthophosphate	mg/l	0.001	0.01	0.01	0.01	0.02	1.51	0.02	0.01	0.07	2741	90
Boston Mountains	Total suspended solids	mg/l	0.500	0.50	1.00	2.50	7.50	744.00	9.68	2.78	34.46	2305	80

Ecoregion	Parameter	Unit	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Boston Mountains	pH	NA	4.780	6.57	6.98	7.37	7.69	11.30	7.32	7.30	0.59	2584	89
Boston Mountains	Temperature	ºC	0.400	7.00	10.00	16.00	23.00	34.00	16.50	14.47	7.54	2647	89
Mississippi Alluvial Plain	Alkalinity, total	mg/l $CaCO_3$	0.203	16.20	36.10	79.30	121.00	456.00	82.92	60.75	54.22	4703	95
Mississippi Alluvial Plain	Bicarbonate	mg/l	0.255	20.49	45.50	98.95	150.84	570.10	103.36	75.90	67.45	4572	95
Mississippi Alluvial Plain	Chloride	mg/l	0.100	2.67	3.79	6.75	21.60	683.00	20.21	9.40	30.76	8077	102
Mississippi Alluvial Plain	Hardness, Ca, Mg	mg/l	0.500	21.00	42.00	94.00	139.00	970.00	97.26	74.01	65.97	4270	102
Mississippi Alluvial Plain	Sulfate	mg/l	0.020	3.71	5.23	7.85	15.40	221.00	13.89	9.22	15.47	8101	102
Mississippi Alluvial Plain	Calcium	mg/l	0.010	5.40	11.00	23.60	34.60	374.00	24.46	18.60	17.70	4287	102
Mississippi Alluvial Plain	Total Recoverable Calcium	mg/l	1.490	5.49	11.40	22.75	34.30	505.00	25.51	18.84	28.05	1550	68
Mississippi Alluvial Plain	Sodium	mg/l	0.010	1.93	3.08	6.29	16.88	481.00	15.23	7.11	24.26	4278	102
Mississippi Alluvial Plain	Potassium	mg/l	0.010	1.16	1.80	3.00	4.38	61.50	3.38	2.74	2.47	4287	102
Mississippi Alluvial Plain	Magnesium	mg/l	0.010	1.80	3.50	7.80	12.60	46.40	8.83	6.52	6.19	4287	102
Mississippi Alluvial Plain	Specific Conductivity	µS/cm	8.440	63.36	116.00	215.00	306.13	957.00	237.13	188.66	158.28	1740	36
Mississippi Alluvial Plain	Total dissolved solids	mg/l	8.000	77.00	117.00	154.50	200.00	1287.50	171.24	149.45	91.52	8119	102
Mississippi Alluvial Plain	Aluminum	mg/l	0.008	0.01	0.01	0.06	0.16	2.66	0.12	0.05	0.21	4286	102
Mississippi Alluvial Plain	Total Recoverable Aluminum	mg/l	0.005	0.09	0.20	0.43	0.92	18.60	0.85	0.42	1.46	1550	68
Mississippi Alluvial Plain	Iron	mg/l	0.001	0.01	0.02	0.06	0.22	5.35	0.17	0.07	0.28	4285	102
Mississippi Alluvial Plain	Total Recoverable Iron	mg/l	0.025	0.19	0.36	0.69	1.30	21.10	1.12	0.68	1.66	1550	68

Ecoregion	Parameter	Unit	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Mississippi Alluvial Plain	Ammonia-nitrogen	mg/l	0.001	0.02	0.02	0.03	0.07	8.67	0.06	0.03	0.15	8056	102
Mississippi Alluvial Plain	Nitrite + Nitrate as Nitrogen	mg/l	0.005	0.02	0.07	0.18	0.31	12.10	0.27	0.14	0.54	8075	102
Mississippi Alluvial Plain	Total Kjeldahl nitrogen	mg/l	0.022	0.24	0.41	0.63	0.89	9.76	0.70	0.58	0.48	6360	101
Mississippi Alluvial Plain	Total Phosphorus	mg/l	0.006	0.04	0.07	0.13	0.21	5.38	0.18	0.12	0.26	7962	102
Mississippi Alluvial Plain	Orthophosphate	mg/l	0.003	0.01	0.02	0.06	0.10	5.39	0.10	0.05	0.21	8077	102
Mississippi Alluvial Plain	Total suspended solids	mg/l	0.500	4.00	7.50	15.50	30.00	1170.00	26.75	14.87	47.04	8073	102
Mississippi Alluvial Plain	pH	NA	2.620	6.55	6.93	7.40	7.80	10.40	7.35	7.33	0.63	7885	102
Mississippi Alluvial Plain	Temperature	°C	0.400	7.50	11.10	18.00	25.00	35.00	18.02	15.89	7.83	7945	102
Mississippi Valley Loess Plains	Alkalinity, total	mg/l $CaCO_3$	3.000	19.57	30.03	64.70	102.00	275.00	70.03	54.78	44.51	168	1
Mississippi Valley Loess Plains	Bicarbonate	mg/l	3.770	24.56	37.61	80.95	126.81	341.35	87.24	68.39	55.17	168	1
Mississippi Valley Loess Plains	Chloride	mg/l	1.080	2.70	4.58	11.40	21.83	186.00	15.31	10.03	17.77	168	1
Mississippi Valley Loess Plains	Hardness, Ca, Mg	mg/l	2.000	26.85	38.78	69.50	96.50	173.00	71.69	60.31	37.04	80	1
Mississippi Valley Loess Plains	Sulfate	mg/l	2.600	4.90	7.08	12.40	17.83	66.70	13.47	11.23	8.52	168	1
Mississippi Valley Loess Plains	Calcium	mg/l	0.352	6.14	9.37	17.60	24.30	46.80	17.50	14.60	9.18	81	1
Mississippi Valley Loess Plains	Total Recoverable Calcium	mg/l	4.140	6.99	9.30	17.20	22.20	53.50	17.24	14.87	9.51	51	1
Mississippi Valley Loess Plains	Sodium	mg/l	1.050	3.42	4.72	14.40	22.80	77.70	16.18	11.07	13.83	81	1
Mississippi Valley Loess Plains	Potassium	mg/l	0.694	2.24	2.71	3.56	4.22	38.00	4.92	3.77	6.01	81	1

Ecoregion	Parameter	Unit	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Mississippi Valley Loess Plains	Magnesium	mg/l	0.182	2.89	3.53	6.69	8.72	20.70	6.77	5.73	3.54	81	1
Mississippi Valley Loess Plains	Specific Conductivity	µS/cm	45.400	70.88	89.00	164.00	318.00	558.00	203.87	165.58	125.91	73	1
Mississippi Valley Loess Plains	Total dissolved solids	mg/l	65.500	91.70	109.00	151.00	210.50	515.00	162.51	150.64	66.66	168	1
Mississippi Valley Loess Plains	Aluminum	mg/l	0.010	0.01	0.01	0.05	0.20	2.47	0.15	0.06	0.30	81	1
Mississippi Valley Loess Plains	Total Recoverable Aluminum	mg/l	0.045	0.11	0.28	0.71	1.27	6.91	1.01	0.55	1.31	51	1
Mississippi Valley Loess Plains	Iron	mg/l	0.010	0.05	0.06	0.13	0.23	2.57	0.18	0.12	0.29	81	1
Mississippi Valley Loess Plains	Total Recoverable Iron	mg/l	0.093	0.36	0.52	0.79	1.30	10.50	1.20	0.82	1.61	51	1
Mississippi Valley Loess Plains	Ammonia-nitrogen	mg/l	0.015	0.02	0.02	0.04	0.11	8.56	0.17	0.05	0.72	167	1
Mississippi Valley Loess Plains	Nitrite + Nitrate as Nitrogen	mg/l	0.005	0.02	0.03	0.14	0.31	5.06	0.26	0.11	0.45	168	1
Mississippi Valley Loess Plains	Total Kjeldahl nitrogen	mg/l	0.224	0.48	0.62	0.73	0.97	21.00	1.05	0.82	1.68	165	1
Mississippi Valley Loess Plains	Total Phosphorus	mg/l	0.060	0.12	0.14	0.27	0.50	5.35	0.53	0.31	0.76	168	1
Mississippi Valley Loess Plains	Orthophosphate	mg/l	0.010	0.03	0.06	0.13	0.29	5.35	0.38	0.15	0.70	168	1
Mississippi Valley Loess Plains	Total suspended solids	mg/l	1.000	3.50	7.38	14.75	29.85	903.00	48.06	16.21	120.06	168	1
Mississippi Valley Loess Plains	pH	NA	6.400	6.91	7.21	7.49	7.81	9.33	7.50	7.48	0.48	168	1
Mississippi Valley Loess Plains	Temperature	°C	0.200	4.81	9.65	16.15	24.70	33.40	16.94	13.57	8.74	168	1
Ouachita Mountains	Alkalinity, total	mg/l $CaCO_3$	0.050	3.00	8.36	14.80	29.35	190.00	21.86	14.48	19.98	4925	102
Ouachita Mountains	Bicarbonate	mg/l	0.026	3.77	10.43	18.45	36.25	238.43	27.09	17.97	24.78	4791	102
Ouachita Mountains	Chloride	mg/l	0.100	1.47	1.77	2.38	3.39	129.00	3.89	2.72	6.23	6913	129

Ecoregion	Parameter	Unit	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Ouachita Mountains	Hardness, Ca, Mg	mg/l	0.234	8.00	11.10	19.00	39.00	1400.00	39.47	21.94	88.04	4147	113
Ouachita Mountains	Sulfate	mg/l	0.020	2.43	3.29	4.71	7.60	1380.00	17.51	5.72	80.43	6910	129
Ouachita Mountains	Calcium	mg/l	0.010	1.30	2.18	4.80	10.90	372.00	10.49	5.01	24.40	4156	113
Ouachita Mountains	Total Recoverable Calcium	mg/l	0.020	1.18	2.22	4.97	12.40	331.00	10.76	5.17	23.72	2508	94
Ouachita Mountains	Sodium	mg/l	0.010	1.26	1.69	2.31	3.47	196.00	3.92	2.51	7.99	4148	113
Ouachita Mountains	Potassium	mg/l	0.010	0.50	0.67	0.96	1.47	71.30	1.49	1.03	2.89	4156	113
Ouachita Mountains	Magnesium	mg/l	0.010	0.94	1.27	1.74	2.68	90.00	3.18	1.99	6.80	4158	113
Ouachita Mountains	Specific Conductivity	µS/cm	2.960	27.72	38.00	56.00	105.00	6370.00	99.73	64.80	195.66	2853	85
Ouachita Mountains	Total dissolved solids	mg/l	6.000	30.00	36.00	46.00	65.00	2100.00	69.61	51.71	119.32	6891	129
Ouachita Mountains	Aluminum	mg/l	0.008	0.01	0.02	0.02	0.06	29.90	0.23	0.03	1.66	4158	113
Ouachita Mountains	Total Recoverable Aluminum	mg/l	0.005	0.02	0.02	0.08	0.22	30.70	0.35	0.09	1.54	2508	94
Ouachita Mountains	Iron	mg/l	0.007	0.02	0.03	0.06	0.14	6.19	0.12	0.06	0.22	4158	113
Ouachita Mountains	Total Recoverable Iron	mg/l	0.010	0.03	0.06	0.15	0.32	7.57	0.27	0.14	0.42	2508	94
Ouachita Mountains	Ammonia-nitrogen	mg/l	0.001	0.02	0.02	0.02	0.03	3.52	0.04	0.02	0.11	6889	129
Ouachita Mountains	Nitrite + Nitrate as Nitrogen	mg/l	0.003	0.01	0.03	0.07	0.19	43.40	0.31	0.08	1.48	6891	129
Ouachita Mountains	Total Kjeldahl nitrogen	mg/l	0.015	0.05	0.11	0.20	0.35	9.05	0.29	0.19	0.35	5756	112
Ouachita Mountains	Total Phosphorus	mg/l	0.004	0.01	0.02	0.03	0.05	23.00	0.15	0.03	1.03	6786	129
Ouachita Mountains	Orthophosphate	mg/l	0.003	0.01	0.01	0.01	0.02	27.52	0.13	0.02	1.05	6907	129
Ouachita Mountains	Total suspended solids	mg/l	0.500	0.50	1.00	2.00	4.00	868.00	4.76	2.00	17.47	6916	129
Ouachita Mountains	pH	NA	3.270	6.12	6.52	6.93	7.24	14.00	6.85	6.82	0.68	6750	132
Ouachita Mountains	Temperature	°C	1.000	7.70	11.40	17.70	24.00	35.00	17.58	15.71	7.34	6814	132
Ozark Highlands	Alkalinity, total	mg/l $CaCO_3$	1.800	83.10	112.00	135.38	177.00	428.00	143.11	133.46	48.90	8236	172
Ozark Highlands	Bicarbonate	mg/l	1.614	103.40	139.03	169.36	220.00	527.42	178.12	166.15	60.49	7997	171
Ozark Highlands	Chloride	mg/l	0.015	2.34	3.10	4.74	9.07	900.00	9.87	5.79	19.39	13583	215

Ecoregion	Parameter	Unit	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Ozark Highlands	Hardness, Ca, Mg	mg/l	0.500	94.00	122.00	145.00	186.00	2160.00	158.48	144.36	96.66	5493	189
Ozark Highlands	Sulfate	mg/l	0.020	3.69	4.78	6.66	10.80	109.00	9.65	7.51	8.70	13573	215
Ozark Highlands	Calcium	mg/l	0.025	29.00	37.00	45.10	52.30	663.00	47.47	43.19	34.93	5570	190
Ozark Highlands	Total Recoverable Calcium	mg/l	1.690	29.72	37.30	46.18	54.70	707.00	54.76	45.69	61.84	2082	104
Ozark Highlands	Sodium	mg/l	0.020	1.39	1.93	3.32	8.08	2515.00	9.21	4.06	37.15	5562	190
Ozark Highlands	Potassium	mg/l	0.045	0.90	1.29	1.82	3.08	47.40	2.69	1.99	2.81	5571	190
Ozark Highlands	Magnesium	mg/l	0.065	1.79	2.17	3.60	17.38	253.00	9.83	5.59	10.86	5571	190
Ozark Highlands	Specific Conductivity	µS/cm	2.000	181.00	248.75	318.00	383.00	1540.00	315.29	294.38	107.75	4124	128
Ozark Highlands	Total dissolved solids	mg/l	6.000	126.00	156.00	190.50	224.00	7701.50	195.35	184.94	97.11	11165	200
Ozark Highlands	Aluminum	mg/l	0.008	0.01	0.01	0.02	0.13	1.03	0.08	0.03	0.10	5571	190
Ozark Highlands	Total Recoverable Aluminum	mg/l	0.005	0.02	0.02	0.05	0.10	8.40	0.16	0.06	0.52	2084	104
Ozark Highlands	Iron	mg/l	0.001	0.01	0.01	0.02	0.04	0.88	0.03	0.02	0.04	5571	190
Ozark Highlands	Total Recoverable Iron	mg/l	0.010	0.03	0.03	0.05	0.11	10.20	0.15	0.06	0.55	2084	104
Ozark Highlands	Ammonia-nitrogen	mg/l	0.000	0.01	0.02	0.02	0.03	5.55	0.03	0.02	0.10	13584	214
Ozark Highlands	Nitrite + Nitrate as Nitrogen	mg/l	0.001	0.06	0.22	0.61	1.74	25.30	1.24	0.52	1.66	13468	214
Ozark Highlands	Total Kjeldahl nitrogen	mg/l	0.005	0.06	0.14	0.23	0.37	60.00	0.32	0.21	0.87	8896	161
Ozark Highlands	Total Phosphorus	mg/l	0.003	0.01	0.03	0.05	0.11	13.83	0.22	0.06	0.68	11310	200
Ozark Highlands	Orthophosphate	mg/l	0.002	0.01	0.01	0.02	0.06	12.50	0.17	0.03	0.61	13572	214
Ozark Highlands	Total suspended solids	mg/l	0.500	0.50	1.00	2.50	6.00	1130.00	9.09	2.81	39.89	11166	200
Ozark Highlands	pH	NA	4.580	7.28	7.60	7.90	8.15	11.93	7.85	7.84	0.45	13128	221
Ozark Highlands	Temperature	°C	0.460	8.00	11.00	15.90	21.86	37.20	16.36	14.84	6.63	13448	221
South Central Plains	Alkalinity, total	mg/l $CaCO_3$	0.050	3.00	10.40	20.40	42.25	1040.00	34.65	19.49	43.62	8935	180
South Central Plains	Bicarbonate	mg/l	0.063	3.77	12.82	25.10	53.29	1306.38	43.59	24.27	55.32	8597	180
South Central Plains	Chloride	mg/l	0.035	2.39	3.37	5.83	17.90	2970.00	24.61	8.53	68.50	13969	195

Ecoregion	Parameter	Unit	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
South Central Plains	Hardness, Ca, Mg	mg/l	0.025	11.00	17.99	27.30	48.00	1710.00	44.78	29.77	62.23	7296	193
South Central Plains	Sulfate	mg/l	0.020	3.19	4.92	9.30	21.20	817.00	26.11	11.29	51.67	13983	195
South Central Plains	Calcium	mg/l	0.010	2.68	4.59	7.50	13.50	680.00	12.70	7.99	19.68	7457	193
South Central Plains	Total Recoverable Calcium	mg/l	0.250	2.50	4.30	7.00	13.30	696.00	13.48	7.81	28.60	3608	165
South Central Plains	Sodium	mg/l	0.010	2.35	3.50	6.36	15.00	566.20	19.31	7.95	39.80	7449	193
South Central Plains	Potassium	mg/l	0.010	0.95	1.30	2.00	3.30	48.70	2.85	2.09	3.02	7457	193
South Central Plains	Magnesium	mg/l	0.010	0.98	1.37	1.98	3.12	64.10	3.10	2.11	4.37	7457	193
South Central Plains	Specific Conductivity	µS/cm	5.350	41.42	60.00	93.70	160.00	1760.00	161.36	105.01	210.06	4313	129
South Central Plains	Total dissolved solids	mg/l	7.000	45.50	62.00	86.50	147.00	5231.00	149.96	103.57	187.59	14022	195
South Central Plains	Aluminum	mg/l	0.008	0.01	0.03	0.06	0.12	1.51	0.10	0.06	0.11	7457	193
South Central Plains	Total Recoverable Aluminum	mg/l	0.005	0.07	0.16	0.32	0.62	14.10	0.50	0.31	0.65	3608	165
South Central Plains	Iron	mg/l	0.001	0.05	0.13	0.28	0.52	7.46	0.40	0.24	0.43	7457	193
South Central Plains	Total Recoverable Iron	mg/l	0.025	0.30	0.57	0.94	1.45	12.50	1.16	0.86	0.95	3608	165
South Central Plains	Ammonia-nitrogen	mg/l	0.001	0.02	0.02	0.03	0.07	151.50	0.18	0.04	1.94	13954	195
South Central Plains	Nitrite + Nitrate as Nitrogen	mg/l	0.001	0.02	0.06	0.15	0.28	211.00	0.71	0.14	3.69	13969	195
South Central Plains	Total Kjeldahl nitrogen	mg/l	0.002	0.24	0.34	0.53	0.79	64.64	0.71	0.53	1.17	11401	191
South Central Plains	Total Phosphorus	mg/l	0.005	0.03	0.04	0.07	0.13	16.50	0.17	0.08	0.49	13729	195
South Central Plains	Orthophosphate	mg/l	0.002	0.01	0.01	0.02	0.05	9.35	0.10	0.03	0.42	13967	195
South Central Plains	Total suspended solids	mg/l	0.500	1.80	3.50	7.00	14.85	3232.00	17.92	7.52	49.95	14016	195
South Central Plains	pH	NA	0.650	6.05	6.46	6.85	7.20	10.05	6.82	6.79	0.63	13668	195
South Central Plains	Temperature	°C	1.000	8.50	12.00	18.10	25.00	39.00	18.37	16.66	7.31	13691	195

Table A.2.3. Summary statistics using multiple samples for least disturbed stations.

Ecoregion	Parameter	Unit	Fraction	Min	Per10	Per25	Per50	Per75	Max	Mean	GeoMean	SD	*N*	Sites
Arkansas Valley	Alkalinity, total	mg/l $CaCO_3$	Dissolved	0.050	3.00	7.20	11.80	18.30	117.18	14.72	10.68	12.41	1022	18
Arkansas Valley	Bicarbonate	mg/l	Dissolved	0.063	3.77	8.92	14.82	22.90	147.17	18.43	13.33	15.70	987	18
Arkansas Valley	Chloride	mg/l	Dissolved	0.190	1.50	2.20	3.33	4.54	112.00	3.76	3.13	4.16	1497	18
Arkansas Valley	Hardness, Ca, Mg	mg/l	Dissolved	4.000	9.00	11.00	13.30	19.00	95.00	16.52	14.73	9.44	753	18
Arkansas Valley	Sulfate	mg/l	Dissolved	0.020	2.14	2.73	3.66	5.87	71.60	4.91	3.95	4.75	1495	18
Arkansas Valley	Calcium	mg/l	Dissolved	1.200	1.90	2.27	2.81	3.71	26.80	3.33	2.99	2.08	757	18
Arkansas Valley	Total Recoverable Calcium	mg/l	Total Recoverable	1.330	2.00	2.33	2.93	3.88	28.30	3.41	3.10	2.01	348	12
Arkansas Valley	Sodium	mg/l	Dissolved	0.020	1.30	1.80	2.70	4.30	167.00	3.63	2.71	6.41	757	18
Arkansas Valley	Potassium	mg/l	Dissolved	0.010	0.63	0.95	1.45	2.20	11.00	1.77	1.43	1.20	757	18
Arkansas Valley	Magnesium	mg/l	Dissolved	0.212	0.90	1.12	1.59	2.42	7.30	1.99	1.70	1.24	757	18
Arkansas Valley	Specific Conductivity	µS/cm	Total	18.500	30.00	35.00	45.80	63.30	423.00	54.29	48.82	31.34	604	13
Arkansas Valley	Total dissolved solids	mg/l	Total	8.000	27.50	33.00	44.00	58.50	387.00	48.09	44.41	22.64	1497	18
Arkansas Valley	Aluminum	mg/l	Dissolved	0.008	0.01	0.02	0.05	0.06	0.93	0.07	0.04	0.09	757	18
Arkansas Valley	Total Recoverable Aluminum	mg/l	Total Recoverable	0.020	0.05	0.08	0.19	0.43	2.14	0.30	0.19	0.31	348	12
Arkansas Valley	Iron	mg/l	Dissolved	0.008	0.05	0.09	0.18	0.31	2.16	0.25	0.17	0.27	757	18
Arkansas Valley	Total Recoverable Iron	mg/l	Total Recoverable	0.103	0.22	0.31	0.52	0.86	3.27	0.67	0.52	0.51	348	12
Arkansas Valley	Ammonia-nitrogen	mg/l	Dissolved	0.002	0.02	0.02	0.02	0.04	3.44	0.04	0.02	0.11	1490	18
Arkansas Valley	Nitrite + Nitrate as Nitrogen	mg/l	Dissolved	0.005	0.03	0.06	0.15	0.28	3.01	0.21	0.12	0.23	1496	18
Arkansas Valley	Total Kjeldahl nitrogen	mg/l	Total	0.025	0.10	0.18	0.31	0.53	3.88	0.39	0.29	0.32	1249	18
Arkansas Valley	Total Phosphorus	mg/l	Total	0.002	0.01	0.02	0.04	0.07	1.17	0.06	0.04	0.07	1472	18
Arkansas Valley	Orthophosphate	mg/l	Dissolved	0.003	0.01	0.01	0.01	0.02	0.45	0.02	0.01	0.03	1493	18
Arkansas Valley	Total suspended solids	mg/l	Total	0.500	0.50	1.50	4.00	9.80	392.50	10.20	4.10	23.25	1495	18
Arkansas Valley	pH	NA	Total	4.000	6.23	6.50	6.75	7.06	8.82	6.78	6.76	0.51	1480	18

Ecoregion	Parameter	Unit	Fraction	Min	Per10	Per25	Per50	Per75	Max	Mean	GeoMean	SD	*N*	Sites
Arkansas Valley	Temperature	°C	Total	1.000	6.90	10.70	17.90	25.00	36.30	17.83	15.60	8.08	1525	18
Boston Mountains	Alkalinity, total	mg/l $CaCO_3$	Dissolved	0.299	8.30	14.00	24.80	35.63	164.00	28.18	21.51	20.89	888	35
Boston Mountains	Bicarbonate	mg/l	Dissolved	0.376	10.43	17.74	31.19	44.87	204.47	35.54	27.12	26.28	863	35
Boston Mountains	Chloride	mg/l	Dissolved	0.250	1.19	1.51	1.97	2.46	239.00	2.56	1.98	7.74	1359	36
Boston Mountains	Hardness, Ca, Mg	mg/l	Dissolved	0.500	9.04	13.00	23.00	35.80	231.00	27.33	21.84	21.20	787	34
Boston Mountains	Sulfate	mg/l	Dissolved	0.500	2.38	3.04	4.05	5.63	82.60	4.81	4.18	3.63	1362	36
Boston Mountains	Calcium	mg/l	Dissolved	0.039	2.29	3.40	6.95	11.60	83.20	8.56	6.32	7.39	788	34
Boston Mountains	Total Recoverable Calcium	mg/l	Total Recoverable	1.110	2.19	3.14	6.48	11.50	42.00	7.93	6.00	6.11	294	28
Boston Mountains	Sodium	mg/l	Dissolved	0.010	0.97	1.26	1.63	2.21	161.00	2.51	1.68	6.98	789	34
Boston Mountains	Potassium	mg/l	Dissolved	0.010	0.50	0.70	0.92	1.24	6.12	1.05	0.91	0.60	789	34
Boston Mountains	Magnesium	mg/l	Dissolved	0.010	0.83	1.04	1.30	1.69	24.70	1.46	1.32	1.03	789	34
Boston Mountains	Specific Conductivity	µS/cm	Total	18.000	31.00	45.00	70.10	92.45	259.00	75.30	65.04	43.18	418	26
Boston Mountains	Total dissolved solids	mg/l	Total	14.500	28.00	35.00	47.00	58.00	519.00	49.89	45.96	26.48	1144	35
Boston Mountains	Aluminum	mg/l	Dissolved	0.008	0.01	0.01	0.02	0.06	1.28	0.05	0.03	0.08	789	34
Boston Mountains	Total Recoverable Aluminum	mg/l	Total Recoverable	0.010	0.04	0.06	0.11	0.26	3.57	0.25	0.13	0.41	294	28
Boston Mountains	Iron	mg/l	Dissolved	0.006	0.01	0.02	0.04	0.06	0.94	0.05	0.03	0.06	789	34
Boston Mountains	Total Recoverable Iron	mg/l	Total Recoverable	0.021	0.06	0.11	0.16	0.24	2.84	0.23	0.17	0.30	294	28
Boston Mountains	Ammonia-nitrogen	mg/l	Dissolved	0.002	0.01	0.02	0.02	0.03	0.27	0.02	0.02	0.02	1362	36
Boston Mountains	Nitrite + Nitrate as Nitrogen	mg/l	Dissolved	0.005	0.01	0.02	0.06	0.15	2.08	0.13	0.05	0.19	1361	36
Boston Mountains	Total Kjeldahl nitrogen	mg/l	Total	0.025	0.03	0.07	0.14	0.24	1.84	0.18	0.13	0.18	949	34
Boston Mountains	Total Phosphorus	mg/l	Total	0.005	0.01	0.01	0.02	0.04	4.81	0.04	0.02	0.17	1167	35
Boston Mountains	Orthophosphate	mg/l	Dissolved	0.003	0.01	0.01	0.01	0.02	1.51	0.02	0.01	0.08	1361	36
Boston Mountains	Total suspended solids	mg/l	Total	0.500	0.50	0.50	1.50	3.90	598.00	6.34	1.82	30.36	1143	35
Boston Mountains	pH	NA	Total	4.780	6.39	6.76	7.16	7.56	10.50	7.16	7.13	0.62	1304	36
Boston Mountains	Temperature	°C	Total	0.800	6.93	10.20	16.00	23.50	33.80	16.70	14.66	7.62	1344	36

Ecoregion	Parameter	Unit	Fraction	Min	Per10	Per25	Per50	Per75	Max	Mean	GeoMean	SD	*N*	Sites
Mississippi Alluvial Plain	Alkalinity, total	mg/l $CaCO_3$	Dissolved	2.500	36.34	55.90	99.70	153.00	263.00	105.22	87.87	55.26	698	7
Mississippi Alluvial Plain	Bicarbonate	mg/l	Dissolved	3.384	45.52	69.69	122.94	191.00	329.95	130.52	109.02	68.69	692	7
Mississippi Alluvial Plain	Chloride	mg/l	Dissolved	1.010	2.44	3.06	5.99	11.20	124.00	11.51	6.73	15.96	1225	7
Mississippi Alluvial Plain	Hardness, Ca, Mg	mg/l	Dissolved	4.000	39.00	63.00	120.00	165.00	772.00	119.46	100.52	66.83	556	7
Mississippi Alluvial Plain	Sulfate	mg/l	Dissolved	0.020	3.00	4.03	6.07	11.27	113.00	8.67	6.63	7.48	1231	7
Mississippi Alluvial Plain	Calcium	mg/l	Dissolved	1.000	10.22	16.80	28.70	36.50	284.00	28.76	24.47	17.83	557	7
Mississippi Alluvial Plain	Total Recoverable Calcium	mg/l	Total Recoverable	2.310	11.14	17.00	26.30	36.65	258.00	28.49	23.93	21.45	195	5
Mississippi Alluvial Plain	Sodium	mg/l	Dissolved	0.020	1.61	2.26	4.50	8.90	297.00	8.34	4.50	20.56	557	7
Mississippi Alluvial Plain	Potassium	mg/l	Dissolved	0.230	0.89	1.40	3.10	4.65	13.10	3.41	2.63	2.30	557	7
Mississippi Alluvial Plain	Magnesium	mg/l	Dissolved	0.434	3.32	5.40	10.80	17.30	31.60	11.61	9.39	6.78	557	7
Mississippi Alluvial Plain	Specific Conductivity	µS/cm	Total	57.400	110.40	152.00	239.00	329.00	891.00	259.08	224.37	146.05	253	5
Mississippi Alluvial Plain	Total dissolved solids	mg/l	Total	48.000	96.65	128.00	159.25	188.00	717.00	167.53	156.14	67.45	1234	7
Mississippi Alluvial Plain	Aluminum	mg/l	Dissolved	0.008	0.01	0.01	0.05	0.15	2.14	0.11	0.04	0.21	557	7
Mississippi Alluvial Plain	Total Recoverable Aluminum	mg/l	Total Recoverable	0.005	0.05	0.10	0.26	0.67	5.38	0.53	0.25	0.73	195	5
Mississippi Alluvial Plain	Iron	mg/l	Dissolved	0.001	0.01	0.02	0.05	0.14	2.37	0.13	0.06	0.23	556	7
Mississippi Alluvial Plain	Total Recoverable Iron	mg/l	Total Recoverable	0.039	0.15	0.23	0.55	1.00	6.76	0.80	0.51	0.86	195	5
Mississippi Alluvial Plain	Ammonia-nitrogen	mg/l	Dissolved	0.003	0.01	0.02	0.02	0.04	0.76	0.04	0.02	0.05	1221	7

Ecoregion	Parameter	Unit	Fraction	Min	Per10	Per25	Per50	Per75	Max	Mean	GeoMean	SD	*N*	Sites
Mississippi Alluvial Plain	Nitrite + Nitrate as Nitrogen	mg/l	Dissolved	0.005	0.01	0.03	0.09	0.22	1.57	0.15	0.07	0.17	1229	7
Mississippi Alluvial Plain	Total Kjeldahl nitrogen	mg/l	Total	0.025	0.14	0.40	0.63	0.83	2.51	0.63	0.50	0.35	872	7
Mississippi Alluvial Plain	Total Phosphorus	mg/l	Total	0.006	0.03	0.07	0.14	0.21	1.05	0.15	0.11	0.11	1202	7
Mississippi Alluvial Plain	Orthophosphate	mg/l	Dissolved	0.003	0.01	0.02	0.07	0.10	0.60	0.08	0.05	0.06	1227	7
Mississippi Alluvial Plain	Total suspended solids	mg/l	Total	0.500	2.00	4.50	10.00	24.50	598.70	23.07	10.50	40.40	1225	7
Mississippi Alluvial Plain	pH	NA	Total	3.420	6.73	7.09	7.49	7.90	10.40	7.46	7.43	0.61	1208	7
Mississippi Alluvial Plain	Temperature	°C	Total	0.400	7.50	11.00	18.00	24.30	34.00	17.74	15.59	7.62	1207	7
Ouachita Mountains	Alkalinity, total	mg/l $CaCO_3$	Dissolved	0.050	4.90	10.30	20.40	42.60	115.00	27.97	19.07	22.36	2267	39
Ouachita Mountains	Bicarbonate	mg/l	Dissolved	0.026	3.79	12.81	24.85	52.44	144.29	34.57	23.51	27.86	2190	39
Ouachita Mountains	Chloride	mg/l	Dissolved	0.250	1.36	1.58	1.94	2.44	37.40	2.20	2.01	1.58	3187	41
Ouachita Mountains	Hardness, Ca, Mg	mg/l	Dissolved	0.500	8.50	12.70	23.00	47.05	406.00	31.83	23.68	25.51	1763	40
Ouachita Mountains	Sulfate	mg/l	Dissolved	0.350	2.71	3.40	4.50	6.11	458.00	5.62	4.67	9.18	3180	41
Ouachita Mountains	Calcium	mg/l	Dissolved	0.010	1.79	3.03	6.48	14.40	115.00	9.37	6.27	8.18	1770	40
Ouachita Mountains	Total Recoverable Calcium	mg/l	Total Recoverable	0.279	1.68	2.74	6.39	14.50	40.90	9.08	6.01	7.54	1088	38
Ouachita Mountains	Sodium	mg/l	Dissolved	0.010	1.08	1.47	1.86	2.39	160.00	2.26	1.79	4.26	1763	40
Ouachita Mountains	Potassium	mg/l	Dissolved	0.010	0.45	0.56	0.74	1.06	5.76	0.87	0.77	0.50	1770	40
Ouachita Mountains	Magnesium	mg/l	Dissolved	0.010	0.88	1.14	1.59	2.50	28.90	2.03	1.71	1.40	1770	40
Ouachita Mountains	Specific Conductivity	µS/cm	Total	2.960	28.00	38.00	58.00	104.00	840.00	73.22	60.20	50.77	1325	32
Ouachita Mountains	Total dissolved solids	mg/l	Total	12.000	28.00	34.50	45.00	63.88	712.00	51.45	46.78	26.39	3178	41
Ouachita Mountains	Aluminum	mg/l	Dissolved	0.008	0.01	0.01	0.02	0.05	0.59	0.04	0.03	0.05	1770	40
Ouachita Mountains	Total Recoverable Aluminum	mg/l	Total Recoverable	0.005	0.01	0.02	0.04	0.11	2.11	0.10	0.05	0.17	1088	38
Ouachita Mountains	Iron	mg/l	Dissolved	0.003	0.01	0.03	0.04	0.08	0.59	0.06	0.04	0.06	1770	40

Ecoregion	Parameter	Unit	Fraction	Min	Per10	Per25	Per50	Per75	Max	Mean	GeoMean	SD	*N*	Sites
Ouachita Mountains	Total Recoverable Iron	mg/l	Total Recoverable	0.010	0.03	0.03	0.08	0.16	2.90	0.13	0.07	0.20	1088	38
Ouachita Mountains	Ammonia-nitrogen	mg/l	Dissolved	0.001	0.02	0.02	0.02	0.03	0.64	0.02	0.02	0.03	3170	41
Ouachita Mountains	Nitrite + Nitrate as Nitrogen	mg/l	Dissolved	0.003	0.01	0.03	0.05	0.14	13.30	0.12	0.05	0.37	3166	41
Ouachita Mountains	Total Kjeldahl nitrogen	mg/l	Total	0.015	0.05	0.09	0.16	0.26	4.68	0.20	0.15	0.20	2565	40
Ouachita Mountains	Total Phosphorus	mg/l	Total	0.005	0.01	0.01	0.03	0.04	2.03	0.04	0.02	0.09	3120	41
Ouachita Mountains	Orthophosphate	mg/l	Dissolved	0.003	0.01	0.01	0.01	0.02	1.50	0.02	0.01	0.06	3180	41
Ouachita Mountains	Total suspended solids	mg/l	Total	0.500	0.50	0.50	1.50	3.25	868.00	4.37	1.68	20.76	3178	41
Ouachita Mountains	pH	NA	Total	4.010	6.39	6.77	7.10	7.36	13.20	7.04	7.02	0.53	3183	42
Ouachita Mountains	Temperature	°C	Total	1.000	8.00	12.00	18.00	24.00	37.80	17.95	16.13	7.22	3209	42
Ozark Highlands	Alkalinity, total	mg/l $CaCO_3$	Dissolved	1.800	68.90	100.00	133.00	199.00	428.00	144.12	129.92	59.34	3817	65
Ozark Highlands	Bicarbonate	mg/l	Dissolved	2.245	85.71	124.95	166.16	247.80	527.42	179.39	161.79	73.47	3720	64
Ozark Highlands	Chloride	mg/l	Dissolved	0.250	2.06	2.65	3.40	5.34	62.60	5.68	4.11	6.19	6629	71
Ozark Highlands	Hardness, Ca, Mg	mg/l	Dissolved	1.000	78.00	113.00	145.00	211.00	2160.00	162.20	143.78	100.80	2459	70
Ozark Highlands	Sulfate	mg/l	Dissolved	0.020	3.21	3.98	5.34	7.83	75.00	7.08	5.87	5.48	6630	71
Ozark Highlands	Calcium	mg/l	Dissolved	0.025	25.80	35.00	42.30	47.88	452.00	43.32	39.37	30.06	2486	70
Ozark Highlands	Total Recoverable Calcium	mg/l	Total Recoverable	5.120	25.48	34.80	42.70	48.80	468.00	48.31	41.04	49.39	869	45
Ozark Highlands	Sodium	mg/l	Dissolved	0.020	1.18	1.59	2.10	5.27	210.00	5.26	2.66	9.02	2476	70
Ozark Highlands	Potassium	mg/l	Dissolved	0.045	0.80	1.17	1.60	2.50	25.10	2.10	1.68	1.71	2486	70
Ozark Highlands	Magnesium	mg/l	Dissolved	0.065	1.80	2.19	7.24	24.90	253.00	13.16	7.15	13.21	2486	70
Ozark Highlands	Specific Conductivity	µS/cm	Total	4.570	147.00	200.50	277.00	380.50	568.00	284.36	261.51	105.30	1899	55
Ozark Highlands	Total dissolved solids	mg/l	Total	6.000	108.00	145.00	190.50	224.00	477.00	182.70	174.14	51.11	5185	68
Ozark Highlands	Aluminum	mg/l	Dissolved	0.008	0.01	0.01	0.02	0.13	1.03	0.08	0.03	0.10	2486	70
Ozark Highlands	Total Recoverable Aluminum	mg/l	Total Recoverable	0.005	0.02	0.05	0.07	0.13	8.40	0.18	0.08	0.58	869	45
Ozark Highlands	Iron	mg/l	Dissolved	0.001	0.01	0.01	0.02	0.04	0.88	0.03	0.02	0.05	2486	70
Ozark Highlands	Total Recoverable Iron	mg/l	Total Recoverable	0.010	0.03	0.05	0.08	0.15	10.20	0.19	0.09	0.63	869	45

Ecoregion	Parameter	Unit	Fraction	Min	Per10	Per25	Per50	Per75	Max	Mean	GeoMean	SD	*N*	Sites
Ozark Highlands	Ammonia-nitrogen	mg/l	Dissolved	0.000	0.01	0.02	0.02	0.03	1.50	0.02	0.02	0.04	6633	71
Ozark Highlands	Nitrite + Nitrate as Nitrogen	mg/l	Dissolved	0.001	0.03	0.12	0.41	1.04	24.80	0.78	0.32	1.02	6578	71
Ozark Highlands	Total Kjeldahl nitrogen	mg/l	Total	0.005	0.05	0.12	0.19	0.30	44.00	0.27	0.18	0.76	3870	57
Ozark Highlands	Total Phosphorus	mg/l	Total	0.005	0.01	0.02	0.04	0.08	4.86	0.09	0.05	0.20	5306	68
Ozark Highlands	Orthophosphate	mg/l	Dissolved	0.002	0.01	0.01	0.02	0.04	4.39	0.06	0.02	0.18	6622	71
Ozark Highlands	Total suspended solids	mg/l	Total	0.500	1.00	2.00	4.00	8.00	1130.00	12.53	3.97	49.97	5179	68
Ozark Highlands	pH	NA	Total	4.580	7.26	7.62	7.91	8.15	10.23	7.85	7.84	0.45	6397	78
Ozark Highlands	Temperature	°C	Total	0.460	7.50	11.00	15.90	22.10	34.00	16.49	14.83	6.92	6570	78
South Central Plains	Alkalinity, total	mg/l $CaCO_3$	Dissolved	0.050	3.00	8.27	20.45	40.85	342.00	28.40	16.67	30.75	1820	28
South Central Plains	Bicarbonate	mg/l	Dissolved	0.063	3.77	10.42	25.57	51.76	428.52	35.69	20.93	38.84	1771	28
South Central Plains	Chloride	mg/l	Dissolved	0.190	2.29	3.07	4.13	5.61	165.00	5.35	4.33	6.29	2975	28
South Central Plains	Hardness, Ca, Mg	mg/l	Dissolved	0.025	10.00	16.03	29.00	44.00	1710.00	36.44	26.25	65.66	1482	28
South Central Plains	Sulfate	mg/l	Dissolved	0.250	3.46	5.29	10.50	20.74	255.00	15.75	10.47	16.08	2981	28
South Central Plains	Calcium	mg/l	Dissolved	0.010	2.49	4.19	7.50	12.00	680.00	10.39	6.92	25.29	1497	28
South Central Plains	Total Recoverable Calcium	mg/l	Total Recoverable	0.909	2.06	3.70	6.83	11.15	627.00	12.26	6.78	35.15	751	28
South Central Plains	Sodium	mg/l	Dissolved	0.010	1.98	3.30	6.03	10.20	187.00	8.37	5.55	9.90	1496	28
South Central Plains	Potassium	mg/l	Dissolved	0.010	0.80	1.15	1.56	2.20	16.50	1.82	1.52	1.24	1497	28
South Central Plains	Magnesium	mg/l	Dissolved	0.010	0.80	1.30	2.32	3.40	33.00	2.52	2.02	1.95	1497	28
South Central Plains	Specific Conductivity	µS/cm	Total	5.940	37.36	57.50	91.50	134.00	1150.00	118.90	90.49	114.19	845	22
South Central Plains	Total dissolved solids	mg/l	Total	12.000	56.00	69.00	83.50	100.00	642.00	90.48	84.09	43.11	2989	28
South Central Plains	Aluminum	mg/l	Dissolved	0.008	0.02	0.04	0.06	0.14	1.09	0.11	0.07	0.12	1497	28
South Central Plains	Total Recoverable Aluminum	mg/l	Total Recoverable	0.020	0.11	0.19	0.37	0.66	4.39	0.50	0.35	0.48	751	28
South Central Plains	Iron	mg/l	Dissolved	0.005	0.07	0.14	0.30	0.53	2.79	0.38	0.26	0.34	1497	28
South Central Plains	Total Recoverable Iron	mg/l	Total Recoverable	0.050	0.29	0.59	0.94	1.48	6.25	1.17	0.89	0.90	751	28
South Central Plains	Ammonia-nitrogen	mg/l	Dissolved	0.003	0.02	0.02	0.03	0.04	10.20	0.04	0.02	0.20	2972	28

Ecoregion	Parameter	Unit	Fraction	Min	Per10	Per25	Per50	Per75	Max	Mean	GeoMean	SD	*N*	Sites
South Central Plains	Nitrite + Nitrate as Nitrogen	mg/l	Dissolved	0.001	0.01	0.03	0.10	0.18	7.75	0.15	0.08	0.31	2979	28
South Central Plains	Total Kjeldahl nitrogen	mg/l	Total	0.025	0.22	0.30	0.43	0.63	11.10	0.50	0.42	0.36	2343	28
South Central Plains	Total Phosphorus	mg/l	Total	0.005	0.02	0.04	0.06	0.09	3.87	0.08	0.06	0.16	2927	28
South Central Plains	Orthophosphate	mg/l	Dissolved	0.003	0.01	0.01	0.02	0.03	2.94	0.04	0.02	0.13	2971	28
South Central Plains	Total suspended solids	mg/l	Total	0.500	2.50	4.30	7.50	12.50	414.00	11.65	7.40	17.76	2990	28
South Central Plains	pH	NA	Total	4.300	6.00	6.41	6.84	7.17	9.39	6.77	6.74	0.62	2943	28
South Central Plains	Temperature	°C	Total	1.000	8.00	12.00	18.00	25.00	36.60	18.27	16.40	7.56	2944	28

Table A.2.4. Summary statistics using multiple samples for all stations.

Ecoregion	Parameter	Unit	Fraction	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Arkansas Valley	Alkalinity, total	mg/l $CaCO_3$	Dissolved	0.050	3.00	10.63	24.65	76.20	418.00	43.20	24.35	41.49	4354	72
Arkansas Valley	Bicarbonate	mg/l	Dissolved	0.063	3.77	13.18	30.65	95.37	321.33	53.82	30.26	51.40	4207	72
Arkansas Valley	Chloride	mg/l	Dissolved	0.035	1.65	2.85	5.70	46.50	1890.00	31.10	9.86	56.14	6976	86
Arkansas Valley	Hardness, Ca, Mg	mg/l	Dissolved	0.500	10.00	13.00	24.00	92.00	1050.00	54.37	31.95	62.56	3346	85
Arkansas Valley	Sulfate	mg/l	Dissolved	0.020	2.51	3.43	10.40	38.20	338.00	23.99	11.51	29.38	6993	86
Arkansas Valley	Calcium	mg/l	Dissolved	0.066	2.00	2.70	5.09	23.00	406.00	14.08	7.13	19.94	3358	85
Arkansas Valley	Total Recoverable Calcium	mg/l	Total Recoverable	1.040	2.04	2.72	4.94	21.45	413.00	14.53	7.07	26.15	1391	48
Arkansas Valley	Sodium	mg/l	Dissolved	0.020	1.41	2.46	6.23	36.30	679.30	24.85	8.46	39.79	3358	85
Arkansas Valley	Potassium	mg/l	Dissolved	0.010	0.70	1.20	2.28	3.80	46.00	3.27	2.15	4.53	3358	85
Arkansas Valley	Magnesium	mg/l	Dissolved	0.010	1.01	1.48	2.90	6.97	58.90	4.65	3.12	4.47	3358	85
Arkansas Valley	Specific Conductivity	µS/cm	Total	2.380	29.00	38.50	61.00	260.00	1300.00	183.47	94.78	228.49	2113	43
Arkansas Valley	Total dissolved solids	mg/l	Total	6.000	30.50	41.00	77.00	249.00	5020.00	154.82	97.05	166.17	7027	86
Arkansas Valley	Aluminum	mg/l	Dissolved	0.008	0.01	0.02	0.05	0.07	1.21	0.08	0.04	0.10	3358	85
Arkansas Valley	Total Recoverable Aluminum	mg/l	Total Recoverable	0.010	0.07	0.12	0.25	0.48	4.47	0.37	0.24	0.39	1391	48
Arkansas Valley	Iron	mg/l	Dissolved	0.001	0.02	0.05	0.11	0.21	7.65	0.17	0.09	0.25	3358	85
Arkansas Valley	Total Recoverable Iron	mg/l	Total Recoverable	0.025	0.17	0.26	0.44	0.78	6.88	0.59	0.44	0.50	1391	48
Arkansas Valley	Ammonia-nitrogen	mg/l	Dissolved	0.001	0.02	0.02	0.03	0.06	19.00	0.21	0.03	1.14	6943	86
Arkansas Valley	Nitrite + Nitrate as Nitrogen	mg/l	Dissolved	0.005	0.02	0.06	0.21	0.45	51.50	0.67	0.17	2.12	6961	86
Arkansas Valley	Total Kjeldahl nitrogen	mg/l	Total	0.025	0.11	0.24	0.46	0.65	25.80	0.73	0.39	1.56	5742	86
Arkansas Valley	Total Phosphorus	mg/l	Total	0.001	0.02	0.03	0.07	0.12	25.76	0.27	0.07	1.07	6865	86
Arkansas Valley	Orthophosphate	mg/l	Dissolved	0.003	0.01	0.01	0.02	0.06	17.80	0.20	0.03	0.96	6960	86
Arkansas Valley	Total suspended solids	mg/l	Total	0.250	1.00	2.50	6.50	13.00	960.00	12.05	5.60	24.68	7029	86

Ecoregion	Parameter	Unit	Fraction	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Arkansas Valley	pH	NA	Total	4.000	6.35	6.68	7.05	7.50	9.91	7.08	7.05	0.63	6735	86
Arkansas Valley	Temperature	°C	Total	0.200	7.00	11.00	17.90	25.00	36.30	17.91	15.63	8.16	6988	86
Boston Mountains	Alkalinity, total	mg/l $CaCO_3$	Dissolved	0.299	10.30	20.22	35.20	55.68	178.00	43.74	32.03	33.44	1706	63
Boston Mountains	Bicarbonate	mg/l	Dissolved	0.376	12.78	25.61	44.00	69.83	219.82	54.82	40.11	41.86	1650	63
Boston Mountains	Chloride	mg/l	Dissolved	0.250	1.28	1.76	2.45	3.52	239.00	3.84	2.66	8.31	2831	90
Boston Mountains	Hardness, Ca, Mg	mg/l	Dissolved	0.500	10.00	17.00	35.80	56.70	622.00	44.89	32.43	39.90	1461	68
Boston Mountains	Sulfate	mg/l	Dissolved	0.020	2.62	3.68	5.91	10.90	110.48	10.18	6.74	12.02	2832	89
Boston Mountains	Calcium	mg/l	Dissolved	0.039	2.50	4.71	11.60	18.90	243.00	14.63	9.80	14.18	1467	68
Boston Mountains	Total Recoverable Calcium	mg/l	Total Recoverable	1.110	2.40	4.08	11.00	17.28	234.00	13.06	8.88	14.26	478	37
Boston Mountains	Sodium	mg/l	Dissolved	0.010	1.03	1.42	2.05	3.54	161.00	3.97	2.35	8.17	1469	68
Boston Mountains	Potassium	mg/l	Dissolved	0.010	0.60	0.80	1.11	1.60	21.50	1.40	1.12	1.25	1469	68
Boston Mountains	Magnesium	mg/l	Dissolved	0.010	0.90	1.20	1.65	2.39	24.70	2.05	1.73	1.43	1469	68
Boston Mountains	Specific Conductivity	µS/cm	Total	18.000	35.00	54.00	90.30	142.75	437.00	112.28	89.17	79.06	742	39
Boston Mountains	Total dissolved solids	mg/l	Total	13.000	32.00	43.50	62.00	92.00	564.00	77.85	65.49	52.66	2415	80
Boston Mountains	Aluminum	mg/l	Dissolved	0.008	0.01	0.01	0.02	0.06	1.28	0.05	0.03	0.08	1469	68
Boston Mountains	Total Recoverable Aluminum	mg/l	Total Recoverable	0.010	0.04	0.06	0.13	0.27	14.70	0.29	0.13	0.79	478	37
Boston Mountains	Iron	mg/l	Dissolved	0.001	0.01	0.01	0.03	0.05	0.94	0.04	0.03	0.06	1469	68
Boston Mountains	Total Recoverable Iron	mg/l	Total Recoverable	0.021	0.06	0.10	0.18	0.29	20.80	0.31	0.18	1.02	478	37
Boston Mountains	Ammonia-nitrogen	mg/l	Dissolved	0.002	0.01	0.02	0.02	0.03	0.39	0.02	0.02	0.03	2848	90
Boston Mountains	Nitrite + Nitrate as Nitrogen	mg/l	Dissolved	0.005	0.01	0.04	0.12	0.39	4.94	0.29	0.11	0.45	2831	90
Boston Mountains	Total Kjeldahl nitrogen	mg/l	Total	0.025	0.05	0.09	0.18	0.32	2.94	0.25	0.16	0.25	1980	67
Boston Mountains	Total Phosphorus	mg/l	Total	0.004	0.01	0.02	0.03	0.05	4.81	0.05	0.03	0.13	2437	78
Boston Mountains	Orthophosphate	mg/l	Dissolved	0.001	0.01	0.01	0.01	0.02	1.51	0.02	0.01	0.07	2846	90
Boston Mountains	Total suspended solids	mg/l	Total	0.500	0.50	1.00	2.50	7.50	744.00	10.39	2.76	40.14	2409	80

Ecoregion	Parameter	Unit	Fraction	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Boston Mountains	pH	NA	Total	4.780	6.56	6.97	7.37	7.69	11.30	7.32	7.29	0.59	2698	89
Boston Mountains	Temperature	°C	Total	0.400	6.60	10.00	16.00	23.00	34.00	16.47	14.40	7.60	2764	89
Mississippi Alluvial Plain	Alkalinity, total	mg/l $CaCO_3$	Dissolved	0.203	16.20	36.00	79.37	122.00	456.00	83.06	60.81	54.31	4817	95
Mississippi Alluvial Plain	Bicarbonate	mg/l	Dissolved	0.255	20.48	45.44	99.07	151.47	570.10	103.53	75.97	67.58	4684	95
Mississippi Alluvial Plain	Chloride	mg/l	Dissolved	0.100	2.67	3.78	6.74	21.80	683.00	20.25	9.41	30.71	8326	102
Mississippi Alluvial Plain	Hardness, Ca, Mg	mg/l	Dissolved	0.500	21.00	42.00	94.00	140.00	970.00	97.37	74.08	65.95	4337	102
Mississippi Alluvial Plain	Sulfate	mg/l	Dissolved	0.020	3.71	5.22	7.85	15.39	221.00	13.89	9.22	15.44	8351	102
Mississippi Alluvial Plain	Calcium	mg/l	Dissolved	0.010	5.40	10.93	23.65	34.60	374.00	24.48	18.61	17.68	4354	102
Mississippi Alluvial Plain	Total Recoverable Calcium	mg/l	Total Recoverable	1.490	5.34	11.40	22.80	34.30	505.00	25.48	18.81	27.93	1567	68
Mississippi Alluvial Plain	Sodium	mg/l	Dissolved	0.010	1.93	3.07	6.27	16.90	481.00	15.24	7.12	24.20	4345	102
Mississippi Alluvial Plain	Potassium	mg/l	Dissolved	0.010	1.16	1.78	3.00	4.39	61.50	3.38	2.74	2.46	4354	102
Mississippi Alluvial Plain	Magnesium	mg/l	Dissolved	0.010	1.80	3.50	7.80	12.70	46.40	8.84	6.53	6.20	4354	102
Mississippi Alluvial Plain	Specific Conductivity	µS/cm	Total	8.440	61.68	114.00	214.00	305.25	957.00	235.62	186.57	158.24	1780	36
Mississippi Alluvial Plain	Total dissolved solids	mg/l	Total	8.000	77.00	116.00	154.75	200.00	1287.50	171.22	149.48	91.29	8376	102
Mississippi Alluvial Plain	Aluminum	mg/l	Dissolved	0.008	0.01	0.01	0.06	0.16	2.66	0.12	0.05	0.21	4353	102
Mississippi Alluvial Plain	Total Recoverable Aluminum	mg/l	Total Recoverable	0.005	0.09	0.20	0.42	0.92	18.60	0.85	0.42	1.47	1567	68
Mississippi Alluvial Plain	Iron	mg/l	Dissolved	0.001	0.01	0.02	0.06	0.22	5.35	0.17	0.07	0.28	4352	102
Mississippi Alluvial Plain	Total Recoverable Iron	mg/l	Total Recoverable	0.025	0.19	0.36	0.69	1.30	21.10	1.12	0.68	1.66	1567	68
Mississippi Alluvial Plain	Ammonia-nitrogen	mg/l	Dissolved	0.001	0.02	0.02	0.03	0.07	8.67	0.06	0.03	0.16	8305	102
Mississippi Alluvial Plain	Nitrite + Nitrate as Nitrogen	mg/l	Dissolved	0.005	0.02	0.07	0.18	0.31	12.10	0.27	0.13	0.55	8337	102
Mississippi Alluvial Plain	Total Kjeldahl nitrogen	mg/l	Total	0.022	0.24	0.41	0.63	0.88	9.76	0.71	0.58	0.49	6517	101
Mississippi Alluvial Plain	Total Phosphorus	mg/l	Total	0.006	0.04	0.07	0.13	0.21	7.06	0.18	0.12	0.28	8198	102
Mississippi Alluvial Plain	Orthophosphate	mg/l	Dissolved	0.003	0.01	0.02	0.06	0.10	7.33	0.10	0.05	0.23	8331	102
Mississippi Alluvial Plain	Total suspended solids	mg/l	Total	0.500	4.00	7.50	15.30	30.00	1170.00	26.67	14.81	46.95	8334	102

Ecoregion	Parameter	Unit	Fraction	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Mississippi Alluvial Plain	pH	NA	Total	2.620	6.54	6.92	7.39	7.80	10.40	7.35	7.32	0.64	8151	102
Mississippi Alluvial Plain	Temperature	°C	Total	0.400	7.50	11.20	18.10	25.00	35.00	18.07	15.95	7.82	8210	102
Mississippi Valley Loess Plains	Alkalinity, total	mg/l $CaCO_3$	Dissolved	3.000	19.59	30.40	65.35	101.75	275.00	70.27	55.10	44.33	170	1
Mississippi Valley Loess Plains	Bicarbonate	mg/l	Dissolved	3.770	24.61	38.18	81.84	126.79	341.35	87.56	68.79	54.95	170	1
Mississippi Valley Loess Plains	Chloride	mg/l	Dissolved	1.080	2.70	4.60	11.45	21.50	186.00	15.29	10.07	17.67	170	1
Mississippi Valley Loess Plains	Hardness, Ca, Mg	mg/l	Dissolved	2.000	26.85	38.78	69.50	96.50	173.00	71.69	60.31	37.04	80	1
Mississippi Valley Loess Plains	Sulfate	mg/l	Dissolved	2.600	4.97	7.12	12.40	17.75	66.70	13.48	11.26	8.48	170	1
Mississippi Valley Loess Plains	Calcium	mg/l	Dissolved	0.352	6.14	9.37	17.60	24.30	46.80	17.50	14.60	9.18	81	1
Mississippi Valley Loess Plains	Total Recoverable Calcium	mg/l	Total Recoverable	4.140	6.99	9.30	17.20	22.20	53.50	17.24	14.87	9.51	51	1
Mississippi Valley Loess Plains	Sodium	mg/l	Dissolved	1.050	3.42	4.72	14.40	22.80	77.70	16.18	11.07	13.83	81	1
Mississippi Valley Loess Plains	Potassium	mg/l	Dissolved	0.694	2.24	2.71	3.56	4.22	38.00	4.92	3.77	6.01	81	1
Mississippi Valley Loess Plains	Magnesium	mg/l	Dissolved	0.182	2.89	3.53	6.69	8.72	20.70	6.77	5.73	3.54	81	1
Mississippi Valley Loess Plains	Specific Conductivity	µS/cm	Total	45.400	70.88	89.00	164.00	318.00	558.00	203.87	165.58	125.91	73	1
Mississippi Valley Loess Plains	Total dissolved solids	mg/l	Total	55.500	91.90	109.75	151.00	210.00	515.00	162.59	150.84	66.28	170	1
Mississippi Valley Loess Plains	Aluminum	mg/l	Dissolved	0.010	0.01	0.01	0.05	0.20	2.47	0.15	0.06	0.30	81	1
Mississippi Valley Loess Plains	Total Recoverable Aluminum	mg/l	Total Recoverable	0.045	0.11	0.28	0.71	1.27	6.91	1.01	0.55	1.31	51	1
Mississippi Valley Loess Plains	Iron	mg/l	Dissolved	0.010	0.05	0.06	0.13	0.23	2.57	0.18	0.12	0.29	81	1
Mississippi Valley Loess Plains	Total Recoverable Iron	mg/l	Total Recoverable	0.093	0.36	0.52	0.79	1.30	10.50	1.20	0.82	1.61	51	1

Ecoregion	Parameter	Unit	Fraction	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Mississippi Valley Loess Plains	Ammonia-nitrogen	mg/l	Dissolved	0.015	0.02	0.02	0.04	0.11	8.56	0.17	0.05	0.71	169	1
Mississippi Valley Loess Plains	Nitrite + Nitrate as Nitrogen	mg/l	Dissolved	0.005	0.02	0.03	0.14	0.31	5.06	0.26	0.11	0.45	170	1
Mississippi Valley Loess Plains	Total Kjeldahl nitrogen	mg/l	Total	0.224	0.48	0.62	0.73	0.97	21.00	1.05	0.82	1.67	167	1
Mississippi Valley Loess Plains	Total Phosphorus	mg/l	Total	0.060	0.12	0.14	0.27	0.53	5.35	0.53	0.31	0.75	170	1
Mississippi Valley Loess Plains	Orthophosphate	mg/l	Dissolved	0.010	0.03	0.06	0.13	0.29	5.35	0.38	0.15	0.70	170	1
Mississippi Valley Loess Plains	Total suspended solids	mg/l	Total	1.000	3.50	7.13	14.40	29.95	903.00	47.66	16.11	119.42	170	1
Mississippi Valley Loess Plains	pH	NA	Total	6.400	6.92	7.21	7.48	7.81	9.33	7.49	7.48	0.48	170	1
Mississippi Valley Loess Plains	Temperature	°C	Total	0.200	4.87	9.55	16.15	24.70	33.40	16.94	13.58	8.72	170	1
Ouachita Mountains	Alkalinity, total	mg/l $CaCO_3$	Dissolved	0.050	3.00	8.40	14.80	29.65	190.00	22.02	14.53	20.19	5231	102
Ouachita Mountains	Bicarbonate	mg/l	Dissolved	0.026	3.77	10.43	18.47	36.36	238.43	27.25	17.99	25.04	5084	102
Ouachita Mountains	Chloride	mg/l	Dissolved	0.100	1.47	1.78	2.40	3.45	129.00	3.93	2.76	6.16	7396	129
Ouachita Mountains	Hardness, Ca, Mg	mg/l	Dissolved	0.234	8.00	11.40	20.00	39.08	1400.00	39.20	22.17	85.44	4486	113
Ouachita Mountains	Sulfate	mg/l	Dissolved	0.020	2.44	3.30	4.77	7.75	1380.00	17.66	5.79	79.79	7384	129
Ouachita Mountains	Calcium	mg/l	Dissolved	0.010	1.30	2.20	4.97	10.90	372.00	10.41	5.06	23.72	4496	113
Ouachita Mountains	Total Recoverable Calcium	mg/l	Total Recoverable	0.020	1.17	2.22	5.02	12.30	331.00	10.60	5.17	22.94	2731	94
Ouachita Mountains	Sodium	mg/l	Dissolved	0.010	1.26	1.70	2.34	3.60	196.00	3.91	2.53	7.78	4488	113
Ouachita Mountains	Potassium	mg/l	Dissolved	0.010	0.50	0.67	0.97	1.49	71.30	1.50	1.04	2.83	4496	113

Ecoregion	Parameter	Unit	Fraction	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Ouachita Mountains	Magnesium	mg/l	Dissolved	0.010	0.95	1.28	1.77	2.79	90.00	3.17	2.01	6.60	4498	113
Ouachita Mountains	Specific Conductivity	µS/cm	Total	2.960	27.03	38.00	57.00	105.00	6370.00	97.59	64.78	184.98	3254	85
Ouachita Mountains	Total dissolved solids	mg/l	Total	6.000	29.50	36.00	47.00	66.00	2100.00	69.99	52.15	117.57	7370	129
Ouachita Mountains	Aluminum	mg/l	Dissolved	0.008	0.01	0.02	0.02	0.06	29.90	0.22	0.03	1.62	4498	113
Ouachita Mountains	Total Recoverable Aluminum	mg/l	Total Recoverable	0.005	0.02	0.02	0.08	0.22	30.70	0.35	0.09	1.49	2731	94
Ouachita Mountains	Iron	mg/l	Dissolved	0.003	0.02	0.03	0.06	0.15	6.19	0.12	0.07	0.22	4497	113
Ouachita Mountains	Total Recoverable Iron	mg/l	Total Recoverable	0.010	0.03	0.06	0.15	0.33	7.57	0.28	0.14	0.43	2731	94
Ouachita Mountains	Ammonia-nitrogen	mg/l	Dissolved	0.001	0.02	0.02	0.02	0.03	3.52	0.04	0.02	0.11	7372	129
Ouachita Mountains	Nitrite + Nitrate as Nitrogen	mg/l	Dissolved	0.003	0.01	0.03	0.07	0.19	43.70	0.31	0.07	1.53	7354	129
Ouachita Mountains	Total Kjeldahl nitrogen	mg/l	Total	0.015	0.05	0.11	0.20	0.34	9.05	0.29	0.19	0.35	6123	112
Ouachita Mountains	Total Phosphorus	mg/l	Total	0.004	0.01	0.02	0.03	0.05	23.00	0.15	0.03	1.02	7223	129
Ouachita Mountains	Orthophosphate	mg/l	Dissolved	0.003	0.01	0.01	0.01	0.02	27.52	0.13	0.02	1.04	7393	129
Ouachita Mountains	Total suspended solids	mg/l	Total	0.500	0.50	1.00	2.00	4.00	868.00	4.82	1.99	17.47	7406	129
Ouachita Mountains	pH	NA	Total	3.160	6.09	6.51	6.92	7.24	14.00	6.84	6.80	0.69	7418	132
Ouachita Mountains	Temperature	°C	Total	0.100	8.00	11.80	18.00	24.00	37.80	17.82	15.94	7.31	7480	132
Ozark Highlands	Alkalinity, total	mg/l $CaCO_3$	Dissolved	1.800	82.40	112.00	135.44	177.00	428.00	142.93	132.99	49.30	8425	172
Ozark Highlands	Bicarbonate	mg/l	Dissolved	1.614	102.49	138.91	169.43	220.06	527.42	177.90	165.55	60.99	8183	171
Ozark Highlands	Chloride	mg/l	Dissolved	0.015	2.34	3.10	4.75	9.12	900.00	9.93	5.81	19.42	13959	215

Ecoregion	Parameter	Unit	Fraction	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
Ozark Highlands	Hardness, Ca, Mg	mg/l	Dissolved	0.500	93.00	122.00	145.00	186.00	2160.00	158.75	144.05	99.25	5604	189
Ozark Highlands	Sulfate	mg/l	Dissolved	0.020	3.69	4.78	6.65	10.71	109.00	9.66	7.51	8.72	13929	215
Ozark Highlands	Calcium	mg/l	Dissolved	0.010	28.90	36.90	45.10	52.30	663.00	47.53	42.95	36.11	5684	190
Ozark Highlands	Total Recoverable Calcium	mg/l	Total Recoverable	1.690	29.62	37.05	46.10	54.75	707.00	54.72	45.60	61.85	2103	104
Ozark Highlands	Sodium	mg/l	Dissolved	0.020	1.37	1.90	3.30	8.00	2515.00	9.17	4.01	36.88	5668	190
Ozark Highlands	Potassium	mg/l	Dissolved	0.010	0.90	1.28	1.82	3.04	47.40	2.68	1.97	2.81	5685	190
Ozark Highlands	Magnesium	mg/l	Dissolved	0.030	1.78	2.17	3.65	17.60	253.00	9.85	5.60	10.85	5685	190
Ozark Highlands	Specific Conductivity	µS/cm	Total	2.000	180.00	249.00	319.00	384.00	1540.00	317.00	295.58	109.51	4319	128
Ozark Highlands	Total dissolved solids	mg/l	Total	6.000	125.00	156.00	190.00	224.00	7701.50	195.33	184.84	96.68	11491	200
Ozark Highlands	Aluminum	mg/l	Dissolved	0.008	0.01	0.01	0.02	0.13	1.03	0.08	0.03	0.10	5685	190
Ozark Highlands	Total Recoverable Aluminum	mg/l	Total Recoverable	0.005	0.02	0.02	0.05	0.10	8.40	0.16	0.06	0.55	2105	104
Ozark Highlands	Iron	mg/l	Dissolved	0.001	0.01	0.01	0.02	0.04	0.88	0.03	0.02	0.05	5685	190
Ozark Highlands	Total Recoverable Iron	mg/l	Total Recoverable	0.010	0.03	0.03	0.05	0.11	10.20	0.16	0.06	0.59	2105	104
Ozark Highlands	Ammonia-nitrogen	mg/l	Dissolved	0.000	0.01	0.02	0.02	0.03	5.55	0.03	0.02	0.10	13986	214
Ozark Highlands	Nitrite + Nitrate as Nitrogen	mg/l	Dissolved	0.001	0.06	0.22	0.61	1.74	28.40	1.24	0.52	1.69	13857	214
Ozark Highlands	Total Kjeldahl nitrogen	mg/l	Total	0.005	0.06	0.14	0.23	0.38	60.00	0.33	0.21	0.86	9149	161
Ozark Highlands	Total Phosphorus	mg/l	Total	0.003	0.01	0.03	0.05	0.11	24.62	0.23	0.06	0.71	11633	200
Ozark Highlands	Orthophosphate	mg/l	Dissolved	0.002	0.01	0.01	0.02	0.06	16.00	0.17	0.03	0.63	13962	214
Ozark Highlands	Total suspended solids	mg/l	Total	0.500	0.50	1.00	2.50	6.00	1130.00	9.68	2.82	43.34	11489	200
Ozark Highlands	pH	NA	Total	4.580	7.28	7.60	7.90	8.14	11.93	7.85	7.83	0.45	13644	221
Ozark Highlands	Temperature	°C	Total	0.460	8.00	11.00	16.00	22.00	37.20	16.43	14.90	6.65	13956	221
South Central Plains	Alkalinity, total	mg/l $CaCO_3$	Dissolved	0.050	3.00	10.40	20.40	42.20	1040.00	34.68	19.50	43.61	9081	180
South Central Plains	Bicarbonate	mg/l	Dissolved	0.063	3.77	12.81	25.13	53.28	1306.38	43.64	24.29	55.30	8739	180
South Central Plains	Chloride	mg/l	Dissolved	0.035	2.39	3.38	5.83	18.00	2970.00	24.63	8.53	68.13	14298	195

Ecoregion	Parameter	Unit	Fraction	Min	10th	25th	50th	75th	Max	Mean	GeoMean	SD	Samples	Stations
South Central Plains	Hardness, Ca, Mg	mg/l	Dissolved	0.025	11.00	18.00	27.60	48.00	1710.00	44.76	29.80	62.10	7404	193
South Central Plains	Sulfate	mg/l	Dissolved	0.020	3.20	4.94	9.33	21.30	817.00	26.41	11.35	52.55	14307	195
South Central Plains	Calcium	mg/l	Dissolved	0.010	2.69	4.60	7.55	13.50	680.00	12.70	8.00	19.63	7566	193
South Central Plains	Total Recoverable Calcium	mg/l	Total Recoverable	0.250	2.50	4.29	7.00	13.30	696.00	13.44	7.80	28.51	3633	165
South Central Plains	Sodium	mg/l	Dissolved	0.010	2.34	3.50	6.34	15.00	566.20	19.37	7.94	39.93	7558	193
South Central Plains	Potassium	mg/l	Dissolved	0.010	0.95	1.30	2.00	3.30	48.70	2.85	2.09	3.05	7566	193
South Central Plains	Magnesium	mg/l	Dissolved	0.010	0.99	1.37	1.99	3.12	64.10	3.11	2.11	4.37	7566	193
South Central Plains	Specific Conductivity	µS/cm	Total	5.350	41.49	60.00	93.65	159.00	1760.00	160.73	104.85	208.96	4390	129
South Central Plains	Total dissolved solids	mg/l	Total	7.000	45.50	62.00	86.50	148.00	5231.00	150.69	103.85	188.52	14362	195
South Central Plains	Aluminum	mg/l	Dissolved	0.008	0.01	0.03	0.06	0.12	1.51	0.10	0.06	0.11	7566	193
South Central Plains	Total Recoverable Aluminum	mg/l	Total Recoverable	0.005	0.07	0.16	0.32	0.63	14.10	0.50	0.31	0.65	3633	165
South Central Plains	Iron	mg/l	Dissolved	0.001	0.05	0.13	0.28	0.52	7.46	0.40	0.24	0.43	7566	193
South Central Plains	Total Recoverable Iron	mg/l	Total Recoverable	0.025	0.30	0.57	0.95	1.45	12.50	1.16	0.86	0.95	3633	165
South Central Plains	Ammonia-nitrogen	mg/l	Dissolved	0.001	0.02	0.02	0.03	0.07	151.50	0.18	0.04	1.92	14270	195
South Central Plains	Nitrite + Nitrate as Nitrogen	mg/l	Dissolved	0.001	0.02	0.06	0.15	0.28	211.00	0.71	0.13	3.66	14299	195
South Central Plains	Total Kjeldahl nitrogen	mg/l	Total	0.002	0.24	0.34	0.53	0.80	64.64	0.71	0.53	1.17	11628	191
South Central Plains	Total Phosphorus	mg/l	Total	0.005	0.03	0.04	0.07	0.13	16.50	0.17	0.08	0.51	14036	195
South Central Plains	Orthophosphate	mg/l	Dissolved	0.002	0.01	0.01	0.02	0.05	9.97	0.10	0.03	0.44	14291	195
South Central Plains	Total suspended solids	mg/l	Total	0.500	1.80	3.50	7.00	14.80	3232.00	17.88	7.49	49.66	14377	195
South Central Plains	pH	NA	Total	0.650	6.05	6.45	6.85	7.20	10.05	6.82	6.79	0.63	14035	195
South Central Plains	Temperature	°C	Total	1.000	8.50	12.10	18.30	25.00	39.00	18.43	16.71	7.32	14048	195

Table A.2.5. Summary station median statistics for relative cation dominance based on mg/l least disturbed stations ($[Ca^{2+}] + [Mg^{2+}])/([Na^{+}] + [K^{+}]$). Molar ratio or microequivalent ratios would differ.

			Centile						
Ecoregion	**Percentage[a]**	**Min**	**10**	**25**	**50**	**75**	**90**	**Max**	**Stations**
Arkansas Valley	67	0.94	0.95	0.97	1.05	1.58	1.69	2.16	18
Boston Mountains	100	1.02	1.37	1.72	2.05	3.90	5.35	9.69	34
Mississippi Alluvial Plain	100	1.64	1.94	2.27	2.59	11.54	19.70	20.43	7
Ouachita Mountains	95	0.86	1.43	2.14	4.56	6.96	9.57	15.03	40
Ozark Highlands	100	1.86	3.99	8.33	15.17	23.40	38.74	156.79	70
South Central Plains	43	0.39	0.73	0.82	0.97	1.13	2.95	6.15	28

[a]$([Ca^{2+}] + [Mg^{2+}])/([Na^{+}] + [K^{+}]) > 1$

Table A.2.6. Summary station median statistics for relative anion dominance based on mg/l least disturbed stations ($[HCO_3^{-}] + [SO_4^{2-}])/[Cl^{-}]$).
Molar ratio or microequivalent ratios would differ.

			Centile						
Ecoregion	**Percentage[a]**	**Min**	**10**	**25**	**50**	**75**	**90**	**Max**	**Stations**
Arkansas Valley	100	2.72	3.47	4.06	4.55	7.42	8.70	10.88	18
Boston Mountains	100	4.46	6.28	8.69	11.75	19.61	24.81	44.13	35
Mississippi Alluvial Plain	100	4.87	5.21	7.68	13.01	42.44	70.35	72.18	7
Ouachita Mountains	100	4.79	6.50	10.10	18.20	27.52	35.55	40.13	39
Ozark Highlands	100	7.72	16.71	34.81	50.82	77.96	103.40	203.09	59
South Central Plains	96.43	0.70	1.91	2.45	3.92	9.95	19.98	28.13	28

[a]$([HCO_3^{-}] + [SO_4^{2-}])/[Cl^{-}]) > 1$

A-3. Temporal comparisons of predicted and observed SC

The predictive performance of the empirical model (Olson and Cormier, 2019) was assessed by comparing long-term predicted and observed SC at USGS gaging stations that had multiple SC measurements. The following factors were considered:

(1) the coincidence of seasonal variation,
(2) the range of seasonal variation (low variation is associated with little or no anthropogenic loadings or continuous anthropogenic inputs),
(3) magnitude of difference between median and minimum observed and predicted values, and
(4) statistics on the general performance of the model in the ecoregion reported in Olson and Cormier (2019).

We identified two long-term records in the Arkansas Valley, five in the Boston Mountains and four in the Mississippi Alluvial Plain.

The two records for the Arkansas Valley coincide with the seasonal variation, but the empirical model over-predicts background SC (USGS-07257500, USGS-07261090).

In the Boston Mountains, three records did not appear to represent background, owing to either high SC or a large SC range—indicative of anthropogenic inputs. One had a median background of twice the predicted background and was located in an area of mixed land use (USGS-07048495). Downstream from that location at another gaging station (USGS-07048550), the observed median was within 12 µS/cm of the predicted value, but the annual monthly range was >100 to 200 µS/cm, indicative of source inputs or influence from the upstream location. A third station occasionally exhibited large annual monthly observed SC (USGS- 07048600), indicative of inputs. Two gage stations appeared to exhibit minimally affected conditions in the Boston Mountains. They were located in forested uplands and had low SC and modest monthly changes in SC (USGS-07075250; 07075270), indicative of background SC regimes; but predicted SC was at least 10X greater than observed SC, indicative that the model overestimates background SC.

Inspection of these example records comparing predicted SC and observed SC indicate that the Arkansas Valley (Figure A.3.1) and Boston Mountains (Figure A.3.2) predicted background estimates are consistently greater than observed values. Therefore, where background is less than the ecoregional background, observations at the station itself best represent minimally affected or least disturbed background. For stations with no observed values, background may be best represented by the observed ecoregional least disturbed background estimate.

For the Mississippi Alluvial Plain (Figure A.3.3), the predicted least disturbed background appears to be reliable without calibration. Using a different least disturbed background estimate for the Mississippi Alluvial Plain is not justified by these data.

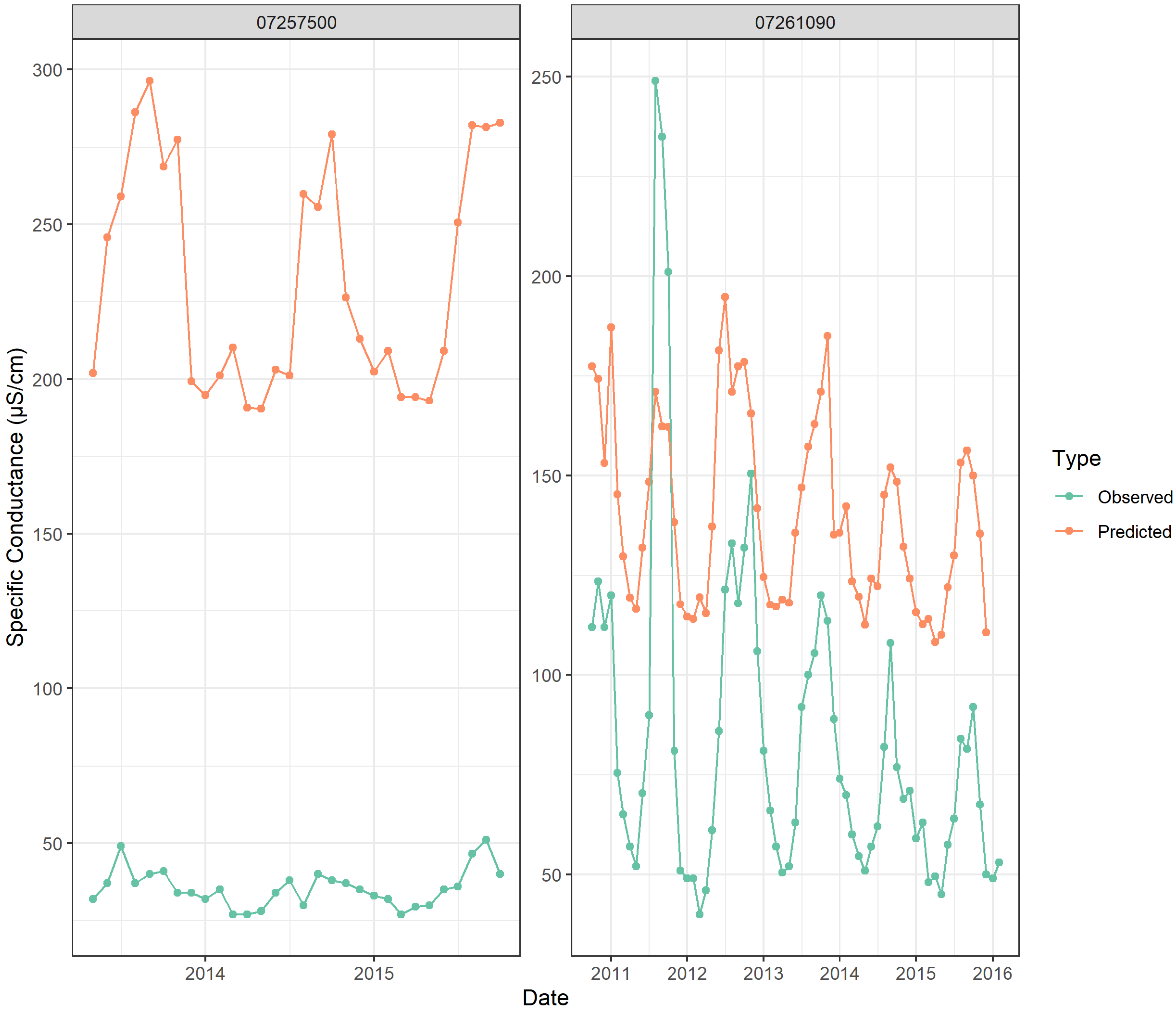


Figure A-3.1. Arkansas Valley, USGS gaging stations and predicted SC.
The monthly averaged predicted SC coincides with the seasonal variation, but over-predicts SC.

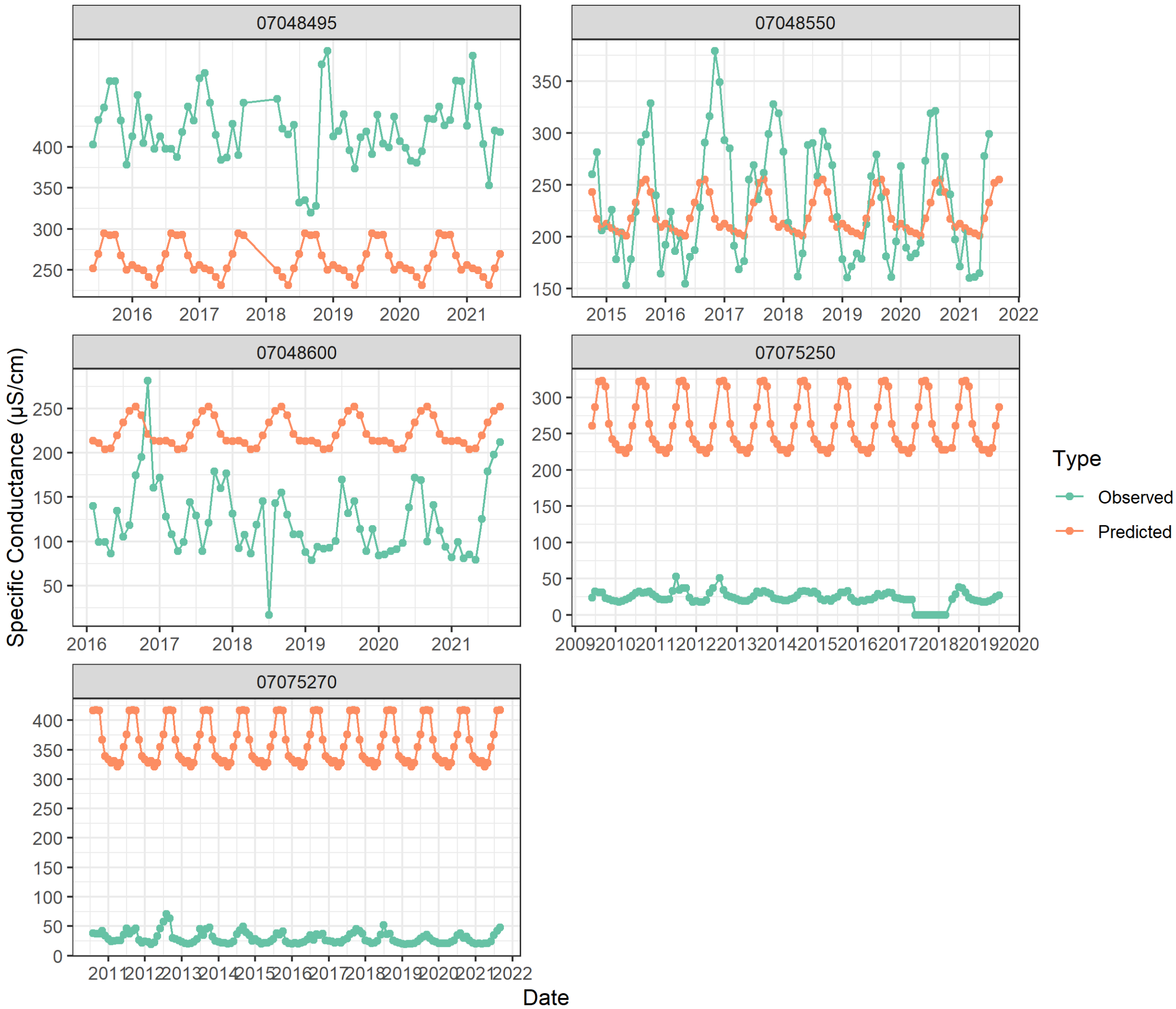


Figure A.3.2. Boston Mountain, USGS gaging stations and predicted SC.
The monthly averaged predicted consistently coincides with the seasonal variation, but over-predicts SC.

Figure A.3.3. Mississippi Alluvial Plain, ADEQ observed data.
The monthly averaged predicted SC coincides with the seasonal variation and somewhat predicts the lower quartile and median. The observed SC variation indicates that these least disturbed stations have some anthropogenic inputs.

A.4. Histograms of number of stations and SC

The distribution and range of SC can influence the estimation of XC95 values and XCD05 values. For the entire Arkansas data set (Figure A.4.1) and the Group 1 (Figure A.4.2) paired data set, the range is broad, with some stations between 500 and 1,000 µS/cm. The number of samples and the range is more restricted in Group 2 (Figure A.4.3).

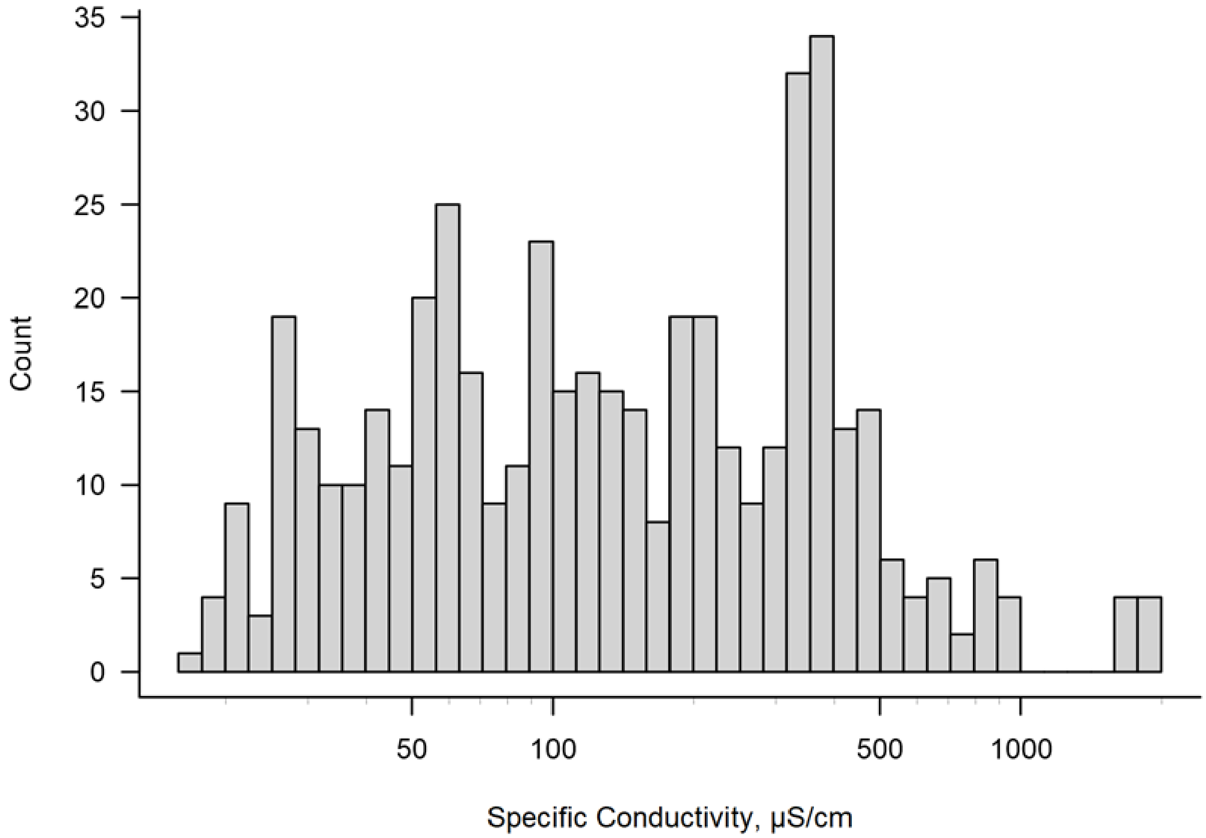


Figure A.4.1. Distribution and range of SC Arkansas data set.

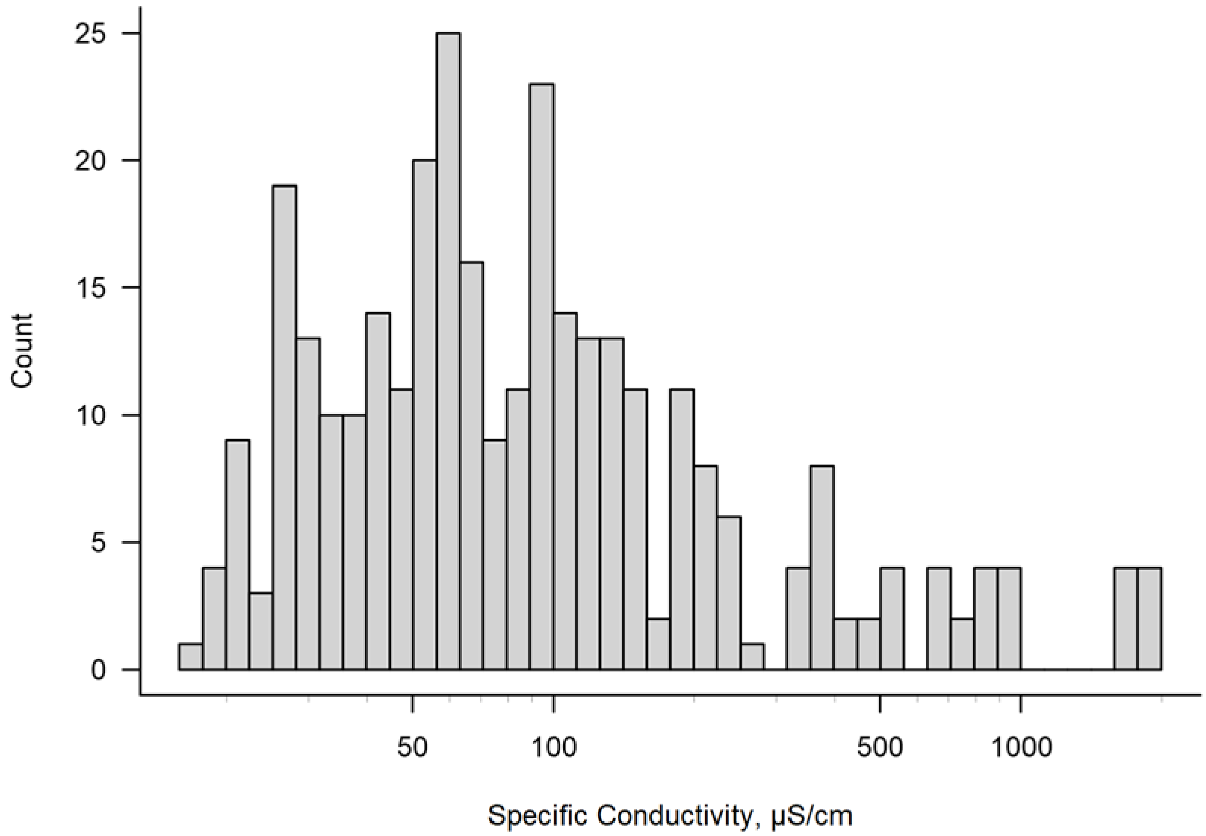


Figure A.4.2. Distribution and range of SC Group 1 data set.

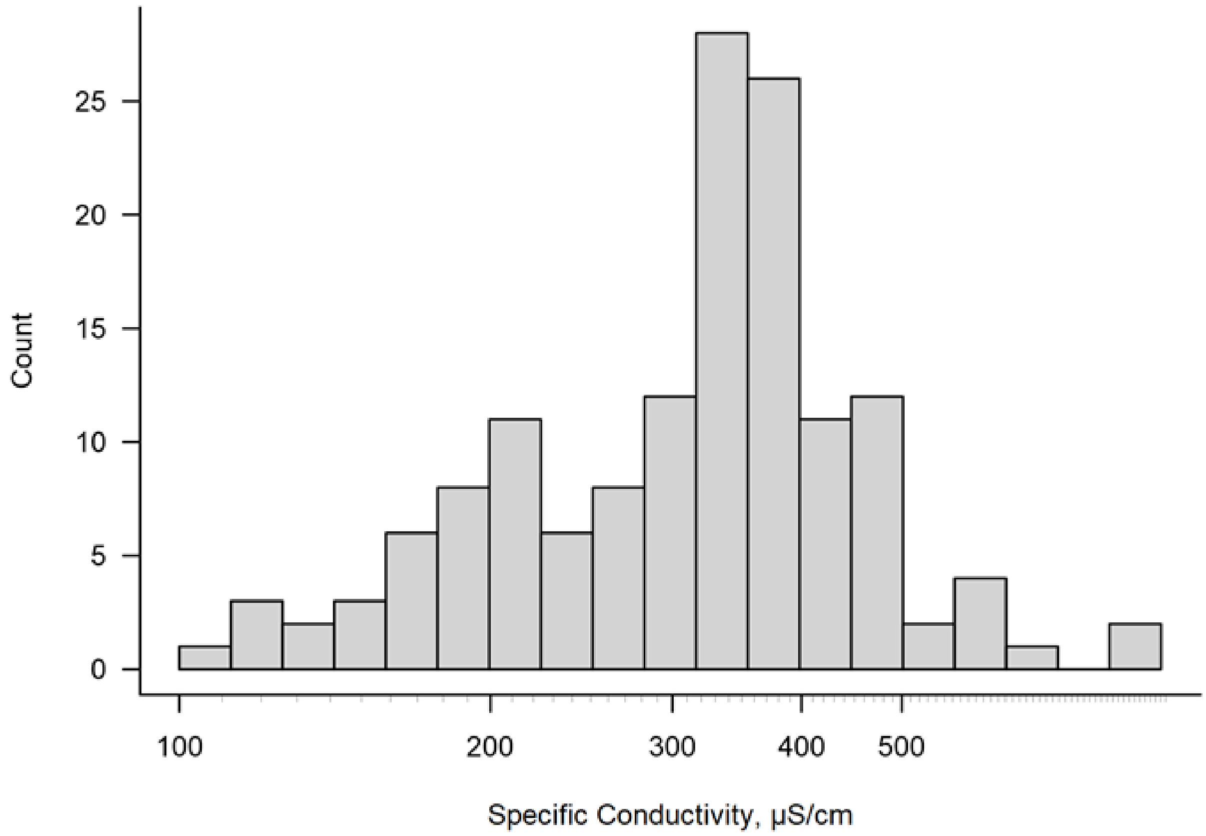


Figure A.4.3. Distribution and range of SC Group 2 data set. The SC range is marginal for estimating XC95 values. Most of the XC95 values were characterized as greater than the estimated value. The permutation test for the XCD05 was also weak and the critical value overlapped the upper 95% Confidence limit (Figure A.5.3).

Extirpation Levels Based on Field-Based Method

This section describes the estimation of 5% extirpation using the field-based extirpation distribution (XCD05) approach for two combined groups of ecoregions. Ecoregions were grouped together to increase sample size and range of exposures (USEPA, 2011, 2016; Cormier et al., 2020). These results are not recommended except as a screening tool because the scale was coarse and not representative of local background SC conditions. However, the XC95 values for individual genera may be useful for causal assessments.

Data sets for field-based method

To increase the number of stations in the data set, both TDS and SC water chemistry measurements were accepted. At stations where TDS data were available, but SC data were not, SC was estimated using regression models (Table 4 and Figure 4). Then, biological records were paired with SC at stations with the nearest spatial and temporal proximity and within two kilometers and sampled within 30 days to maximize the data set. Ecoregions were grouped into two larger regional data sets for subsequent analysis. Ecoregion Group 1, a lower background SC area, consists of the Arkansas Valley, Boston Mountains, Ouachita Mountains, and South Central Plains (Table A.5.1). Ecoregion Group 2, a higher expected background area, consisted of the Ozark Highlands, the Mississippi Alluvial Plain, and the Mississippi Valley Loess Plains (Table A.5.1). Merging ecoregions also helped to increase the sample size. XC95 values were calculated for genera with a minimum of 25 occurrences.

Field-based method application

Analyses were performed using paired data for the entire state of Arkansas, and Ecoregion Groups 1 and 2. The 5^{th} centile extirpation values (XCD05) were calculated in a two-step process following a field-based method using an extirpation concentration distribution (XCD) (USEPA, 2011b; Cormier and Suter, 2013; Cormier et al., 2013). First, the extirpation concentration (XC95) values for each genus with ≥25 occurrences were calculated as the 95^{th} centile of a weighted cumulative frequency distribution (CFD) of SC levels at sites where a genus had been collected. Then, a frequency distribution of XC95 values was constructed, and the 5^{th} centile was identified from the CFD by a log linear 2-point interpolation.

Confidence of individual XC95 values was assessed using generalized additive models (GAM) with 3 degrees of freedom that estimate the probability of a genus being observed with increasing SC. The probability of observing a genus is the percentage of sampled stations in a given SC bin of stations with the genus present. The uncertainty bounds of a GAM indicate the confidence in the calculated XC95 and whether the value is greater than the observed SC range (USEPA, 2011). Confidence in the XC95 was qualitatively scored as follows. If the GAM mean-fitted curve at maximum SC was approximately equal to zero (defined as less than 1% of the maximum modeled probability), then the XC95 was listed without qualification; otherwise, the XC95 was designated as approximate or greater than the calculated value. If the generalized additive model mean curve at maximum SC was > 0 but the lower confidence limit approximated 0 (<1% of the maximum mean modeled probability), then the value was listed as approximate. If the generalized additive model lower confidence limit was > 0, then the XC95 was listed as greater than the 95th centile.

Confidence in the XCD05 was evaluated using two simulation methods (Cormier et al., 2020). (1) Bootstrapping with replacement was used to estimate the 95% confidence interval for XC95 and XCD05 values. (2) A permutation test was used to estimate the probability that the XCD05 values could have arisen by chance. The permutation test evaluated whether the data set was large enough and the sample distribution covered a wide enough range of SC levels to provide a defensible 5% extirpation value. The permutation test simulates conditions where the SC has no influence on occurrence of a genus. Confidence in the observed XCD05 value depends upon the lack or degree of overlap with the permutated XCD05 values. Details for both methods can be found in Cormier et al. (2020).

For bootstrapping, in the paired biological and SC data sets for Arkansas and Ecoregions Groups 1 and 2, samples were randomly selected with replacement from the original set of samples. Next, the XC95 values were calculated for each genus in the bootstrapped data set by the same methods applied to the original data, and the XCD05 was calculated. The process was repeated to generate 1,000 bootstrapped data sets. Two-tailed 95% confidence bounds were generated for these bootstrap-derived XC95 values and the distribution of the 1,000 XCD05 values.

The permutation test evaluated whether the XCD05 values could have occurred by chance. XC95 values were recalculated using the observed sample sizes for the 86, 72 and 24 genera in Arkansas, and Ecoregion Groups 1 and 2, respectively—as if they occurred randomly, with respect to SC, across the sites in the original three data sets. Genera met the inclusion criteria of ≥ 25 occurrences in a data set. This randomization process was repeated 1,000 times, generating XC95 values for each genus and 1,000 sensitivity distributions. Thus, each of the new 1,000 permutated data sets maintained the number of occurrences of a genus but randomized their SC exposure. The results are shown in Figures A.5.1, A.5.12, and A.5.3. Also, to estimate the probability that the XCD05 values could have arisen by chance, we fitted the 1,000 permutation XCD05 values to a normal distribution in each run. Then, the probability of an observed XCD05 value occurring by chance was calculated based on centiles of the fitted normal distribution. The 5th centile of the 1,000 permutated XCD05 values corresponds to the 1-tailed critical value that defines the XCD05 value that may have occurred by chance, with an alpha of 0.05.

Field-based XC95 and XCD05 values results

XC95 values and CFD and GAM plots are available from the authors at cormier.susan@epa.gov.

The Arkansas and Ecoregion Group 1 and 2 XCD05 values pass the permutation test, but due to the low number of genera and modest number of stations, the estimate for Ecoregion Group 2 is much less confident (Figures A.5.1, A.5.2, A.5.3, and Table A.5.1). The XCD05 for Group 2 is only 10 μS/cm less than the critical value for accepting the hypothesis that the XCD05 could have arisen by chance. Also, the two genera with the lowest XC95 values in Ecoregion Group 2 met the minimum sample size for inclusion, i.e., $N \geq 25$, but their XC95 values are ambiguous based on uncertainty bounds of their GAM plots as indicated as triangles in the XCD plot (Figure A.5.3).

For the Arkansas data set, the observed XCD05 is 156.2 µS/cm with a two-tailed 95% CI of 97.5-195.94 µS/cm (Figure A.5.1). The 5th centile of the permutation values is 428.24 µS/cm. This corresponds to the 1-tailed critical value that defines the upper limit of the rejection region (alpha = 0.05). Therefore, for an observed XCD05 value of <428.4 µS/cm, the hypothesis that the XCD05 is not associated with SC is rejected.

For the Ecoregion Group 1 data set, the observed XCD05 is 125.5 µS/cm with a two-tailed 95% CI of 72.7-170.54 µS/cm (Figure A.5.2). The 5th centile of the permutation values is 382 µS/cm. This corresponds to the 1-tailed critical value that defines the upper limit of the rejection region (alpha=0.05). Therefore, for an observed XCD05 value of < 380 µS/cm, the hypothesis that the XCD05 is not associated with SC is rejected.

For the Ecoregion Group 2 data set, the observed XCD05 is 403.5 µS/cm with a two-tailed 95% CI of 390.7-455.8 µS/cm (Figure A.5.3). The 5th centile of the permutation values is 413.2 µS/cm. This corresponds to the 1-tailed critical value that defines the upper limit of the rejection region (alpha=0.05). Therefore, for an observed XCD05 value of < 413.2 µS/cm, the hypothesis that the XCD05 is not associated with SC is rejected. However, confidence is not strong because the 95% CI of the observed XCD05 from the bootstrapping procedure (upper 95% CL=457.8 µS/cm) overlaps with the 5th centile permutation value (413.2 µS/cm). Furthermore, there were only 24 genera and most of their XC95 values were undefined, that is greater than the estimated XC95 (USEPA 2011, 2016).

Summary: Field-based Extirpation Estimates

The derivation of a field-based SC benchmark using the currently available paired biological and chemical data are a reasonable XCD05 estimate for Arkansas as a whole and for Ecoregion Group 1. The XCD05 value for Ecoregion Group 2 is best considered as a screening benchmark because the statistical test for confidence was weaker, probably because the SC exposure range was too narrow and the number of genera were so few. Group 1 and Group 2 data sets had only 72 and 24 genera, respectively. For greater confidence, a data set that yields around 90 genera or species gives a more consistent XCDC05 (Cormier et al., 2020). The number of genera may be increased either with identification of all individuals in fewer sites or with fewer individuals identified from more sites (~500 samples). The data set could be increased by using data from the entire ecoregion outside of Arkansas or collected by other entities.

For all three XCD05 estimates, there is potential unmeasured variation due to the necessity to match water chemistry samples with macroinvertebrate data that were not collected at the same river mile or date. As a result, the water chemistry at a station may not be optimally matched with the biological sample in space or time. For example, a low SC measurement may be upstream of a point source and the biological data downstream of a source where the SC could be high. Also, biology may have been obtained from one tributary and chemistry from a nearby tributary or main stem.

The XCD05 values are not recommended because the B-C method provided comparable results and had the benefit of being at the stream segment scale for most of Arkansas, a more reliable scale than the grouped ecoregions.

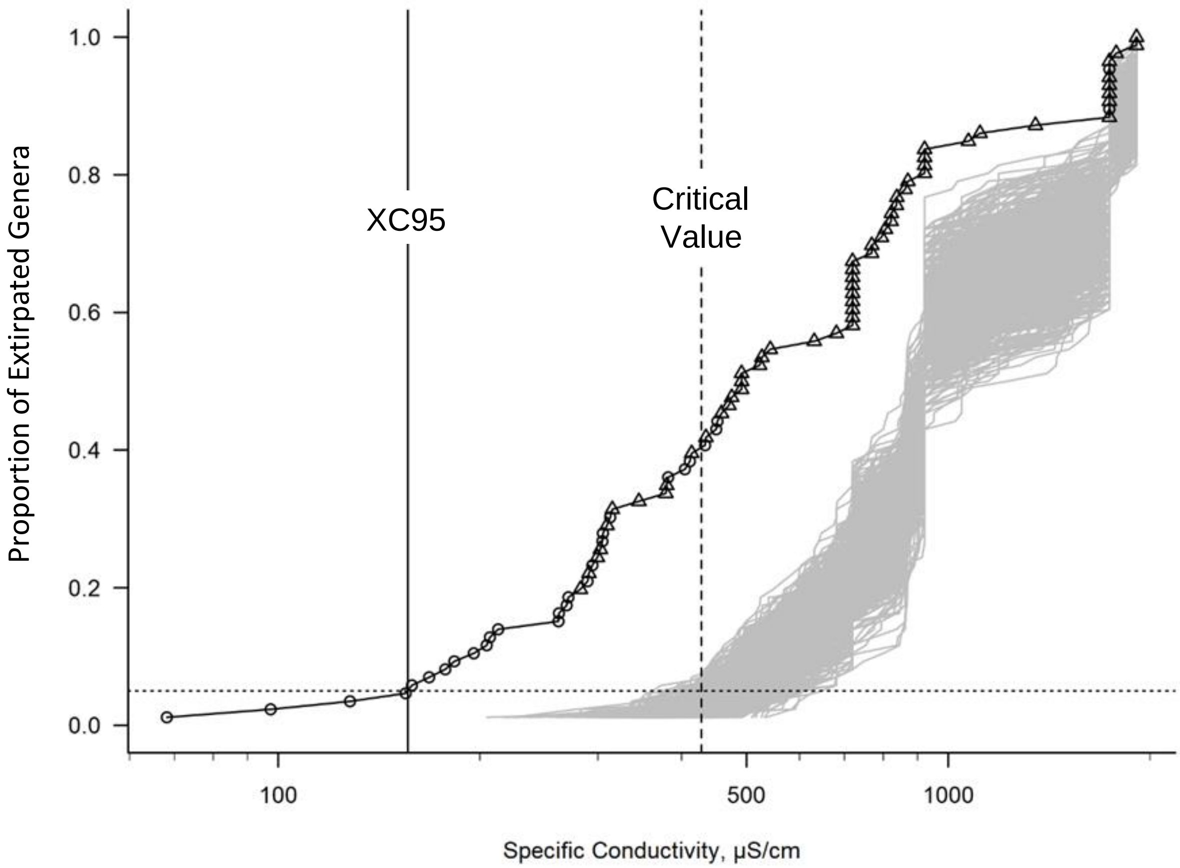


Figure A.5.1. Benthic invertebrate genus extirpation concentration distributions (XCD) in Arkansas. XCD05 = 156.2 (95% CI 97.5-195.9) µS/cm. Each open circle or triangle is an observed extirpation concentration (XC95) value for one genus forming an XCD. Approximate or greater-than XC95 values are designated by triangles. The observed 5% extirpation level (XCD05) is the SC at the intersection of the solid horizontal line at the 5th centile. The XCDs simulate when there is no influence of SC by randomly shuffling the occurrence of taxa among stations independent of actual SC. A thousand permutated simulated XCDs are the solid gray lines on the right. The critical value is shown at the intersection of the dashed horizontal line at the 5th centile. There is a clear delineation between the observed XCD05 (156.2 µS/cm) and the permutation test critical-XCD05 value (428.24 µS/cm, alpha = 0.05), indicating that the observed XCD05 did not arise by chance.

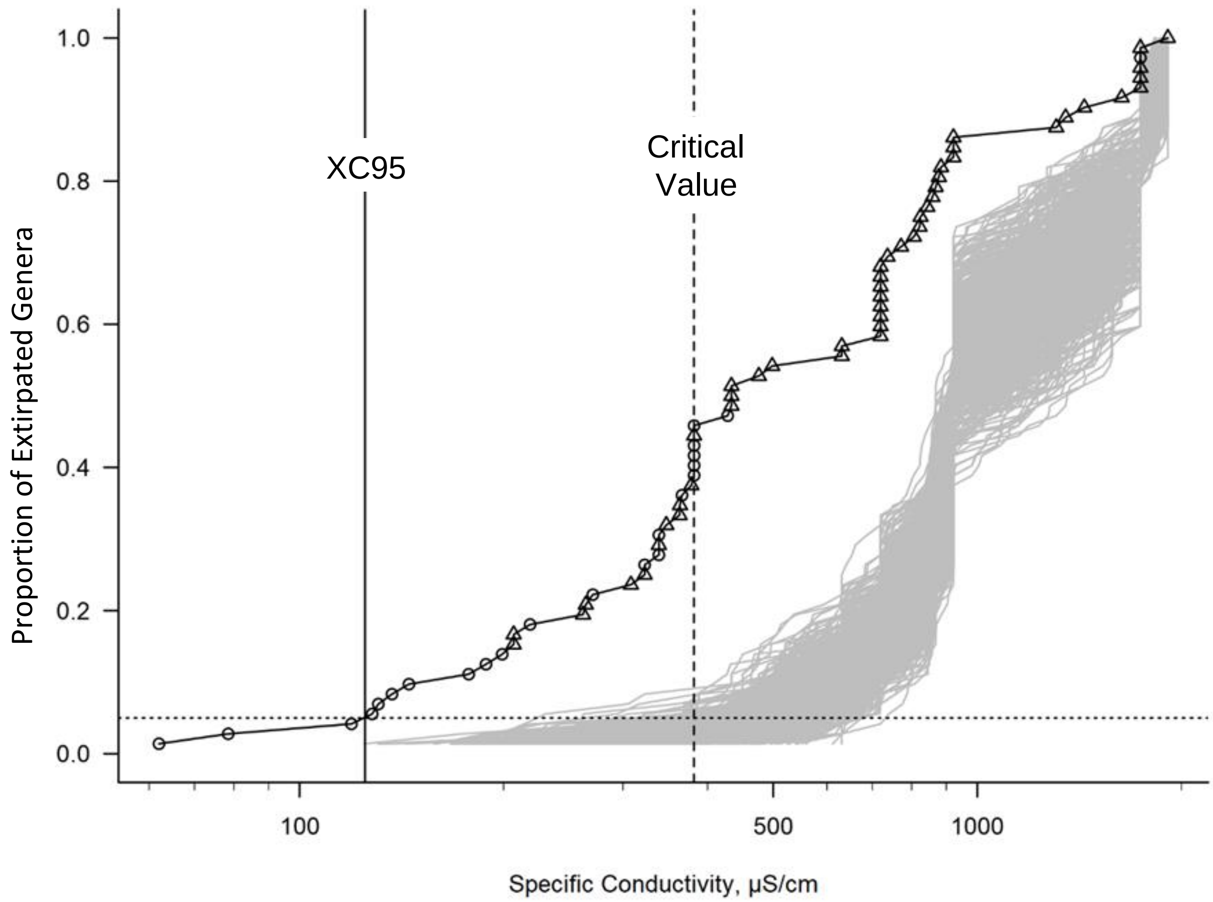


Figure A.5.2. Benthic invertebrate genus extirpation concentration distributions (XCD) for Region 1. XCD05 = 125 (95% CI 72.7-1670.5) µS/cm. Each open circle or triangle is an observed extirpation concentration (XC95) value for one genus forming an XCD. Approximate or greater-than XC95 values are designated by triangles. The observed 5% extirpation level (XCD05) is the SC at the intersection of the solid horizontal line at the 5th centile. The XCDs simulate when there is no influence of SC by randomly shuffling the occurrence of taxa among stations independent of actual SC. A thousand permutated simulated XCDs are the solid gray lines on the right. The critical value is shown at the intersection of the dashed horizontal line at the 5th centile. There is a clear delineation between the observed XCD05 (125 µS/cm) and the permutation test critical-XCD05 value (382 µS/cm, alpha=0.05), indicating that the observed XCD05 did not arise by chance.

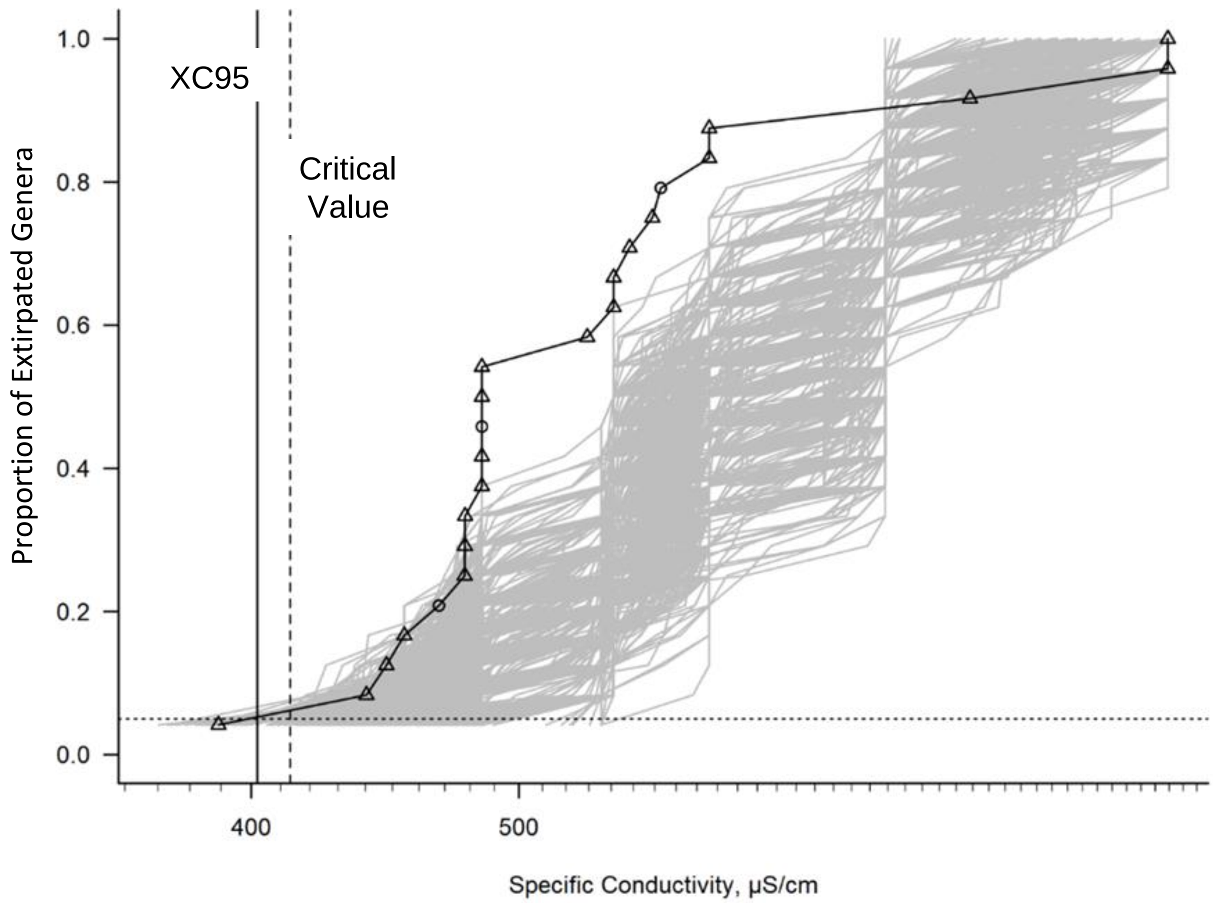


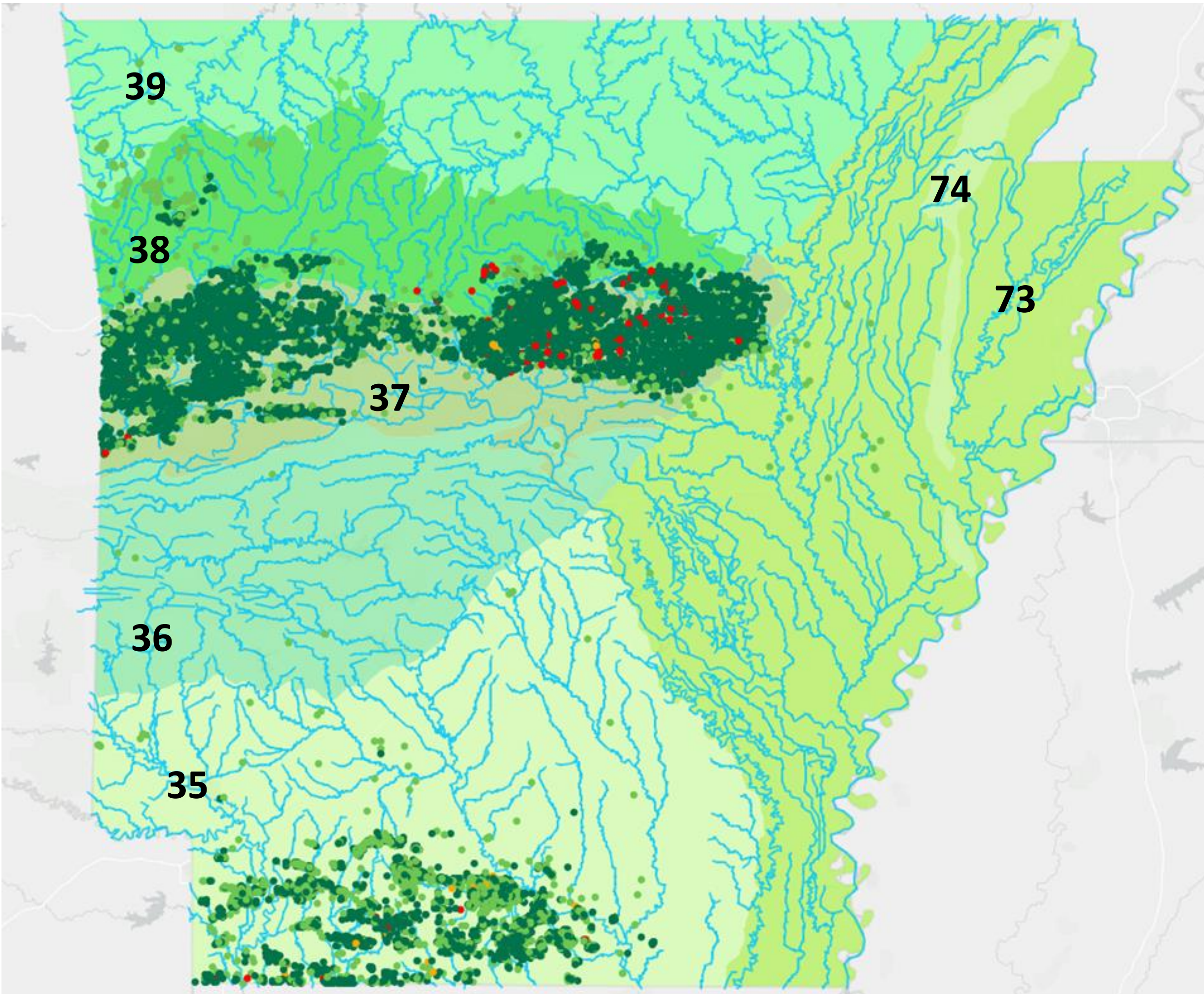
Figure A.5.3. Benthic invertebrate genus extirpation concentration distributions (XCD) for Region 2. XCD05 = 403.5(95% CI 390.7-455.8). Each open triangle is an observed extirpation concentration (XC95) value for one genus; most are greater-than XC95 values and therefore not confidently assigned. The observed 5% extirpation level (XCD05) is the SC at the intersection of the solid horizontal line at the 5th centile. The XCDs generated by permutation simulating no influence of SC by randomly shuffling of taxa occurrences are solid gray lines on the right. The critical value is shown at the intersection of the dashed horizontal line at the 5th centile. Observed XCD05 (403.5 µS/cm) and the permutation test critical-XCD05 value (413.2 µS/cm, alpha=0.05) are statistically different, but discrimination is not as strong as in Region 2. Number of genera is small; thus, the uncertainty in the XCD05 value is greater, as indicated by the overlap of the observed and simulated XCDs and the small difference between the observed and simulated XCD05s.

Table A.5.1. XCD_{05} values in different regions, sample sizes, number of genera, XCD 95% confidence intervals, and XCD05 critical values.
SC = specific conductivity

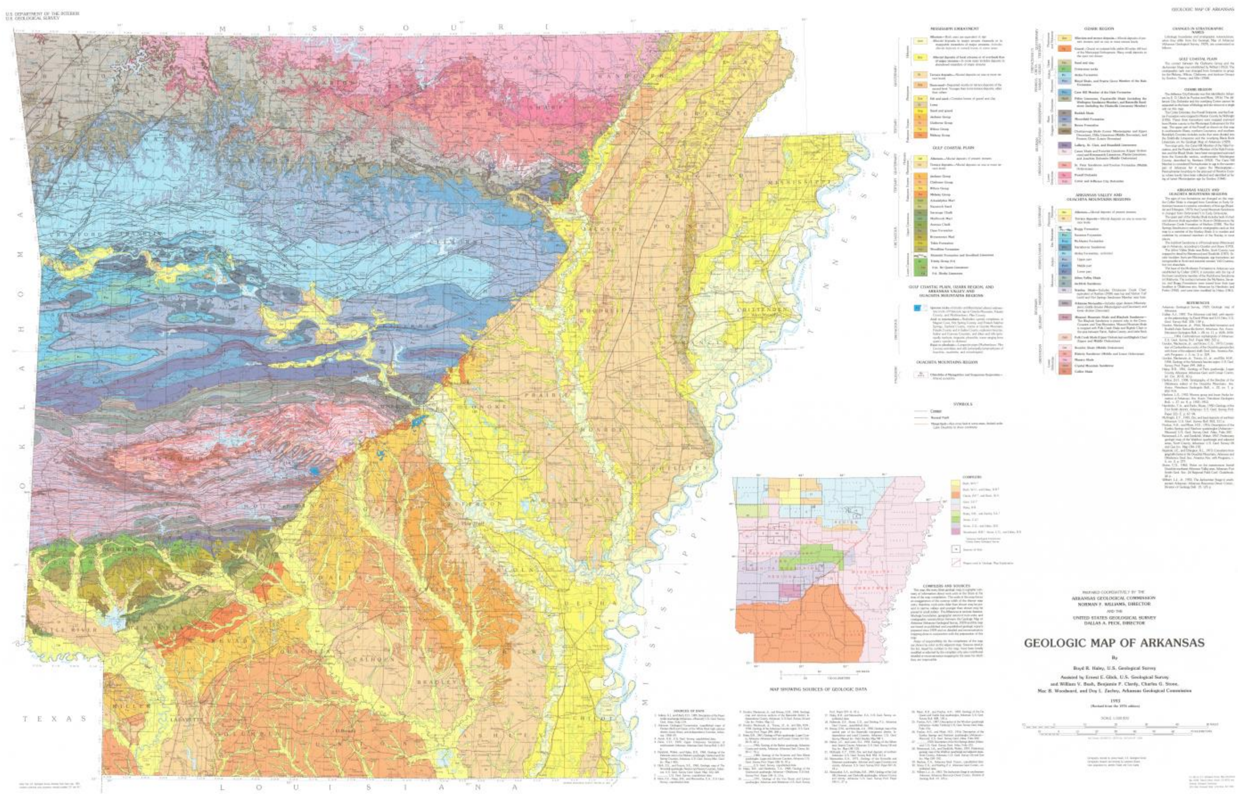
	USEPA Technical Document 2016[a]			Present study			
	N Samples	*N* Genera	$XCD05_{05}$ SC (µS/cm)	*N* Samples	*N* Stations	*N* Genera	$XCD05_{05}$ SC (µS/cm) (95% CI). [Critical value]
Entire ADEQ paired dataset	380	64	328.5	465	198	86	156.2 (97.5-195.9) [428.2]
ADEQ Region 1 (35, 36, 37, 38)	187	31	204	319	121	72	125.0 (72.7-170.5) [382.0]
ADEQ Region 2 (39, 73, 74)	193	27	358	146	77	24	403.5 (390.7-455.8) [413.2]

[a]*USEPA, 2016. Final Report: EPA Technical Support: Evaluation of Several Approaches to Develop Mineral Criteria in Arkansas. February 2016. Pp. 85.*

Map A.6. Maps of Arkansas



Map A.6.1. Oil and Gas wells 2017. Active (green circles), Inactive (light green), Permitted (orange), Spud (read). Blue lines are stream network. South Central Plains (35), Ouachita Mountains (36), Arkansas Valley (37), Boston Mountains (38), Ozark Highlands (39), Mississippi Alluvial Plain (73), Mississippi Valley Loess Plains (74). Source: https://services.arcgis.com/jDGuO8tYggdCCnUJ/arcgis/rest/services/Arkansas_Oil_Gas_Map/FeatureServer



Map A.6.2. Geologic Map of Arkansas
Haley B.R. and Arkansas Geological Commission staff. 1993. Geologic Map of Arkansas.
Download map at: https://www.geology.arkansas.gov/maps-and-data/geologic_maps/geologic-map-of-arkansas-1993-revised-from-1976-edition.html