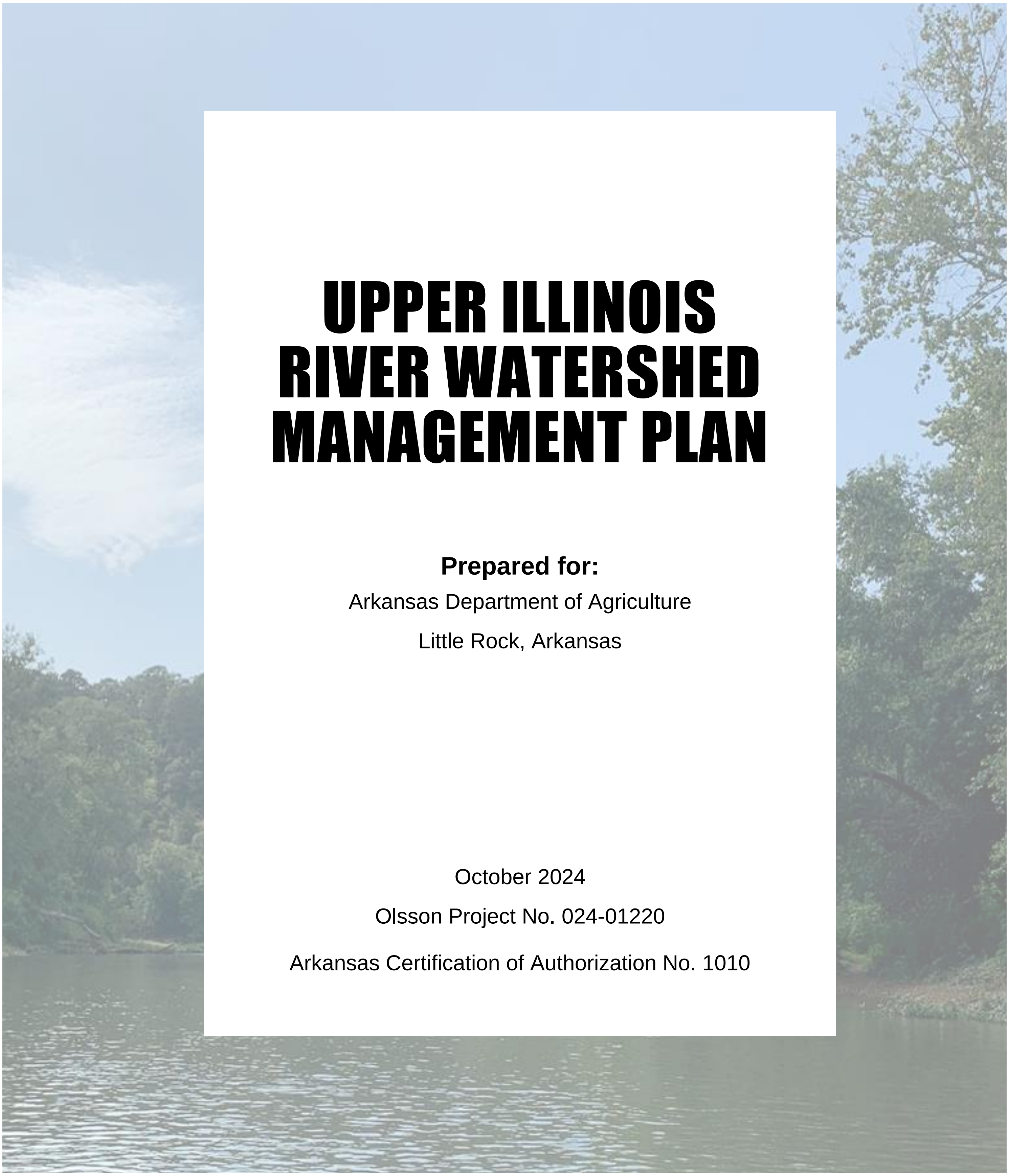

UPPER ILLINOIS RIVER WATERSHED MANAGEMENT PLAN

Prepared for:

Arkansas Department of Agriculture

Little Rock, Arkansas

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ACRONYMS AND ABBREVIATIONS

APCEC........................ ………………………..Arkansas Pollution Control and Ecology Commission

AU .... ……………………………………………………………Assessment Unit

AWRC .... …………………………………………...Arkansas Water Resource Center

BMP………………………………………………………………………Best Management Practices

BOD .... …………………………………………………Biochemical Oxygen Demand

°C .... ……………………………………………………………Degrees Celsius

CRP…………………………………………………………………..Conservation Reserve Program

CSP……………………………………………………………...Conservation Stewardship Program

DEQ .... ………………………Arkansas Department of Energy and Environment

……………………………………………………………………Division of Environmental Quality

DO............................. …………………………………………………………..Dissolved Oxygen

EPA .... ………………………………………………Environmental Protection Agency

EQIP………………………………………………………..Environmental Quality Incentives Program

ERW……………………………………………………………………Extraordinary Resource Waters

ESM………………………………………………………………Environmentally Sensitive Maintenance

FSA……………………………………………………………………………..Farm Services Agency

HUC12…………………………………………………………………12-digit Hydrologic Unit Code

IBI............................... ……………………………………………………..Index of Biotic Integrity

IRWP .... ……………………………………………Illinois River Watershed Partnership

Mg .... ………………………………Megagrams (10^6 grams), also called metric ton

mg/L .... …………………………………………………………Milligrams Per Liter

mi2 .... ……………………………………………………………...Square Miles

MMI…………………………………………………………………………………Multimetric Index

MSA…………………………………………………………………………Metropolitan Statistical Area

NLCD…………………………………………………………………………National Land Cover Dataset

NOAA…………………………………………...National Oceanic and Atmospheric Administration

NRCS……………………………………………………..Natural Resources Conservation Service

NTU......................... …………………………………………………Nephelometric Turbidity Unit

NWARPC……………………………………Northwest Arkansas Regional Planning Commission

NWIS……………………………………………………………..National Water Information System

OSEPI…………………………………………………………Ozark Stream Erosion Potential Index

SARP…………………………………………………….Southeast Aquatic Resources Partnership

SRP......................... ……………………………………………..Soluble Reactive Phosphorus

SSC......................... …………………………………….Suspended Sediment Concentration

STATSGO………………………………………………………..State Soil Geographic Database

STP…………………………………………………………………………Soil Test Phosphorus

Su........................... ………………………………………………………Standard Units (of pH)

SWAT…………………………………………………………Soil and Water Assessment Tool

TDS......................... …………………………………………………………Total Dissolved Solids

TKN………………………………………………………………………..Total Kjeldahl Nitrogen

TSS......................... ……………………………………………………Total Suspended Solids

UofA…………………………………………………………………….University of Arkansas

USACE…………………………………………………...United States Army Corps of Engineers

USDA……………………………………………………United States Department of Agriculture

USFWS…………………………………………………..United States Fish and Wildlife Service

USGS………………………………………………………….United States Geological Survey

WCRC……………………………………………….Watershed Conservation Resource Center

WWTP..................... …………………………………………………Wastewater Treatment Plant

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EXECUTIVE SUMMARY

The Upper Illinois River is one of the 12 Nonpoint Source Program priority watersheds designated by Arkansas Department of Agriculture's Natural Resources Division (Natural Resources Division) in the 2022 (Nonpoint Source Management - Arkansas Department of Agriculture).

There are stream reaches in the watershed that are included in the approved 2018 state impaired waters list (303(d) list) due in part to pollution from nonpoint sources. The update to the Upper Illinois River Watershed Management Plan was initiated in response to the changing landscape of the Illinois River watershed and the current plan was over twelve years old. This updated plan re-evaluates current water quality conditions, re-evaluates target sub-watersheds for implementation of conservation practices, engages existing and new stakeholders, and establishes new milestones for water quality improvement in accordance with US EPA guidance for a nine-element watershed management plan.

The primary focus of this plan is the protection and improvement of surface water quality in the Illinois River and its tributaries, and groundwater quality, through management of unregulated nonpoint sources of pollution. The mission of this plan is to encourage and support improvement of the integrity of the Illinois River watershed through public education, outreach, and voluntary implementation of conservation and restoration practices throughout the watershed.

The US EPA has established nine key elements of a watershed management plan. Summary of these nine key elements are: 1) Identify causes and sources of pollution; 2) Estimate pollutant loading into the watershed and anticipated load reductions; 3) management measures to achieve load reductions in targeted areas; 4) estimate technical and financial assistance needed to implement the plan; 5) develop informational and educational components; 6) develop a project schedule; 7) describe interim measurable milestones; 8) identify indicators to measure progress; and 9) develop a monitoring plan. The US EPA will review any draft watershed management plan using these nine elements to determine whether to accept the plan. Acceptance of the plan is required in order to utilize US EPA funding through the Nonpoint Source Program to implement conservation practices in the respective watershed.

For the Upper Illinois River Watershed Management Plan, 12-digit HUC (HUC12) sub-watersheds delineated by the USGS are utilized as focus areas for nonpoint source pollution management. To identify HUC12 sub-watersheds to recommend for additional management of nonpoint source pollution under this plan, available information was used to rank the focus HUC12 sub-watersheds of the Upper Illinois River watershed (those with at least 50 percent of their area in Arkansas), in terms of water quality concerns. Four (4) sets of water quality-related information were used to rank these HUC12 sub-watersheds to include water quality impairment, modeled nutrient and sediment instream loads, water quality natural resource concerns from the 2015 NRCS State Resources Assessment, and estimated condition of macroinvertebrate communities.

Six Category 1 HUC12 sub-watersheds ranked for highest return on investment for conservation practice installation to improve water quality include Moores Creek (11101030102), Lower Muddy Fork (111101030103), Little Osage Creek (111101030302), Lake Wedington-Illinois River (111101030403), and Lake Frances-Illinois River (111101030606). For each Category 1 sub-watershed, water quality targets to address nonpoint source pollutants were established. Water quality targets established were for nutrients (i.e., phosphorus and nitrogen), sediment, *Escherichia coli*, chlorides, and sulfates.

To meet water quality targets, the Upper Illinois River Watershed Management Plan outlines voluntary conservation practices and anticipated reductions to nonpoint source pollutants. For all six sub-watersheds stakeholders identified between 11 and 16 conservation practices identified for implementation in either rural or urban watersheds, respectively. Voluntary conservation practices range from pasture management techniques such as filter strips and utilization of nutrient management plans to urban practices for stormwater management.

The units of a practice to be implemented are based on the extent of the targeted source, and the amount of that source to treat to meet the load reduction targets for a sub-watershed. Estimates of pollutant sources and the approaches used to derive them are described in Appendix N. Individual implementation costs for rural conservation practices ranged from minimums of $4/foot for exclusion fencing and $40/acre for prescribed grazing. Maximum individual implementation for rural conservation practices ranged from $3,000/foot for streambank stabilization and $19,000/facility for litter/waste storage facilities. Maximum implementation costs for each individual conservation practice were estimated as singular improvements to meet water quality targets based on the range of anticipated load reduction achieved with installation. If all potential conservation practices were implemented at the maximum possible goal, the estimated cost would be over $600 million. Detail of each practice by sub-watershed is provided in Tables 6.1 - 6.5 within the plan. Not all induvial practices and projects are required to meet the water quality improvement goals, but it provides a road map of possible opportunities.

Successful implementation of the Upper Illinois River Watershed Management Plan relies on a well-defined framework of schedules and milestones. The schedule follows an adaptive management process, which involves several key steps of implementation, monitoring, evaluation, and modification. The implementation timeline begins following EPA acceptance of the plan with iterative assessment of performance measures annually. The goal will be to fully evaluate the watershed management plan by 2031.

1. INTRODUCTION

This management plan addresses the Upper Illinois River watershed. This is the portion of Hydrologic Unit Code 11110103 within the borders of Arkansas.

1.1 Plan Need and Mission

The Upper Illinois River is one of the 12 Nonpoint Source Program priority watersheds designated by Arkansas Department of Agriculture's Natural Resources Division (Natural Resources Division) in 2022 (Nonpoint Source Management - Arkansas Department of Agriculture). There are stream reaches in the watershed that are included in the 2018 state impaired waters list (303(d) list) due in part to pollution from nonpoint sources.

In November 2018, Arkansas and Oklahoma entered into a Memorandum of Agreement (MOA) regarding actions to improve water quality in the Illinois River. One of the actions specified in this agreement is for Arkansas and Oklahoma to "develop and begin implementing a Watershed Improvement Plan (WIP)" within four (4) years of effective date of the MOA. The states have agreed that each will prepare nine (9) element watershed management plans addressing nonpoint sources of phosphorus and other pollutants causing impairments within their portion of the Illinois River watershed. The two (2) nine (9) element watershed management plans will be incorporated into the WIP.

It has been over 10 years since a watershed management plan was developed for the Upper Illinois River watershed (FTN Associates, Ltd., 2012). The adaptive management approach utilized by the Natural Resources Division and outlined in the 2012 watershed management plan, requires periodic evaluation of progress and adaptation of the management plan to changes in the watershed.

The primary focus of this plan is the protection and improvement of surface water quality in the Illinois River and its tributaries, and groundwater quality, through management of unregulated nonpoint sources of pollution. The mission of this plan is to encourage and support improvement of the integrity of the Illinois River watershed through public education, outreach, and implementation of conservation and restoration practices throughout the watershed.

1.2 Watershed Vision

The vision for the Upper Illinois River watershed is: The Illinois River and its tributaries will be a fully functioning ecosystem, where ecological protection, conservation, and economically productive uses support diverse aquatic and riparian communities, meet all state and federal water quality standards, promote economic sustainability, and provide recreational opportunities (IRWP, n.d.).

Each community, landowner, and producer has their own vision for their part of the Upper Illinois River watershed. In addition, there are a number of agricultural and natural resources agencies and other organizations that work within the watershed to manage its natural resources. Some of them have developed plans that document their missions, visions and/or goals for the Upper Illinois River watershed. Overall, the vision above is compatible with, and supportive of, those of other programs and organizations active in the watershed.

1.3 Process

Development of the Upper Illinois River watershed management plan followed the steps outlined by US Environmental Protection Agency (EPA) in the Handbook for Developing Watershed Plans (EPA 2008):

- Building partnerships
- Characterizing the watershed
- Finalizing management goals and identifying solutions
- Designing an implementation program

The Natural Resources Division worked with consultants to develop this watershed management plan, utilizing the input of watershed stakeholders. Four (4) joint public meetings were held as part of the process of developing the Arkansas and Oklahoma Illinois River watershed management plans. These public meetings were held at various locations within the Illinois River watershed, in both Arkansas and Oklahoma. The purposes of these public meetings were to inform stakeholders of the plans and the process for developing them, and to request and obtain stakeholder input for the plans. Stakeholder input was sought specifically in identifying priority issues in the watershed and selecting management practices for addressing nonpoint source pollution in the watershed. Stakeholders who participated in development of this plan included local residents, representatives of federal and state legislatures, and county and municipal government, US Army Corps of Engineers (USACE), US Department of Agriculture Natural Resources Conservation Service (NRCS), the Cherokee Nation, Southwestern Power Company, Arkansas natural resources agencies, University of Arkansas (UofA) Division of Agriculture

Cooperative Extension Service, County Conservation Districts, and recreation and environmental interest groups. Attendance summaries from the meetings are included in Appendix A.

1.4 Document Overview

This document contains elements recommended by EPA for watershed management plans. Section 2 describes many of the features of the watershed. Section 3 summarizes conditions in the watershed, including water quality, hydrology, and ecology, and nonpoint pollutant sources in the Upper Illinois River watershed. Section 4 identifies sub-watersheds recommended for water quality protection and management of nonpoint pollutant sources, pollutant load reduction targets, and management strategies for controlling nonpoint source pollution in the sub-watersheds recommended for management. Section 5 outlines the overall implementation plan, with schedule, list of management and outreach activities, and identification of indicators and monitoring to track progress and effects. Section 6 discusses costs and benefits of proposed management, and assistance that is available for implementation of nonpoint source pollution management practices. Watershed-based management plans developed to meet the requirements for Clean Water Act Section 319 funding must address nine (9) planning elements required by EPA to manage and protect against nonpoint source pollution. Table 1.1 provides a roadmap for where the required planning elements are addressed in this plan.

Table 1.1. Planning elements in management plan.

Element	Report Section(s)
Element A: Identification of Causes and Sources	
Sources identified, described, and mapped	3.4, 4.6
Sub-watershed sources	4.6
Data Sources are accurate and verifiable	all
Data gaps	3.1.7, 3.2.5, 3.3.6
Element B: Expected Load Reductions	
Load reductions achieve environmental goal	4.5, 4.8
Table 1.1. Planning elements in management plan (continued).	

Load reductions linked to sources	4.8, Appendix M
Model complexity appropriate	Appendix M
Basis of effectiveness estimates explained	Appendix M
Methods and data cited and verified	Appendix M

Element	Report Section(s)
Element C: Management Measures Identified	
Specific management measures are identified	4.7
Priority areas	4.3, Appendix J, 4.6
Measure selection rationale documented	4.7
Technically sound	4.0
Element D: Technical and Financial Assistance	
Estimate of technical assistance	6.3
Estimate of financial assistance	6.1, 6.4, Appendix N
Element E: Education/Outreach	
Public education/information	5.1
All relevant stakeholders are identified in outreach process	1.0, Appendix A, 5.2
Stakeholder outreach	5.1
Public participation in plan development	Appendix A
Emphasis on achieving water quality standards	1.0, 4.4, 4.5, 4.8, 5.5, 5.6
Operation & maintenance of BMPs	4.8, 5.3

Element F: Implementation Schedule	
Includes completion dates	5.7
Schedule is appropriate	5.7

Table 1.1. Planning elements in management plan (continued).

Element	Report Section(s)
Element G: Milestones	
Milestones are measurable and attainable	5.7
Milestones include completion dates	5.7
Progress evaluation and course correction	5.5, 5.6, 5.7
Milestones linked to schedule	5.7

2. WATERSHED DESCRIPTION

2.1 Geography

The Upper Illinois River watershed is defined for this plan as the Arkansas portion of the eight (8)-digit hydrologic unit code (HUC8) 11110103, Illinois watershed. The Upper Illinois River watershed encompasses 758 square miles in northwestern Arkansas (Figure 2.1). A number of cities are located within the watershed, including Fayetteville, Gentry, Prairie Grove, Rogers, Siloam Springs, and Springdale. The largest towns are located along the eastern watershed boundary, Rogers, Springdale, and Fayetteville. US Highways 62 and 412, and Interstate 49, cross the watershed.

The Illinois River originates near Hogeye, Arkansas in Washington County. The river flows westerly, crossing the Ozarks of northwest Arkansas and into Oklahoma approximately five (5) miles south of Siloam Springs, Arkansas, near Watts, Oklahoma. The river continues southwesterly in Oklahoma to Lake Tenkiller and eventually flows into the Arkansas River near Gore, Oklahoma. Other Counties that are part of the watershed are Benton and Crawford Counties (Table 2.1). Washington County accounts for 60 percent of the watershed, and Benton County accounts for 40 percent of the watershed.

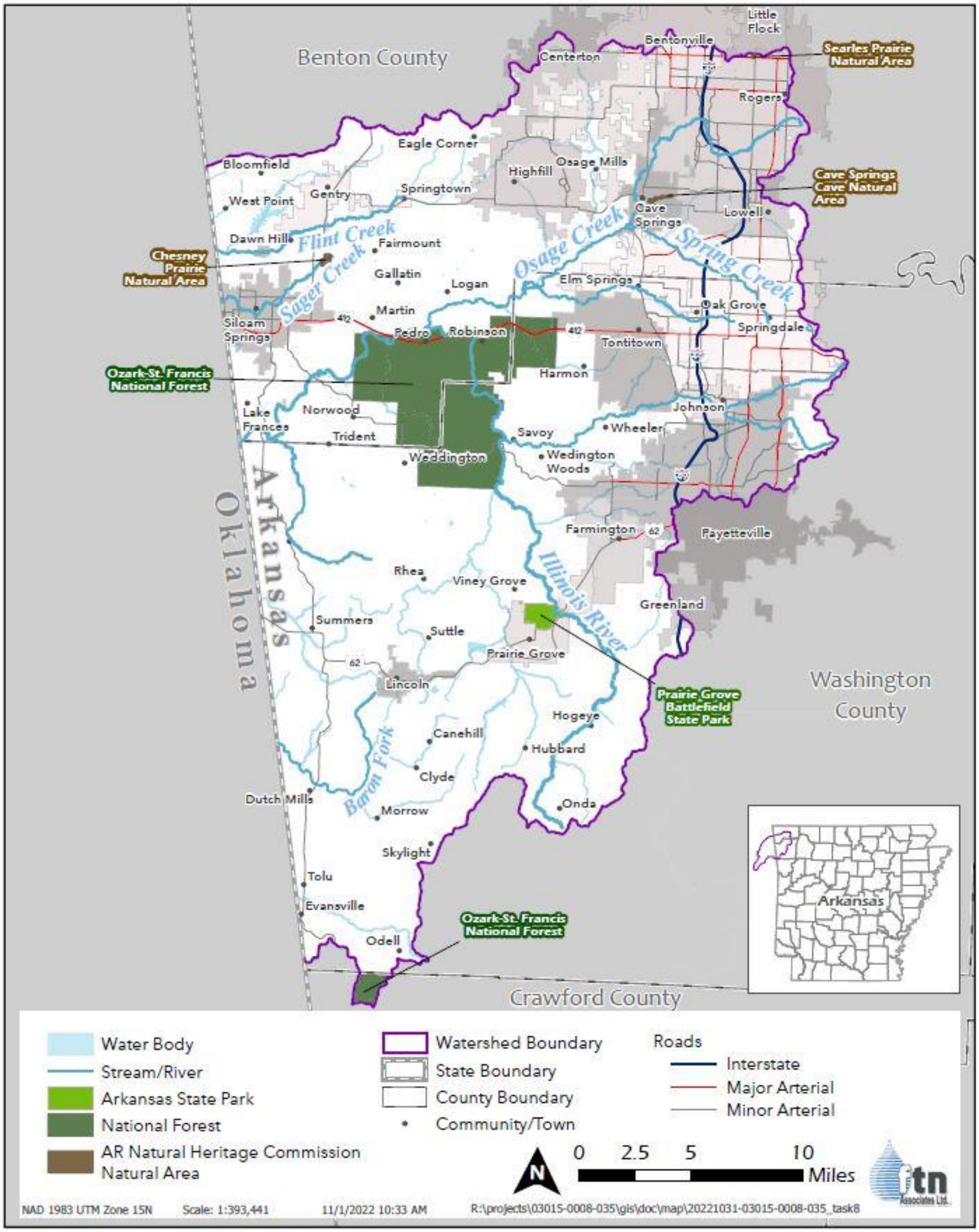

Figure 2.1. Upper Illinois River watershed, Arkansas.

Table 2.1. County areas within the Upper Illinois River watershed.

Counties	County area (square miles)	County area within watershed (square miles)	Percent of County within watershed	Percent of watershed within County
Benton	884.1	299	34%	40%
Crawford	605.4	1.67	<1%	<1%
Washington	951.7	456	48%	60%
Totals	2,441.2	756.7	-	100%

Table 1Table 2

2.2 Socioeconomics

This section summarizes demographic and economic information for the Upper Illinois River watershed. Demographic information from the US Census Bureau for the counties of the Upper Illinois River watershed is presented.

2.2.1 Population

In 2020 the Upper Illinois River watershed was home to over 347,000 Arkansans (US Census Bureau 2021a). Numbers of people reported in the 2020 US Census for Benton and Washington Counties, and the state of Arkansas are presented in Table 2.2. These counties all experienced population increases between 2010 and 2020 and are expected to continue to see population growth through 2035.

The majority of the watershed is within the Fayetteville-Springdale-Rogers Metropolitan Statistical Area (MSA), which consists of Benton, Madison, and Washington Counties (US Census Bureau, 2021b). This is the fastest growing area in Arkansas, and one of the fastest growing areas in the country. The population within this MSA increased by 24 percent between 2010 and 2020 (Della Rosa, 2021). The rapid population growth in this region has implications for water quality and nonpoint source pollution.

Table 2.2. Population information for Benton and Washington Counties and Arkansas as a whole.

Area	2010 Total Population[a]	Population Change 2010 to 2020	2020 Total Population[a]	2035 Projection[b]
Benton County	221,339	62,994	284,333	368,796
Washington County	203,065	42,806	245,871	356,468
State of Arkansas	2,915,918	95,606	3,011,524	3,388,943

a (Arkansas Economic Development Institute, 2020)
b (Arkansas Economic Development Institute, 2013)

2.2.2 Economics

Per capita income and median household income are higher in Benton and Washington Counties than for the state as a whole, and unemployment rates are lower. The relative distribution of the available civilian work force among occupations in the listed counties is similar to that for the state overall.

The Upper Illinois River watershed is home to commercial poultry and non-commercial beef grazing production systems, which are essential to the economic well-being of the region. Arkansas is the second largest producer of broilers in the United States, with Benton and Washington counties the largest contributors of poultry and beef in the state. In addition, northwest Arkansas is home to Walmart headquarters, the world's second largest public corporation, and Tyson Foods, the largest meat producer in the world, as well as hundreds of small businesses supporting these industries.

Agriculture is not an economic sector reported in the US economic census. However, agriculture contributes value to manufacturing, real estate, wholesale trade, and transportation and warehousing economic sectors (English and Popp 2022). These two counties account for over one (1) percent of the value of state agricultural sales. Cattle sales account for the most agricultural sales value in Benton County, while poultry and egg sales account for the majority of agricultural sales value in the other four counties. Note that cattle sales from Benton County account for over 70 percent of the state total value of cattle sales. In these counties, hay sales account for the majority of crop sales value (Table 2.3).

Tourism in Arkansas rebounded in 2021 after declining in 2020. From 2020 to 2021 visitor spending increased 33 percent, returning to 2019 levels. Tourism related jobs increased 24 percent between 2020 and 2021 but were still five (5) percent lower than in 2019 (Arkansas Department of Parks, Heritage and Tourism, 2022). County-level data from 2021 have not yet been released, so a summary of 2020 travel-related revenue for Benton and Washington Counties is provided in Table 2.4.

Table 2.3. Value of county and state sales of agricultural commodities in thousands of dollars.

Commodity	Benton County	Washington County	State of Arkansas
All agricultural products	$871,156,000.00	$701,917,000.00	$13,899,149,000.00
All crops	$8,257,000.00	$11,555,000.00	$5,338,554,000.00
Rice	N/A	N/A	$1,371,074,000.00
Soybeans	$253,000.00	$633,000.00	$2,265,404,000.00
Cotton	N/A	N/A	$342,825,000.00
Corn	(D)	$ 395,000.00	$794,212,000.00
Wheat	$285,000.00	(D)	$67,244,000.00
Other crops and hay	$3,918,000.00	$5,962,000.00	$142,215,000.00
Fruit & tree nut	$661,000.00	$326,000.00	$11,474,000.00
Vegetable (including seeds, transplants)	$810,000.00	$2,164,000.00	$64,871,000.00
All livestock	$862,899,000.00	$690,363,000.00	$8,560,595,000.00
Cattle and calves	$35,877,000.00	$38,382,000.00	$687,223,000.00
Poultry and eggs	$818,311,000.00	$643,510,000.00	$7,675,365,000.00
Hogs and pigs	(D)	$5,719,000.00	$62,830,000.00
Horses, et cetera	$1,398,000.00	$1,406,000.00	$5,719,000.00
Sheep and goat product	$609,000.00	$313,000.00	$7,552,000.00

D - Withheld to avoid disclosing data for individual companies; data are included in higher level totals
N/A- Data is not available

Table 2.4. Travel impact data for selected counties of the Upper Illinois River watershed. (Arkansas Department of Parks, Heritage and Tourism, 2022).

Industry	Benton County	Washington County	Sum
Total County Expenditures (Millions)	$548.00	$382.00	$930.00
Travel-Generated Payroll (Millions)	$134.60	$120.10	$254.70
Travel-Generated Employment (Jobs, Thousands)	$5,478.00	$4,105.00	$9,583.00
Travel-Generated State Tax (Millions)	$40.50	$24.30	$64.80
Travel-Generated Local Tax (Millions)	$17.70	$8.10	$25.80
2% Tax (Thousands)	$1,305.20	$880.50	$2,185.70

2.3 Ecoregions

Two (2) Level III, and three (3) Level IV ecoregions occur in the Upper Illinois River watershed (Figure 2.2). Table 2.5 summarizes the characteristics of these ecoregions. These characteristics are described in greater detail in the following subsections.

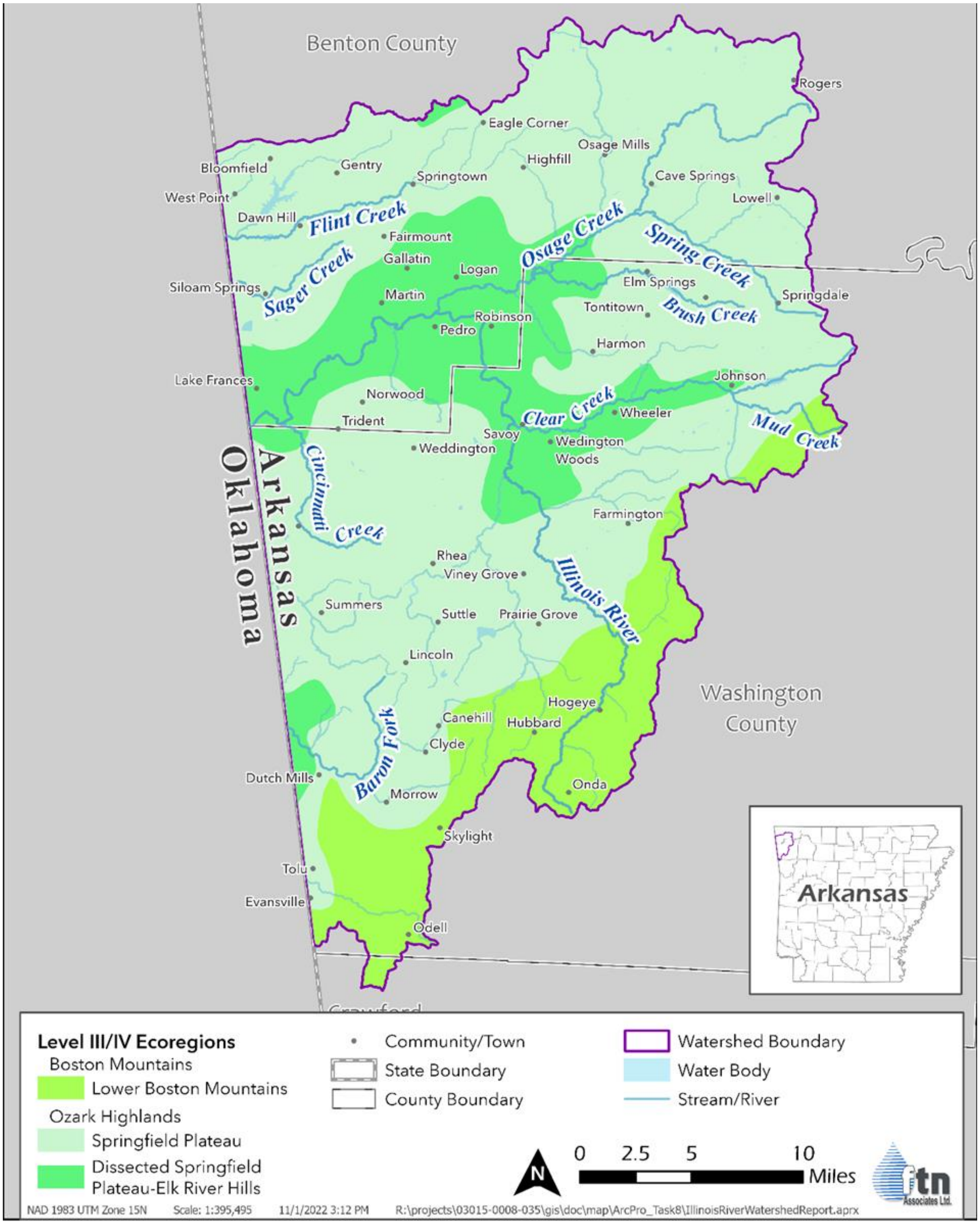

Figure 2.2. Ecoregions map of the Upper Illinois River watershed (US EPA, 2014).

Table 2.5. Characteristics of Level IV ecoregions of the Upper Illinois River watershed (from Woods et al. 2004).

Level III Ecoregion code and name	Level IV ecoregion code and name	Topography	Hydrology	Elevation/local relief (feet)	Geology	Common soil series	Mean annual precipitation (inches)	Natural vegetation
38. Boston Mountains	38b. Lower Boston Mountains	Low mountains, rounded high hills, and undulating plateaus.	Summer flow in many streams is zero or near zero but enduring pools fed by interstitial flow occur.	Mostly 200-1900; up to 2300/ 150-800	Quaternary colluvium and alluvium. Pennsylvanian sandstone, shale, limy sandstone, sandy limestone, and siltstone. Mountaintops are usually capped by resistant sandstone. Sideslopes are often underlain by interbedded sandstone, siltstone, and shale.	Uplands: Enders, Nella, Mountainburg, Steprock, Nella, Linker, Sidon; in east, Steprock and Linker are more widespread than in west. On floodplains and terraces: Ceda, Cleora, Razort, Spadra. Upland soils have low natural fertility.	46-52. The east is moister than the west.	Potential natural vegetation: oak–hickory–pine forest and oak–hickory forest. Mixed oak and oak–pine forests, woodland, or savanna occur on uplands; northern red oak, white oak, post, scarlet, black, blackjack oak, pignut hickory, shagbark hickory, mockernut hickory, and shortleaf pine are native. On lower, drier south- and west-facing sites: shortleaf pine. On narrow floodplains and low terraces: sweetgum, willows, birch, American sycamore, hickories, southern red oak, and white oak.
39. Ozark Highlands	39a. Springfield Plateau	Nearly level to rolling, undissected or slightly dissected portion of the Springfield Plateau. Karst features including caves, sinkholes, and solution valleys occur.	Springs are common and contribute substantially to streamflow in the summer and fall. Many streams flow year-round, but some dry valleys occur.	260-1600; uplands are lowest in the east/mostly 50-200	Quaternary cherty clay solution residuum and limited amounts of alluvium. Extensive limestone and interbedded chert of the Mississippian Boone Formation.	On uplands underlain by cherty limestone: Noark, Clarksville, Nixa, Captina, Tonti. On uplands underlain by sandstone: Linker, Mountainburg. On floodplains or low terraces: Secesh, Razort.	44-48. Parts are in the rainshadow of the Boston Mountains.	Potential natural vegetation: oak–hickory forest and some oak–hickory–pine forest. Prior to the 19th century, savanna or tall grass prairies were common and maintained by fire. Native on uplands: mixed deciduous forest (containing black oak, white oak, blackjack oak, post oak, and hickories) with some mixed deciduous–shortleaf pine forest. Native on floodplains and low terraces: willows, maples, hickories, birch, American elm, and American sycamore.

Table 2.5. Characteristics of Level IV ecoregions of the Upper Illinois River watershed (from Woods et al. 2004) (continued).

Level III ecoregion code and name	Level IV ecoregion code and name	Topography	Hydrology	Elevation/local relief (feet)	Geology	Common soil series	Mean annual precipitation (inches)	Natural vegetation
39. Ozark Highlands	39b. Dissected Springfield Plateau-Elk River Hills	Moderately to highly dissected, hilly part of the Springfield Plateau. Gently sloping, narrow ridge tops are separated by steep V-shaped valleys. Karst features occur.	Springs are common and contribute to streamflow in the summer and fall. Streams are usually perennial but some dry valleys occur.	300-1850/ 50-800	Quaternary cherty clay solution residuum, colluvium, and alluvium. On uplands: limestone and interbedded chert of the Mississippian Boone Formation. Along deeply entrenched rivers: early Mississippian or Devonian Chattanooga Shale and Ordovician Cotter Dolomite. Rock outcrops.	Clarksville, Nixa, Noark, Arkana, Moko, Portia, Estate	44-48. Parts are in the rainshadow of the Boston Mountains.	Potential natural vegetation: oak–hickory–pine forest and oak–hickory forest. Native on uplands: oak–woodland, mixed deciduous forest, or mixed deciduous–pine forest containing black oak, white oak, blackjack oak, post oak, hickories, and shortleaf pine. Native on north-facing slopes and in ravines: mesic forest containing sugar maple, white oak, northern red oak, and beech.

2.3.1 Climate

Climate normals are 30-year averages of climate data, calculated at individual recording stations for the United States by the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information. The 1991-2020 normal annual precipitation for the Upper Illinois River watershed is 45.4, normal low temperature is between 26.7- and 68.5-degrees Fahrenheit, and normal maximum temperature is between 47.5- and 90.3-degrees Fahrenheit (NOAA 2021). Climate normal average monthly precipitation and the average monthly minimum and maximum temperatures at the Northwest Arkansas Regional Airport (station id USW00053922) are shown on Figure 2.3.

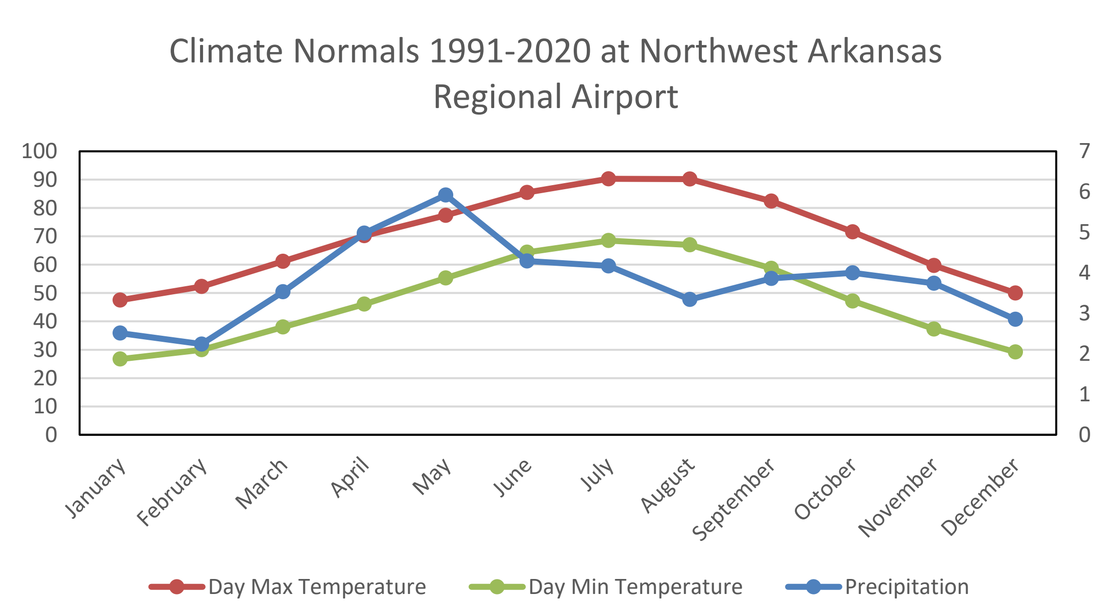

Figure 2.3. Climate normals at Northwest Arkansas Regional Airport, 1991-2020 (NOAA, 2021).

2.3.2 Geology

The Upper Illinois River watershed includes areas in the Springfield Plateau and the Boston Mountains physiographic provinces (Figure 2.4). The Springfield Plateau is underlain by karst limestone and cherty limestone of the Mississippian age, while the Boston Mountains are underlain by sandstone, shale, and limestone of the Pennsylvanian age (Adamski et al. 1995, Freiwald 1987). Both the Springfield Plateau and the Boston Mountains are underlain by the Boone Formation, which is characterized as an immature karst system (Brahana 2005). Karst topography is the landscape created when groundwater dissolves limestone, creating pathways for water to quickly move through the soil surface. Karst systems are marked by the presence of karst elements, such as sinkholes, springs, caves, and disappearing streams. An immature karst system, such as that underlying the Upper Illinois River watershed, characteristically has very few, and underdeveloped, examples of karst elements (Brahana 2005). The karst elements present in the Upper Illinois River watershed create a scenic landscape that has hidden vulnerabilities to the transport of pollutants (such as nitrates, fertilizers, manures, et cetera) through groundwater. There are several caves in the Upper Illinois River watershed, including those in the US Fish and Wildlife Service (USFWS) Logan Cave Natural Wildlife Refuge and the Cave Springs Cave Natural Area.

A surface geology map of the Upper Illinois River watershed is shown in Figure 2.5. Table 2.6 summarizes the stratigraphy of the geology underlying the Upper Illinois River watershed. Surface geology has been identified as influencing stream water quality in the White River watershed. White (2001) identified friable sandstone formations as the source of sandy river sediments in the Kings River watershed. Scott and Haggard (2019) suggest that limestone and shale outcrops along the West Fork White River contribute to variations in sulfate and total dissolved solids (TDS) concentrations in that river.

Table 2.6. Stratigraphy of geology underlying Upper Illinois River watershed (youngest formations at the top, oldest at the bottom) (McFarland, 2004) (King, King, & Boss, 2001) (Dowell, Hutchinson, & Boss, 2005).

System	Formation	General Geology
Pennsylvanian	Atoka Formation	Silty sandstone, shale
	Bloyd Shale	Limestone, shale
	Hale Formation	Shale, limestone, sandstone
Mississippian	Pitkin Limestone	Limestone
	Fayetteville Shale	Shale
	Batesville Sandstone	Sandstone
	Boone Formation	Limestone
	St. Joe Formation	Shale
Devonian	Chattanooga Shale	Shale
	Clifty Limestone	Limestone
Ordovician	Everton Formation	Sandstone
	Powell Dolomite	Dolomite
	Cotter Dolomite	Dolomite

* (Dowell, Hutchinson, & Boss, 2005)

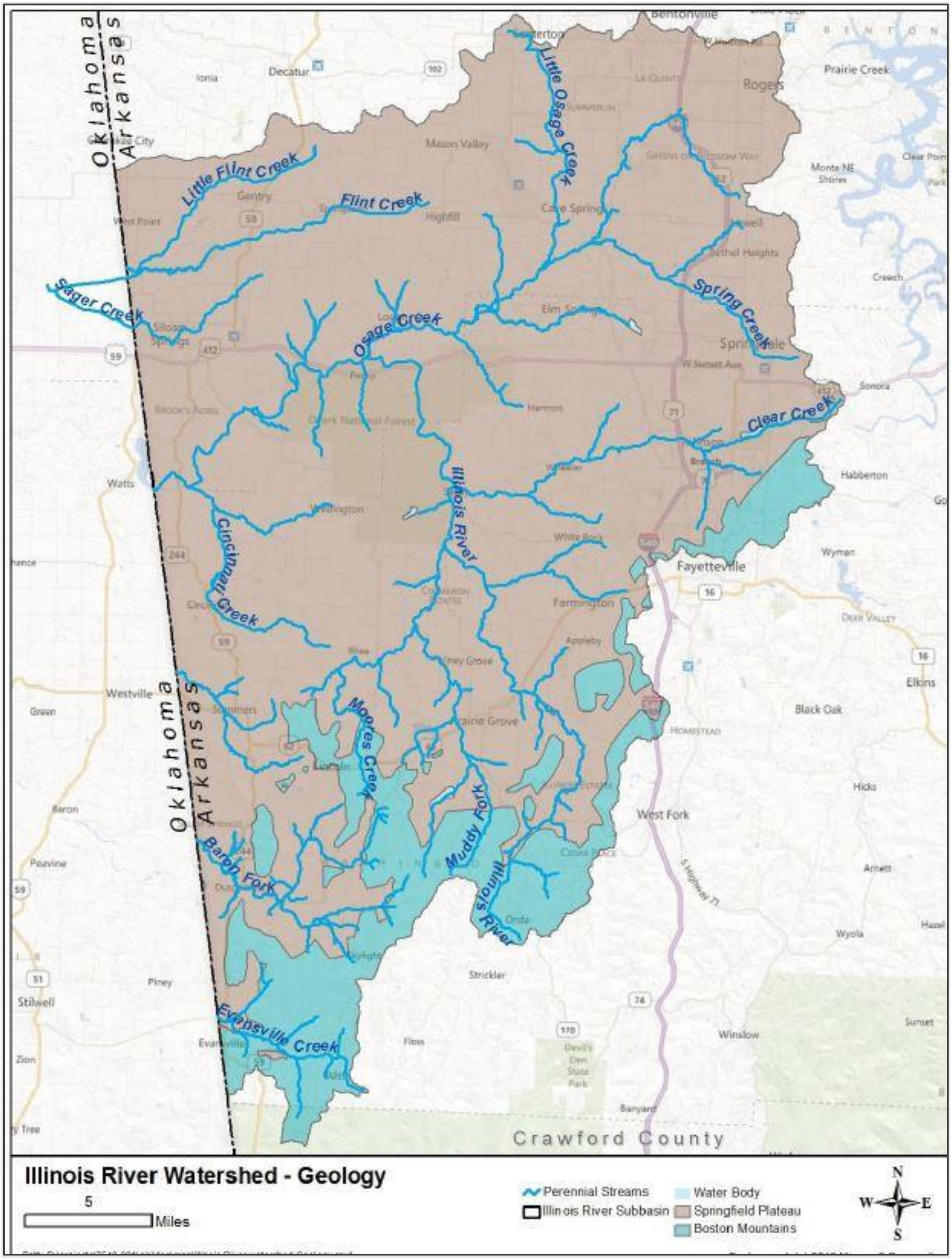

Figure 2.4. Map of physiographic provinces of the Upper Illinois River watershed.

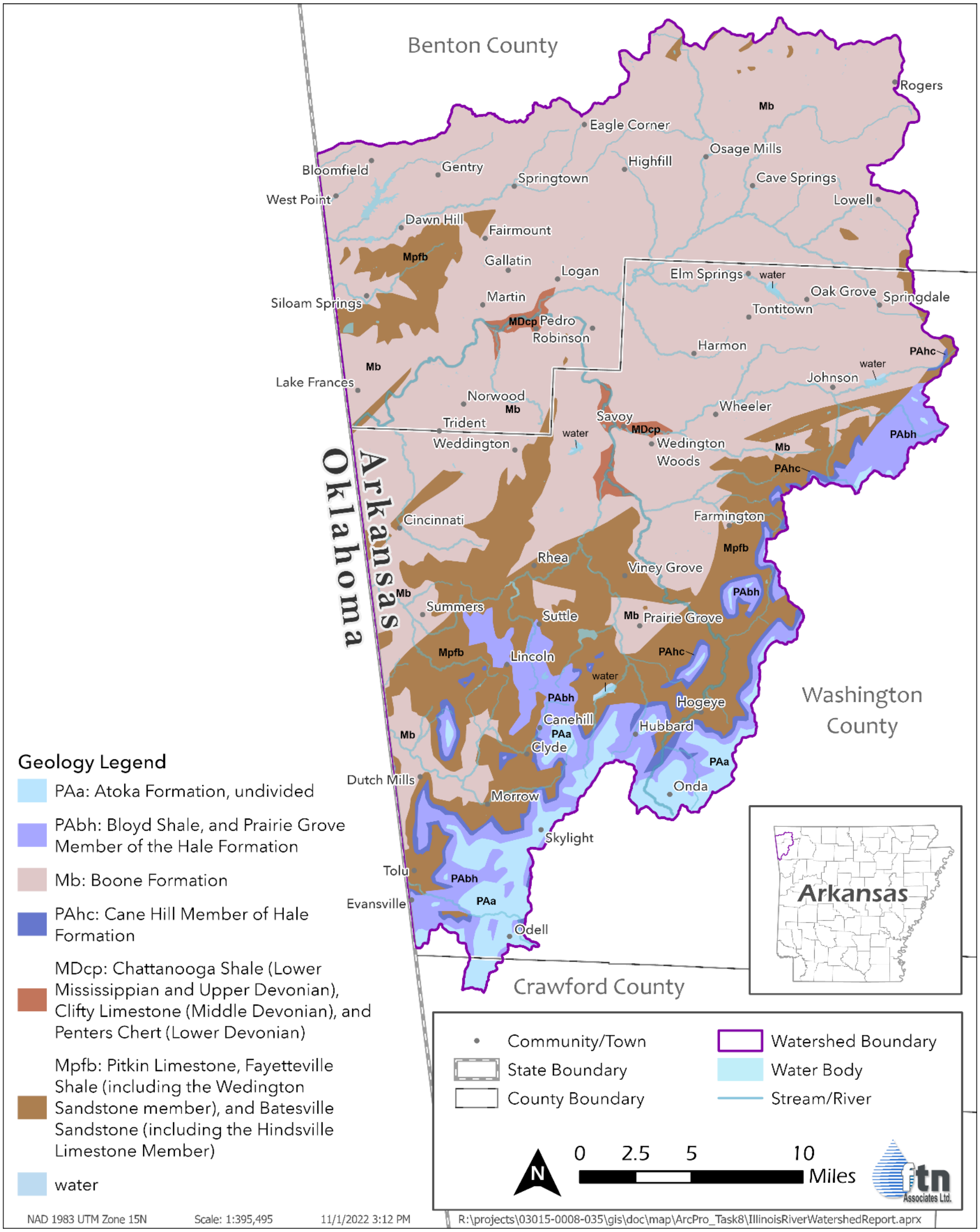

Figure 2.5. Surface geology map of Upper Illinois River watershed.

2.3.3 Topography

There are two (2) distinct topographic subdivisions in the Upper Illinois River watershed; the Springfield Plateau and the Boston Mountains (Figure 2.4). The southern watershed (headwaters) is in the Boston Mountains. The Boston Mountains have the highest elevations of the three (3) subdivisions, and are the most extensively eroded, resulting in rugged terrain characterized by ravines and gorges 500 to 1,200 feet deep. The Springfield Plateau is north of the Boston Mountains. The topography of this division is characterized as gently rolling hills (Miller, 2006).

Elevations within the Upper Illinois River watershed range from 1,965 feet above sea level in the Boston Mountains of the watershed headwaters, to 918 feet above sea level where the Illinois River crosses the Oklahoma state line (Center for Advanced Spatial Technologies 2006). Overall, the watershed slopes generally to the north.

Land slopes in the Upper Illinois River watershed range from less than three (3) percent in the Springfield Plateau, to around 30 percent on cliff faces and hill sides in the Boston Mountains and along stream channels. Slopes of 15 percent or more are considered steep, while areas with slopes of five (5) percent or less are considered flat lands. Geographic Information System (GIS) analysis indicates that approximately 48 percent of the watershed has slopes flatter than five (5) percent. Table 2.7 lists the proportion of the Upper Illinois River watershed considered flat lands, steep, and in between. Figure 2.6 shows a map of the locations of areas within the three (3) slope ranges.

Table 2.7. Slope areas in the Upper Illinois River watershed.

Slope ranges, degrees	Area within the watershed, acres	Percent of watershed
<5%	253,472	52%
5-10%	95,221	20%
10%-15%	50,100	10%
>15%	85,581	18%
Total	484,374	100%

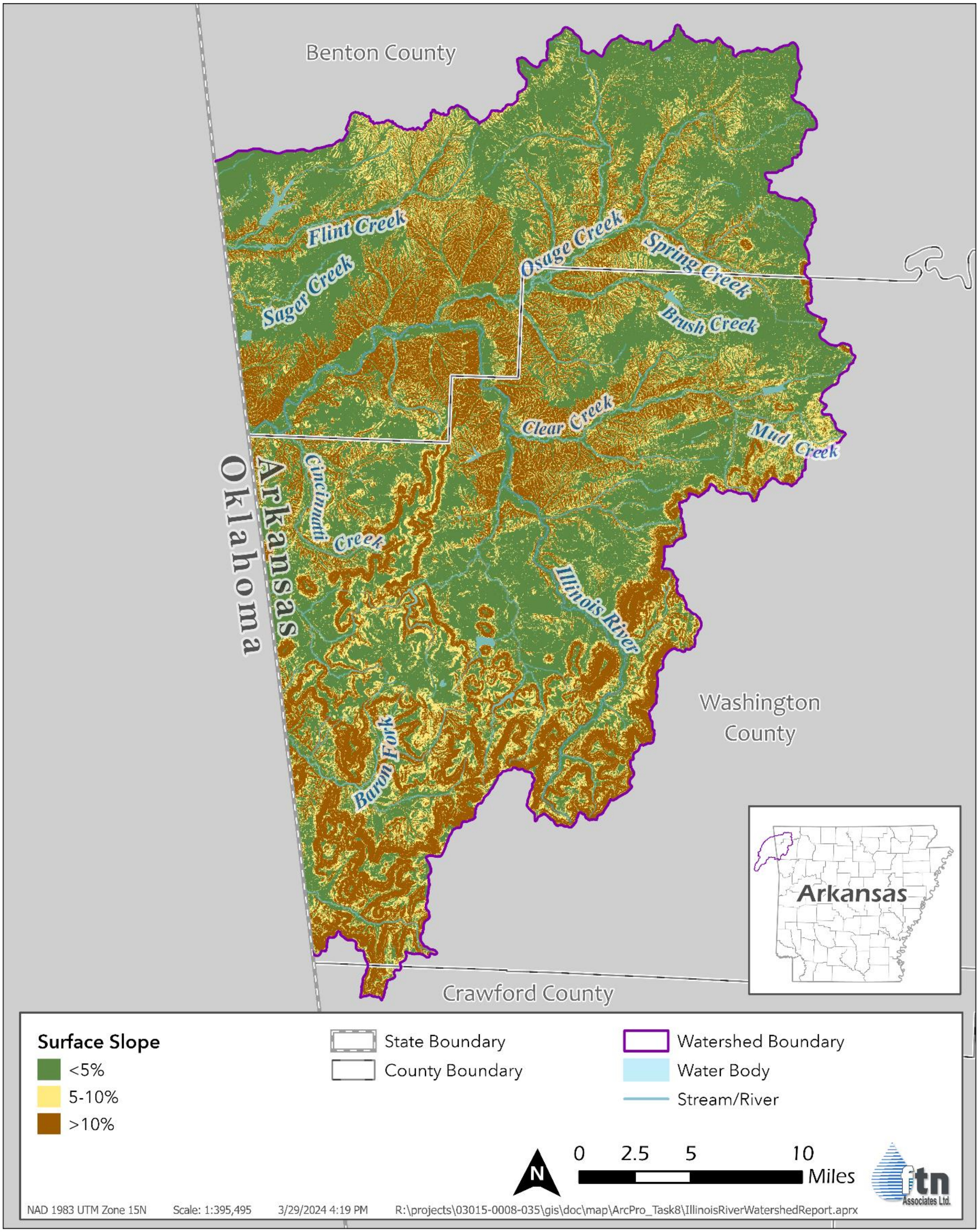

Figure 2.6 Slope map of the Upper Illinois River watershed.

2.3.4 Soils

The common soil types within the Upper Illinois River watershed (i.e., the Clarksville, Enders, and Linker series) are Ultisols, which are found primarily in humid, temperate areas across the southeastern United States. The Clarksville series covers the majority (~74 percent) of the watershed, with Enders (~19 percent) and Linker (~seven (7) percent) covering the rest, based on the State Soil Geographic Database (STATSGO).

The word “Ultisol” is derived from “ultimate,” because Ultisols are seen as the ultimate product of continuous weathering of minerals in a humid temperate climate. Because of this weathering, Ultisols are naturally acidic, generally with low concentrations of nitrogen, phosphorus, potassium, and calcium, and have inherently poor fertility, requiring the application of lime and fertilizer to be agriculturally productive. The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) detailed soil series reports indicate the following:

- Clarksville soils are gravelly silt loams; these soils are generally considered very deep (greater than 80 inches to bedrock), and somewhat excessively drained soils that are moderately permeable with medium to high runoff; slopes range from one (1) percent to 65 percent.
- Enders soils are typically gravelly fine sandy loams; these soils are generally deep (40 to 60 inches to bedrock), well-drained, and slowly permeable with medium to very rapid runoff. Ender soils are typically found on level to moderately steep upland mountain tops and ridges to very steep mountain sides and bases with a slope that can range from one (1) percent to 65 percent.
- Linker soils are generally fine sandy loams; these soils are moderately deep (20 to 40 inches to bedrock), well-drained, and moderately permeable with slow to rapid runoff, dependent upon slope. Linker soils are generally found on broad plateaus, benches, and mountain and hilltops, with much of the slope ranging from two (2) percent to eight (8) percent. The full range of the slope is from one (1) percent to 15 percent, with a few isolated locations up to 30 percent.

These descriptions represent the general characteristics of these soils as observed across their larger geographic area, but these soils may have some characteristics specific to the Upper Illinois River watershed and northwest Arkansas. As water moves through soil, impurities are filtered out when the molecules bind to soil components such as clays and iron or aluminum minerals. Many of the soils within the watershed have a shallow depth to bedrock, where the local geology may have karst features. As a result, water moves from the soil surface to the groundwater without much natural filtering of the water, making groundwater more vulnerable to pollution. Figure 2.7 shows a map of these soil associations in the watershed.

Application of poultry litter and byproducts to these infertile soils has greatly increased agricultural productivity in the region over the past several decades. Phosphorus levels in poultry litter are higher than nitrogen levels. Thus, historically, when producers applied poultry litter to the point where desired nitrogen levels were achieved, phosphorus was over-applied. Ultisols can store nutrients (e.g., phosphorus) when they are applied in excess of forage and crop needs. As phosphorus built up in the soil over time, soils became a significant source of phosphorus inputs to surface water and groundwater. State regulations on poultry litter application in state Nutrient Surplus Areas, including the Upper Illinois River watershed, are intended to stop phosphorus build up in soils. However, there is still concern among stakeholders that soil phosphorus levels in the watershed may be increasing due to the application of poultry litter.

To get an idea of whether the state regulations are having the desired effect, we compared soil phosphorus concentrations in soils samples from Benton, Crawford, and Washington counties analyzed during 1996 and 2020. The Arkansas Agricultural Experiment Station prepares annual soil fertility reports. These reports compile testing results from soil samples submitted to the Extension service for analysis. Soil samples can be submitted by anyone in the county, so the results include soil samples from cropland, pasture, lawns, and home garden plots. Table 2.8 shows the comparison of soil test phosphorus (STP) data from the 1996 and 2020 Arkansas soil fertility reports.

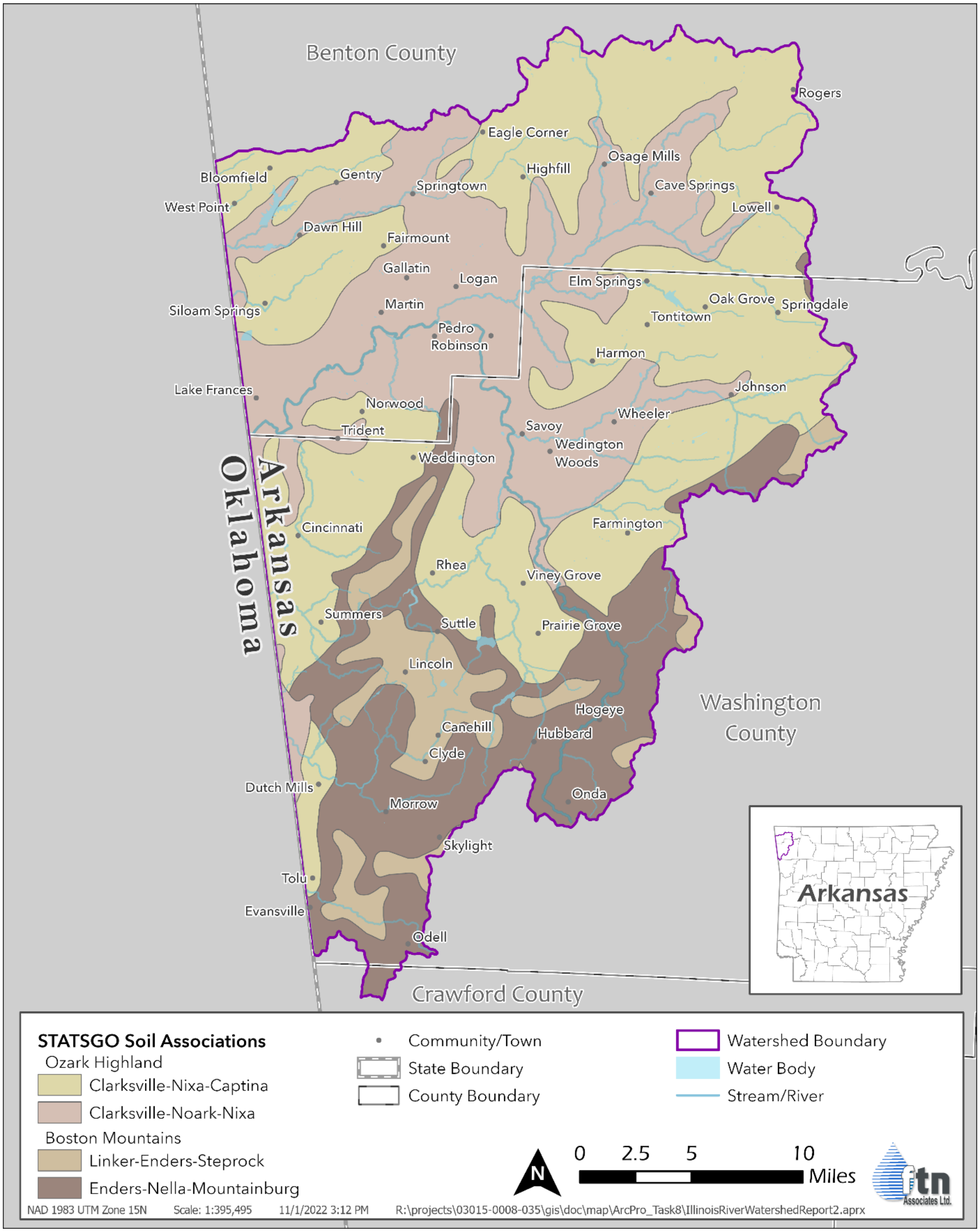

Figure 2.7. Map of major soil associations within the Upper Illinois River watershed.

Table 2.8. Comparison of STP results from 1996 and 2020 Arkansas soil fertility reports.

	1996 condition							2020 condition					
Category	<26 lb P/acre	26-44 lb P/acre	45-100 lb P/acre	101-300 lb P/acre	>300 lb P/acre	Calculated median, lb P/acre	Calculated median, ppm	<16 ppm	16-25 ppm	26-35 ppm	36-50 ppm	>50 ppm	Median, ppm
County	% of sampled soil that falls in the category							% of sampled soil that falls in the category					
Benton	2	5	16	41	36	240	118	4	9	9	14	64	70
Crawford	13	16	34	29	8	122	60	13	17	12	16	42	42
Washington	4	9	21	38	28	207	101	5	11	7	10	67	86

In the 1996 report, the median STP of samples was not reported, and the phosphorus concentration was in the units of "pounds of the extractable phosphorus per acre (lb P/acre)", while the 2020 report has sample median values and concentration reported in parts per million (ppm). The county-level median STP of 1996 soil samples were calculated and converted to ppm. All the lb/acre to ppm conversions were based on assuming a dry soil bulk density of 1.5 g/cm3 and a soil depth of 0.5 ft. With these assumptions, one (1) lb P/acre is equivalent to approximately 0.49 ppm. The median of STP concentration in 2020 soils samples is less than the median for 1996 in Benton, Crawford, and Washington counties. This suggests that the state regulations on poultry litter application in Nutrient Surplus Areas are reducing the buildup of phosphorus in upper Illinois River watershed soils.

2.3.5 Land Use/Land Cover

Historically, the Upper Illinois River watershed was primarily covered with hardwood forest and mounded upland prairies. However, around the start of the 20th century, much of this forest was cleared and prairies leveled for use as pasture. Land use change has been identified as a concern in this watershed. Figure 2.8 shows forest and pastureland cover in the Upper Illinois River watershed has declined while development and other open covers (barren land, scrub/shrub, and herbaceous) have increased. Figure 2.9 shows the change in National Land Cover Dataset (NLCD) impervious cover within the watershed from 2001 to 2019. This graph shows the most rapid increase in impervious cover within the watershed during that period occurred between 2016 and 2019. These kinds of changes in land cover affect hydrology and water quality.

Upper Illinois River watershed land use/land cover information from 2019 is summarized in Figure 2.10 and mapped in Figure 2.11. Land use information from 2019 for HUC12 sub-watersheds of the upper Illinois River watershed is provided in Appendix C.

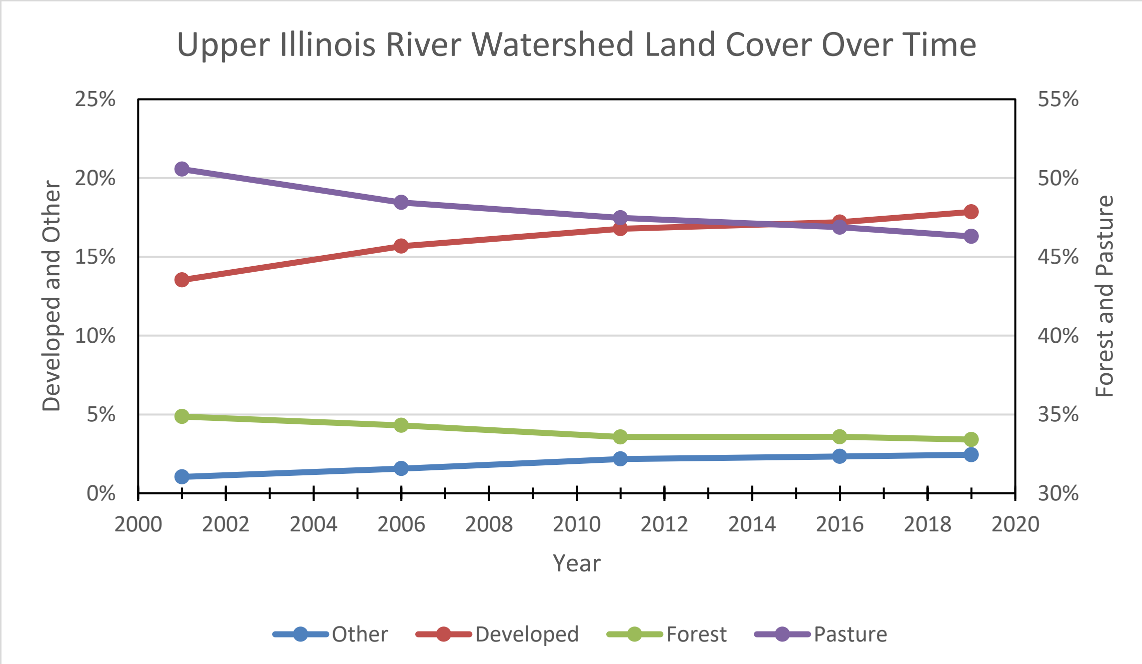

Figure 2.8. Changes in land cover in the Upper Illinois River watershed over time.

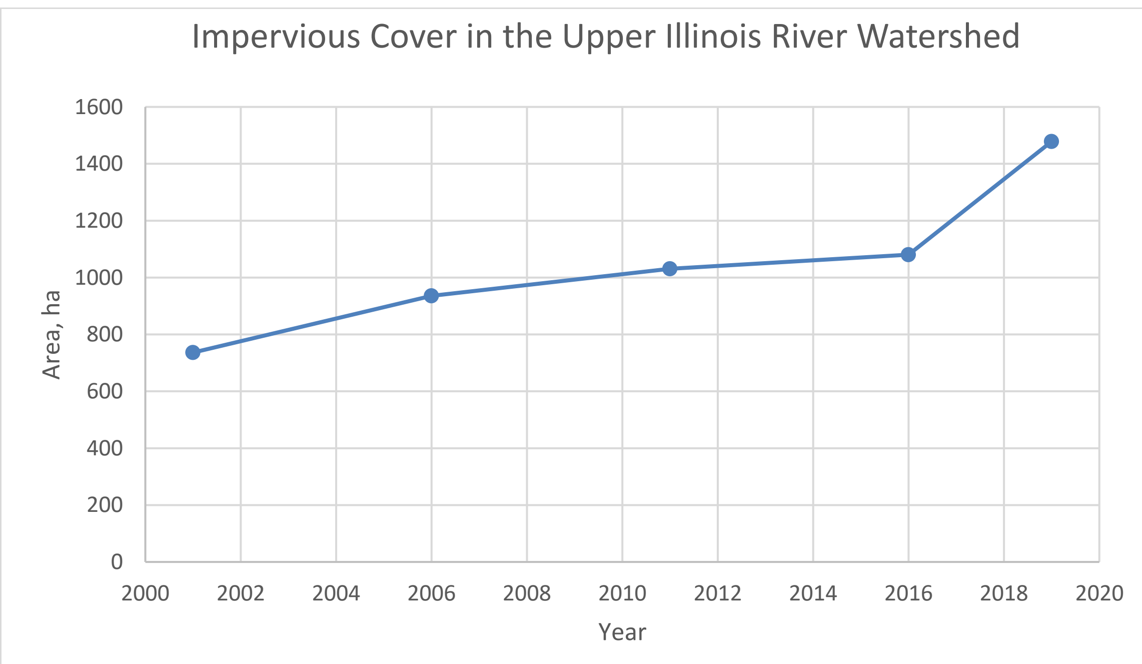

Figure 2.9. Change in impervious cover in the Upper Illinois River watershed since 2001 (NLCD data provided by Tyler Fox, UofA, January 24,2023).

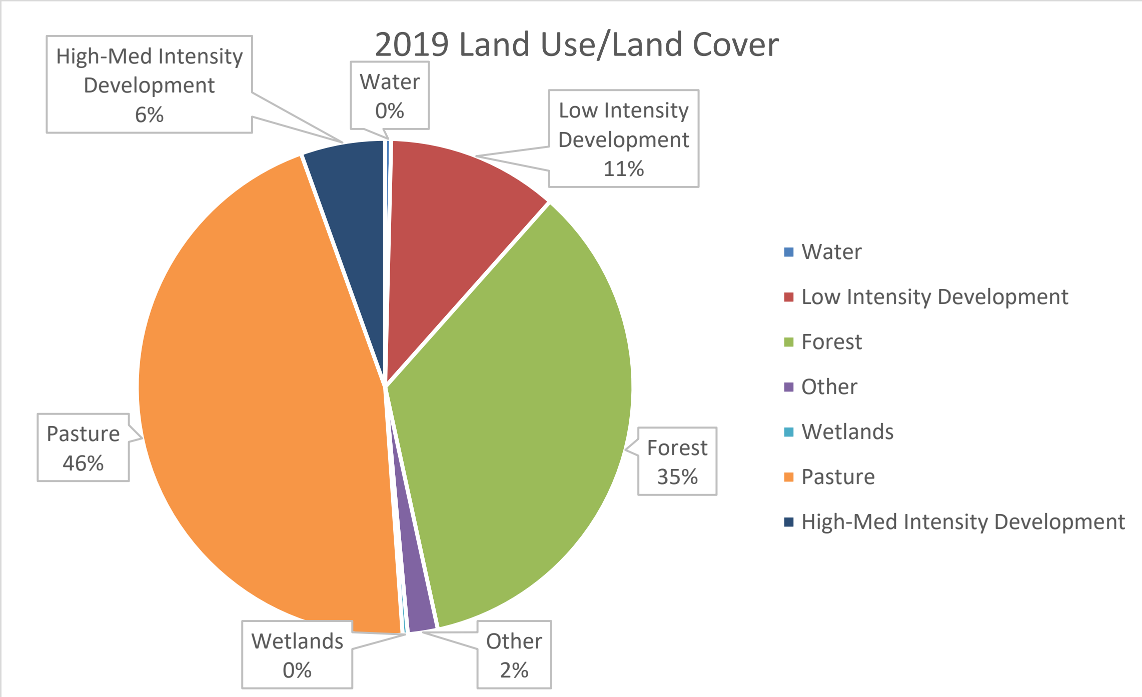

Figure 2.10. Upper Illinois River summary of 2019 land cover (Dewitz & USGS, 2021).

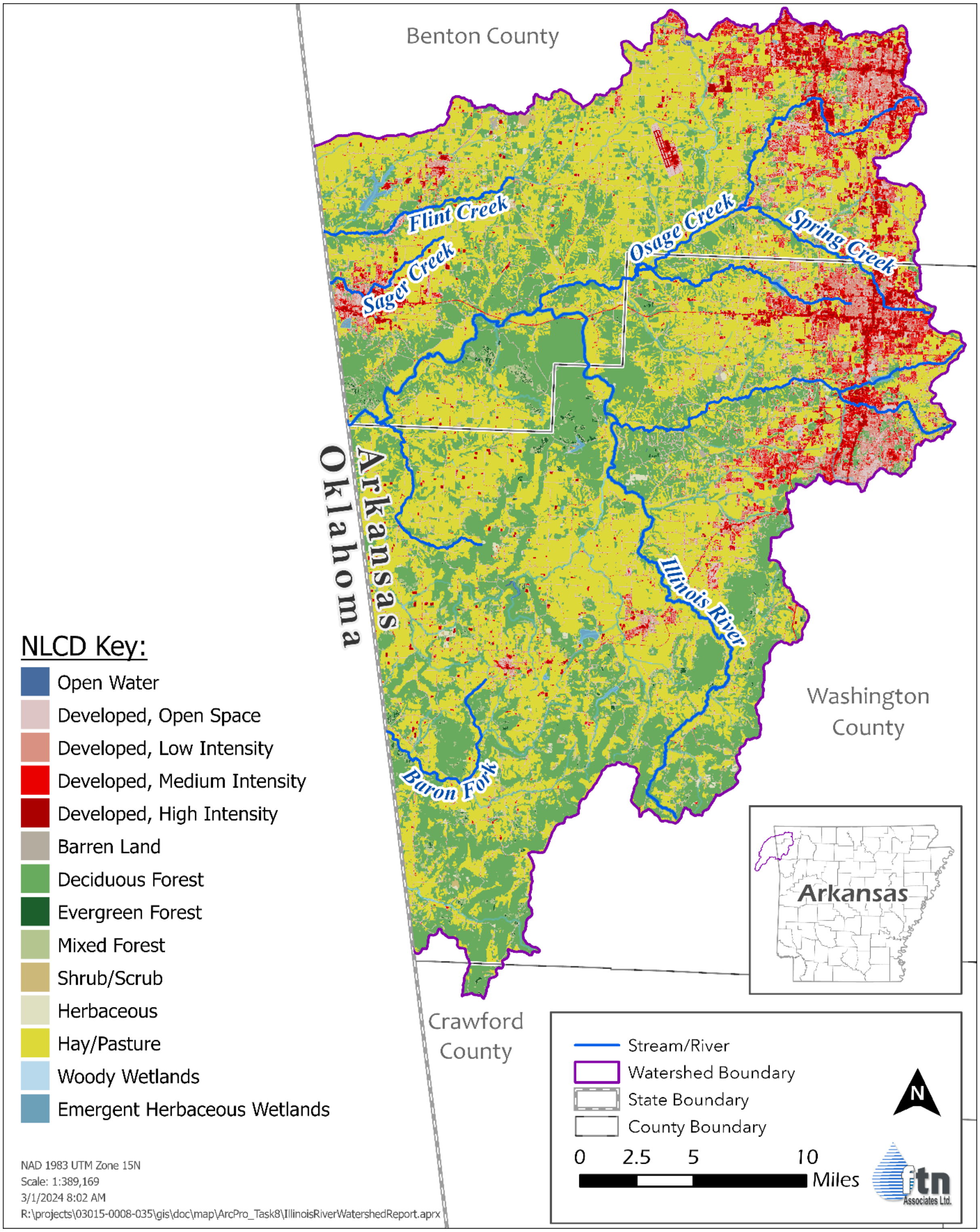

Figure 2.11. Upper Illinois River map of 2019 land cover (Dewitz & USGS, 2021).

2.4 Water Resources

Surface water and groundwater resources of the Upper Illinois River watershed are described below.

2.4.1 Surface Water

There are over 1,000 miles of streams in the Upper Illinois River watershed (Figure 2.1). The Illinois River is around 53 miles long from its headwaters near Hogeye to the Arkansas-Oklahoma state line. The main tributary streams to the Illinois River in Arkansas include Osage Creek, Flint Creek, Clear Creek, and Baron Fork Creek. However, only Osage Creek and Clear Creek join the Illinois River before it crosses the state border. Baron Fork Creek and Flint Creek join the Illinois River in Oklahoma. Stream gradients are relatively high, generally exceeding three (3) feet per mile, even in larger streams. The gradient of the Illinois River from the headwaters to the Oklahoma state line, 53 miles, is approximately seven (7) feet/mile. Several small impoundments (e.g., Flint Creek Lake, Lake Wedington, Elmdale Lake) are present in the UIRW. As part of the Arkansas River Basin Compact between Arkansas and Oklahoma, Arkansas is not allowed to reduce Illinois River annual yield at the state border by more than 60 percent (A.C.A. {symbol} 15-23-401).

2.4.2 Groundwater

The UIRW is underlain by the Ozark Plateaus aquifer system. The Springfield Plateau aquifer is unconfined in the Springfield Plateau region and mostly confined in the Boston Mountains (Figure 2.12). Most wells in the watershed tap this aquifer. Well yields in this aquifer are generally less than 20 gallons per minute (Adamski et al. 1995). This aquifer is associated with Boone limestone formation (Gillip, Czarnecki and Mugel 2008) (see Table 2.9). The Boone Formation underneath the UIRW is characterized as an immature karst system (Brahana 2005). This karst geology has resulted in several springs and wet caves in the UIRW. This karst system exhibits systems of localized karst flow that behave independently of the overall Ozark Plateaus aquifer system (Brahana 2011).

In the UIRW, the Ozark aquifer occurs below the Springfield Plateau Aquifer and is separated from it by the Chattanooga shale (Ozark confining unit). In the Upper Illinois River watershed, the Ozark aquifer is associated with Clifty, Everton, Powell, Cotter, and deeper formations (see Table 2.9). This aquifer is confined at the bottom by the St. Francois confining unit. The thickness of the series of water-bearing formations associated with the Ozark aquifer ranges from 2,000 to 3,000 feet (Kresse, et al., 2014). The Ozark aquifer is also used as a water supply in the UIRW. Well yields in this aquifer are commonly around 75 gallons per minute (Adamski et al. 1995). Because of the confining layer, the Ozark Aquifer is less susceptible to contamination from surface activities in the UIRW (Petersen et al. 1998).

Table 2.9. Geologic formations in the Upper Illinois River watershed associated with aquifers.

System	Formation	Regional Geohydrologic Unit
Pennsylvanian	Atoka Formation	Western Interior Plains confining system
	Bloyd Formation	
	Hale Formation	
Mississippian	Pitkin Limestone	
	Fayetteville Shale	
	Batesville Sandstone	
	Boone Formation	Springfield Plateau aquifer
	St. Joe Formation	
Devonian	Chattanooga Shale	Ozark confining unit
	Clifty Limestone	Upper Ozark aquifer
Ordovician	Everton Formation	
	Powell Dolomite	
	Cotter Dolomite	
	Jefferson City Dolomite	
	Roubidoux Formation	Lower Ozark aquifer
	Gasconade Dolomite	
	Gunter Sandstone	
	Van Buren Formation	

Groundwater wells are common throughout the Western Interior Plains confining system, Springfield Plateau aquiver, and Ozark aquifer. These wells are typically for domestic or livestock supplies. There are also a limited number of small communities, resorts, and parks supplied by groundwater wells. Most municipal and regional water systems within the Upper Illinois River watershed are supplied by surface water.

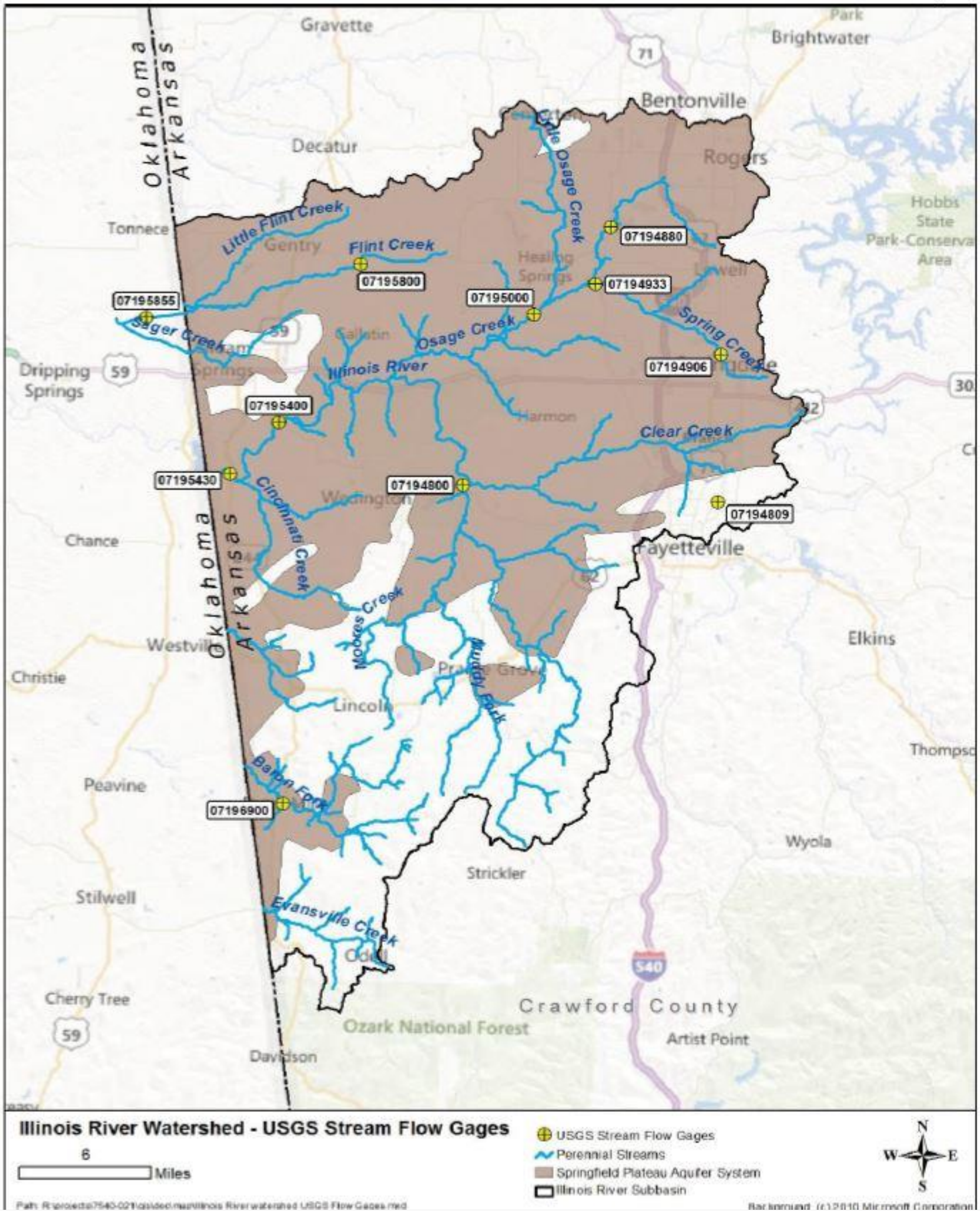

Figure 2.12 Map of aquifers in Upper Illinois River watershed.

2.4.3 Interaction Between Surface Water and Groundwater

Surface water and groundwater interaction is primarily a function of climate, soil type, geology, and topography (Adamski et al. 1995; Winter et al. 1998). In the Upper Illinois River watershed, differences in the amount of interaction between surface water and groundwater are primarily the result of differences in the geology and topography of the two (2) physiographic provinces present in the watershed.

In general, there is less surface water-groundwater interaction in the Boston Mountains than in the Springfield Plateau. In the Boston Mountains, streamflow is primarily derived from surface runoff, and none of the streams are considered perennial. Groundwater occurrence is limited to permeable sandstone and limestone beds separated by thick layers of impermeable shale referred to as the Western Interior Plains confining system (Adamski et al. 1995).

In the Springfield Plateau, a high degree of surface water-groundwater interaction exists because of the abundant karst features associated with the shallow groundwater aquifer. In this setting, concentrated flow occurs in dissolution tubes, fractures, and bedding planes that terminate as springs and seeps, which serve as tributaries to primary streams (DEQ 2008). Along the north and central portions of the Illinois River, Freiwald (1987) identified several small tributaries where flow is sustained by numerous springs. These springs are well-distributed, and many are associated with faults. Groundwater contributes around 49 percent of the Upper Illinois River watershed streamflow at USGS gage 07195430 (Pugh & Westerman, 2014).

In 1983, a losing and gaining stream survey was performed on the Illinois River by Freiwald (1987). Results of the survey indicate that the Illinois River has gaining and losing reaches. In the Boston Mountains (south of Prairie Grove, Arkansas), pools of non-flowing water primarily occur in the channel as depression storage from surface runoff. Flow in the channel was observed north of Viney Grove, Arkansas, where the stream transitions into the Springfield Plateau. Between Viney Grove, Arkansas, and County Road 66 (approximately four (4) miles), the Illinois River is gaining. North of County Road 66 to the Arkansas-Oklahoma border (28 miles), the Illinois River is generally a losing stream, with small reaches that are gaining but are insignificant to total flow. A similar survey of Osage Creek in 2001 identified one (1) losing and two (2) gaining reaches on the main stem (Moix et al. 2003).

2.5 Wildlife Resources

The karst terrain of northwest Arkansas supports numerous springs and spring-fed tributaries that harbor threatened, endangered or endemic species including the Ozark cavefish (*Amblyopsis rosae*), least darter (*Etheostoma microperca*), Oklahoma salamander (*Eurycea tynerensis*), and Neosho mucket (*Lampsilis rafinesqueana*). The presence of endangered species, and other aquatic species of concern, has resulted in several streams within the Upper Illinois River watershed being classified as extraordinary resource waters (ERWs) or ecologically sensitive waters (ESWs) as defined by the Arkansas Pollution Control and Ecology Commission (APCEC). In addition, all lakes and reservoirs and most streams in the Upper Illinois River watershed are designated as fisheries.

There are several species present in the Upper Illinois River watershed that are listed as threatened or endangered by the state or federal government. There are also a number of native species present that the state has identified as species of greatest conservation need. In addition, there are plants and animals present in the watershed that are not native and that are believed to pose a threat to native species.

2.5.1 Protected Species

There are 12 species that may be found in the Upper Illinois River watershed that are listed as threatened or endangered by the state and/or federal government (Table 2.10). In addition, there is one bat species possibly present in the watershed that is proposed for endangered classification, a turtle species that is proposed for threatened species classification, and the Monarch butterfly, which is a candidate species for listing. There are two (2) protected cave dwelling aquatic species present in the watershed, and two protected clam species.

Table 2.10. Listed protected species of the Upper Illinois River watershed (US Fish and Wildlife Service, 2023).

Common Name	Scientific Name	Category	Federal Status	State Status	Designated Critical Habitat Within Watershed	Counties (streams, if they are listed)
Gray Bat	*Myotis grisescens*	Mammals	Endangered	S2- Imperiled in Arkansas	No	Benton, Crawford, and Washington
Indiana Bat	*Myotis sodalis*	Mammals	Endangered	S1-Critically Imperiled in Arkansas	No	Benton, Crawford, and Washington
Northern Long-eared Bat	*Myotis septentrionalis*	Mammals	Threatened	S1-Critically Imperiled in Arkansas	No	Benton, Crawford, and Washington
Ozark Big-eared Bat	*Corynorhinus townsendii ingens*	Mammals	Endangered	S1-Critically Imperiled in Arkansas	No	Benton, Crawford, and Washington
Tricolored Bat	*Perimyotis subflavus*	Mammals	Proposed Endangered	S5- Secure in Arkansas	No	Benton, Crawford, and Washington
Eastern Black Rail	*Laterallus jamaicensis Jamaicans*	Birds	Threatened	SU- Presumed Extirpated in Arkansas	No	Benton, Crawford, and Washington
Piping Plover	*Charadrius melodus*	Birds	Threatened	S1M- Critically Imperiled Migrant	No	Benton, Crawford, and Washington
Red Knot	*Calidris canutus rufa*	Birds	Threatened	SNA-Not Applicable	No	Benton, Crawford, and Washington
Alligator Snapping Turtle	*Macrochelys temminckii*	Reptiles	Proposed Threatened	S3-Vulnerable in Arkansas	No	Benton, Crawford, and Washington
Ozark Cavefish	*Amblyopsis rosae*	Fish	Threatened	S1-Critically Imperiled in Arkansas	No	Benton and Washington
Neosho Mucket	*Lampsilis rafinesqueana*	Clam	Endangered	S1-Critically Imperiled in Arkansas	Yes	Benton and Washington (Illinois River and tributaries)
Rabbitsfoot	*Quadrula cylindrica Quadruple*	Clam	Threatened	S3-Vulnerable in Arkansas	No	Benton and Washington
Monarch Butterfly	*Danaus plexippus*	Insect	Candidate	S5B- Secure Breeding Population	No	Benton, Crawford, and Washington
Benton County Cave Crayfish	*Cambarus aculabrum*	Crustacean	Endangered	S1-Critically Imperiled in Arkansas	No	Benton and Washington
Missouri Bladderpod	*Physaria filiformis*	Flowering Plant	Threatened	S1-Critically Imperiled in Arkansas	No	Washington

2.5.2 Species of Greatest Conservation Need

There are an additional 35 or so aquatic species of greatest conservation need identified by Arkansas Game and Fish Commission in the Arkansas Wildlife Action Plan for the ecobasin that includes the Upper Illinois River watershed (Ozark Highlands-Arkansas River) (Fowler & Anderson, 2015). There are ten aquatic karst species of greatest conservation need identified in the Arkansas Wildlife Action Plan that have been identified as present in the watershed (Inlander, Gallipeau and Slay 2011).

2.5.3 Nuisance Species

There are a number of non-native species of plants and animals present in the Upper Illinois River watershed. Non-native aquatic invasive species that have been reported in the Upper Illinois River watershed are listed in Table 2.11. Asian clams have been identified as having the potential to affect populations of native mussels, including protected species present in the Upper Illinois River watershed; Rabbitsfoot and Neosho Mucket (US Fish and Wildlife Service, 2021; US Fish and Wildlife Service, 2020).

Table 2.11. Non-native aquatic invasive species reported in the Upper Illinois River watershed (USGS, 2023).

Common Name	Scientific Name	Category	Source	Location	Status
Single-vein Sweet Flag	*Acorus calamus*	Plants	Exotic	Washington County	Established
Curly-leaf pondweed	*Potamogeton crispus*	Plants	Exotic	Benton County	Established
narrow-leaved cattail	Typha angustifolia	Plants	Exotic	N Dinmant Lane, Fayetteville, AR	Established
parrot feather	Myriophyllum aquaticum	Plants	Exotic	Siloam Springs	Unknown
Water-cress	Nasturtium officinale	Plants	Exotic	Benton County	Established
a water cress	Nasturtium sp.	Plants	Exotic	Benton County	Established
Yellow Iris	*Iris pseudacorus*	Plants	Exotic	Fayetteville, AR	Established
Purple Loosestrife	*Lythrum salicaria*	Plants	Exotic	Benton County	Established
Brittle Waternymph	*Najas minor*	Plants	Exotic	unnamed creek north of Lake Bentonville	Unknown
Yellow Floating-Heart	*Nymphoides peltate*	Plants	Exotic	W Village Parkway, Rogers, AR	Unknown
Water Lettuce	*Pistia stratiotes*	Plants	Exotic	Washington County	Unknown
Water Speedwell	*Veronica anagallis-aquatica*	Plants	Exotic	I-49 N, Springdale, AR	Established
Asian clam	Corbicula fluminea	Mollusks-Bivalves	Exotic	Illinois River	Established
Common Carp	Cyprinus carpio	Fishes	Exotic	Osage Creek	Established
White Catfish	*Ameiurus catus*	Fishes	Native Transplant	Illinois River drainage, Washington County	Established
Flathead Catfish	Pylodictis olivaris	Fishes	Native Transplant	Illinois River	established
Goldfish	Carassius auratus	Fishes	Exotic	Flint Creek	Unknown

Table 2.11. Non-native aquatic invasive species reported in the Upper Illinois River watershed (USGS, 2023) (continued).

Common Name	Scientific Name	Category	Source	Location	Status
Grass Carp	*Ctenopharyngodon idella*	Fishes	Exotic	Illinois River drainage, Benton County	Unknown
Northern Pike	*Esox lucius*	Fishes	Native Transplant	Illinois River drainage, Washington County	Unknown
Rock Bass	*Ambloplites rupestris*	Fishes	Native Transplant	Illinois River drainage, Benton County	Established
Ozark Shiner	*Notropis ozarcanus*	Fishes	Native Transplant	Osage Creek	Established
Threadfin Shad	Dorosoma petenense	Fishes	Native Transplant	Flint Creek	Established
pirapitinga, red-bellied pacu	*Piaractus brachypomus*	Fishes	Exotic	pond at Fairview Memorial Gardens, Fayetteville	Failed
Cuban Treefrog	*Osteopilus septentrionalis*	Amphibian	Exotic	Benton County	Unknown
White River Crawfish	*Procambarus acutus*	Invertebrate	Native transplant	Siloam Springs golf course	Established

2.5.4 Sensitive Areas

Sensitive areas within the Upper Illinois River watershed include state wildlife management areas, federal wildlife refuges, national forest, state natural areas, and state designated Ecologically Sensitive Waterbodies. Figure 2.13 shows the locations of these sensitive areas within the watershed. Illinois River, Cave Springs Cave, and over ten springs in the watershed are classified as "Ecologically Sensitive Waterbodies" (Arkansas Pollution Control and Ecology Commission, 2022). Table 2.12 Lists designated management areas within the watershed with some descriptive information about these areas.

Table 2.12. Designated conservation and protected areas in the Upper Illinois River watershed.

Name	County	Area, ac	Focus habitat	Owned By
Logan Cave National Wildlife Refuge	Benton	123	Cave	US Fish and Wildlife Service
Ozark-St. Francis National Forest	Benton & Washington	1.2 million	Forest	US Forest Service
Garret Hollow WMA and Natural Area	Washington	670	Forest	Arkansas Game and Fish Commission, Arkansas Natural Heritage Commission
Lee Creek WMA	Crawford & Washington Counties	58,548	Forest	US Forest Service, Arkansas Game and Fish Commission
Wedington WMA	Washington	15,915	Forest	US Forest Service, Arkansas Game and Fish Commission
Cave Springs Cave Natural Area	Benton	57	Cave	Arkansas Natural Heritage Commission
Chesney Prairie Natural Area	Benton	82	Prairie	Arkansas Natural Heritage Commission
Searles Prairie Natural Area	Benton	12.5	Prairie	Arkansas Natural Heritage Commission

A groundwater quality vulnerability map developed by The Nature Conservancy using the DRASTIK model, indicates that groundwater quality is moderately to highly vulnerable to impacts from surface land management activities in the watershed (Inlander, Gallipeau, & Slay, 2011). A map of the groundwater vulnerability in the Upper Illinois River watershed is shown in Figure 2.13. Studies have been conducted to identify recharge areas for several springs in the Upper Illinois River watershed, including Cave Spring, Logan Spring, Hewitt Spring, and Elm Spring (Northwest Arkansas Regional Planning Commission, 2013). These recharge areas are shown on Figure 2.14.

The Nature Conservancy DRASTIK model also evaluated threats to aquatic cave species due to issues with groundwater quality and/or quantity. The caves studied in the Upper Illinois River watershed received medium-high to high threat rankings (Figure 2.15).

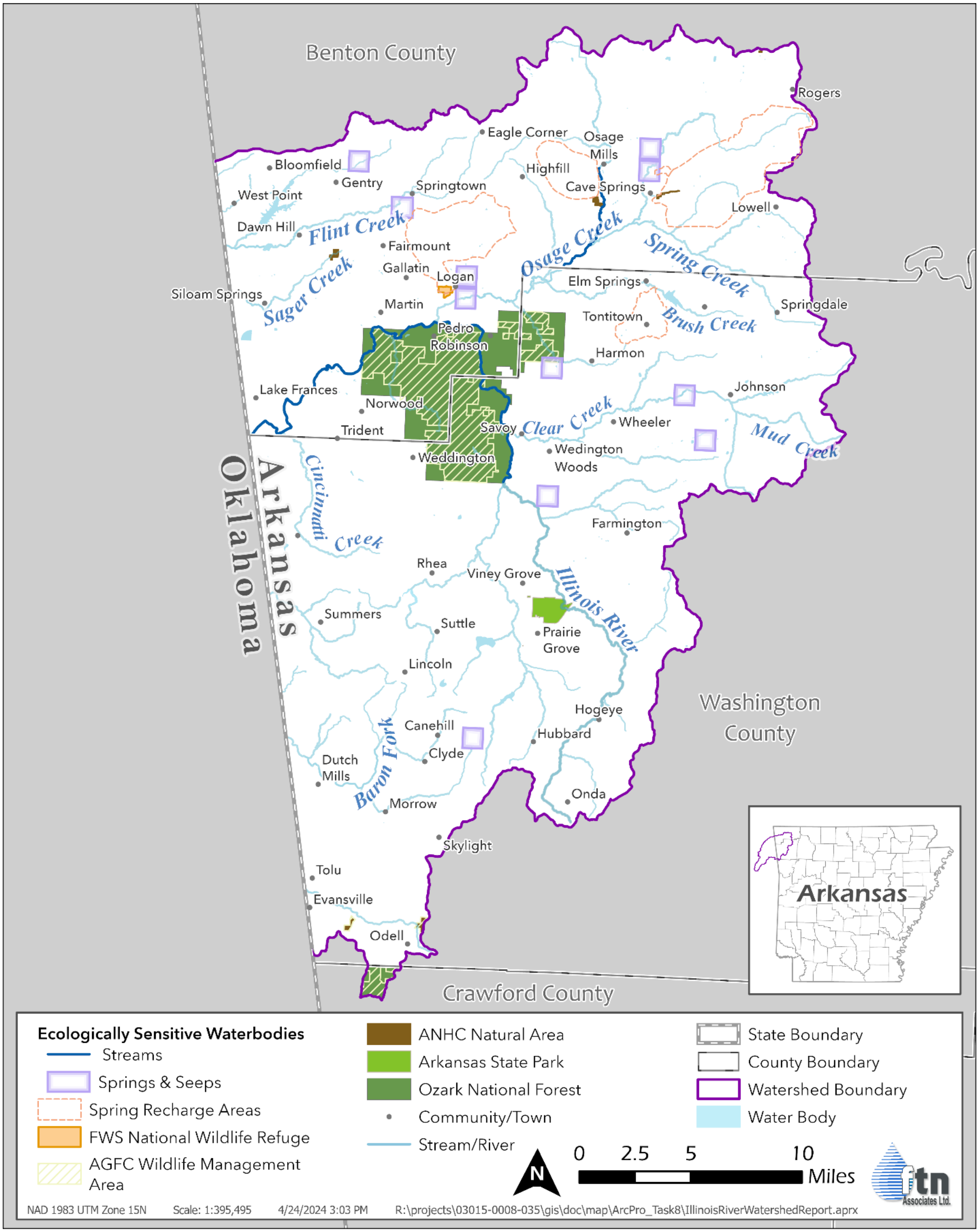

Figure 2.13. Map of sensitive areas within Upper Illinois River watershed.

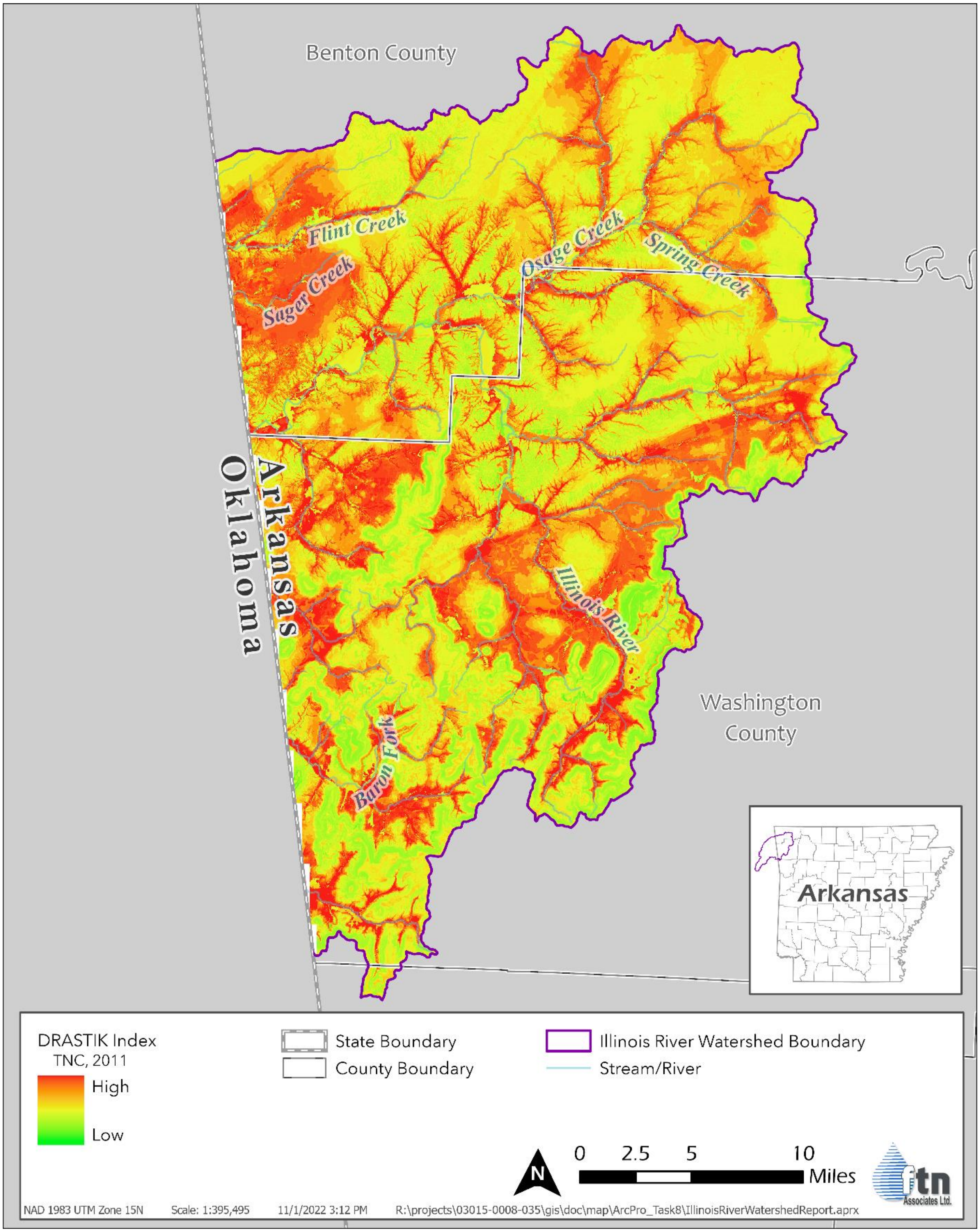

Figure 2.14. Map of groundwater vulnerability in the Upper Illinois River watershed (Inlander, Gallipeau and Slay 2011).

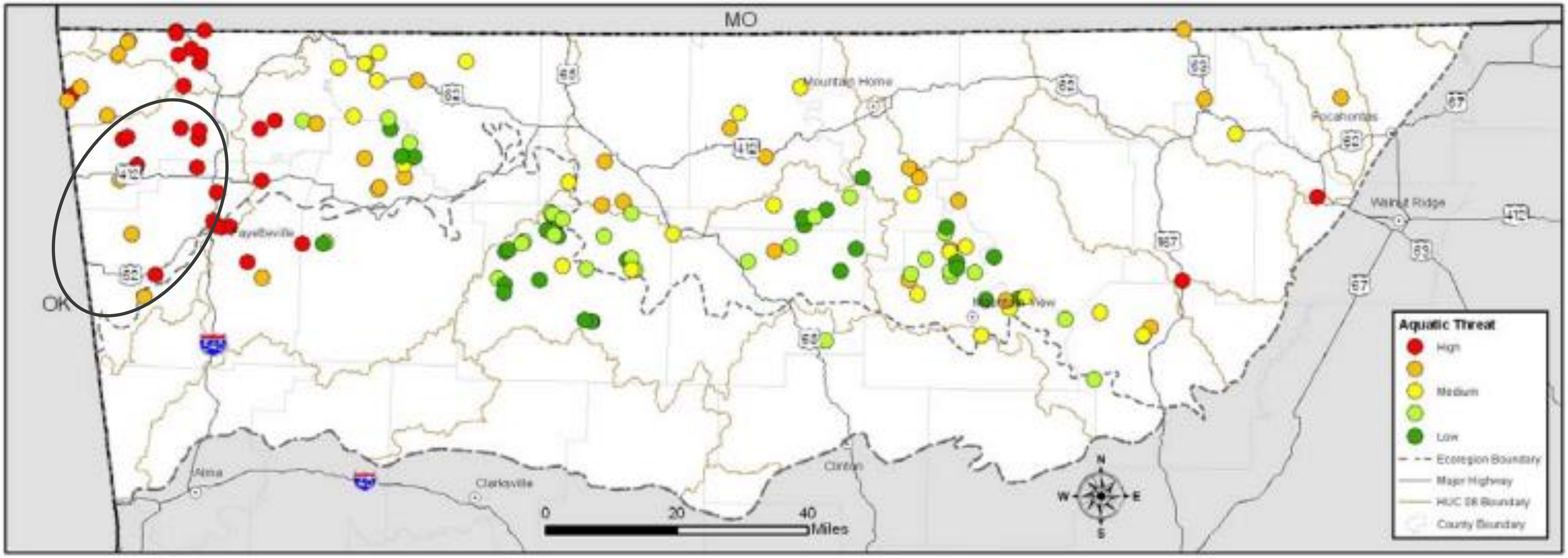

Figure 2.15. Overall threat scores for sites occupied by aquatic cave species of conservation concern (Figure 53 from Inlander, Gallipeau and Slay 2011). The oval encompasses evaluated sites within the Upper Illinois River watershed.

3. WATERSHED ASSESSMENT

This section describes water quality and ecological condition of the Upper Illinois River watershed, and nonpoint sources of pollution that are present.

3.1 Surface Water Quality

This subsection describes surface water quality in the Upper Illinois River watershed in terms of measured concentrations of selected parameters. This includes a summary of the water quality standards that apply in the watershed and the water quality monitoring programs active in the watershed. Recent (2017-2021) surface water quality data are summarized and discussed, and trends in long-term water quality data are evaluated.

3.1.1 Water Quality Standards

Arkansas state water quality standards consist of designated uses for waterbodies, numeric standards for selected water pollutants or water quality indicators, narrative criteria for pollutants or indicators without numeric standards, and an antidegradation statement. State water quality standards that apply to surface waters in Upper Illinois River watershed are described below.

3.1.1.1 Designated Uses

Designated uses of almost all the streams in the watershed are primary contact recreation (watersheds >10mi^2); secondary contact recreation; seasonal aquatic life (watersheds < 10 . mi^2.), and perennial aquatic life (watersheds ≥ 10mi^2 and streamflow ≥ 1 cfs). The designated uses of primary and secondary contact recreation and seasonal and perennial aquatic life do not apply to Railroad Hollow Creek. Columbia Hollow Creek is designated for seasonal aquatic life instead of perennial aquatic life. Additionally, all streams have Domestic, Industrial and Agricultural Water Supply as a designated use. Designated uses of lakes and reservoirs in the watershed are primary contact recreation, secondary contact recreation, perennial aquatic life, and Domestic, Industrial and Agricultural Water Supply. Illinois River, Cave Springs Cave, and over 10 springs in the watershed are classified as “Ecologically Sensitive Waterbodies” (APCEC, 2022).

3.1.1.2 Numeric Criteria

Numeric water quality criteria for selected parameters that apply in the Upper Illinois River watershed are listed in Table 3.1. Numeric water quality criteria for toxic substances and metals can be found in Rule 2 of the APCEC (2022).

Table 3.1. Numeric water quality criteria for surface waters in the Upper Illinois River watershed (Arkansas Pollution Control and Ecology Commission, 2022).

Parameter	Season	Location	Conditions	Criteria
Temperature	All	Ozark Highlands non-trout streams	All	29°C (84.2°F)
		Boston Mountains non-trout streams	All	31°C (87.8°F)
		Lakes and Reservoirs	1-meter depth	32°C (89.6°F)
		SWEPCO Lake	1-meter depth	54°C (129.2°F)
Turbidity	Baseflow[a]	Ozark Highlands and Boston Mountain streams	All	10 NTU
		Lakes and Reservoirs	1-meter depth	25 NTU
	All Flows[b]	Ozark Highlands streams	All	17 NTU
		Boston Mountain streams	All	19 NTU
		Lakes and Reservoirs	1-meter depth	45 NTU
pH	All	All	All	6 - 9 S.U.
		Lakes and Reservoirs	1-meter depth	6 - 9 S.U.
Dissolved Oxygen	Primary Season[c]	Ozark Highlands and Boston Mountains streams	22°C	6 mg/L
		Ozark Highlands and Boston Mountains streams	$\leq$10°C, flow $\geq$15cfs, March-May	6.5 mg/L
		Railroad Hollow Creek	Headwaters to mouth	2 mg/L
	Critical Season[d]	Ozark Highlands and Boston Mountains streams	<10 mi^2	2 mg/L
		Ozark Highlands streams	10 mi^2 to 100 mi^2	5 mg/L
		Ozark Highlands	>100 mi^2	6 mg/L
		Boston Mountains stream	> 10 mi^2	6 mg/L
		Railroad Hollow Creek	Headwaters to mouth	2 mg/L
	All	Lakes and Reservoirs	1-meter depth	5 mg/L

Table 3.1. Numeric water quality criteria for surface waters in the Upper Illinois River watershed (Arkansas Pollution Control and Ecology Commission, 2022) (continued).

Parameter	Season	Location	Conditions	Criteria
Chloride	All	Illinois River	All	20 mg/L
		Ozark Highlands and Boston Mountains streams	All	250 mg/L (17 mg/L[e])
Sulfate	All	Illinois River	All	20 mg/L
		Ozark Highlands streams	All	250 mg/L (23 mg/L[e])
		Boston Mountains streams	All	250 mg/L (15 mg/L[e])
Total Dissolved Solids (TDS)	All	Illinois River	All	300 mg/L
		Ozark Highlands streams	All	500 mg/L (319 mg/L[e])
		Boston Mountains streams	All	500 mg/L
Fecal Coliforms	Primary Contact[f]	All	Individual sample criterion	400 (col/100ml)
			Geometric mean	200 (col/100ml)
	Secondary Contact[g]	All	Individual sample criterion	2000 (col/100ml)
			Geometric mean	1000 (col/100ml)
Escherichia coli	Primary Contact[f]	Extraordinary Resource Waters Ecologically Sensitive Waterbodies Reservoirs	Individual sample criterion	298 (col/100ml)
			Geometric mean	126 (col/100ml)
		All other waters	Individual sample criterion	410 (col/100ml)
	Secondary Contact[g]	Extraordinary Resource Waters Ecologically Sensitive Waterbodies Reservoirs	Individual sample criterion	1490 (col/100ml)
			Geometric mean	630 (col/100ml)
		All other waters	Individual sample criterion	2050 (col/100ml)

[a]Baseflow = June - October
[b]All Flows = Entire Year
[c]Primary Season = when water temperature is 22°C or less, usually September - May
[d]Critical Season = when water temperature is > 22°C, usually May – September
e 1.33 * ecoregion reference value, per Arkansas Pollution Control and Ecology Commission (2022)
f Primary Contact = applies May 1 to September 30
g Secondary Contact = applies year round

Arkansas water quality standards include site-specific numeric criteria for sulfate. A site-specific numeric sulfate criterion, 20 mg/L, applies to the Illinois River (APCEC, 2022). The rest of the streams in this watershed are assessed using the domestic water supply sulfate criterion, 250 mg/L (DEQ, 2018d).

3.1.1.3 Narrative Criteria

In addition to numeric water quality criteria, state narrative criteria have been developed for the following: nuisance species; color; taste and odor; solids, floating material, and deposits; toxic substances; and oil and grease.; and nutrients (APCEC, 2022).

3.1.2 Current Surface Water Quality Monitoring

Surface water quality data have been collected by several entities in the Upper Illinois River watershed, including DEQ, US Geological Survey (USGS), Arkansas Water Resources Center (AWRC), universities, and Arkansas Stream Teams. An inventory of historical surface water quality monitoring locations is included as Appendix D. Table 3.2 lists water quality monitoring locations active during the period 2018-2022, which are mapped in Figure 3.1. Data collected from 2018 through 2022 reflect current water quality conditions in the watershed. Table 3.3 lists water quality parameters that were measured at water quality stations active during 2018-2022. There are 35 water quality monitoring stations in the Upper Illinois River watershed at 24 locations that were active during 2018-2022. Table 3.4 lists Water quality parameters and sampling frequency for monitoring programs active in the Upper Illinois River watershed 2018-2022.

Table 3.2. Surface water quality monitoring stations active in the Upper Illinois River watershed during 2018-2022 (AGFC, 2021; DEQ, 2018, 2021b; USGS, 2021).

County	Stream	Location	Entity	Program	Station ID	Start year (earliest year during target period)	End year	Number of sample dates 2018-2022
Washington	Baron Fork	SR45 E of Dutch Mills	DEQ	Special study	ARK0007A	1998 (2018)	2022	56
Washington	Baron Fork	Highway 59	USGS	Routine	07196900	1959 (2018)	2022	20
			AWRC	319 projects	Baron	2009 (2018)	2018	124
Washington	Cincinnati Creek	SR244 7 miles S of Siloam Springs	DEQ	Ambient	ARK0141	1998 (2018)	2022	51
Washington	Clear Creek	Hwy. 112 Bridge	DEQ	Ambient	ARK0010C	1994 (2018)	2022	53
Delaware, Oklahoma	Flint Creek	CR DO553 Rd 4 miles NW of W Siloam Springs	DEQ	Ambient	ARK0004A	1990 (2018)	2022	51
			USGS	Routine	07195855	1979 (2018)	2022	31
Delaware, Oklahoma	Sager Creek	Beaver Springs Road 2 miles NW of Siloam Springs	DEQ	Ambient	ARK0005	1990 (2018)	2022	50
Delaware, Oklahoma	Sager Creek	County Rd 556 NW of Siloam Springs	USGS	Routine	07195865	1996 (2018)	2022	30
Benton?	Sager Creek	At Siloam Springs	AWRC	319 projects	Sager	2011 (2018)	2018	33
Adair, Oklahoma	Illinois River	Near Watts, Oklahoma	AWRC	319 projects	Watts	2009 (2018)	2018	128
			USGS	Routine	07195500	1955 (2018)	2022	64
Benton	Illinois River	At Hwy 59 south of Siloam Springs	DEQ	Ambient	ARK0006	1992 (2018)	2022	46
			USGS	Routine	07195430	1972 (2018)	2022	20
			AWRC	319 projects	IR59	2009 (2018)	2018	127

Table 3.2. Surface water quality monitoring stations active in the Upper Illinois River watershed during 2018-2022 (DEQ, 2021b) (DEQ, 2018) (USGS, 2021) (AGFC, 2021) (continued).

County	Stream	Location	Entity	Program	Station ID	Start year (earliest year during target period)	End year	Number of sample dates 2018-2022
Washington	Illinois River	SR16 W of Savoy	DEQ	Ambient	ARK0040	1990 (2018)	2022	54
			USGS	Routine	07194800	1968 (2018)	2022	20
			AWRC	319 projects	Savoy	2009 (2018)	2018	124
Benton	Osage Creek	Logan Rd in Logan, 14 miles W of Springdale	DEQ	Special study	ARK0082	2008 (2018)	2022	56
Benton	Osage Creek	CR71 1 MI. W. of Hwy. 112	DEQ	Special study	OSC0004/ ARK0068B	1995 (2018)	2022	53
Benton	Osage Creek	Near Elm Springs	USGS	Routine	07195000	1951 (2018)	2022	20
			AWRC	319 projects	Osage	2009 (2018)	2018	123
Benton	Spring Creek	At Hwy 112 near Springdale	USGS	Routine	07194933	1978 (2018)	2022	27
			AWRC	319 projects	Spring	2012 (2018)	2018	126
Washington	Mud Creek	Near Johnson, AR	USGS	Study	071948095	2011 (2018)	2021	24
Washington	Mud Creek	Gregg Ave near Johnson	AWRC	319 projects	Mud (07194809)	2015 (2018)	2018	128
Benton	Osage Creek	At Hwy 112 near Cave Springs	USGS	Routine	07194880	1978 (2018)	2021	9
			AWRC	319 projects	OC112	2015 (2018)	2018	126
Washington	Spring Creek	Sanders Ave, Springdale	USGS	Study	07194906	2009 (2018)	2021	4
Benton	Spring Creek		Troop 107	Stream Team	NA	2021	2021	1

Table 3.2. Surface water quality monitoring stations active in the Upper Illinois River watershed during 2018-2022 (DEQ, 2021b) (DEQ, 2018) (USGS, 2021) (AGFC, 2021) (continued).

County	Stream	Location	Entity	Program	Station ID	Start year (earliest year during target period)	End year	Number of sample dates 2018-2022
Washington	Spring Creek		Springdale High School	Stream Team	NA	2021	2021	1
Washington	Lake Fayetteville	W of spillway above boat docks	DEQ	Significant Publicly Owned Lakes	LARK015A	1994 (2019)	2021	12
Benton	Cave Spring	Mouth of Cave Springs Cave	DEQ	Special study	ARK0199	2016 (2018)	2018	9
Washington	Lake Elmdale	Southeast of Elm Springs	DEQ	Significant Publicly Owned Lakes	LARK014A	1994 (2020)	2020	0
Washington	Unnamed tributary of Brush Creek	Just upstream of confluence with Brush Cr	DEQ	Special study	ARK0204	2016 (2018)	2018	9
Benton	Logan Spring	Mouth of Logan Cave	DEQ	Special study	ARK0202	2016 (2018)	2018	9

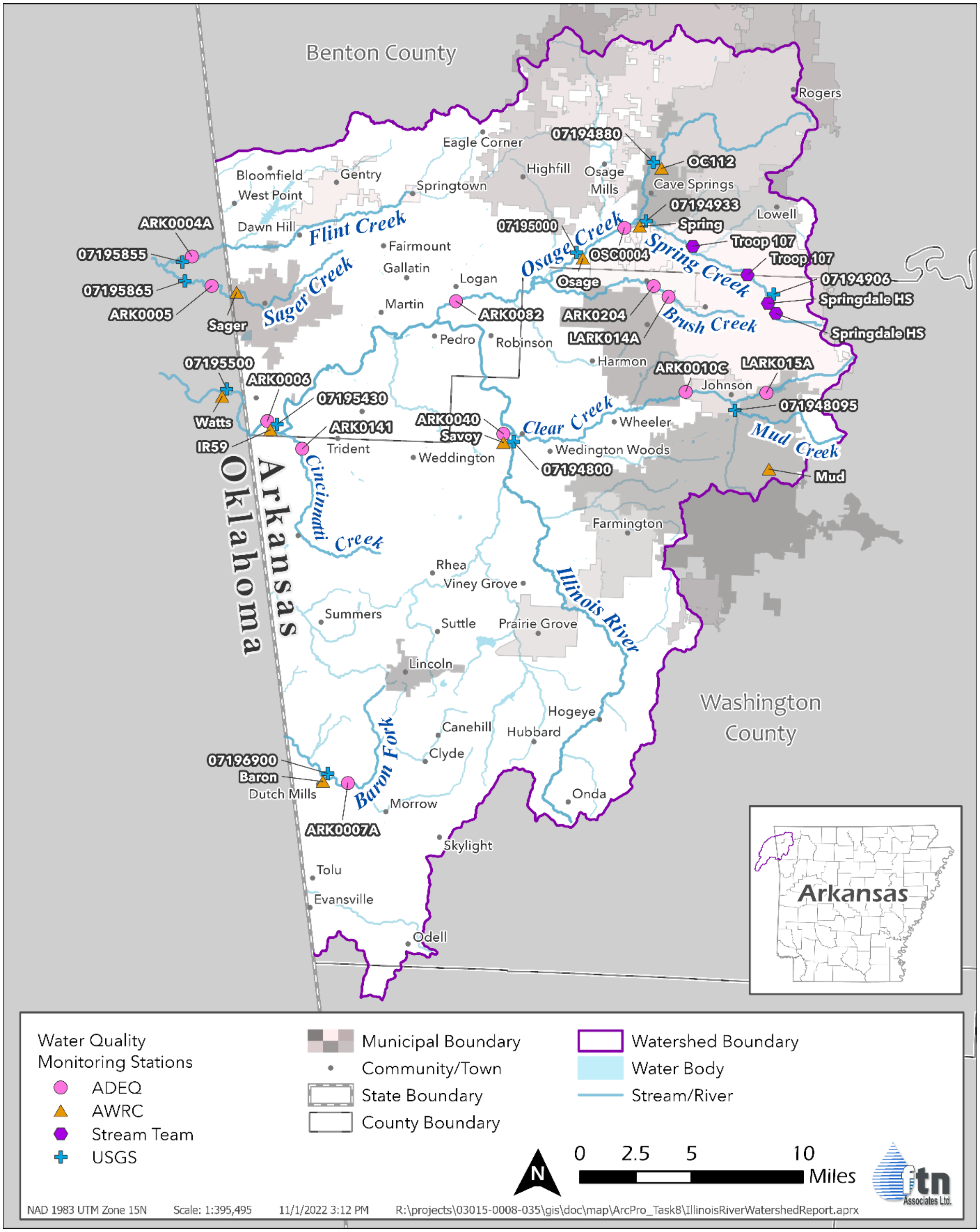

Figure 3.1. Surface water quality monitoring locations sampled 2018-2022.

Table 3.3 Water quality parameters and sampling frequency for monitoring programs active in the Upper Illinois River watershed 2018-2022.

Parameter	DEQ Ambient	DEQ Special Study	DEQ Lake	USGS Streams	AWRC	Stream Teams
Mercury	-	-	-	-	-	-
Other metals	X	-	Q	Q	-	-
DO	M	B	Q	X	-	X
Turbidity	M	B	Q	S	X	X
Transparency	-	-	Q	-	-	-
Nutrients	M	B	Q	S	X	X
TSS	M	B	Q	-	X	-
Suspended sediment	-	-	-	S	-	-
Pathogens	H	-	-	S	-	-
Alkalinity	M	B	Q	-	-	X
Minerals	M	B	Q	S	X	X
Temperature	M	B	Q	X	-	X
Specific conductance	M	X	Q	X	X	-
pH	M	B	Q	X	-	X
Hardness	Q	B	Q	S	-	X
Total organic carbon	9-10/yr	H	Q	-	-	-
Organics	H	-	-	-	-	-
Biochemical oxygen demand	7-11/yr+	-	-	-	-	-

D=daily, M=monthly; B=every two months; H=historically, but not in the last five years; Q=quarterly, X=varies; S=some stations
+ one station only, ARK0005

3.1.3 Summary of Current Surface Water Quality

Water quality measurements collected during the period 2018-2022 by DEQ, AWRC, and USGS in the Upper Illinois River Watershed were summarized and evaluated to characterize current water quality conditions. Parameters were *E. coli*, pH, turbidity, total suspended solids (TSS), suspended sediment concentration (SSC), temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), nutrients (ammonia nitrogen, nitrate+nitrite nitrogen, total nitrogen and total phosphorus), and minerals (chloride, sulfate, and TDS). Below is a summary of key findings from this evaluation. The details of the water quality analysis and presentation and discussion of all the results is provided in Appendix E.

Overall, during 2018-2022 there is no clear indication that Illinois River water quality at the upstream end (near Savoy) is statistically significantly different from water quality at the state border (Interstate 59 and near Watts).

Spring Creek median total phosphorus and mineral levels are statistically significantly higher than most of the other monitored streams. The high levels of these constituents appear to be influencing water quality in Osage Creek downstream of the Spring Creek confluence. However, by the time Osage Creek joins the Illinois River, phosphorus and mineral levels have decreased significantly, to the point that median concentrations are not statistically significantly different from median concentrations in the Illinois River at Savoy.

Median nitrate+nitrite, total nitrogen, total phosphorus, chloride, and sulfate concentrations in Sager Creek downstream of the Oklahoma border (West Siloam Springs) are statistically significantly higher than the median concentrations in Sager Creek upstream of the state border (in Siloam Springs). Median nitrate and nitrite and total nitrogen concentrations in Sager Creek in Oklahoma are statistically significantly higher than at all the other stations in the Upper Illinois River watershed. Median phosphorus and chloride concentrations in Sager Creek in Oklahoma are statistically significantly higher than other stations in the watershed, except those on Spring Creek.

Mud Creek, Clear Creek, Brush Creek, and Baron Fork Creek are the only streams where median total phosphorus concentrations for 2018-2022 are less than 0.037 mg/L. Median total phosphorus concentrations for 2018-2022 at monitoring locations on other streams in the watershed are greater than 0.037 mg/L.

3.1.4 Assessed Water Quality Impairments

Several streams in the Upper Illinois River watershed cross the Arkansas-Oklahoma border, including Baron Fork, Ballard Creek, Evansville Creek, Flint Creek, Illinois River, and Sager Creek. Streams flowing from Arkansas into Oklahoma are required to support Oklahoma water quality standards. Thus, impairments in both Arkansas and Oklahoma are discussed in this section.

3.1.4.1 Arkansas

At the time of this writing, the most recent US Environmental Protection Agency (EPA) approved state impaired waters list (i.e., 303(d) list) for Arkansas is from 2018. The EPA is reviewing comments submitted on Arkansas's partially approved 2020 303(d), and the draft 2022 303(d) list is in preparation. Impaired waters in the Upper Illinois River watershed from the final 2018 303(d) list are listed in Table 3.4 and mapped on Figure 3.2. On the 2018 303(d) list, 53 miles of streams and Lake Fayetteville (171 acres) in the watershed are classified as impaired. Table 3.5 also indicates impaired waters in the Upper Illinois River watershed from the partially approved 2020 and draft 2022 lists. On the partially approved 2020 list over 53 miles of stream in the watershed are listed as impaired. New impairments from the partially approved 2020 list are also indicated on Figure 3.2.

Table 3.4. Impaired waterbodies in the Upper Illinois River watershed from the final 2018 303(d) list, partially approved 2020, and draft 2022 303(d) lists.

Assessment unit number	Assessment unit description	Category	Designated use not supported	Pollutant(s) causing impairment	Monitoring Station	Suspected source(s) of pollutants	Year listing initiated	Draft 2020 listing change from 2018*	Draft 2022 listing change from 2018*
11110103-018	Illinois River	Not listed	Not listed	Not listed	Not listed	Not listed	2022	NC	+Turbidity
11110103-020	Illinois River	5	Not identified	Chloride, sulfate	ARK006A, ILL0007, IR59, 07195430	Unknown	2016	-Chloride	-Chloride
11110103-024	Illinois River	5	Not identified	Chloride, sulfate	ARK0040, ARK0066, Savoy, 07194800, AWRCIR024A	Unknown	2016	-Chloride, +Turbidity	-Chloride
11110103-028	Illinois River	5 alt	Primary contact recreation	Pathogens	IR028D (Scott et al 2015)	Industrial & municipal point sources, surface erosion, agriculture	2008 (not listed 2010-2016)	NC	NC
11110103-026	Moores Creek	5	Not identified	Sulfate	(ARK0040)	Unknown	2014	NC	NC
		5 alt	Primary contact recreation	Pathogens		Industrial & municipal point sources, surface erosion, agriculture	2014	NC	NC
11110103-027	Muddy Fork Illinois River	5	Not identified	Sulfate	MFI0002B (ARK0040)	Unknown	2014	NC	NC
		5 alt	Primary contact recreation	Pathogens		Industrial & municipal point sources, surface erosion, agriculture	2014	NC	NC
11110103-4080	Lake Fayetteville	5	Not identified	pH	LARK015A	Not identified	2018	NC	NC
11110103-630	Little Osage Creek	5 alt	Primary contact recreation	Pathogens	LO933B (Scott et al 2015)	Industrial & municipal point sources, surface erosion, agriculture	2018	NC	NC
11110103-933	Little Osage Creek	5 alt	Primary contact recreation	Pathogens	LO933C (Scott et al 2015)	Industrial & municipal point sources, surface erosion, agriculture	2008 (not listed 2010-2016)	NC	NC
11110103-813	Baron Fork	Not listed	Not listed	Not listed	Not listed	Unknown	2020	+low DO (Critical Season)	+low DO (Critical Season)
11110103-932	Sager Creek	Not listed	Not listed	Not listed	Not listed	Unknown	2020	+Ammonia	NC
11110103-733	Unnamed tributary to Brush Creek	Not listed	Not listed	Not listed	Not listed	Unknown	2020	+low DO (Primary Season)	+low DO (Primary Season)

* NC=no change, NA=not available (category 4a listings are not included on draft 2022 303(d) list), + indicates the parameter has been added (unless otherwise indicated, additions are Category 5), - indicates the parameter has been removed/delisted.

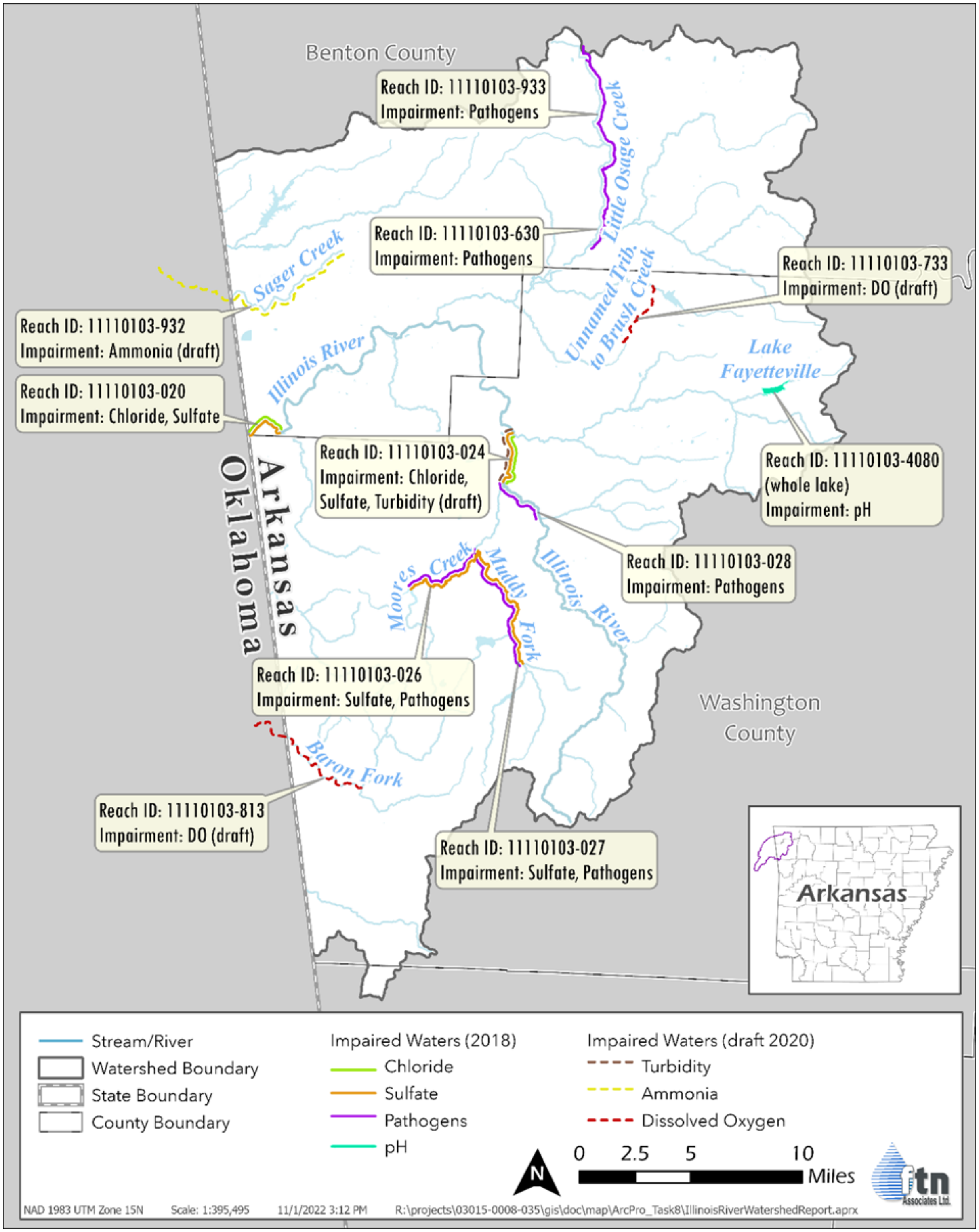

Figure 3.2. Impaired waterbodies of the Upper Illinois River watershed from the Arkansas final 2018 303(d) list and the partially approved 2020 303(d) list.

Table 3.5 lists the impaired stream reaches at the time of the 2012 watershed management plan. The most recent EPA-accepted Arkansas list of impaired waterbodies at that time was for 2008. About 124 miles of streams in the Upper Illinois River watershed were listed as impaired on the 2008 303(d) list. Around 76 miles of streams on the 2008 303(d) list are classified as meeting water quality standards in 2018 (note that lengths of some listed stream reaches are shorter in 2018 than they were in 2008). The majority of the delisted stream segments had been added to the 2008 303(d) list by EPA for total phosphorus and/or pathogens. There are only two (2) assessment units on both the 2008 and 2018 303(d) lists for the same parameter, -028 (Moore's Creek) and -933 (lower Little Osage Creek), both for pathogens. Note that both of these assessment units were classified as meeting standards in 2010 and then classified as impaired for the 2018 303(d) list. Three assessment units on the 2008 303(d) list are also on the 2018 303(d) list, but because of different pollutants, -020 (Illinois River), -024 (Illinois River), and -027 (Muddy Fork).

Table 3.5. Status of waterbodies on 2008 final 303(d) list.

Impaired Reach	Designated Use Impaired	2008 Pollutant of Concern	Predominant Pollutant Source	Status
11110103-020	Aquatic Life Fisheries	Sediment	Surface Erosion	Delisted 2010, listed 2016 new pollutants
11110103-023	Primary Contact	Pathogens	Agriculture	Delisted 2018
11110103-024	Primary Contact	Sediment, pathogens	Sediment: Surface Erosion Pathogens: Agriculture	Delisted sediment 2014, pathogens 2018; new pollutants 2014, 2016
11110103-025	Primary Contact	Pathogens, total phosphorus	Agriculture	Delisted 2018
11110103-029	Primary Contact	Pathogens	Urban	Delisted 2016
11110103-932	Not stated	Nitrate	Municipal Point Source	Delisted 2018, relisted 2020 ammonia
11110103-013	Primary Contact	Pathogens	Unknown	Delisted 2010
11110103-027	Not stated	Total phosphorus	Unknown	Delisted 2010, listed 2014 new pollutants
11110103-028	Primary Contact	Pathogens	Unknown	Delisted 2010, relisted 2018
11110103-030	Primary Contact	Pathogens, total phosphorus	Unknown	Delisted 2010
11110103-930	Not stated	Total phosphorus	Unknown	Delisted 2010
11110103-933	Primary Contact	Pathogens	Unknown	Delisted 2010, relisted 2018
11110103-931	Primary Contact	Pathogens, total phosphorus	Unknown	Delisted 2010
SWEPCO Lake	Aquatic Life	Unknown	Unknown	Delisted 2018

3.1.4.2 Oklahoma

Two (2) Oklahoma stream segments just downstream of the Arkansas border are included on the 2022 EPA-approved Oklahoma list of impaired waterbodies. Information about these impairments is provided in Table 3.6. Note that on the partially approved Arkansas 2020 303(d) list, Sager Creek is listed as impaired due to ammonia nitrogen levels, but not pathogens or turbidity. In Arkansas the section of the Illinois River just upstream of the Oklahoma border is listed as impaired due to chloride and sulfate, but not pathogens or nutrients.

Table 3.6 Illinois River watershed stream segments just downstream of the border listed as impaired in Oklahoma 2022 (Oklahoma Department of Environmental Quality, 2022).

Reach Number	Reach Description	Category	Designated Use Not Supported	Pollutant(s) Causing Impairment	Suspected Source(s) of Pollutants
OK121700060080_00	Sager Creek	5a	Primary body contact recreation	*Enterococcus*	Animal feeding operations, riparian grazing, land application of waste, municipal pt source, on-site treatment systems, grazing, pet waste, wildlife (not waterfowl), unknown, outside of state
		5a	Cool water aquatic community	sediment/silt	unknown
OK121700030350_00	Illinois River	5a	Primary body contact recreation	*Enterococcus, E. coli*	Animal feeding operations, riparian grazing, land application of waste, unknown
		5a	Aesthetics	phosphorus	Animal feeding operations, MS4, riparian grazing, land application of waste, municipal pt source, on-site treatment systems, CAFOs, grazing, pet waste, wildlife (not waterfowl), unknown, outside of state

3.1.5 Long Term Trends/Changes in Water Quality

While it is important to look at current water quality conditions in the watershed, it is also important to determine if water quality is changing over time. Pollutant concentrations that are decreasing over time suggest that water quality is improving and that upstream pollution management practices are providing benefits. Of particular interest in this regard are trends at impaired water bodies. Also of interest are locations where water quality still meets water quality standards, but long-term trends suggest that water quality standards may not be met in the future if no action is taken.

3.1.5.1 Comparison of Measurements from Two Time Periods

In the 2012 Upper Illinois River watershed management plan, summary statistics were presented for DEQ (or USGS for total nitrogen) measurements from 1997-2011. To get an idea of whether water quality has changed since then, we compared median values for current water quality measurements (2017-2021) to median values for the water quality information presented in the 2012 Upper Illinois River watershed management plan. The actual comparison analysis is provided in Appendix F. A summary of the findings is provided in Table 3.7. Only two (2) parameters exhibited an increase in concentration and at only one (1) location each; sulfate increased at ARK0040 on the Illinois River at Savoy (stream reach listed as impaired due to sulfate), and TSS increased at ARK0005 on Sager Creek at Beaver Springs Road in Oklahoma (stream reach listed as impaired due to turbidity in Oklahoma). All parameters but DO exhibit a decrease in concentrations at a minimum of two (2) locations. No change was apparent in DO concentrations between the two (2) data periods.

Table 3.7. Summary of comparison of concentrations of selected parameters from 1997-2011 and 2017-2021.

Site	Stream	Chloride	DO	Nitrite + Nitrate as N	Sulfate	Total Phosphorus	Total Nitrogen	Total Suspended Solids
ARK0040	Illinois River	no change	no change	no change	increase	decrease	no change	no change
ARK0010C	Clear Creek	decrease	no change	decrease	decrease	decrease	decrease	decrease
07195000	Osage Creek	no change	no change	no change	no change	decrease	no change	decrease
ARK0006	Illinois River	decrease	no change	no change	no change	no change	no change	no change
ARK0004A	Flint Creek	decrease	no change	no change	decrease	no change	no change	decrease
ARK0005	Sager Creek	decrease	no change	decrease	no change	decrease	decrease	increase
ARK0007A	Baron Fork	decrease	no change	no change	no change	decrease	no change	no change

Only one (1) of the water quality stations evaluated is located on an impaired assessment unit. Station ARK0040 is located on an Illinois River assessment unit listed in 2018 as impaired due to high sulfate and high chloride concentrations. As noted previously, sulfate concentrations appear to have increased at this station over time, which explains the addition of a sulfate impairment to this assessment unit in 2016. Chloride concentrations at this location do not appear to have changed significantly between the two (2) time periods.

3.1.5.2 Trends Reported to Arkansas-Oklahoma Arkansas River Compact Commission

In the 2019 Arkansas report to the Arkansas-Oklahoma Arkansas River Compact Commission, graphs of data from 1999 through 2019 indicate declining trends in total phosphorus loads and concentrations in the Illinois River south of Siloam Springs (ARK0006), Sager Creek (ARK0005), and Baron Fork at Dutch Mills (ARK0007A); and a possible slight increasing trend in phosphorus concentrations in Flint Creek northwest of Siloam Springs (ARK0004A) (State of Arkansas Environmental Committee, 2020). In the 2020 report to the Arkansas-Oklahoma Arkansas River Compact Commission graphs of data from 1990 through 2020 indicate declining trends in total phosphorus concentrations at all four (4) Arkansas monitoring locations, Flint Creek (ARK0004A), Sager Creek (ARK0005), Illinois River (ARK0006), and Baron Fork (ARK007A). Total phosphorus concentrations at most of the monitoring locations reported have exhibited little change since around 2012 (Illinois River Basin Arkansas-Oklahoma Compact, 2020).

3.1.5.3 Trend Analysis of Arkansas Water Resource Center Measurements

Grantz and Haggard (2023) performed trend analysis of flow-normalized concentrations of seven (7) constituents (nitrate nitrogen, total nitrogen, soluble reactive phosphorus (SRP), total phosphorus, TSS, chloride, and sulfate) collected 2009-2022 at eight (8) AWRC water quality monitoring stations in the Illinois River watershed (Watts, IR59, Savoy, Osage, Baron, Spring, OC112, and Mud). Statistically significant trends identified are summarized in Table 3.8. Note that no trends were identified for total nitrogen or TSS at any of the stations. Gantz and Haggard (2023) suggest that decreasing trends in phosphorus concentrations at most of the stations are due to both improvements in municipal wastewater treatment plants (WWTPs) and nonpoint source pollution management activities.

Table 3.8. Summary of statistically significant trend analysis results for data from AWRC water quality monitoring stations (Grantz & Haggard, 2023). Increasing trends are highlighted in yellow.

Station ID[a]	Stream	Data period	Constituent	Trend Direction
Savoy (impaired)	Illinois River	2010-2022	Nitrate N	Decreasing[b]
			Chloride	Decreasing[b]
Mud	Mud Creek	2016-2020	SRP	Decreasing[c]
			Total phosphorus	Decreasing[c]
			Chloride	Increasing[b]
			Sulfate	Increasing[b]
OC112	Osage Creek	2016-2022	Total phosphorus	Decreasing[b]
			Chloride	Increasing[b]
			Sulfate	Increasing[c]
Spring	Spring Creek	2013-2022	SRP	Decreasing[b]
			Total phosphorus	Decreasing[c]
			Chloride	Decreasing[c]
Osage	Osage Creek	2010-2022	SRP	Decreasing[c]
			Total phosphorus	Decreasing[c]
			Sulfate	Increasing[c]
IR59 (impaired)	Illinois River	2010-2022	SRP	Decreasing[b]
			Total phosphorus	Decreasing[b]
Watts	Illinois River	2010-2022	SRP	Decreasing[c]
			Total phosphorus	Decreasing[c]
			Sulfate	Increasing[c]
Baron	Baron Fork	2010-2022	Total phosphorus	Decreasing[b]
			Chloride	Decreasing[c]

a stations listed in downstream order
b “likely” trend, p between 0.05 and 0.10
c “very likely” trend, p<0.05

The increasing trend in sulfate concentrations at the Illinois River stations is interesting. Reaches of the Illinois River where the Savoy and IR59 stations are located are currently listed as exceeding the ambient sulfate water quality criterion (see Table 3.4). The increasing trend in sulfate at the Osage monitoring station suggests that there is the potential for the sulfate criterion to be exceeded at this location in the future.

3.1.6 Pollutant Loads

Pollutant loads are the product of concentration and stream flow. As a result, streams with low concentrations can contribute large loads if they have very large flow. Vice versa, a stream with a high concentration but a low flow, may have a relatively small load. Yield is the load for a stream divided by the drainage area of the stream. This section discusses and compares estimates of loads and yields for the Illinois River and some of its tributaries. The parameters for which loads are discussed are chloride, sulfate, pathogens, TSS, total phosphorus, and total nitrogen. Loads and yields calculated using flow and water quality measurements are discussed, as well as loads and yields estimated using water quality models.

3.1.6.1 Loads Estimated from Measurements

Gantz and Haggard (2023) calculated annual loads of seven (7) constituents (nitrate nitrogen, total nitrogen, SRP, total phosphorus, TSS, chloride, and sulfate) collected 2009-2022 at eight (8) AWRC water quality monitoring stations (Watts, IR59, Savoy, Osage, Baron, Spring, OC112, and Mud). They found that annual loads increased with increasing watershed area and annual discharge. Yields calculated from 2022 annual loads are graphed in Figure 3.3. For most constituents the highest yields are from the drainage area of the Spring Creek station. For TSS the highest yield was at the Mud Creek station, followed by the Spring Creek station. For total phosphorus the highest yield was at the Savoy Illinois River station followed by the Spring Creek station.

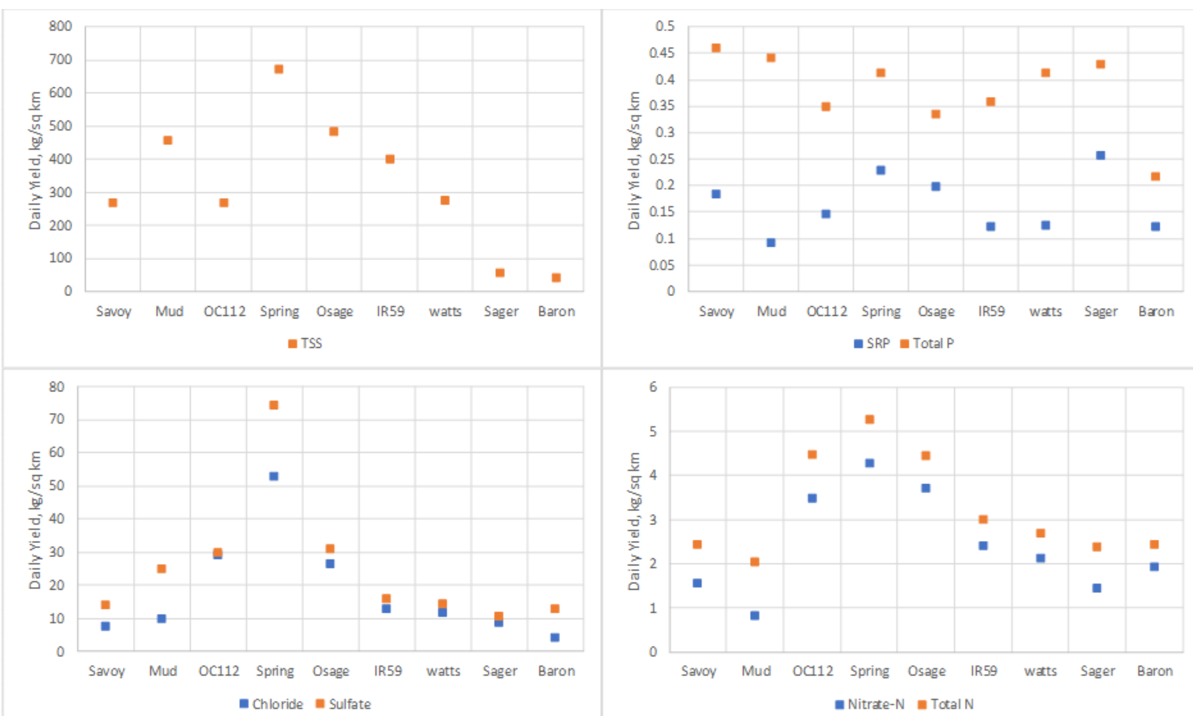

Figure 3.3. Mean daily yields of selected constituents calculated using measurements from AWRC water quality monitoring stations.

Gantz and Haggard (2023) report that yields of chloride and sulfate are higher from more developed watersheds and watersheds with WWTP discharges. They postulate that higher sulfate yields may be related to the use of alum in wastewater treatment systems and household detergents in wastewater. They interpreted higher yields of nitrate and total nitrogen for Stations OC112, Spring, and Osage as the influence of WWTP discharges.

3.1.6.2 USGS SPARROW Model

Recently, USGS updated SPARROW modeling of the US to the period 2000-2014, and estimated streamflow and nitrogen, TSS, and phosphorus yields for 2012 (Robertson & Saad, 2019). Estimated 2012 yields from the Illinois River watershed from the updated Midwest SPARROW model are listed in Table 3.9. Note that these yields are for the entire HUC8, not just the Upper Illinois River watershed. The estimated Illinois River 2012 nutrient and sediment yields are in the upper range (i.e., greater than average) for the Midwest (USGS, 2019). Figures 3.4-3.6 show maps of SPARROW estimated yields of total nitrogen, total phosphorus, and sediment from catchments of the Upper Illinois River watershed.

Table 3.9. Estimated yields from the Illinois River watershed for 2012 using SPARROW model (USGS, 2019).

Parameter	Estimated 2012 aggregated yield	Midwest ranking
Total nitrogen	877.2 kg/sq km	Fourth quintile (580-1,070)
Total phosphorus	154.7 kg/sq km	Top quintile (>138)
Suspended sediment	133.7 Mg/sq km	Fourth quintile (123-200)
Streamflow	359.6 mm/year	Fourth quintile (358-471)

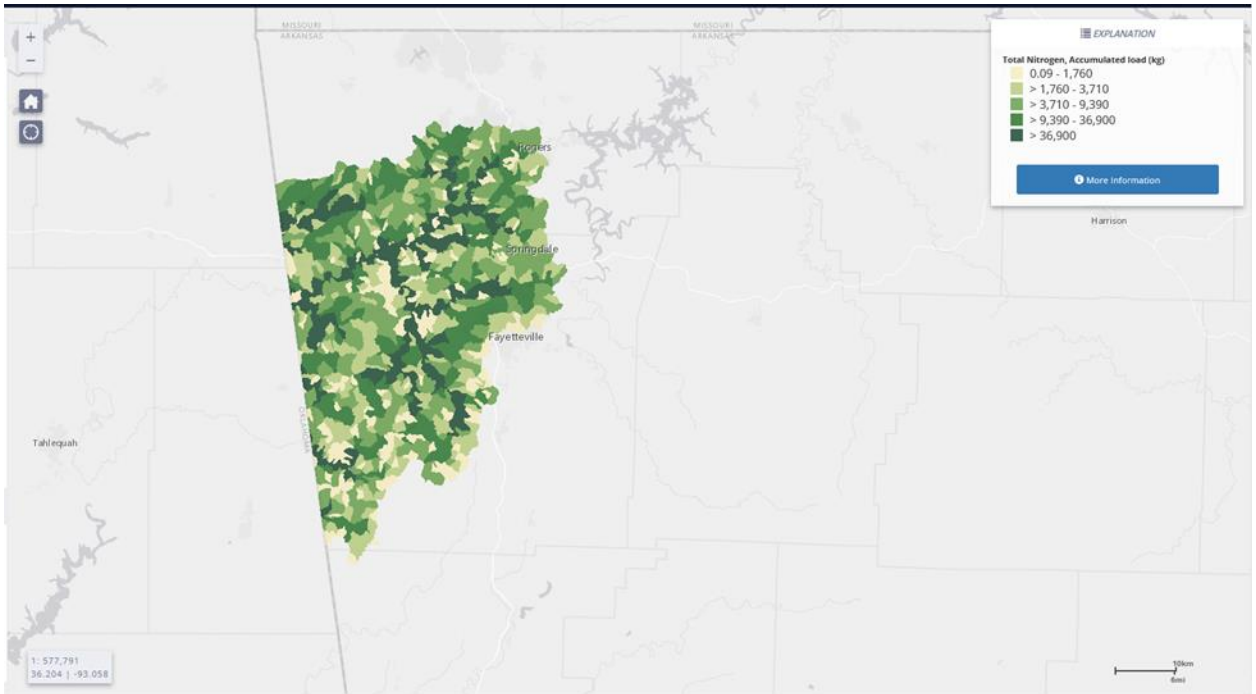

Figure 3.4. SPARROW model total nitrogen yields from Upper Illinois River catchments.

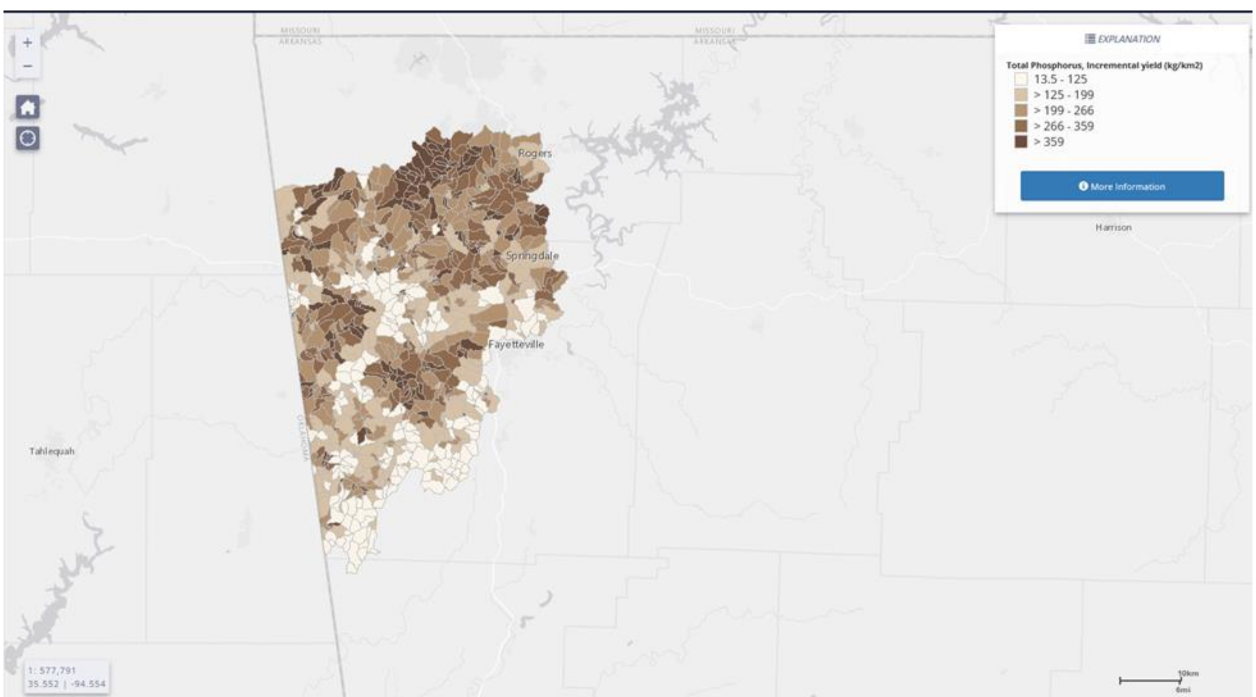

Figure 3.5. SPARROW model total phosphorus yields from Upper Illinois River catchments.

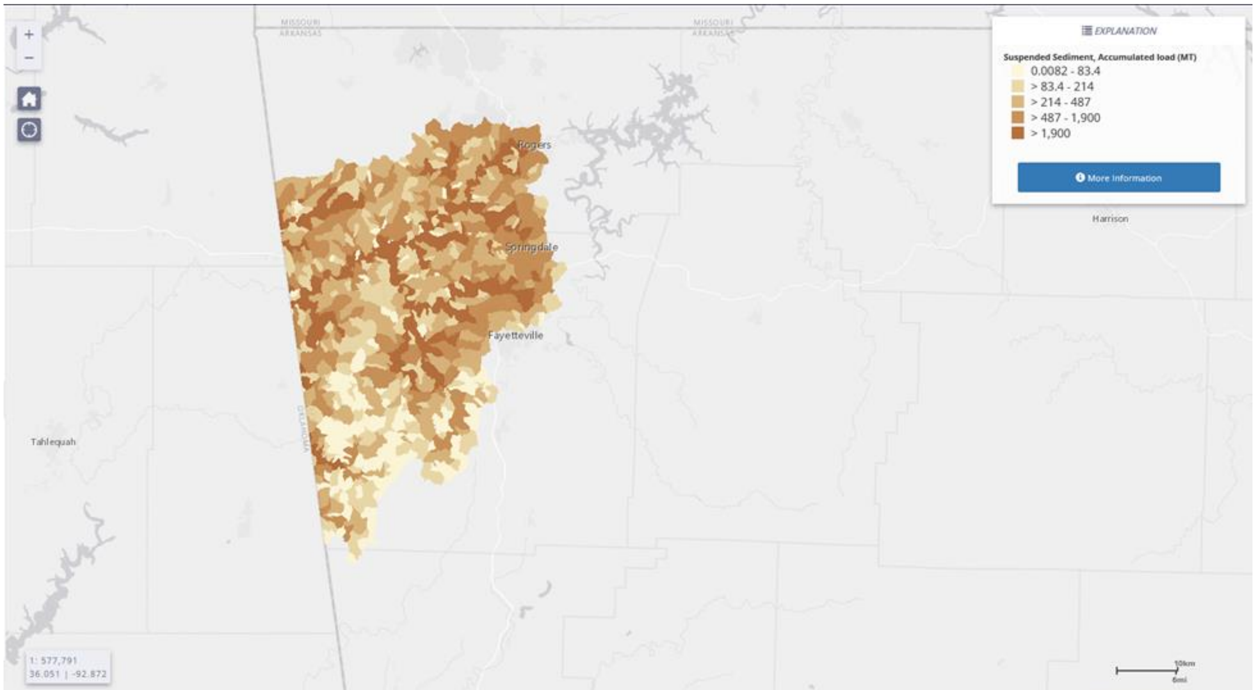

Figure 3.6. SPARROW model sediment yield from Upper Illinois River catchments.

3.1.6.3 HSPF Model

Aqua Terra Consultants and Michael Baker Jr. Inc. prepared an HSPF model of the Illinois River watershed under contract to EPA for the purpose of determining "reductions in phosphorus loads needed to meet water quality standards in both states, Arkansas and Oklahoma" (Michael Baker Jr Inc., Aqua Terra Consultants, Dynamic Solutions LLC, 2015). Table 3.10 lists HSPF modeled annual nutrient loads at the Arkansas/Oklahoma state line and annual yields calculated from those values. The HSPF drainage area at the Arkansas/Oklahoma state line (Model Reach 635) is 569. One (1) square miles, or 147,396 hectares (ha) (Michael Baker Jr Inc., Aqua Terra Consultants, Dynamic Solutions LLC, 2015).

Table 3.10. HSPF model average annual nutrient loads at the Arkansas/Oklahoma state line.

	Total Phosphorus	Total Nitrogen
Annual load, pounds	355,727	3,619,216
Annual load, kg	161,355	1,641,647
Yield, kg/ha	1.09	11.14

3.1.6.4 SWAT Models

At least seven (7) Soil and Water Assessment Tool (SWAT) models have been prepared of the Illinois River watershed over the years (2005-2021) (FTN 2024). Three (3) of these modeled just the portion of the Illinois River watershed in Arkansas (White M. , 2009; Saraswat, Daniels, Tacker, & Pai, 2008; Pai, Saraswat, & Daniels, 2011). Most of the reports describing these SWAT models do not report the loads estimated for the Upper Illinois River watershed. Average annual loads were reported in White (2009) that are listed here in Table 3.11, along with yields estimated from these loads. The loads reported in White (2009) were estimated using SWAT2005 run for the period 1995-2007. The modeled loads were from 228,914 ha.

Table 3.11. SWAT estimated average annual loads from the Illinois River watershed.

Parameter	Average annual load		Average annual yield	
	White 2009	FTN 2024	White 2009	FTN 2024
Total Nitrogen	1,781,748 kg/yr	2,725,806 kg/yr	7.8 kg/ha/yr	13.4 kg/ha/yr
Total Phosphorus	210,685 kg/yr	301,771 kg/yr	0.9 kg/ha/yr	1.5 kg/ha/yr
Sediment	43,634 Mg/yr	168,306 Mg/yr	0.2 Mg/ha/yr	0.8 Mg/ha/yr

An updated SWAT model of the Upper Illinois River watershed was prepared in 2022, in conjunction with an updated SWAT model of the entire Illinois River watershed. These models use SWAT2012 to simulate total nitrogen, total phosphorus, and sediment yields. The 2022 Upper Illinois River watershed SWAT model used updated land use (2019) and poultry litter application data reported to Natural Resources Division, which was not available for the previous modeling efforts. Overall average annual loads and yields for Upper Illinois River watershed from the 2022 Upper Illinois River watershed SWAT model are listed in Table 3.11. This updated model was run for the period 1990-2020 and calibrated to water quality data from 1996-2020. The 2022 modeled loads reported in Table 3.10 were from 203,130 ha (FTN 2024).

The purpose of the 2022 Upper Illinois River watershed SWAT modeling effort was to rank the HUC12 sub-watersheds in terms of yields of nutrients and sediment. Figures 3.7-3.9 illustrate the relative rankings of the HUC12 sub-watersheds based on simulated instream yields of total nitrogen, total phosphorus, and sediment from the 2022 Upper Illinois River SWAT model.

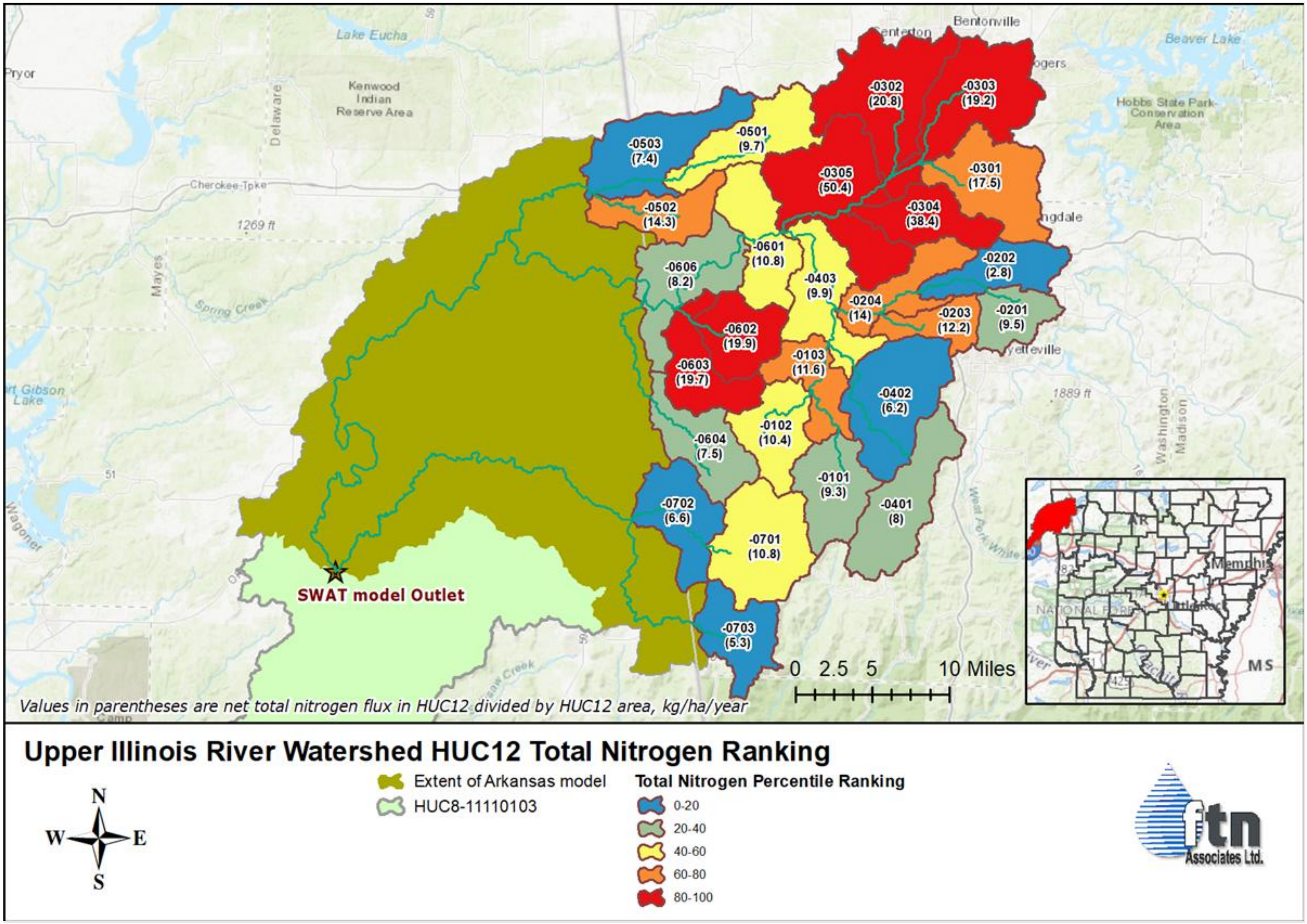

Figure 3.7 Ranking of Upper Illinois River HUC12s based on modeled instream yields of total nitrogen (FTN, 2024).

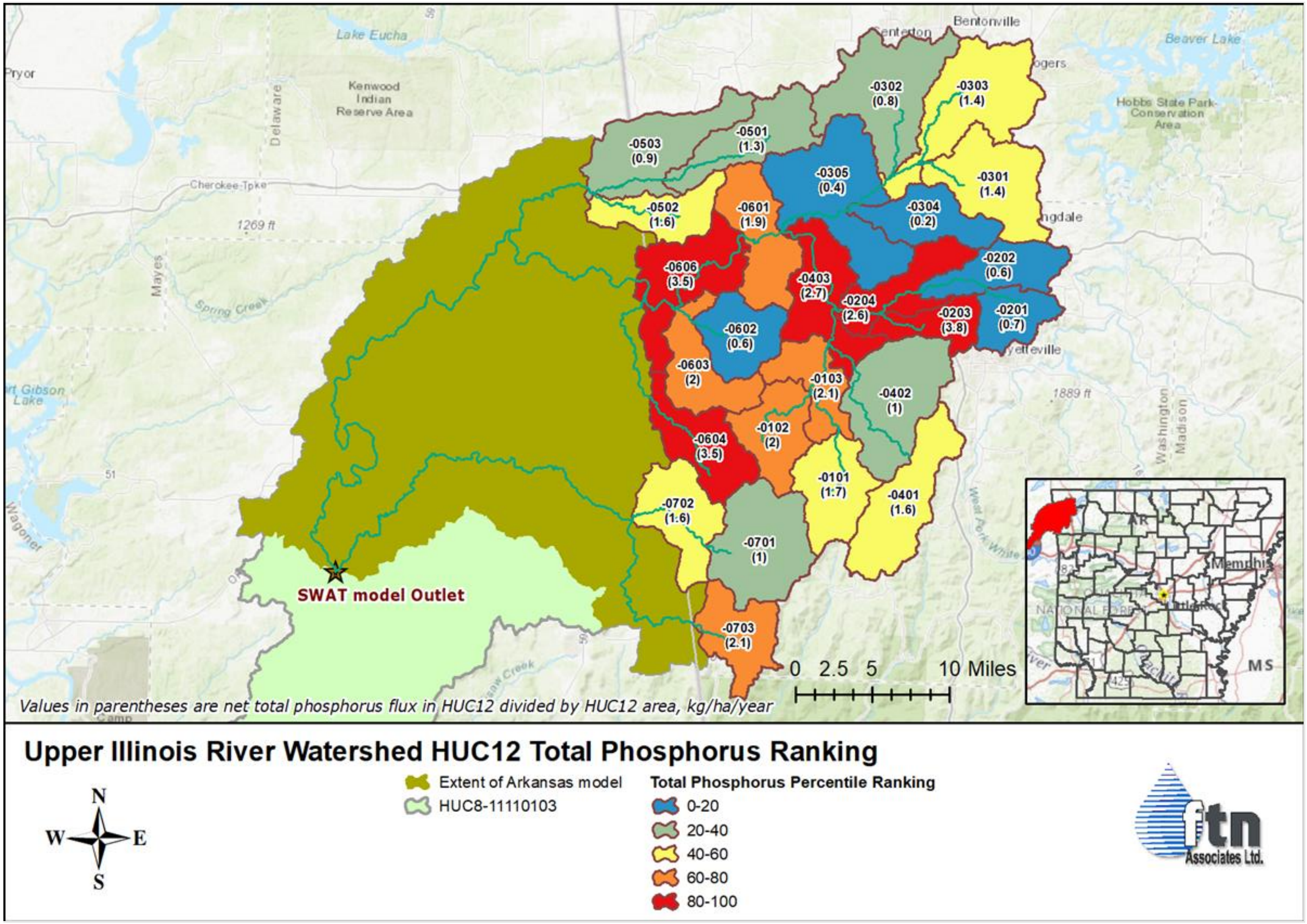

Figure 3.8 Ranking of Upper Illinois River HUC12s based on modeled instream yields of total phosphorus (FTN, 2024).

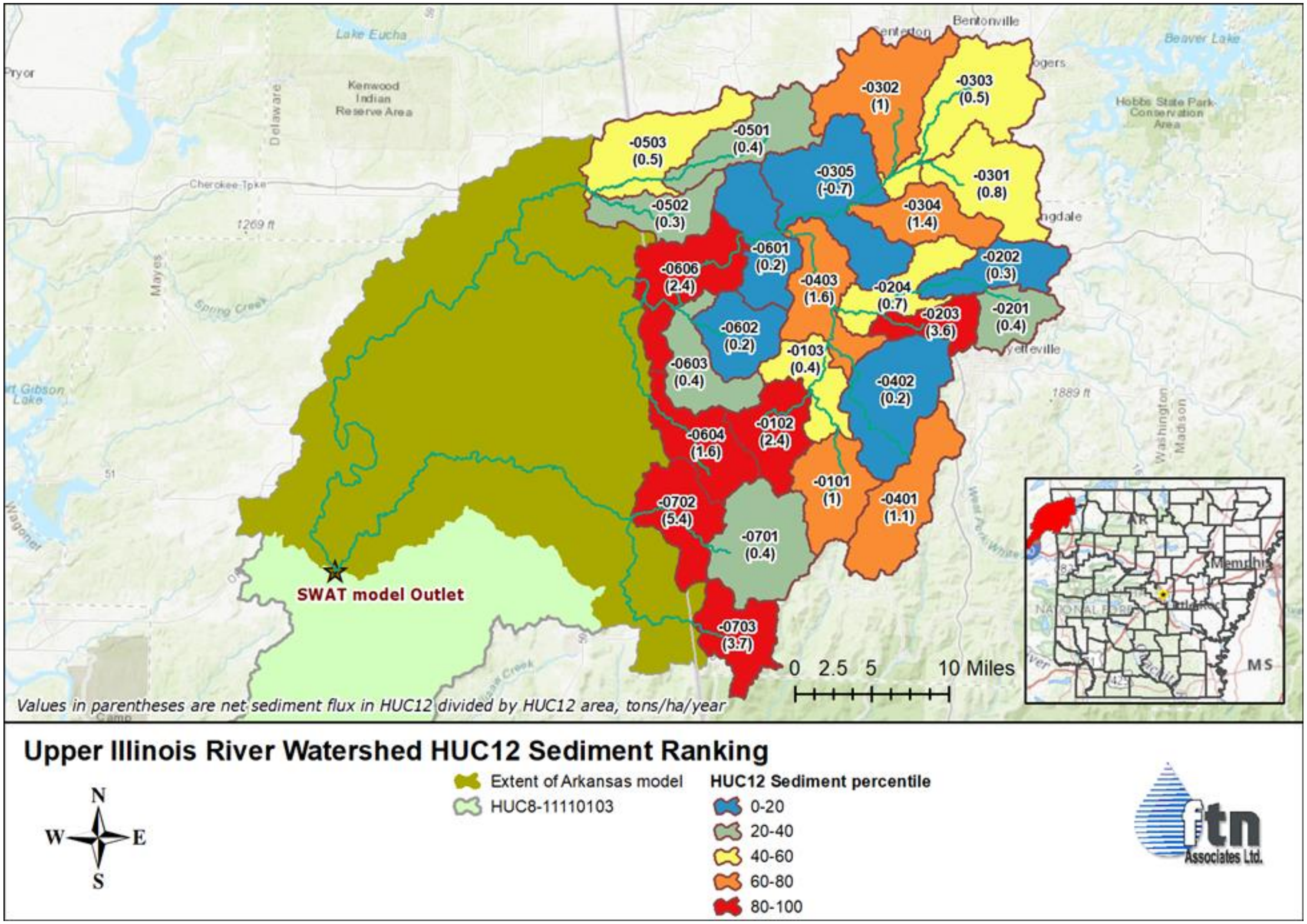

Figure 3.9 Ranking of Upper Illinois River HUC12s based on modeled instream yields of sediment (FTN, 2024).

3.1.6.5 Phosphorus Load Targets

The Arkansas River Compact Commission established baseline total phosphorus loads and 40 percent load reduction targets for four transborder streams in the Illinois River watershed (Illinois River Basin Arkansas-Oklahoma Compact, 2020). Under the Arkansas River Compact, load change at these locations is evaluated based on five (5)-year rolling average loads. Average total phosphorus loads from the period 2015-2019 for three (3) of these streams were less than the 40 percent reduction target (see Table 3.12).

Table 3.12. Arkansas River Compact Commission total phosphorus target loads for transborder streams in Illinois River watershedInvalid source specified.

Stream	Monitoring/evaluation location	Target total phosphorus load, kg/year	2015-2019 average total phosphorus load, kg/year
Flint Creek	Northwest of West Siloam Springs	1,960	2,487
Sager Creek	Near West Siloam Springs	10,540	7,626
Illinois River	South of Siloam Springs	114,346	39,200
Baron Fork	At Dutch Mills	4,296	3,644

3.1.7 Data Gaps

Several stream assessment units classified as impaired have not been sampled recently, including Moores Creek, Muddy Fork, and Little Osage Creek. Of particular interest are sulfate and E. coli concentrations. *E. coli* sampling was last conducted on these streams in 2014 (Gibson K. , 2015). Sulfate data was last collected from Muddy Fork in 2008. No water quality sampling data from Moores Creek is available from the DEQ online water quality database (DEQ, 2021b).

3.1.8 Summary

Phosphorus levels in streams have been a concern in the Upper Illinois River watershed for decades. While phosphorus levels in most streams are still a concern, decreasing trends in phosphorus concentrations are evident at most of the water quality monitoring stations where trends have been analyzed. Of particular note are decreasing trends in phosphorus concentrations in streams crossing the Arkansas-Oklahoma border, Illinois River, Baron Fork, Flint Creek, and Sager Creek.

Several other water constituents do not meet Arkansas ambient water quality standards in some streams of the Upper Illinois River watershed. These are sulfate, pathogens, pH, low DO, ammonia, and turbidity. Several streams listed as impaired on the 2008 303(d) list (the most recent at the time of the 2012 watershed management plan) have been delisted and the miles of impaired streams in the watershed on the 2018 303(d) list is less than half what it was in 2008. However, the miles of impaired streams in the watershed on the 2020 303(d) list is almost double the miles on the 2018 303(d) list, though still less than the miles on the 2008 303(d) list.

While there are several entities collecting water quality data in the Upper Illinois River watershed, there are streams classified as impaired where water quality sampling has not been conducted in almost 10 years.

3.2 Groundwater Quality

This section describes groundwater quality in the Upper Illinois River watershed in terms of measured concentrations of selected parameters. This includes a summary of the water quality standards that apply in the watershed and the water quality monitoring programs active in the watershed. Recent groundwater quality data are summarized and discussed. The interactions between surface and groundwater in this watershed mean that groundwater quality can influence, and be influenced by, surface water quality.

3.2.1 Groundwater Quality Standards

There are various environmental regulations in Arkansas that are designed to prevent contamination of groundwater, but Arkansas has not promulgated any numeric water quality criteria that apply to groundwater. However, groundwater that is used for drinking water is evaluated based on national primary drinking water standards. These standards include numeric criteria for organic chemicals, metals, microorganisms, radioactive materials, and nitrate and nitrite (EPA, 2020b).

3.2.2 Groundwater Quality Monitoring

There is no DEQ routine groundwater quality monitoring focus area within this watershed. However, DEQ routinely samples water quality in two (2) springs within the Upper Illinois River watershed, Logan Spring and Cave Spring. These monitoring locations are shown on Figure 3.10. The USGS National Water Information System (NWIS) lists only four (4) locations where groundwater quality has been sampled since 2007. Two (2) locations were sampled in 2014 and two (2) in 2015. No more recent USGS groundwater quality data was found for this watershed.

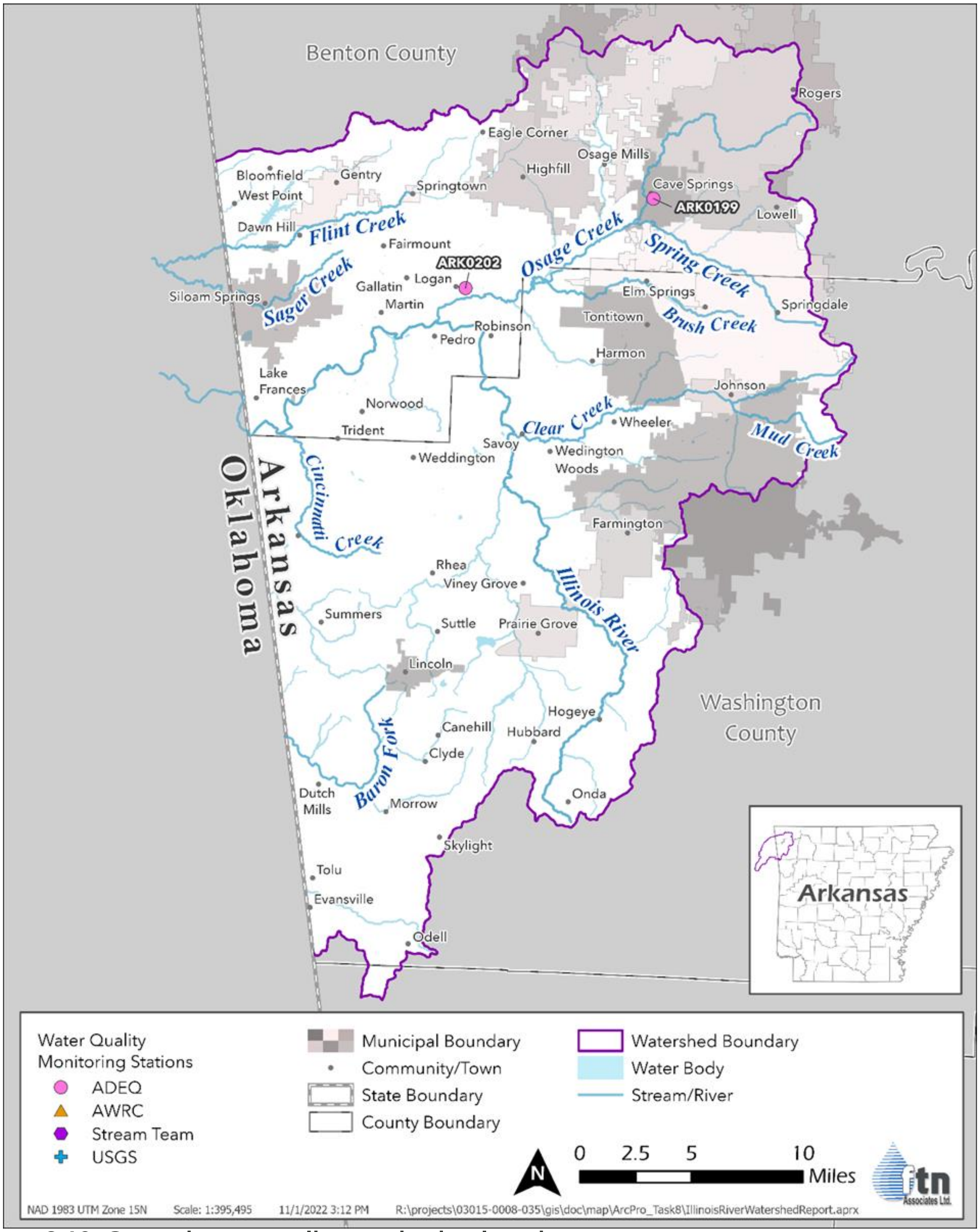

Figure 3.10. Groundwater quality monitoring locations map.

3.2.3 Groundwater Quality Summary

With regard to human health, the primary water quality parameters of concern are nitrate, nitrite, pathogens, and toxics. The potential for groundwater to contribute phosphorus to surface waters is also of interest. A detailed evaluation of groundwater quality is provided in Appendix G. The findings of this evaluation are summarized below.

- Nitrite concentrations measured by USGS in wells and springs were below the drinking water standard of 1 mg/L.
- USGS reported nitrate concentrations greater than the 10 mg/L drinking water in Springfield Plateau aquifer springs and wells.
- Measurements of all other water quality parameters in springs and wells are below drinking water standards.
- DEQ reported nitrate+nitrite concentrations from Cave Spring and Logan Spring 2018-2022 are all less than 10 mg/L.
- Median and maximum nitrate+nitrite concentrations from Cave Spring and Logan Spring are greater than median and maximum stream concentrations.
- Reported nitrate and nitrate+nitrite concentrations from wells and springs are greater than the estimated natural background nitrate level of 0.4 mg/L.
- Groundwater may contribute over 40 percent of Illinois River total nitrogen load at Siloam Springs (USGS station 07195430).
- Median and maximum total phosphorus concentrations from Cave Spring and Logan Spring are greater than 0.037 mg/L. Total phosphorus concentrations in these springs do not appear to be very different from stream concentrations.
- Groundwater may contribute around 15 percent of Illinois River total nitrogen load at Siloam Springs (USGS station 07195430).
- *E. coli* in has been identified as an issue in the Springfield Plateau aquifer in this watershed. No recent *E. coli* measurements from this aquifer in the watershed were found.

3.2.4 Groundwater Quality Vulnerability

A groundwater vulnerability map developed by The Nature Conservancy using the DRASTIK model, indicates that groundwater quality is moderately to highly vulnerable to impacts from surface land management activities in the watershed (Figure 2.14).

3.2.5 Data Gaps

Since *E. coli* levels have been identified as an issue in the Springfield Plateau aquifer in this watershed, routine tracking of *E. coli* levels in springs would be beneficial. Particularly where surface waters are listed as impaired due to *E. coli* levels.

3.2.6 Summary

Groundwater has been classified as vulnerable to impacts from land management activities over much of the Upper Illinois River watershed. Available groundwater quality data indicate that nutrient levels in groundwater may be being influenced by past and/or current land management activities and may contribute to nutrient levels in watershed streams. Land management activities appear to also contribute *E. coli* to groundwater, which could transport *E. coli* to streams in the watershed.

3.3 Ecological Condition

The ecological condition of the Upper Illinois River watershed is characterized by evaluating hydrology, geomorphology, aquatic habitat condition, aquatic communities, and an index of watershed integrity.

3.3.1 Stream Hydrology

There are nine (9) USGS flow gages on the Illinois River and its tributaries in Arkansas that were active in 2022 (Table 3.13, Figure 3.11). There are also six (6) active USACE gages in the watershed (Table 3.13). The USACE gages are co-located with USGS flow gages and measure water levels and flows hourly.

Table 3.13. Flow and stage gages in the Upper Illinois River watershed active during 2022.

USGS Gage Number	USGS Gage Name	USGS Period of Record		Stations with flow analysis			
		Begin date	End date	Wagner et al. 2014	Hart et al. 2023	Fox 2023	USACE Gage ID
07194800	Illinois River at Savoy, Arkansas	6/21/1979	5/29/2023			X	SVYA4
071948095	Mud Creek near Johnson, Arkansas	9/30/2015	5/29/2023				
07194880	Osage Creek near Cave Springs, Arkansas	10/1/1990	5/29/2023			X	
07194933	Spring Creek at Hwy 112 near Springdale, Arkansas	10/17/2011	5/29/2023				
07195000	Osage Creek near Elm Springs, Arkansas	10/1/1950	5/29/2023		X	X	ELMA4
07195400	Illinois River at Hwy 16 near Siloam Springs, Arkansas	6/21/1979	5/29/2023			X	SLSA4
07195430	Illinois River South of Siloam Springs, Arkansas	7/14/1995	5/29/2023			X	SLOA4
07194906	Spring Creek at Sanders Ave at Springdale, Arkansas	7/10/2011	5/23/2023				
07195800	Flint Creek at Springtown, Arkansas	7/1/1961	5/29/2023		X	X	SPRA4
07196900	Baron Fork at Dutch Mills, Arkansas	4/1/1958	5/29/2023	X	X	X	DMLA4

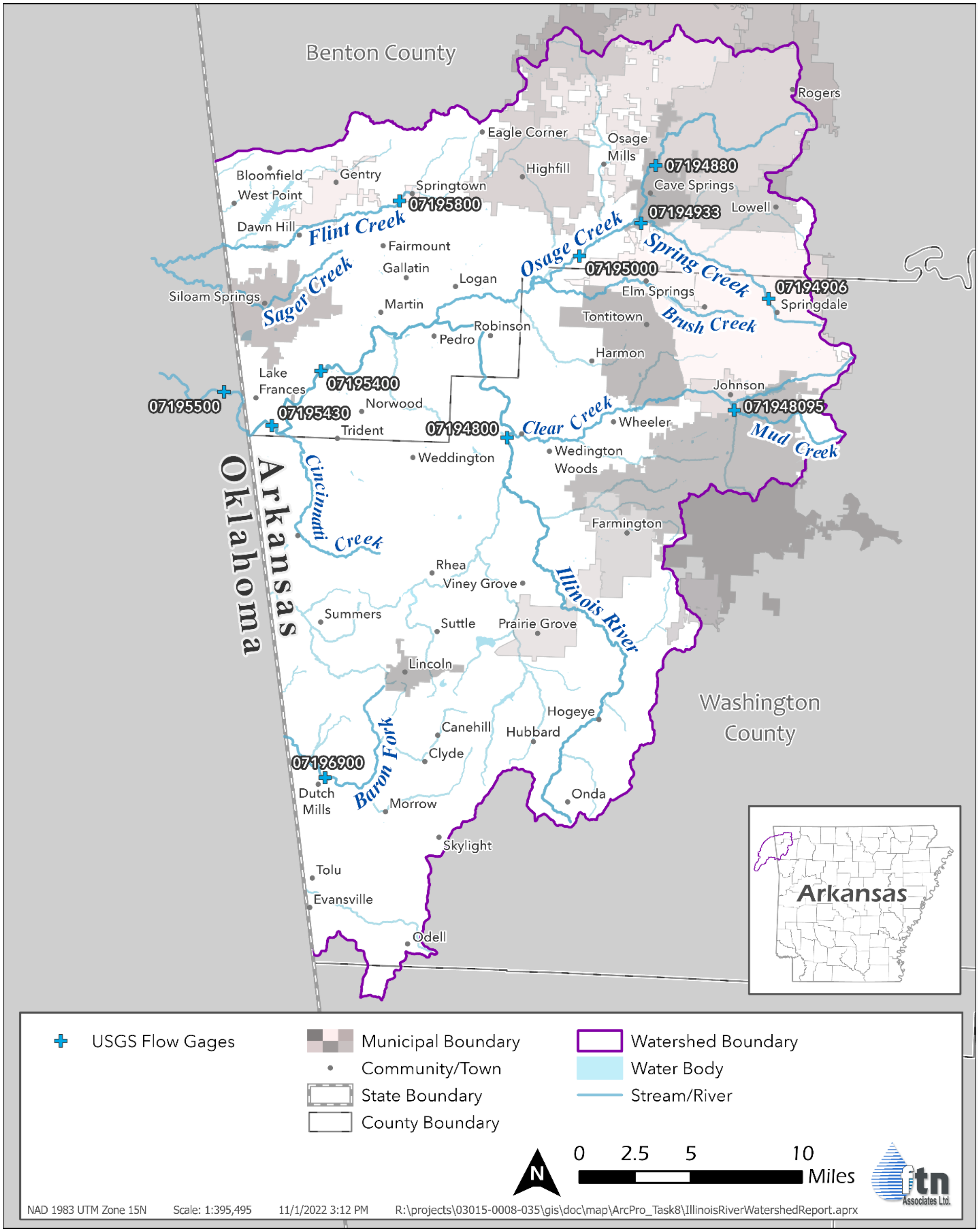

Figure 3.11. Locations of USGS flow gages in the Upper Illinois River watershed active during 2022.

Averages of daily flows from 2012-2020 for each month for each of the active USGS gages are graphed in Figure 3.12. At most of these gages, May is the month with the highest average daily flow. In Spring Creek, the month with the highest average daily flow is April. At all of the USGS gages, the month with the lowest average daily flow is September. Note that in the 2012 Plan, the month with the highest average daily flow was April and the month with the lowest average daily flow was October.

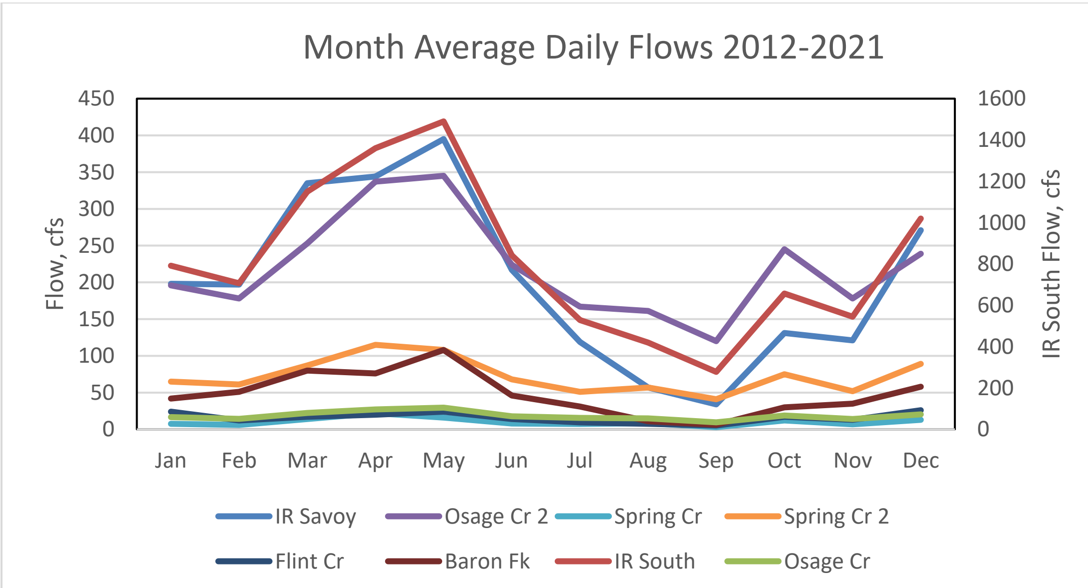

Figure 3.12. Average daily flows 2012-2021 by month from USGS stations in Upper Illinois River watershed.

The 2012 Plan noted that hydrology in the Upper Illinois River system has been altered. The USGS analyzed flow data from 1951-2011 for 38 stream gages across the state to identify long term trends. Two (2) of the stream gages analyzed were in the Upper Illinois River watershed, 07195500 and 07196900. A statistically significant increasing trend in mean daily annual flow was identified at the Baron Fork gage (07196900). Mean daily annual flow at the Illinois River gage (07195500) also exhibited an increasing trend but it was not statistically significant (Wagner, Krieger, & Merriman, 2014).

A flood study of the Illinois River basin was recently completed by the USACE (Hart, Howe, & Blankenship, Effects of Climate and Land-Use on Flooding in the Illinois River Basin of Oklahoma and Arkansas, 2023). This study evaluated flow records at long period USGS stations on Baron Fork (07196900), Flint Creek (07195800), Illinois River (07195500 [Watts, OK] and 07196500 [Talequah, OK]), and Osage Creek (07195000). The study found that flow at these gages exhibit increasing trends. This study also evaluated annual and seasonal precipitation at the gage locations The researchers concluded that increasing precipitation is contributing to increasing stream flows. The study also showed that impervious area in the watershed has increased, most significantly since 1990. Thus, increased development is identified by the authors as contributing to increasing trends in Illinois River basin stream flow. However, flood modeling conducted as part of this study indicated that impervious area had a relatively small effect on flood flows and flood elevations. At most USGS gage locations model results for zero impervious scenarios were not that different from results for 2016 impervious area scenarios, i.e., flood elevations changed less than five (5) feet. Hart et al (2023) concluded that increasing impervious area has only a localized effect on flooding magnitude and frequency in developed areas.

Fox (2023) also examined flow records at seven (7) USGS gaging stations in the upper Illinois River watershed (see Table 3.14) to evaluate changes in hydrology. He compared flow-duration curves for the entire period of record to curves for the periods 1980-2000, 2001-2011, and 2012-2022. This analysis found little change in the flow duration curves for USGS gages on Baron Fork (07196900) and Flint Creek (07195800) 1980-2022. Flow duration curves for the gages on Osage Creek (07194880 and 07195000) and Illinois River (07194800, 07195400, 07195430) showed increases in both high (20 percent exceedance) and low (80 percent exceedance) flows over time. Fox also attributed increases in flow to increased precipitation and impervious cover in the watershed.

In addition, flow magnitude, flood frequency, minimum and maximum one-(1) day average flows, and rates of flow rise and fall are all higher after 1990 than they were before 1990. Hart et al. (2023) also evaluated flow rate of change at USGS gages on Osage Creek at Elm Springs, Arkansas (07195000) and Illinois River near Watts, Oklahoma (07195500) and found that these streams are more “flashy” 1990-2022 than they were prior to 1990. This means that flows both increase and decrease more quickly after rainfall. The increase in “flashiness” of these streams is attributed to increases in impervious cover.

Increases in point source discharges associated with the marked increase in population and development in the Illinois River watershed, particularly municipal wastewater discharges, are likely also contributing to increasing stream flows in this watershed. A comparison of annual average discharges from municipal wastewater treatment plants to annual average stream discharge at downstream USGS gages for selected years, 2010-2020, found that municipal wastewater discharges may account for from one (1) percent to over 25 percent of stream flow (see Appendix H). Some of these municipal wastewater discharges also exhibit increasing trends in flow over time (see Appendix H). Increases in point source discharges are most likely to have increased minimum flows in receiving streams. They do not contribute significantly to flood events (Hart, Howe, & Blankenship, Effects of Climate and Land-Use on Flooding in the Illinois River Basin of Oklahoma and Arkansas, 2023).

3.3.2 Geomorphology

Natural stream channels in the watershed generally consist of a series of well-defined riffle and pools with channel beds predominantly consisting of coarse gravels, rubble, boulders, and bedrock. Stream gradients are relatively high, even in larger streams (FTN Associates, Ltd., 2012).

In general, streams in the Ozark Plateaus physiographic region of Arkansas are considered to be somewhat unstable. These streams are responding to the changes in land use and land cover that have occurred in this region since settlement. Specific land use/land cover changes believed to affect stream stability in the Ozark Highlands include large-scale commercial timber harvest that occurred in the region between the 1880s and 1920s, and removal of riparian forest. Symptoms of stream instability in Ozark Highlands streams include large gravel bars and bank erosion (Jacobson & Primm, 1997).

Land clearing and leveling has altered the hydrology in the Upper Illinois River watershed. In addition, hydrologic alteration of some channels has occurred through the installation of ditches, other drainage structures, and urban/exurban development. Therefore, some streams have moved, or are moving, toward a different channel configuration.

Two (2) studies in the Upper Illinois River watershed have confirmed that land use changes in the watershed are impacting stream geomorphology. In one study, researchers characterized channel geometry, substrates, and stream power in headwater streams with predominantly urban, agricultural (pasture), and forested watersheds (Shepherd, Dixon, Davis, & Feinstein, 2010). Overall, their findings were that geomorphology impacts are greatest in predominantly developed sub-watersheds, and less so in predominantly agricultural sub-watersheds. A summary of findings is provided in Table 3.14. Note that for most of the characteristics reported, channel morphology in forested and agricultural sub-watersheds are fairly similar. The researchers found that streams eroded to bedrock (found most often in urban sub-watersheds) exhibited greater streambank erosion, resulting in wider channels.

Table 3.14. Summary of geomorphologic characteristics of headwater streams with different predominant land use categories.

	Predominant Land Use		
Characteristic	**Urban/developed**	**Agriculture/pasture**	**Forest**
Mean bank full cross-sectional area, square miles	14.4	10.1	7.8
Mean bank full width, miles	17.0	13.7	13.8
Channel slope, %	1.17	0.71	0.69
Channel sinuosity	1.1	1.1	1.9
Unit stream power, W/square miles	334	103	85
Dominant substrate	Bedrock and sand (<2mm)	Coarse gravel to small cobbles (16-90mm)	Medium to coarse gravel (8-25mm)

In another study, Fox (2023) estimated the riparian area (100-meter buffer along streams) converted to water, i.e., eroded, between 2010 and 2019 in the HUC12 sub-watersheds of the Upper Illinois River watershed. These estimates were developed from National Aerial Imagery Program images using a Random Forest Algorithm decision tree change detection analysis. Fox reported changes from trees to water, barren to water, field to water, and impervious to water, in hectares and acres. Table 3.15 shows sums of these areas for each sub-watershed with an estimate of the percentage of riparian area lost. The area within 50 meters of streams were estimated for these sub-watersheds by multiplying stream length from StreamCat by 100 meters. If we assume that the amount of land lost is an indicator of stream instability then sub-watersheds where more land, or a greater percentage of riparian land, was lost have more unstable streambanks. Fox's analysis determined that between two (2) and 24 hectares of sub-watershed riparian land was lost to erosion between 2010 and 2019, which accounted for between 0.4 percent and 3.0 percent of the total 100 meters riparian buffer within the sub-watersheds. Table 3.15 shows that sub-watersheds with the greatest area of riparian land converted to water are not necessarily the sub-watersheds where the greatest percentage of riparian land was lost.

Table 3.15. Estimated streambank erosion in HUC12 sub-watersheds between 2010 and 2019.

Sub-watershed name	HUC12 ID number	Total area converted to water, hectares	Riparian area (100 miles), hectares	Percent riparian area converted to water
Lake Frances-Illinois River	111101030606	24.24	815.44	3.0%
Osage Creek-Illinois River	111101030305	21.61	1436.97	1.5%
Headwaters Osage Creek-Illinois River	111101030303	21.04	1119.18	1.9%
Lake Wedington-Illinois River	111101030403	18.78	788.99	2.4%
Spring Creek-Osage Creek	111101030301	14.23	712.02	2.0%
Little Osage Creek	111101030302	13.62	1142.63	1.2%
Goose Creek-Illinois River	111101030402	12.42	913.74	1.4%
Headwaters Illinois River	111101030401	10.5	868.43	1.2%
Little Wildcat-Clear Creek	111101030204	9.86	503.55	2.0%
Lake Fayetteville-Clear Creek	111101030202	9.58	369.02	2.6%
Chambers Hollow-Illinois River	111101030601	8.77	742.71	1.2%
Headwaters Baron Fork	111101030701	8.65	1166.03	0.7%
Headwaters Flint Creek	111101030501	7.81	622.64	1.3%
Mud Creek-Clear Creek	111101030201	7.38	363.85	2.0%
Upper Muddy Fork-Illinois River	111101030101	6.38	583.5	1.1%
Brush Creek-Osage Creek	111101030304	6.38	513.04	1.2%
Lower Muddy Fork-Illinois River	111101030103	6.27	378.57	1.7%
Cincinnati Creek	111101030603	5.87	475.07	1.2%
Middle Flint Creek	111101030503	5.08	724.35	0.7%
Sager Creek	111101030502	4.59	336.29	1.4%
Hamestring Creek	111101030203	4.56	267.88	1.7%
Upper Evansville Creek	111101030703	4.25	547.92	0.8%
Wedington Creek	111101030602	3.5	555.28	0.6%
Moores Creek-Muddy Fork	111101030102	3.32	549.81	0.6%
Upper Ballard Creek	111101030604	2.06	583.83	0.4%

Fox (2023) conducted Ozark Stream Erosion Potential Index (OSEPI) surveys along 500-meter stream reaches upstream and downstream of 12 active USGS stream gages in the Illinois River watershed. Table 3.16 lists the results of the surveys within the Upper Illinois River watershed.

Table 3.16. OSEPI survey scores for stream reaches upstream and downstream of selected active USGS stream gages in the Upper Illinois River watershed (Fox 2023).

USGS Gage ID	USGS Gage Name	Bank Stability Rating
7194800	Illinois River at Savoy, Arkansas	Unstable
7194880	Osage Creek near Cave Springs, Arkansas	Stable
7195000	Osage Creek near Elm Springs, Arkansas	Unstable
7195400	Illinois River at Hwy. 16 near Siloam Springs Arkansas	Moderately Unstable
7195430	Illinois River South of Siloam Springs, Arkansas	Unstable
7195800	Flint Creek at Springtown, Arkansas	Moderately Stable
7196900	Baron Fork at Dutch Mills, Arkansas	Stable

Illinois River Watershed Partnership (IRWP) collects information on stream habitat at 21 sites in four (4) streams in the Upper Illinois River watershed, Clear Creek, Moore’s Creek, Muddy Fork, and Sager Creek. Data were collected from these streams four (4) times each year in 2018 and 2019. This habitat information includes geomorphologic characteristics. Clear Creek sites exhibited “incision” due to development. Some sites in Moore’s Creek and Muddy Fork also exhibited “incision” and unstable streambanks. Removal of riparian vegetation was suggested as the cause of observed channel instability. No mention was made of channel instability at survey sites on Sager Creek (IRWP, 2022).

IRWP and Natural State Streams, LLC have been monitoring streambank erosion at 15 sites in the watershed since 2017 (Figure 3.13). Results from this program suggest that approximately 20 acres of land per year are being lost to streambank erosion in the Upper Illinois River watershed. Using an empirical erosion model based on measurements from this study, erosion rates were estimated for 923 bank segments along 48.8 miles of stream in the watershed, including portions of Illinois River, Moores Creek, Muddy Fork, Clear Creek, and Sager Creek. The model results indicate that 109 bank segments, or approximately 12 percent of the modeled segments, will have very high or extreme average annual erosion rates, i.e., greater than two (2) feet per year. Changes in flood hydrology caused by development and deforestation of riparian areas contribute to channel instability and streambank erosion (Natural State Streams, LLC, 2021).

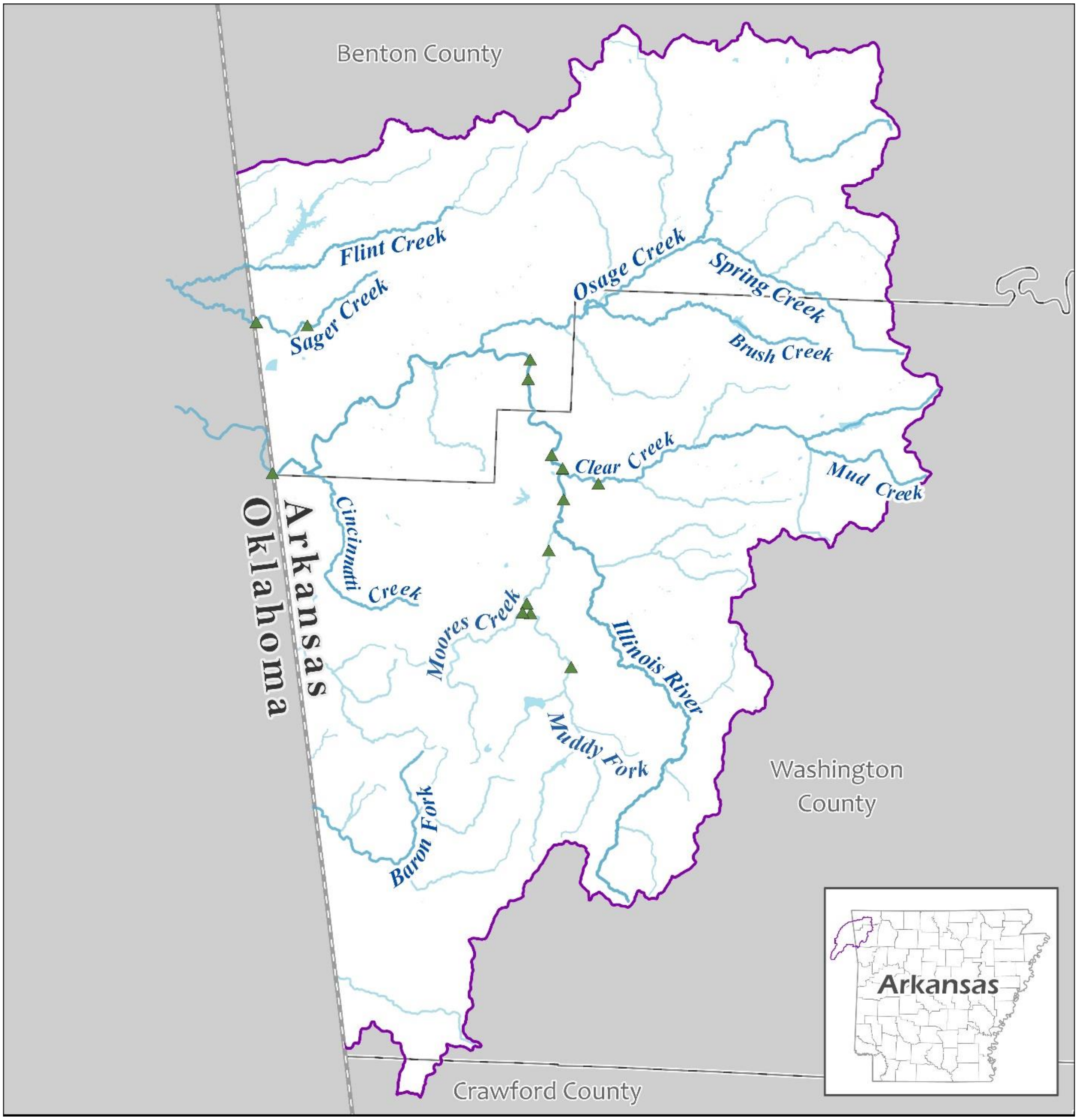

Figure 3.13. Streambank monitoring locations in the Upper Illinois River watershed.

3.3.3 Aquatic Habitat

Physical habitat in streams is a combination of factors that support aquatic organisms, including water depth, water velocity, water temperature, channel substrate (i.e., what kind of material makes up the stream bottom), and cover. Physical habitat in streams, and the condition of that habitat, varies naturally, but can also be affected by human activities.

3.3.3.1 Habitat Surveys

IRWP collects information on stream habitat at 21 sites in four (4) streams in the Upper Illinois River watershed, Clear Creek, Moore's Creek, Muddy Fork, and Sager Creek. Data were collected from these streams four (4) times each year in 2018 and 2019. Analysis of the data collected found positive relationships between macroinvertebrate diversity and the percentage of the streambed in cobbles and gravel, and a negative relationship between macroinvertebrate diversity and the percentage of the streambed in silt/clay/mud (IRWP, 2022). Habitat information for the four streams is summarized below.

Six (6) sites were surveyed in Clear Creek. The percentage of stream substrate in silt/clay/mud at these sites ranged from 20 percent to <5 percent. The percentage of stream substrate at these sites in gravel and cobbles ranged from 80 percent to around 20 percent.

Five (5) sites were surveyed in Moore's Creek. The percentage of silt/clay/mud substrate in the stream bed at these sites ranged from almost 40 percent to around 15 percent. The percentage of gravel and cobbles stream substrate at these sites ranged from a little over 40 percent to around 25 percent.

Five (5) sites were surveyed in the Muddy Fork. The percentage of silt/clay/mud stream substrate at these sites ranged from 40 percent to 10 percent. The percentage of gravel and cobble stream substrate ranged from 60 percent to around 30 percent.

Five (5) sites were surveyed in Sager Creek. The percentage of silt/clay/mud stream substrate at these sites ranged from over 90 percent to <five (5) percent. The percentage of gravel and cobble stream substrate at these sites ranged from around 60 percent to <10 percent (IRWP, 2022).

Fox (2023) conducted Rapid Habitat Assessment surveys along 500-meter stream reaches upstream and downstream of 12 active USGS stream gages in the Illinois River watershed. Table 3.17 lists the average survey scores within the Upper Illinois River watershed. Higher score values indicate better habitat quality.

Table 3.17. Rapid Habitat Assessment survey scores for stream reaches upstream and downstream of selected active USGS stream gages in the Upper Illinois River watershed (Fox 2023).

USGS gage ID	USGS gage name	Average rapid habitat assessment scores
7194800	Illinois River at Savoy, Arkansas	122
7194880	Osage Creek near Cave Springs, Arkansas	127
7195000	Osage Creek near Elm Springs, Arkansas	130
7195400	Illinois River at Hwy. 16 near Siloam Springs Arkansas	105
7195430	Illinois River South of Siloam Springs, Arkansas	99
7195800	Flint Creek at Springtown, Arkansas	166
7196900	Baron Fork at Dutch Mills, Arkansas	129

3.3.3.2 Stream Barrier Inventory

Dams and road crossings can restrict the movement of fish and mussel species, preventing expansion of populations into new areas, or prevent fish from accessing historic spawning areas. The Southeast Aquatic Resources Partnership recently created the online Southeast Aquatic Barrier Prioritization Tool to access their Comprehensive Southeast Aquatic Barrier Inventory (Southeast Aquatic Resources Partnership, 2023). This inventory indicates that there are over 450 dams present in the Upper Illinois River watershed. Thirty-five of these dams have been assessed for feasibility for removal. Ten were classified as likely or possibly feasible for removal. The majority of the dams present in the watershed are for small ponds. The SARP inventory indicates there are over 4,500 road stream crossings in the watershed. Approximately 25 of these crossings have been evaluated and seven of these are identified as a moderate to complete barrier that impacts aquatic life.

3.3.4 Aquatic Communities

Aquatic communities respond to changes in habitat, including water quality, and are useful indicators of stream health. The condition of aquatic communities is characterized based on information such as the abundance of animals, the number of different species present, the water quality and habitat requirements of the species that are present, and how sensitive the species that are present are to changes in water quality or physical habitat. In some cases, selected information about the aquatic communities present is used to develop a score or grade that reflects the health of streams, such as an Index of Biotic Integrity (IBI) or multimetric index (MMI).

DEQ has surveyed aquatic communities in the Illinois River watershed since the 1980s. Universities, state and federal natural resource agencies, and IRWP have also conducted surveys of aquatic communities in the Illinois River watershed.

3.3.4.1 Fish Surveys

The most recent fish survey conducted by DEQ in the Upper Illinois River watershed was in 2023 (J. Wise, DEQ, personal communication 7/23/2024). USGS conducted fish surveys in the watershed in 2011 and 2012 (Petersen, Justus, & Meredith, 2014). The US Department of Agriculture Forest Service (Forest Service) has surveyed fish communities in Lake Wedington. The most recent fish community survey of Lake Wedington we found reported was from 2013 (US Department of Agriculture Forest Service, 2016).

DEQ has developed a fish IBI for the Ozark Highlands. However, metrics have not yet been calculated for the results from the DEQ 2023 fish survey (J. Wise, DEQ, personal communication 7/23/2024).

Fox (2023) compiled fish survey results from mussel survey locations in the Illinois River watershed. Fish surveys from 24 locations identified between one (1) and 39 species.

The US Fish and Wildlife Service (UWFWS) and their partners survey populations of the endangered Ozark Cavefish (Troglichtys rosae) present within the Upper Illinois River watershed, every two (2) years (Figure 3.14). The 2019 five (5)-year review of Ozark Cavefish populations classifies the populations in the Upper Illinois River watershed as stable (USFWS Arkansas Ecological Services Field Office, 2019).

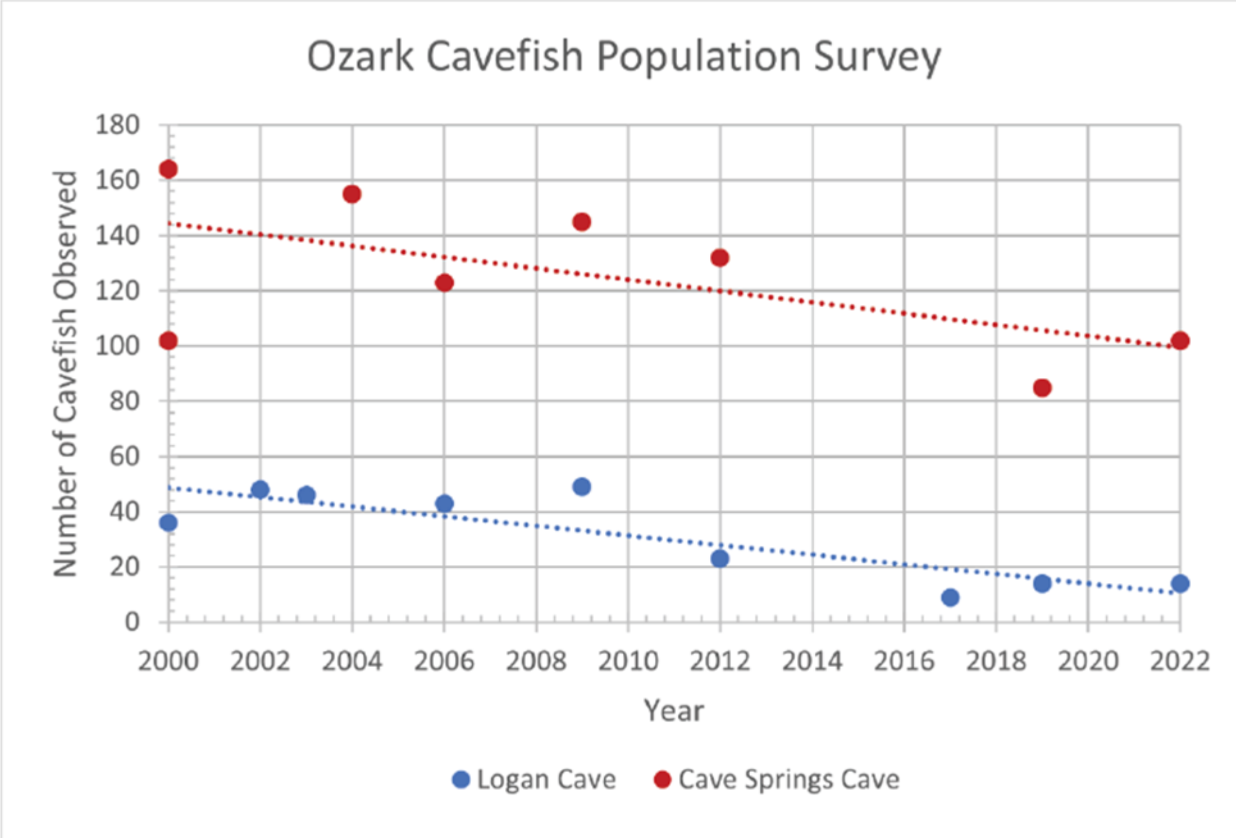

Figure 3.14. Results of Ozark Cavefish population surveys in Upper Illinois River watershed (IRWP, 2023).

3.3.4.2 Macroinvertebrate Surveys

The most recent macroinvertebrate survey conducted by DEQ in the Upper Illinois River watershed was in 2001 (DEQ, 2022). USGS conducted macroinvertebrate surveys in the watershed in 2011 and 2012 (Petersen, Justus, & Meredith, 2014). The IRWP surveyed macroinvertebrates at 21 sites in four (4) tributaries of the Illinois River in Arkansas in 2018 and 2019 (IRWP, 2022). Diversity scores from these surveys are summarized in Figure 3.15. The USFWS and their partners survey populations of endangered macroinvertebrates that are present in the Upper Illinois River watershed, including Neosho Mucket clam, Rabbitsfoot clam, and Benton County Cave Crayfish.

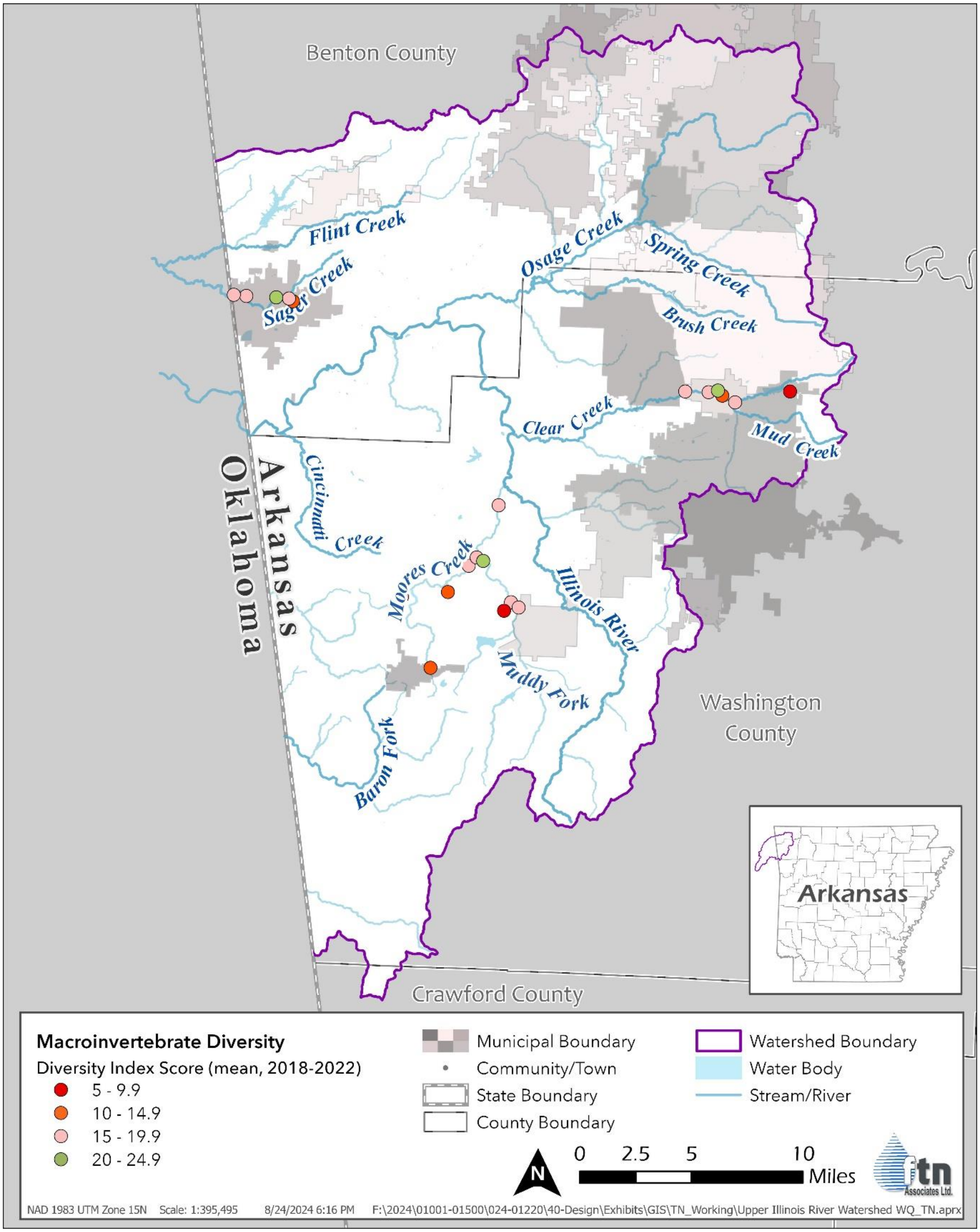

Figure 3.15. Diversity scores from IRWP 2018 and 2019 macroinvertebrate surveys.

Fox (2023) compiled “a multi-state georeferenced mussel occurrence database” from a variety of sources. This database included information from 39 locations in the Illinois River watershed, 35 of which were located in the Upper Illinois River watershed. He determined that the Illinois River HUC12 sub-watersheds with the highest surveyed mussel species richness were Lake Wedington-Illinois River (27 species, the maximum number), Chambers Hollow-Illinois River (20 species), and Lake Frances-Illinois River (18 species). Analysis of factors influencing changes in mussel communities found that mean annual flow from runoff had the greatest influence. This suggests that the hydrologic changes occurring in the Illinois River watershed are likely to impact mussel communities. Percentage of impervious surface within 50 meters of a stream was a significant predictor of change in mussel communities.

3.3.5 Watershed Integrity

Watershed integrity is defined as “the capacity of a watershed to support and maintain the full range of ecological processes and functions essential to the sustainability of biodiversity and of the watershed resources and services provided to society” (Flotemersch, et al., 2016). EPA researchers have developed a metric of watershed integrity that uses national data sets (Thornburgh, et al., 2018). Information used to score this metric includes indicators of hydrologic regulation, water chemistry, sediment, hydrologic connectivity, temperature, habitat condition, and the extent of human activity. Basically, this index is an indicator of the modification of a watershed from its natural state. Index values have been calculated for the catchments associated with every stream segment of the National Hydrologic Dataset. Index values calculated for catchments in the Upper Illinois River watershed are shown in Figure 3.16. Lower index values indicate lower integrity and greater modification, and higher index values indicate higher integrity with less modification. The majority of the catchments in the Upper Illinois River watershed have been significantly modified from their natural condition and exhibit lower integrity.

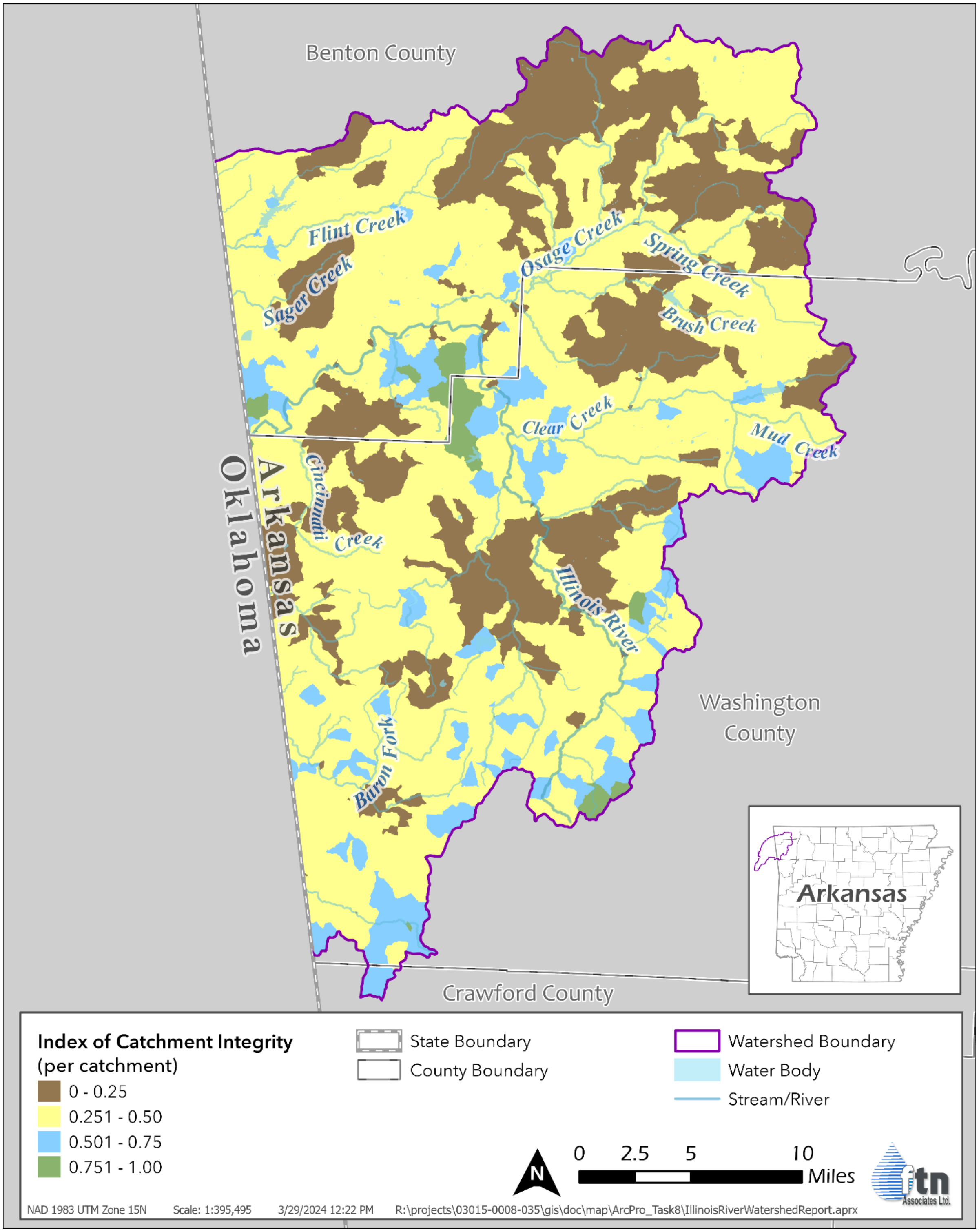

Figure 3.16. EPA catchment integrity index values for Upper Illinois River watershed (Thornburgh, et al. 2018).

3.3.6 Data Gaps

No significant data gaps were identified. IBIs still need to be calculated from the DEQ 2023 fish surveys. Fish surveys at additional locations could improve understanding of the condition of Upper Illinois River streams.

3.3.7 Summary

The majority of the Upper Illinois River watershed catchments have experienced moderate to high levels of modification from their natural state and exhibit low integrity. This modification has impacted stream hydrology and geomorphology, and the condition of aquatic habitats and communities.

3.4 Nonpoint Sources of Pollutants Causing Impairment

Pollutants causing impairments in the Upper Illinois River watershed include ammonia, pathogens (*E. coli*), chloride, pH, sulfate, and turbidity. Two (2) streams in the watershed are also listed as impaired due to low DO. Nutrients can contribute to low DO in streams and high pH in Lake Fayetteville by supporting excessive growth (i.e., blooms) of algae and aquatic plants. In Lake Fayetteville, respiration by algae and aquatic plant blooms can release enough carbon dioxide to raise the pH in the upper water column (where pH standards are evaluated). In streams, decomposition of algae and plant blooms uses oxygen and can lower the DO levels. In freshwater waterbodies, growth of algae and other aquatic plants is often controlled more by available phosphorus than by available nitrogen. Decomposition of other types of organic matter transported to streams, e.g., leaves, grass clippings, or animal waste, can also lower stream DO levels. Table 3.18 shows a summary of nonpoint sources of pollutants of concern in the Upper Illinois River watershed. Sources of each pollutant are discussed in the following subsections.

Table 3.18. Nonpoint sources of pollutants of concern in the Upper Illinois River watershed.

Source	Pollutants						
	Pathogens	Phosphorus	Nitrogen	Sulfate	Chloride	Turbidity	Organic materials
Runoff from pastures	X	X	X	X	X	X	X
Livestock	X	X	X			X	X
Runoff from animal feeding operations	X	X	X				X
Poultry operations	X	X	X			X	X
Failing septic systems	X	X	X	X	X		X
Runoff from developed areas	X	X	X	X	X	X	X
Streambank erosion		X	X			X	X
Unpaved roads and stream crossings		X	X			X	
Hydrologic alteration		x	x			x	X
Sediment	X	X	X				
Groundwater	x	X	X				

3.4.1 Pathogens

Almost 60 miles of streams in the Upper Illinois River watershed are classified as impaired due to high pathogen levels (DEQ, 2020; DEQ, 2021). Nonpoint sources of pathogens identified by DEQ are agriculture and surface erosion (DEQ, 2020). Potential nonpoint sources of pathogens identified by stakeholders are livestock, runoff from pastures (livestock and land applied poultry litter), runoff from poultry operations, failing septic systems, and runoff from developed areas, which could carry pathogens from pet and wildlife wastes, illicit discharges, sanitary sewer overflows, or wastewater treatment system upsets, and groundwater. University of Arkansas Division of Agriculture Cooperative Extension Service has estimated that nearly 5,000 tons of dog waste is generated each year in Northwest Arkansas (Washington County Cooperative Extension Service, 2023).

A 2012-2014 *E.coli* monitoring study in the Upper Illinois River watershed included sampling at 29 sites on 10 assessment units (AUs). Samples were collected from the Illinois River, Clear Creek, Osage Creek, Little Osage Creek, Spring Creek, Muddy Fork, and Baron Fork. This study identified pasture in riparian zones, and deposition of manure in streams by livestock, and possibly wildlife, as the most likely sources of high bacterial levels at sampling sites. The study also noted that high bacteria levels in most sampled streams is a localized issue, and bacteria levels can vary significantly over time (Scott et al., 2015). The results of this study suggest that bacteria sources causing impairment of AUs in this watershed are most likely located near the water quality stations (within 2 km). Possible pathogen sources associated with riparian pastures include manure/litter application runoff, and livestock access to streams (FTN 2012).

Another study attempted to identify *E. coli* sources by identifying associated viruses. Samples were collected from February 2014 through September 2015 and analyzed for the presence of *E. coli* and viruses specific to humans, cows, and swine (Gibson K. , 2016). Samples were collected in the following streams/AUs:

- AR_11110103_013 Baron Fork
- AR_11110103_023 Illinois River
- AR_11110103_029 Clear Creek
- AR_11110103_028 Illinois River
- AR_11110103_025 Muddy Fork
- AR_11110103_030 Osage Creek
- AR_11110103_931 Spring Creek

- AR_11110103_933 Little Osage Creek (Gibson K. E., Fecal Source Characterization in Select 303(d) listed Streams in the Illinois River Watershed with Elevated Levels of *Escherichia col*i, 2013)

The results of one (1) of the tests in this study indicate that, in samples with high virus levels, associated with rainstorms, a higher proportion (71 percent) of fecal pollution in Clear Creek, Muddy Fork, and Little Osage Creek is from animal sources (no differentiation was made between wildlife and domestic animals) than from human sources. Other test results indicate that, at other times and in other streams, human wastewater may account for the majority of fecal pollution in the sampled streams. Unfortunately, while there was a statistically significant relationship between *E. coli* and virus levels ($p < 0.0001$), the correlation was not strong ($r2 = 0.379$), i.e., high *E. coli* levels did not necessarily occur in the same samples as high virus levels (Water Currents, 2016) (Gibson K. , Use of Coliphage and Enteric Viruses for FST in Impaired Streams in the Illinois River Watershed, 2015) (Gibson K. , 2016). The results of this study suggest that both human and animal waste contribute E. coli to the streams sampled but did not show that either human waste or animal waste contributes the majority of E. coli in the streams.

Groundwater can transport pathogens from non-riparian areas to streams where groundwater discharges to surface flow (Davis et al. 2006). E. coli have been found in groundwater and springs in the UIRW (Davis et al. 2000, 2006; Brown et al. 1998; and Graening and Brown 1999, 2000).

Research has also shown that pathogens can survive in freshwater sediments and can reenter the water column when sediments are disturbed by high flow events (EPA, 2017?) (Davis, Hamilton, & Brahana, 2007) (Baker, Almeida, Lee, & Gibson, 2021) (Pachepsky & Shelton, 2011).

Results of the research above suggests that both agriculture and development nonpoint sources of E. coli will need to be addressed to reduce pathogen impairments in the Upper Illinois River watershed. Estimates of the extents of these nonpoint sources in the watershed are provided below.

- Approximately 46 percent of the watershed 2019 land cover is classified as pasture or hayland (Dewitz & USGS, 2021)
- Approximately 44% of the land within 50 meters of a mapped stream had an agriculture land cover in 2019 (Hill, Weber, Leibowitz, Olsen, & Thornbrugh, 2016)
- Based on information provided by Benton and Washington Counties in 2023, there are around 11,200 septic systems active in the Upper Illinois River watershed (Appendix I)
- Approximately 17 percent of the watershed 2019 land cover is classified as developed (Dewitz & USGS, 2021)

- Approximately 14 percent of the land within 50 meters of a mapped stream had developed land cover in 2019 (Hill, Weber, Leibowitz, Olsen, & Thornbrugh, 2016)
- During the years 2017-2022 communities of the Illinois River watershed reported 894 sanitary sewer overflow and wastewater treatment system upsets to DEQ. Fayetteville reported the greatest number, followed by Siloam Springs and Springdale (see Table 3.19).
- Cattle numbers in Benton County have declined since 2012, while numbers in Washington County have not changed much (see Figure 3.17)
- While poultry inventories in Benton and Washington Counties have increased since 2012, the amount of poultry litter applied in these counties has declined (Figure 3.18). In 2019 1,197 poultry houses were reported active in the upper Illinois River watershed (T. Wentz, Natural Resources Division, personal communication, 5/12/2022).

Table 3.19. Reported sanitary Sewer Overflows/Upsets 2017-2022 in communities of the Illinois River watershed (DEQ, 2024).

Community/facility name	Number of events
AEP-SWEPCO Flint Creek Power Plant	2
Bentonville	62
Bethel Heights	1
Decatur	35
Fayetteville	387
Gentry	62
Huntsville	22
Lincoln	33
Rogers	91
Siloam Springs	101
Springdale	98
Total	**894**

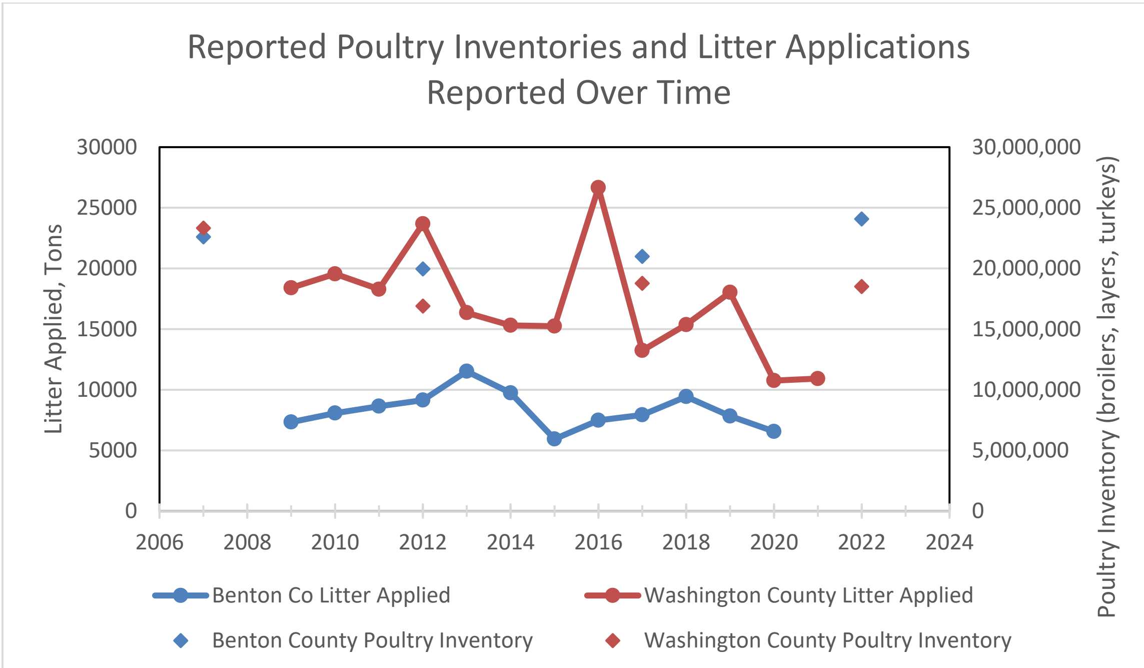

Figure 3.17. Comparison of reported poultry inventories and poultry litter applications over time.

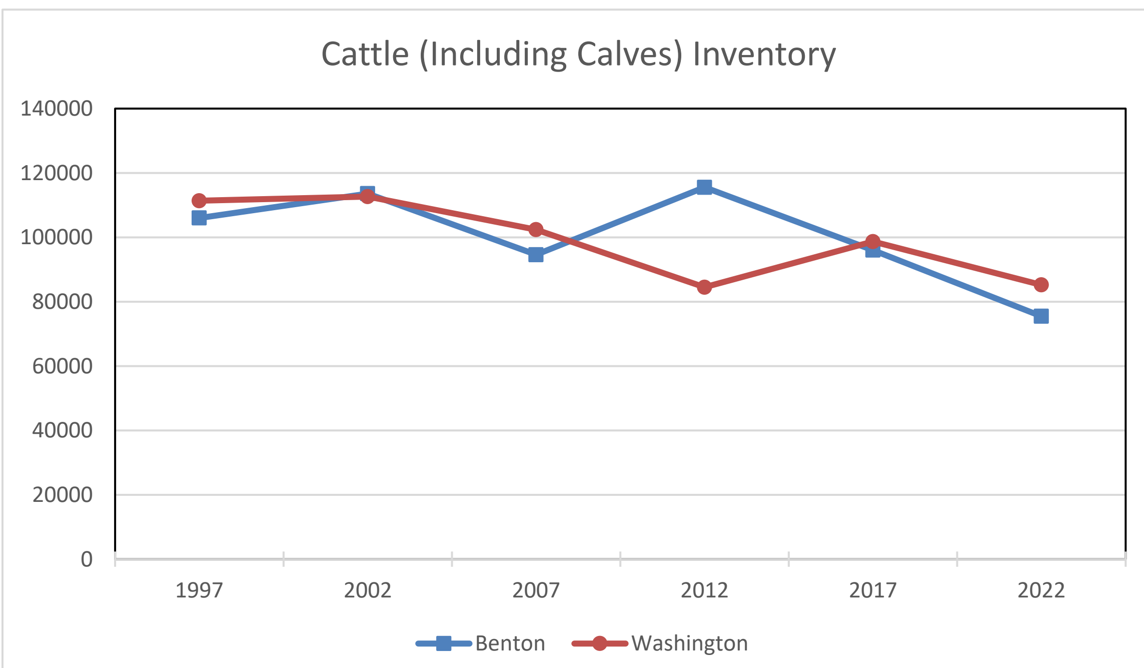

Figure 3.18. Cattle inventories in Benton and Washington Counties over time.

3.4.2 Minerals (Sulfate, Chloride)

There are just over 19 miles of stream in the watershed listed as impaired due to high levels of sulfate. A recent study evaluated factors influencing turbidity and mineral levels in the West Fork White River and other streams of the Ozark Highlands and Boston Mountains ecoregions of Arkansas (Scott & Haggard, Natural characteristics and human activity influence turbidity and ion concentrations in streams, 2021). This study found that streams in the Ozark Highlands and Boston Mountains with higher proportions of watershed area in agriculture and urban land uses (combined) tend to have higher sulfate concentrations. Gantz and Haggard (2023) report that yields of chloride and sulfate are higher from Upper Illinois River sub-watersheds with more developed area and/or WWTP discharges. They postulate that higher sulfate yields may be related to the use of alum in wastewater treatment systems and household detergents in wastewater. Thus, the nonpoint sources of sulfate in the Upper Illinois River watershed may include runoff from pastures, failing septic systems, runoff from developed areas, illicit discharges, and sanitary sewer overflows.

3.4.3 Phosphorus

Phosphorus loads to streams may contribute to low DO impairments of streams. Potential nonpoint sources of phosphorus in streams that have been identified by stakeholders are livestock, runoff from pastures (livestock manure and land applied poultry litter), runoff from poultry feeding operations (poultry house dust), failing septic systems, streambank erosion, and runoff from developed areas (pet and wildlife wastes, illicit discharges, sanitary sewer overflows) In addition, groundwater and sediments can be sources of phosphorus. See Section 3.4.1 for information on livestock numbers, poultry litter application, poultry feeding operations, septic systems, and development sources. The Midwest SPARROW model estimates phosphorus load contributions from a variety of sources (Robertson and Saad 2019). Figure 3.19 illustrates the SPARROW estimated relative phosphorus load contributions from sources in the upper Illinois River watershed. This model identifies manure as the largest contributor to phosphorus load. The 2022 Upper Illinois River watershed SWAT model results also identify pasture as contributing the majority of the phosphorus load (72 percent) (Figure 3.20). See Section 3.4.1 for extents of most phosphorus nonpoint sources in the watershed.

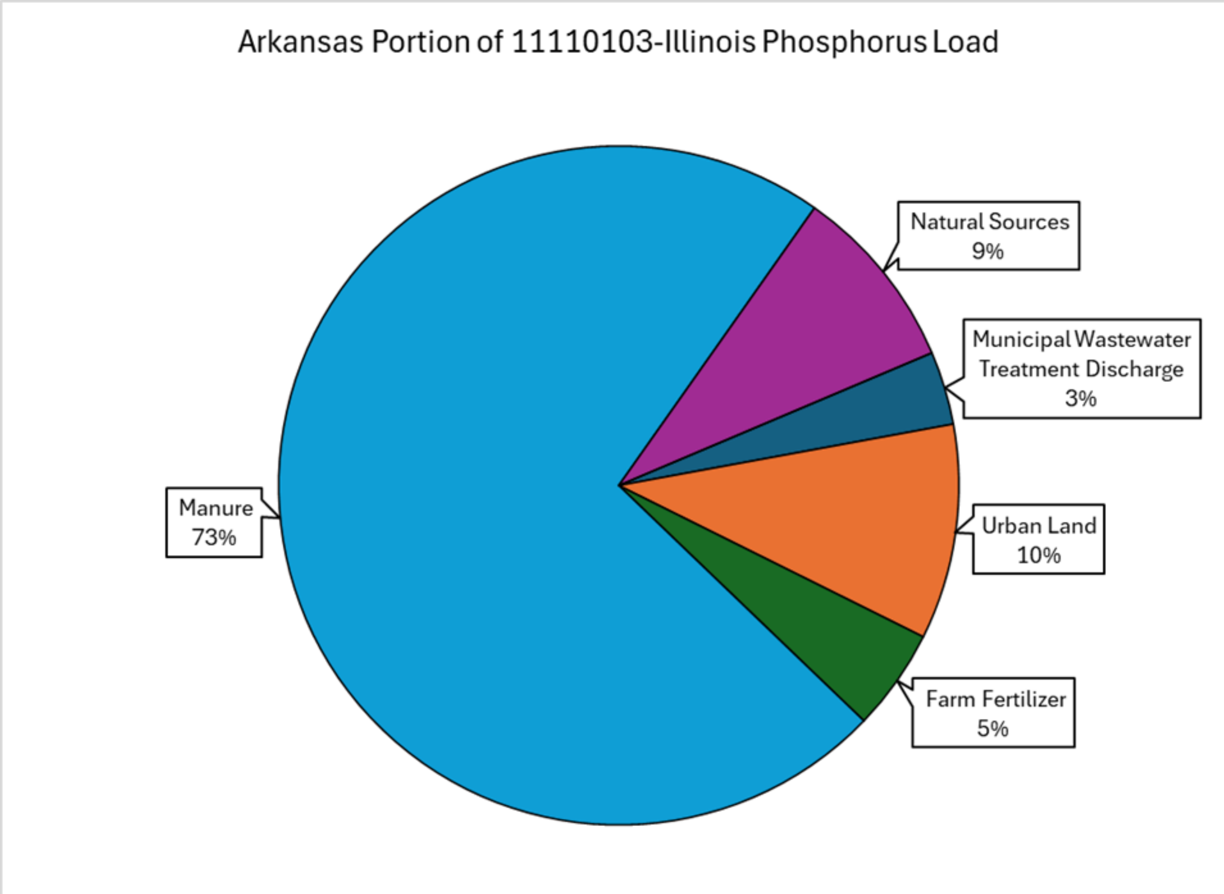

Figure 3.19. SPARROW phosphorus load sources for upper Illinois River watershed (USGS, 2019).

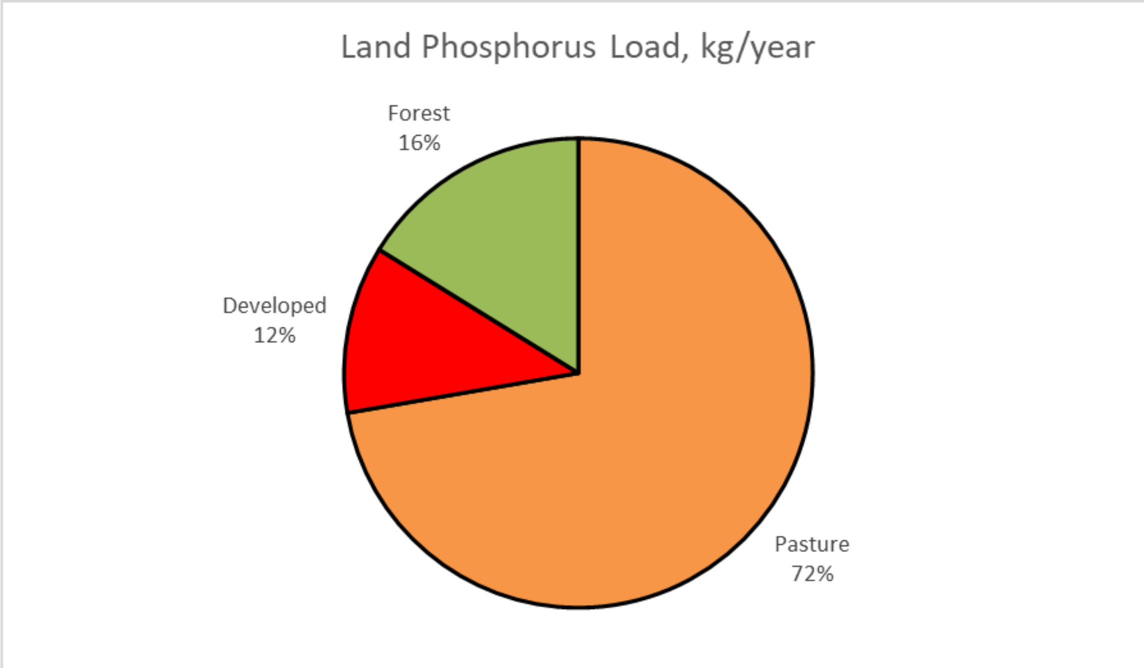

Figure 3.20. SWAT phosphorus load from Upper Illinois River land uses (FTN 2024).

IRWP has reported that, based on streambank erosion monitoring and analysis by Natural State Streams LLC, as much as one-third of the phosphorus load to surface waters in the upper Illinois River watershed may come from streambank erosion (IRWP, 2022b). Other, more localized studies in this watershed have also estimated phosphorus loads from streambank erosion. Table 3.20 lists examples of estimated phosphorus loads associated with streambank erosion in the Upper Illinois River watershed.

Table 3.20. Examples of phosphorus loads from streambank erosion estimated for locations in the Upper Illinois River watershed.

Location	Total Phosphorus load	Source
Little Osage Creek	2,522 pounds/year	(WCRC, 2020?)
Osage Creek	29,276 pounds/year	(WCRC, 2020?)
Lake Fayetteville Watershed	208 pounds/year	(WCRC, 2022)
Upper Illinois River Watershed	154,233 Pounds/year	(Natural State Streams, LLC, 2021)

Additional phosphorus sources in the watershed include stream, pond, wetland, and reservoir sediments, and groundwater. Because phosphorus tends to sorb to soil particles, it can be present in deposited sediments. Phosphorus can be stored in stream, pond, wetland, and reservoir sediments for a long time. Under certain conditions, including sediment erosion during high flow events, the phosphorus stored in sediments can contribute to stream phosphorus concentrations. Phosphorus stored in sediments is referred to as legacy phosphorus, because it may have entered the system a long time previous, before conservation practices were in place. One (1) analysis of water quality data from the Illinois River watershed concluded that stream legacy phosphorus could contribute up to one-third of the Illinois River annual phosphorus load south of Siloam Springs (USGS station 07195430) (Jarvie, et al., 2012).

As noted in Section 3.2, phosphorus levels in monitored springs in the Illinois River watershed are greater than the Oklahoma total phosphorus target (0.037 mg/L). Green and Haggard (2001) estimated that, between 1997 and 1999, groundwater contributed, on average, 15 percent of the annual total phosphorus load to the Illinois River south of Siloam Springs (USGS station 07195430).

3.4.4 Turbidity

There are no stream reaches or reservoirs listed as impaired due to high turbidity levels on the final Arkansas 2018 303(d) list. However, there are Illinois River stream reaches listed as impaired due to high turbidity on the Arkansas partially approved 2020 and draft 2022 303(d) lists. Turbidity impairments are the result of high levels of suspended sediment. Potential nonpoint sources of sediment and turbidity in streams that have been identified by stakeholders are runoff from pastures (erosion), streambank erosion, unpaved roads, stream crossings, runoff from developed areas (erosion), and hydrologic alteration (land use changes, including increasing impervious area, and poorly designed stream crossings). Stakeholders are concerned about erosion and stream instability in this watershed both because of loss of land and property damage, and because of the effects of sedimentation and turbidity on aquatic communities and stream habitat. There are also concerns that eroded soil contributes phosphorus and nitrogen to streams.

The Midwest SPARROW model estimates sediment load contributions from a variety of sources (Robertson and Saad 2019). Figure 3.21 illustrates the estimated relative sediment load contributions from sources in the upper Illinois River watershed. Erosion and runoff from agricultural lands, i.e., pasture, is identified as contributing the highest percentage of the sediment load (46 percent), followed by erosion and runoff from urban areas (29 percent). Channel sources, i.e., streambank and channel erosion, are identified as contributing about 13 percent of the sediment load.

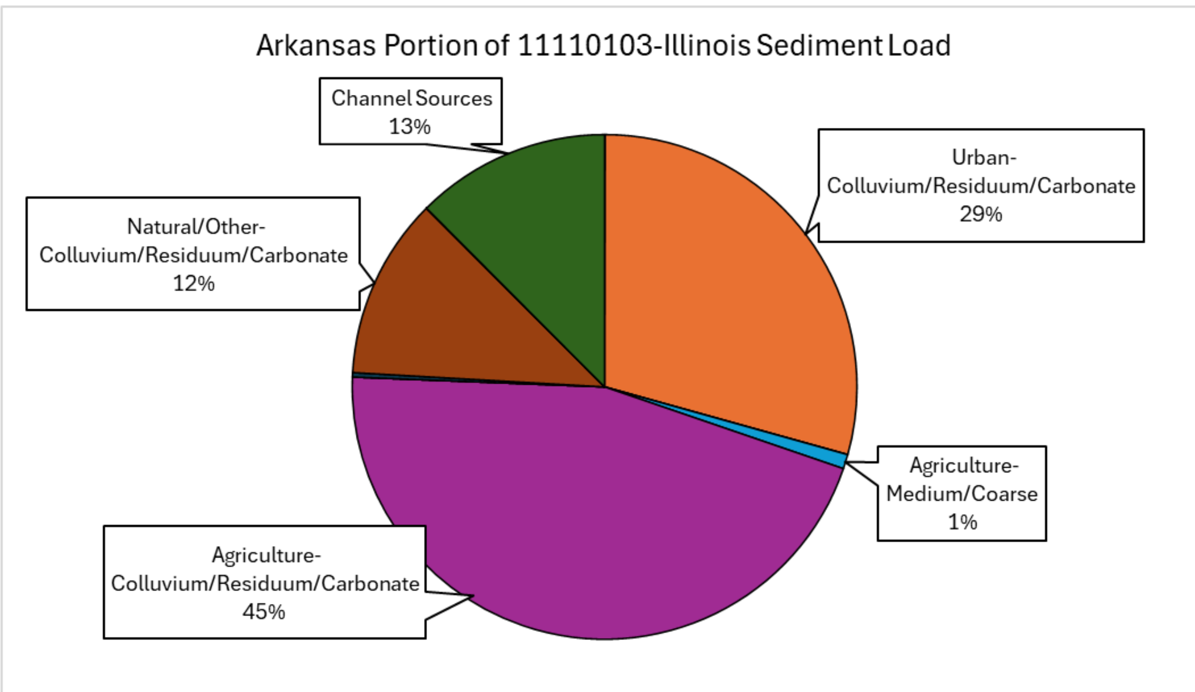

Figure 3.21. SPARROW sediment load sources for upper Illinois River watershed (USGS, 2019).

The 2022 Upper Illinois River watershed SWAT model results also identify pasture as contributing the majority of the sediment load (60 percent), followed by developed areas (23 percent) (Figure 3.22). The SWAT model output does not specifically identify streambank erosion contributions to sediment load.

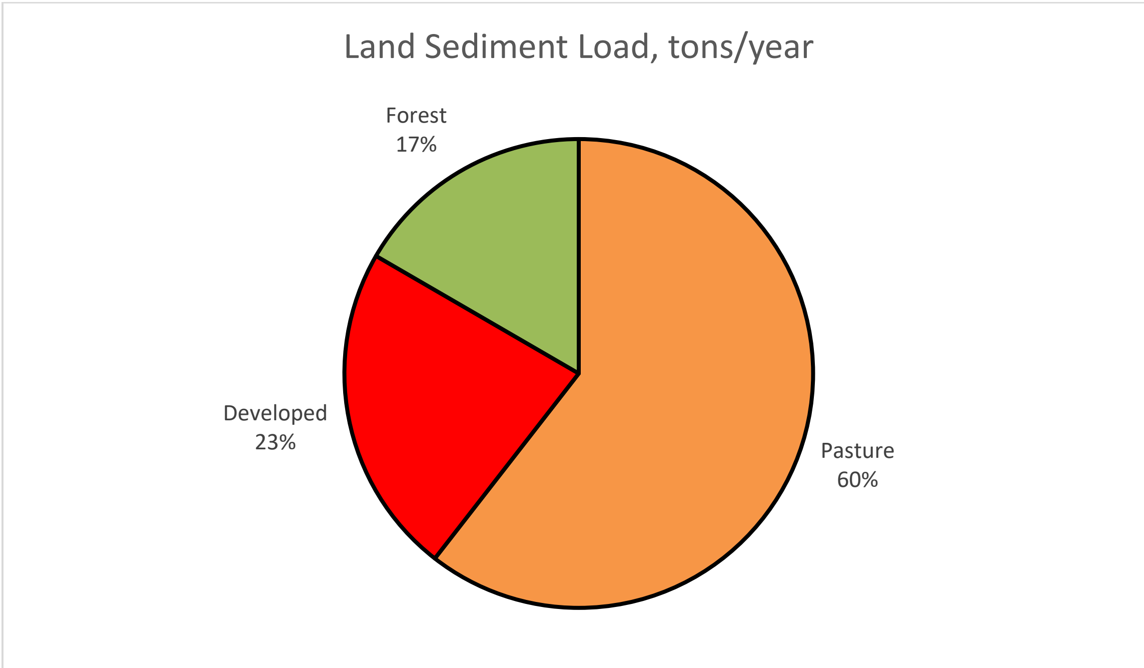

Figure 3.22. SWAT sediment load from Upper Illinois River land uses (FTN 2024).

In the 2015 State Resource Assessment, NRCS identified much of the watershed as having a higher-than-average risk for erosion, sheet/rill/wind erosion, gully erosion, and streambank erosion. Figures 3.23 through 3.25 show 2015 erosion risk maps published by NRCS with the Illinois River watershed shown.

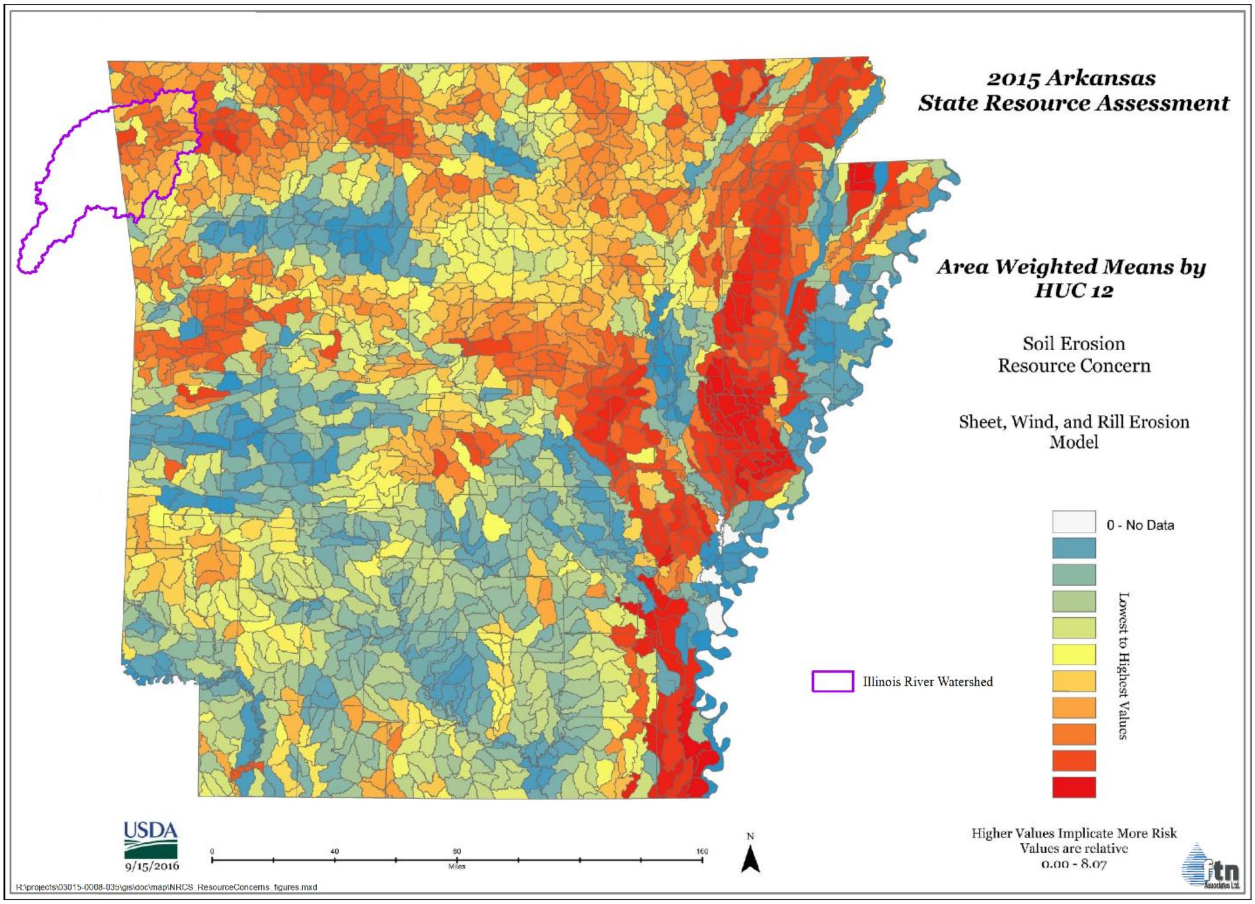

Figure 3.23. 2015 State Resource Assessment map of risk of sheet, rill, and wind erosion in Arkansas, with Illinois River watershed highlighted (NRCS, 2016).

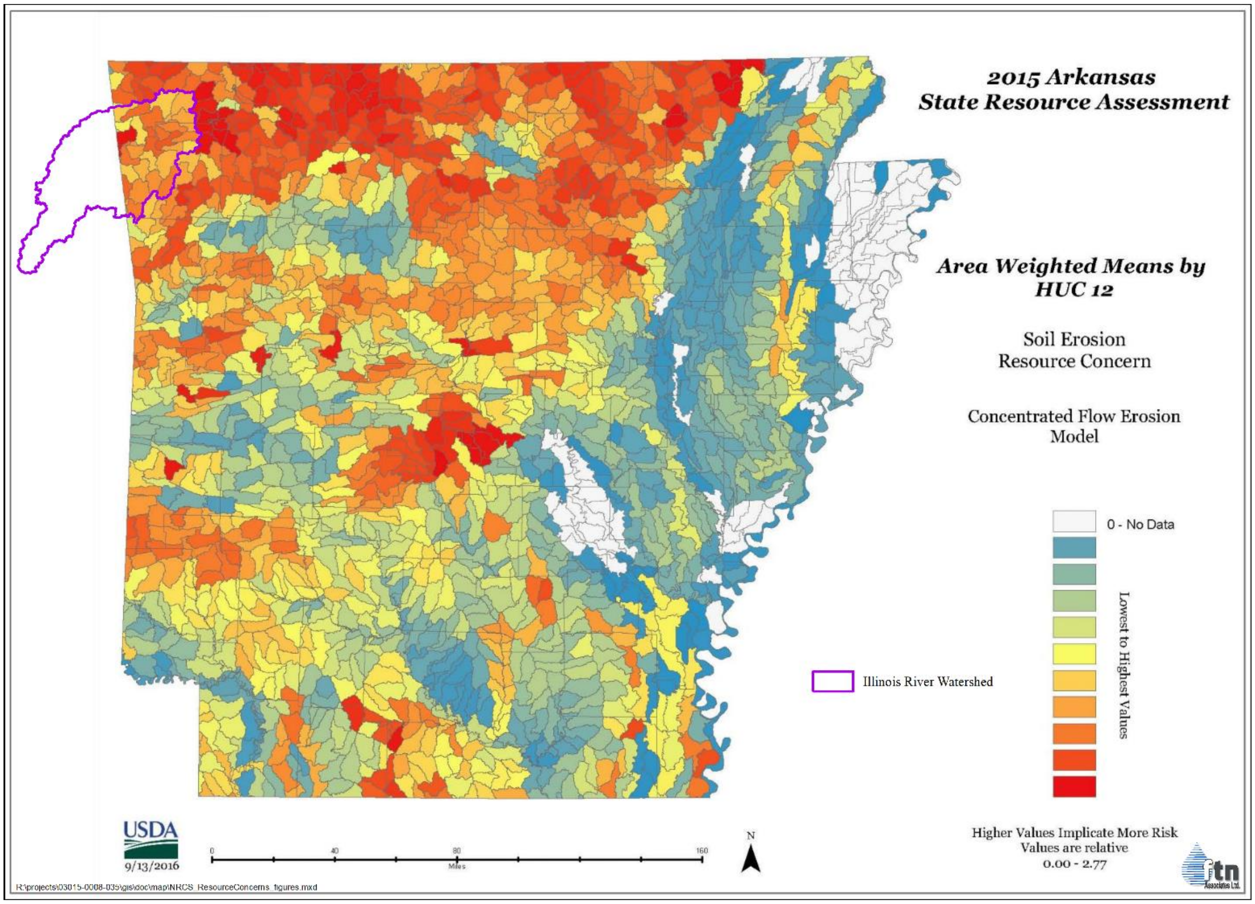

Figure 3.24. 2015 State Resource Assessment map of risk of concentrated flow (gully) erosion in Arkansas, with Illinois River watershed highlighted (NRCS, 2016).

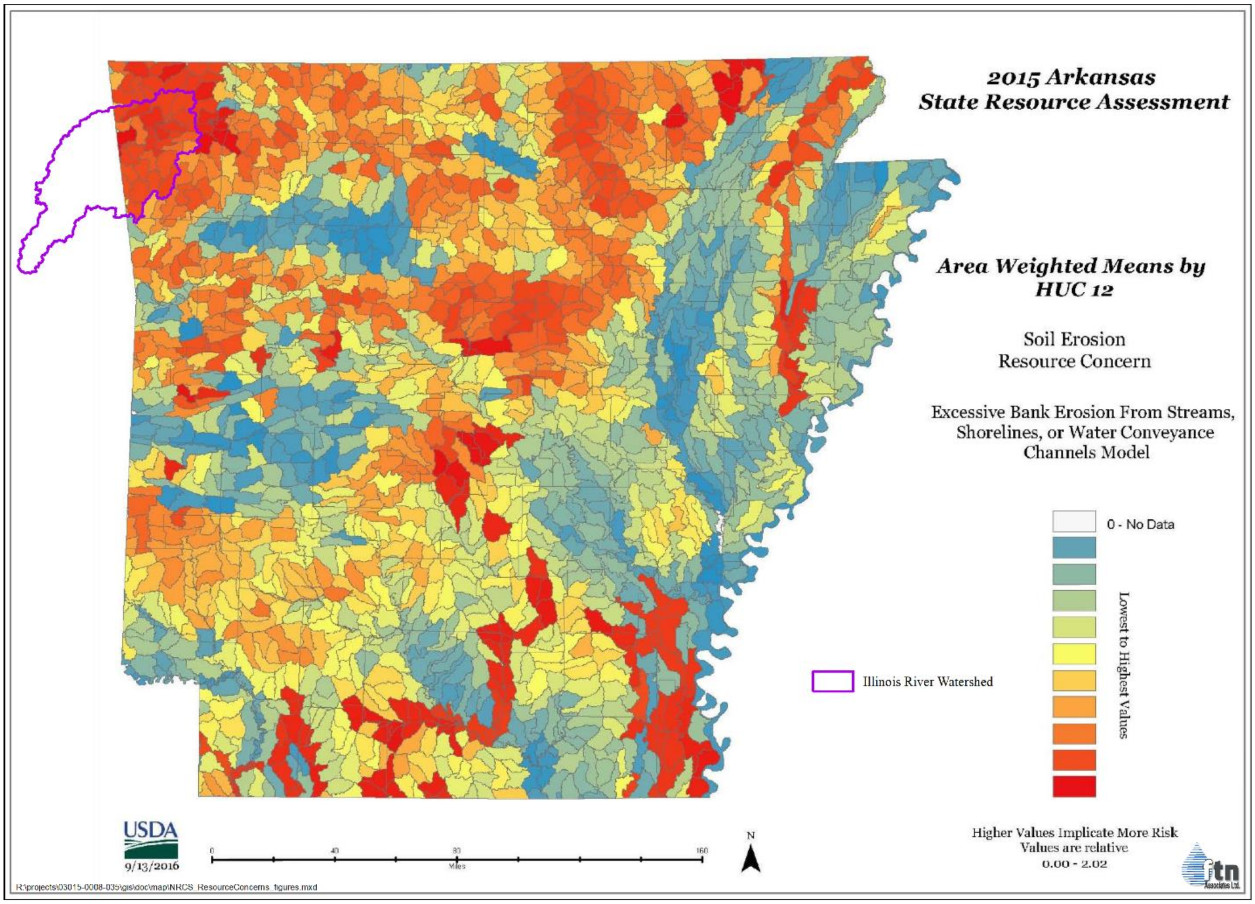

Figure 3.25. 2015 State Resource Assessment map of risk of excessive bank erosion in Arkansas, with Illinois River watershed highlighted (NRCS, 2016).

As discussed in Section 3.3.2, streambank erosion monitoring and studies have been conducted at several locations in the Upper Illinois River watershed. Table 3.21 lists examples of estimated sediment loads from streambanks in the watershed. At the IRWP streambank erosion monitoring sites, researchers have concluded that excessive streambank erosion is driven primarily by land use change and increasing precipitation, which have altered the hydrology of the watershed (Natural State Streams, LLC, 2021). Research in the nearby West Fork White River watershed suggests that streambank erosion is more likely to occur where stream channels pass through soils with moderate to high erosivity hazard and runoff potential (Cotton & Haggard, 2011).

Table 3.21. Examples of sediment loads from streambank erosion estimated for locations in the Upper Illinois River watershed.

Location	Sediment load	Source
Little Osage Creek	6808 ton/year	(WCRC, 2020?)
Osage Creek	68827 ton/year	(WCRC, 2020?)
Lake Fayetteville Watershed	879 ton/year	(WCRC, 2022)
Clear Creek watershed	49,210 ton/year	(WCRC, 2022)
Upper Illinois River Watershed	102,822 tons	(Natural State Streams, LLC, 2021)

Unpaved roads can be a significant source of stream sediment in rural watersheds in the Arkansas Ozarks (Inlander, Clingenpeel, Crump, Van Epps, & Formica, 2007). In the Upper Illinois River watershed, erosion from unpaved roads has been identified as a threat to species of greatest conservation need (Slay, Knighten, & Gallipeau, 2018). As of 2023 there are approximately 660 miles of unpaved roads in the Upper Illinois River watershed (Arkansas Geographic Information Systems Office, 2023). Both Benton and Washington County are certified for Environmentally Sensitive Road Maintenance through the Arkansas Unpaved Roads Program and have received program grants for unpaved road improvement projects (K. McGaughey, Natural Resources Division, personal communication, 5/20/2024).

Stream crossings are the locations where roads usually have the greatest effect on water quality, stream habitat, and aquatic life. Stream crossings are the most likely place for eroded material from unpaved roads or roadside ditches to enter streams. Improperly designed stream crossings can cause stream instability and streambank erosion (presentation at watersheds conference NLR). Road crossings can also be barriers to aquatic species of concern (Slay, Knighten, & Gallipeau, 2018). The Southeast Aquatic Resources Partnership (SARP) has identified 4,500 road crossings in the Upper Illinois River watershed (SARP, 2024).

3.4.5 Nitrogen

No streams in the watershed are listed as impaired due to high nitrogen levels on the 2018 303(d) list, however nitrogen loads to streams may contribute to low DO impairments of streams identified in the partially approved 2020 and draft 2022 303(d) lists. Potential nonpoint sources of nitrogen in streams that have been identified by stakeholders are livestock, runoff from pastures (livestock, land applied poultry litter, applied fertilizer), runoff from poultry feeding operations (poultry house dust), failing septic systems, runoff from developed areas (pet and wildlife wastes, illicit discharges, combined sewer overflows, fertilizer applications), and groundwater. See Section 3.4.1 for information on livestock numbers, poultry litter application, poultry feeding operations, septic systems, and development sources.

The Midwest SPARROW model estimates nitrogen load contributions from a variety of sources (Robertson and Saad 2019). Figure 3.26 illustrates the estimated relative total nitrogen load contributions from sources in the upper Illinois River watershed. This model identifies manure as the greatest contributor to total nitrogen load in the watershed. The 2022 Upper Illinois River watershed SWAT model results identify pasture as contributing the majority of the nitrogen load (78 percent), followed by developed areas (16 percent) (Figure 3.27).

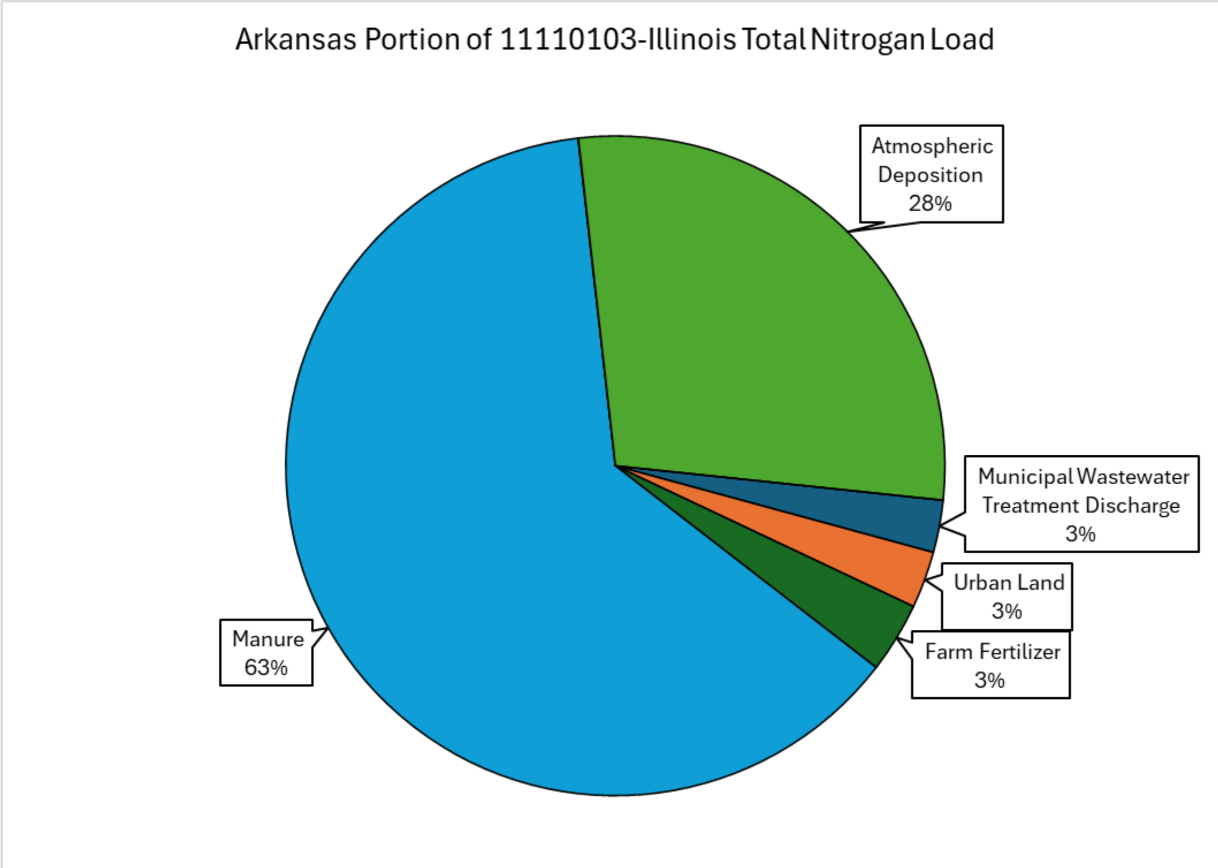

Figure 3.26. SPARROW nitrogen load sources for upper Illinois River watershed (USGS, 2019).

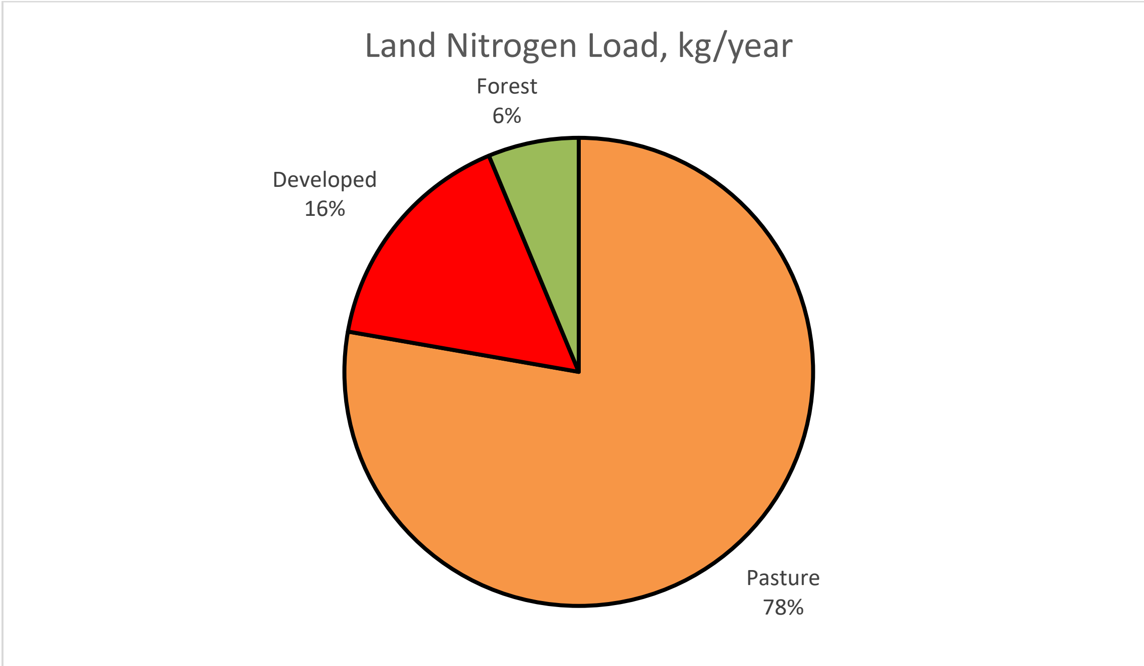

Figure 3.27. SWAT nitrogen load from Upper Illinois River land uses (FTN in process).

See Section 3.4.1 for information about livestock, poultry litter applications, septic systems, and combined sewer overflows. See Section 3.4.3 for information about animal feeding operations. Table 3.22 provides examples of estimated nitrogen loads from streambank erosion.

Table 3.22. Examples of nitrogen loads from streambank erosion estimated for locations in the Upper Illinois River watershed (WCRC, 2020?).

Location	Total Nitrogen Load
Little Osage Creek	5,311 lb/yr
Osage Creek	62,252 lb/yr

As noted in Section 3.2, nitrate concentrations in monitored springs in the Illinois River watershed are greater than the estimated natural background concentration. Green and Haggard (2001) estimated that, between 1997 and 1999, groundwater contributed, on average, 46 percent of the annual total nitrogen load to the Illinois River south of Siloam Springs (USGS station 07195430).

3.4.6 Organic Materials

Organic materials can come from a variety of sources present in the Upper Illinois River watershed. Runoff from pastures can carry organic matter from livestock manure or poultry litter applied as fertilizer, or from mowing. Livestock in streams also contribute organic matter when they loiter and defecate in the stream. Runoff from animal feeding operations can carry organic matter from poultry litter or other animal waste stored on site. Runoff from developed areas can carry organic materials such as grass clippings, fall leaves, trash, and waste from pets or wildlife to waterbodies. Discharges from failing septic systems, or sewer overflows also contain organic materials that can lower DO as they decompose. See Section 3.4.1 for information on livestock numbers, poultry litter application, poultry feeding operations, septic systems, and development sources. Eroding streambanks can cause plant material from the bank to enter streams.

4. MANAGEMENT PLAN

This section identifies management concerns and goals for the Upper Illinois River watershed, as well as areas to target management of nonpoint source pollution and protection of existing high-quality- resources, and practices to achieve the watershed goals.

4.1 Management Goals

There are six (6) management goals to achieve the vision of the Illinois River watershed:

- Restore waterbody uses currently not being attained
- Sustain waterbody uses that are being attained
- Keep pollutants out of surface water and groundwater
- Minimize activities that disturb the stream channel, streambanks, and lakeshores
- Restore eroding streambanks and degraded riparian areas
- Meet water quality requirements of interstate compact

There are several stream reaches and reservoir segments in the Upper Illinois River watershed listed by DEQ and Oklahoma DEQ as currently not meeting water quality standards required to support some of their designated uses (see Section 3.1.4). To achieve the vision for the Upper Illinois River watershed (see Section 1.2), water quality in the streams and reservoirs in this watershed will need to meet all water quality standards so that all designated uses are supported. This includes meeting water quality requirements of the Arkansas-Oklahoma Arkansas River Compact. In addition, good water quality needs to be protected and maintained in those waterbodies that currently meet water quality standards and attain their designated uses. The management goals of keeping pollutants out of surface water and groundwater, minimizing activities that disturb the stream and reservoir beds and banks, and restoring eroding streambanks and degraded riparian areas all contribute to the goals of achieving water quality standards and attaining designated waterbody uses.

4.2 Management Concerns

Concerns about the Upper Illinois River watershed were identified from public meetings and online information, in addition to waterbody impairments. Table 4.1 is a list of the water quality related issues identified by stakeholders for this watershed.

Table 4.1. Water quality related issues identified by stakeholders for the Upper Illinois River.

In-stream	Watershed
Phosphorus	Unpaved roads
Sediment, turbidity	Poultry litter application to land
Streambank erosion	Septic systems
chloride	Road crossings
sulfate	Removal of riparian trees, vegetation
Pathogens	development in floodplains
pH (Lake Fayetteville)	Impervious area
Nitrogen	Urban runoff
Low DO	Use of fertilizer and pesticides
Livestock in streams	Pet waste
Groundwater quality	Land application of industrial, municipal nutrient-containing wastes

4.3 Sub-Watersheds Recommended for Nonpoint Source Pollution Management

For this watershed management plan, 12-digit HUC (HUC12) sub-watersheds delineated by the USGS are utilized as focus areas for nonpoint source pollution management. To identify HUC12 sub-watersheds to recommend for additional management of nonpoint source pollution under this plan, available information was used to rank the focus HUC12 sub-watersheds of the Upper Illinois River watershed (those with at least 50 percent of their area in Arkansas), in terms of water quality concerns. Four (4) sets of water quality-related information were used to rank these HUC12 sub-watersheds:

- Water quality impairment
- Modeled nutrient and sediment instream loads
- Water quality natural resource concerns from the 2015 NRCS State Resources Assessment
- Estimated condition of macroinvertebrate communities

A detailed description of the data used, and the ranking approach is included as Appendix J. The HUC12 sub-watersheds were assigned to one of three categories based on the total rank scores. HUC12 sub-watersheds with total rank scores greater than 2.5 were assigned to Category 1. HUC12 sub-watersheds with total rank scores between 2.5 and 1.75 were assigned to Category 2, and HUC12 sub-watersheds with total rank scores of less than 1.75 were assigned to Category 3. Figure 4.1 shows the HUC12 categories. Higher total rank scores indicate that more of the data sources indicate poor water quality or a threat to water resources. Therefore, nonpoint source pollution management recommendations in this plan will focus on Category 1 sub-watersheds (Table 4.2).

This does not mean that there are no water quality issues in Category 2 and 3 sub-watersheds. For example, in the Category 3 Lake Fayetteville-Clear Creek sub-watershed, Lake Fayetteville has been classified as impaired due to high pH levels. Mud Creek sub-watershed, which is also in Category 3, had the highest probability of poor macroinvertebrate communities, and Grantz and Haggard (2023) identified increasing trends in sulfate and chloride concentrations in Mud Creek. This plan is not intended to restrict management activities in areas outside the Category 1 HUC12 sub-watersheds. Water quality management is essential, and is encouraged, throughout the Upper Illinois River watershed.

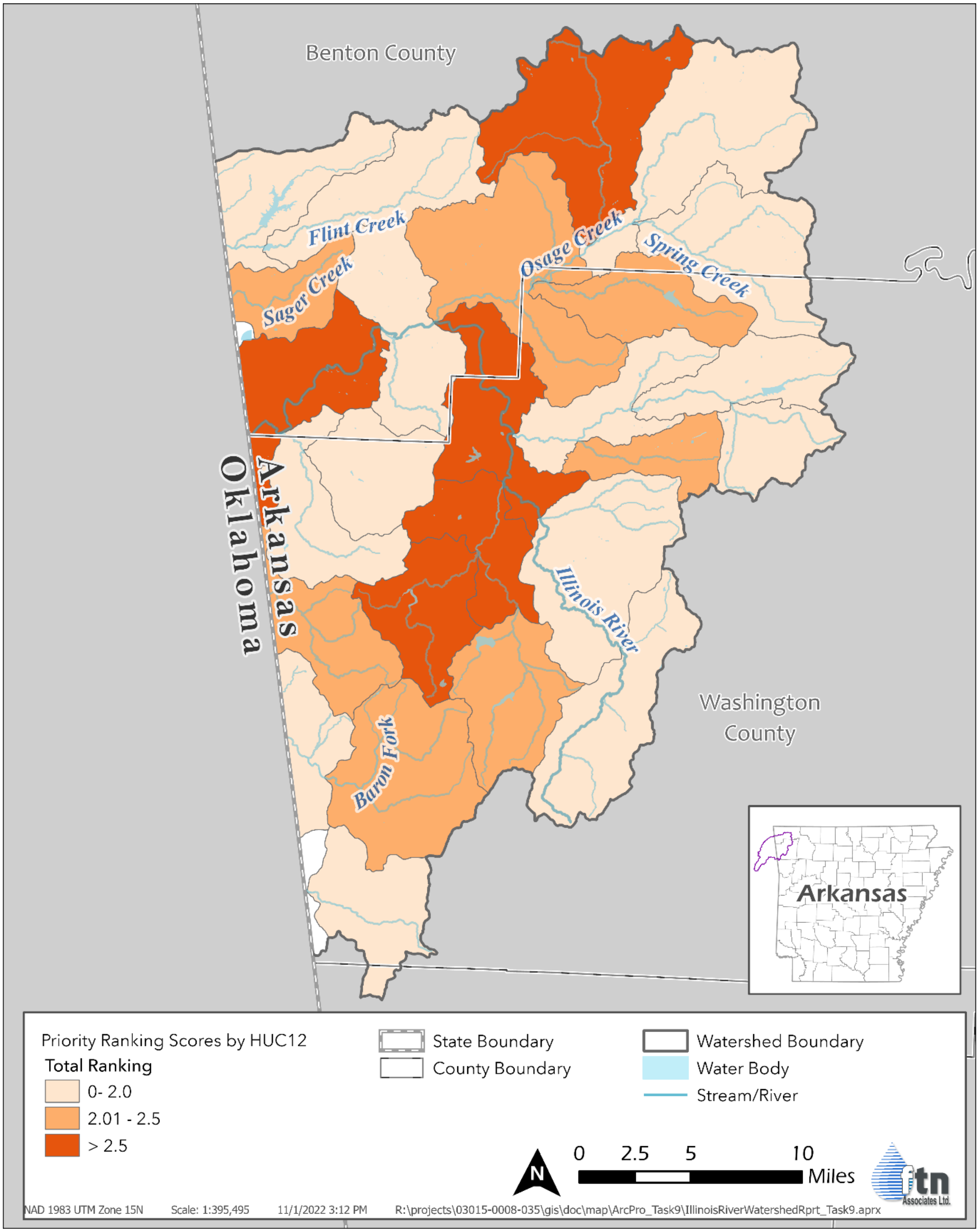

Figure 4.1. Map of Upper Illinois River HUC12 sub-watershed rank categories for nonpoint source pollution management.

Table 4.2. Category 1 HUC12 sub-watersheds recommended for nonpoint source pollution management under this watershed management plan.

HUC12 ID Number	HUC12 Name	Ranking Score (out of 3 possible)	Ecoregion (Rule 2)*	County	2019 land cover percentages: Developed	Forested	Pasture and hayland	Wetland	Other undeveloped
111101030102	Moores Creek	2.74	OH & BM	Washington	8.6%	30.6%	58.3%	0.1%	2.4%
111101030103	Lower Muddy Fork	2.54	OH & BM	Washington	7.0%	23.4%	68.4%	0.2%	1.0%
111101030302	Little Osage Creek	2.71	OH	Benton	25.1%	12.0%	61.6%	<0.1%	1.3%
111101030403	Lake Wedington-Illinois River	2.71	OH	Benton & Washington	4.8%	61.5%	29.5%	1.2%	3.1%
111101030606	Lake Frances-Illinois River	2.58	OH	Benton & Washington	7.7%	50.1%	38.6%	1.7%	1.9%

*BM = Boston Mountains ecoregion, OH = Ozark Highlands ecoregion as delineated in Arkansas Pollution Control and Ecology Commission Rule 2 (Arkansas Pollution Control and Ecology Commission, 2022)

Table 4.3 identifies issues and concerns in the Category 1 sub-watersheds. The sub-watershed issues are identified based on assessed water quality impairments, water quality trend analysis, the 2015 NRCS State Resource Assessment, SWAT model results, EPA analysis (estimated condition of benthic community), Arkansas water quality standards (Ecologically Sensitive Waterbody), US Fish and Wildlife Service threatened and endangered species listings, and studies of the groundwater system underlying the watershed (spring recharge areas, groundwater vulnerability).

Table 4.3. Upper Illinois River watershed water quality issues of concern in Category 1 sub-watersheds.

Concerns	Moores Creek (111101030102)	Lower Muddy Fork (111101030103)	Little Osage Creek (111101030302)	Lake Wedington-Illinois River (111101030403)	Lake Frances-Illinois River (111101030606)
Phosphorus	N	N, S, s	N	S	O, S, s
Sediment, turbidity	S			i	N, S
Petroleum & heavy metals	N	N	N		
Pesticides			N		N
chloride				I	I
sulfate	I	I		I	I, T(Watts)
Pathogens	I, N	I, N	I, N	I	O
Nitrogen	N	N	N, S		
Habitat degradation			N, B	N	
T&E aquatic species	Neosho Mucket, Rabbitsfoot mussel, Missouri Bladderpod	Neosho Mucket, Rabbitsfoot mussel, Missouri Bladderpod	Neosho Mucket, Rabbitsfoot mussel, Ozark Cavefish, Benton County Cave Crayfish	Neosho Mucket, Rabbitsfoot mussel, Ozark Cavefish, Benton County Cave Crayfish, Missouri Bladderpod	Neosho Mucket, Rabbitsfoot mussel, Benton County Cave Crayfish, Missouri Bladderpod
Ecologically Sensitive Waterbody			Little Osage Creek (various)	Illinois River (Neosho Mucket), spring	Illinois River (Neosho Mucket)
Recharge area for spring			Hewlitt's Spring		

B=estimated probability of poor macroinvertebrate community >75%, I=2018 impairment, i=2020 impairment only, N=2015 State Resource Assessment risk in top 20%, O=stream in this HUC12 is impaired in Oklahoma at border, S=SWAT modeled instream flux/land area in the top 20%, s=SWAT land yield in the top 20%, T=increasing trend identified by Grantz and Haggard (2023)

4.4 Management Targets

Based on the water quality concerns listed in Table 4.3, pollutants of concern in the Category 1 sub-watersheds are phosphorus, turbidity/sediment, chloride, sulfate, nitrogen, and pathogens (*E. coli*). These pollutants are targets for management under this plan. Management targets for these pollutants are the applicable water quality standards.

4.4.1 Phosphorus

There are no numeric water quality criteria for phosphorus in the Arkansas water quality regulations that apply in the Upper White River watershed. However, a numeric phosphorus criterion of 0.037 mg/L applies to the Illinois River, Flint Creek, and Baron Fork at the state line in Oklahoma (Oklahoma Water Resources Board, 2020). Therefore, 0.037 mg/L is a phosphorus target in this plan for the Illinois River at the state line in the Lake Frances-Illinois River Category 1 sub-watershed.

Arkansas-Oklahoma Arkansas River Compact Commission has set total phosphorus load targets for Baron Fork (4,296 kg/year), Flint Creek (1,960 kg/year), Illinois River (114,346 kg/year), and Sager Creek (10,540 kg/year) (State of Arkansas Environmental Committee, 2020). The Compact Illinois River load target is a target in this plan for the Lake Frances-Illinois River Category 1 sub-watershed.

The DEQ method for assessing whether wadeable streams are nutrient impaired uses the 75th percentile of total nitrogen and total phosphorus measurements from each of the state ecoregions, along with DO and pH measurements and the condition of biological communities (DEQ, 2021). The 75th percentile of total phosphorus concentrations reported for DEQ Ozark Highlands stream stations 2018-2022 is 0.07 mg/L. This value is a target for the Category 1 sub-watersheds for this plan.

Water quality measurements are not available for 2017-2021 from all the Category 1 sub-watersheds. SWAT model output loads were used to calculate phosphorus load targets for Category 1 sub-watersheds. Target phosphorus yields were calculated by taking the median of phosphorus yields predicted for the Category 3 sub-watersheds. Targets were calculated for both upland yields and instream yields. The resulting target upland phosphorus yield was 1.3 kg/ha/year. The resulting target instream phosphorus yield was 1.0 kg/ha/year. The data used to calculate the phosphorus yield target is provided in Appendix K.

4.4.2 *E. coli* Management Target

Bacteria management targets for this watershed management plan, for all waterbodies in Category 1 HUC12s except the Illinois River in the Lake Frances-Illinois River are the *E. coli* primary contact individual sample water quality criteria. To be assessed as achieving the *E. coli* individual sample criteria, DEQ requires that 75 percent or more of at least eight (8) *E. coli* measurements from the assessment period (see Table 3.1 For Primary and Secondary Contact assessment periods) must be less than the individual sample criterion (DEQ, 2021). The applicable individual sample Primary Contact *E. coli* criterion in the Category 1 sub-watersheds where pathogens have been identified as a concern are listed in Table 4.4.

For the Illinois River in the Lake Frances-Illinois River HUC12 the bacteria management target is the *E. coli* primary contact geometric mean water quality criterion. To be assessed as achieving the *E. coli* geometric mean criterion, the geometric mean of at least five (5) samples collected within a 30-day period of the primary contact season must be less than the criterion (DEQ 2021). The geometric mean criterion is listed in Table 4.6. Note that the same geometric mean criterion applies to the Illinois River on both sides of the Arkansas-Oklahoma border (UNOFFICIAL (ok.gov)).

Table 4.4. *E. coli* individual sample water quality criteria applicable in Category 1 sub-watersheds where pathogens have been identified by stakeholders as a concern. Yellow highlighted water bodies are classified as impaired due to high *E. coli* levels.

HUC12 ID Number	HUC12 Name	Assessed Water Body	Primary Contact Criterion, cfu/100mL
111101030102	Moores Creek	Moores Creek	410
111101030103	Lower Muddy Fork	Muddy Fork	410
111101030302	Little Osage Creek	Little Osage Creek	410
111101030403	Lake Wedington- Illinois River	Illinois River upstream of Muddy Fork	410
		Illinois River downstream of Muddy Fork	298
111101030606	Lake Frances-Illinois River	Illinois River	126*

*126 is standard for geometric mean of at least 5 samples collected within 30 days

4.4.3 Sulfate Management Targets

The sulfate management target for this watershed management plan is to attain the sulfate water quality criteria. This management target applies to Category 1 sub-watersheds where waterbodies are listed as impaired due to sulfate (Table 4.5). To be assessed as meeting the sulfate criteria, DEQ requires that at least 90 percent of at least 10 measurements from the assessment period meet the sulfate criteria.

Table 4.5. Sulfate criteria management targets for Category 1 sub-watersheds with sulfate impairments.

HUC12 ID Number	HUC12 Name	Impaired Stream	Sulfate Criterion, mg/L
111101030403	Lake Wedington-Illinois River	Illinois River	20
111101030606	Lake Frances- Illinois River	Illinois River	20
111101030102	Moores Creek	Moores Creek	250
111101030103	Lower Muddy Fork	Muddy Fork	250

4.4.4 Chloride Management Targets

The chloride management target for this watershed management plan is to attain the chloride water quality criteria. This management target applies to Category 1 sub-watersheds where waterbodies are listed as impaired due to chloride (Table 4.6). To be assessed as meeting the sulfate criteria, DEQ requires that at least 90 percent of at least 10 measurements from the assessment period meet the chloride criteria.

Table 4.6. Chloride criteria management targets for Category 1 sub-watersheds with chloride impairments.

HUC12 ID Number	HUC12 Name	Impaired Stream	Chloride Criterion, mg/L
111101030403	Lake Wedington-Illinois River	Illinois River	20
111101030606	Lake Frances- Illinois River	Illinois River	20

4.4.5 Sediment Management Targets

Available information suggests that turbidity, sediment, and/or erosion are issues in all of the Category 1 sub-watersheds. One of the sediment management targets for this plan is to attain the turbidity water quality criteria. For the majority of the assessed waterbodies in the Category 1 sub-watersheds these will be the Ozark Highlands stream criteria: 10 NTU during June-October and 17 NTU during November-May.

Water quality measurements are not available for 2018-2022 from all the Category 1 sub-watersheds. SWAT model output loads were used to calculate sediment load targets for Category 1 sub-watersheds. There are 11 HUC12 sub-watersheds where turbidity was measured 2018-2022 and met water quality standards. The median of modeled instream and upland yields from these 11 HUC12s are used as sediment yield targets for this plan. The resulting target upland sediment yield was 2.5 ton/ha/year. The resulting target instream sediment yield was 0.4 ton/ha/yr. The data used to calculate the sediment yield targets are provided in Appendix K.

4.4.6 Nitrogen

The DEQ method for assessing whether wadable streams are nutrient impaired uses the 75th percentile of total nitrogen and total phosphorus measurements from each of the state ecoregions, along with DO and pH measurements and the condition of biological communities (DEQ, 2021). The 75th percentile of total nitrogen concentrations reported for DEQ Ozark Highlands stream stations 2018-2022 is 2.28 mg/L. This value is used as a target for the Category 1 sub-watersheds for this plan.

Water quality measurements are not available for 2018-2022 from all the Category 1 sub-watersheds. Therefore, SWAT model output loads were used to calculate nitrogen load targets for Category 1 sub-watersheds. Target nitrogen yields (load/HUC12 area) were calculated by taking the median nitrogen yields predicted for the Category 3 sub-watersheds. Targets were calculated for both upland yields and instream yields. The resulting target upland nitrogen yield was 37.5 kg/ha/year. The resulting target instream nitrogen yield was 7 kg/ha/yr. The data used to calculate the nitrogen yield targets is provided in Appendix K.

4.5 Pollutant Reduction Targets

Based on the water quality targets identified in Section 4.4 and available water quality information, it should be possible to determine pollutant load reductions needed to achieve the water quality targets. Determination of load reduction targets for this watershed management plan is discussed in the following subsections.

4.5.1 E. coli

Four (4) of the Category 1 sub-watersheds have waterbodies listed as impaired due to high levels of *E. coli* (see Table 3.4). The DEQ approach for evaluating attainment of the *E. coli* Primary Contact criterion uses a data set of at least eight measurements collected between May 1 and September 30 (DEQ 2021). There are no recent (2018-2022) *E. coli* data sets from the Category 1 HUC12s that meet the data criteria to evaluate attainment of the *E. coli* water quality criteria and estimate needed load reductions. There is only one water quality station in the Category 1 HUC12s where *E. coli* data have been collected 2018-2022, USGS station 07194800 on the Illinois River in the Lake Wedington-Illinois River HUC12 (111101030403). *E. coli* measurements have not been collected from the remaining Category 1 HUC12 sub-watersheds. Therefore, no load reduction targets are set for *E. coli* in this plan sulfate.

Table 4.7 lists the number of sulfate criterion exceedances during 2018-2022 at water quality stations in Category 1 sub-watersheds that are on stream segments identified as impaired due to high sulfate concentrations in the 2018 303(d) list. Note that there are no water quality stations located in the Moores Creek or Lower Muddy Fork Category 1 sub-watersheds that were sampled 2018-2022.

Table 4.7. Comparison of 2018-2022 sulfate measurements from sulfate impaired streams in Category 1 sub-watersheds, to applicable criteria.

HUC12 ID Number	HUC12 Name	Impaired Stream	Sulfate Criterion mg/L	Water Quality Station ID	Number of measurements 2018-2022	Number > criterion	Target number*
111101030403	Lake Wedington-Illinois River	Illinois River	20	ARK40	52	15	8
				Savoy	33	14	6
				71948000	20	7	4
111101030606	Lake Frances-Illinois River	Illinois River	20	ARK0006	43	11	7
				IR59	36	14	6
				07195430	20	4	4
111101030102	Moores Creek	Moores Creek	250	--			
111101030103	Lower Muddy Fork	Muddy Fork	250	--			

* (DEQ, 2021)

A reduction target for sulfate in the Lake Frances and Lake Wedington Illinois River sub-watersheds was calculated by multiplying all sulfate measurements from Illinois River stations in the sub-watersheds from 2018-2022 by a series of reduction factors until the number of criterion exceedances in the reduced data set was less than the DEQ 10 percent exceedance target (DEQ 2021). The resulting reduction factor was 10 percent for both sub-watersheds, i.e., if sulfate concentrations were reduced by 10%, it is likely the sulfate criterion would be met in the Illinois River.

4.5.2 Chloride

The Illinois River in Category 1 HUC12 sub-watersheds is listed on the 2018 303(d) list as impaired due to high chloride levels. However, this impairment is proposed to be removed on the partially approved 2020 and draft 2022 303(d) lists, indicating that chloride levels in the Illinois River have declined. AWRC identified a statistically significant declining trend in chloride concentrations at the Savoy station on the Illinois River in the Lake Wedington-Illinois River Category 1 HUC12 (see Table 3.6). Evaluation of the number of chloride measurements from 2018-2022 that exceed the chloride criterion supports the conclusion that Illinois River chloride concentrations are less than the criterion (Table 4.8). Chloride reductions in Category 1 HUC12s will not be a focus of this watershed management plan.

Table 4.8. Exceedances of chloride criteria 2018-2022 in Category 1 sub-watershed streams impaired due to chloride.

HUC12 ID Number	HUC12 Name	Impaired Stream	Chloride Criterion mg/L	Water Quality Station ID	Number of measurements 2018-2022	Number > criterion	Target number*
111101030403	Lake Wedington - Illinois River	Illinois River	20	ARK0040	52	2	8
				Savoy	124	8	>31
				71948000	20	2	4
111101030606	Lake Frances-Illinois River	Illinois River	20	ARK0006	43	2	7
				IR59	127	7	>31
				07195430	20	0	4

4.5.3 Sediment

Comparison of Illinois River base flow turbidity measurements to the base flow criterion suggests that reduction may be needed in sediment loads to reduce turbidity (Table 4.9).

Table 4.9. Exceedances of base flow criteria 2018-2022 in Category 1 HUC12 sub-watershed streams impaired due to turbidity.

HUC12 ID Number	HUC12 Name	Impaired Stream	Water Quality Station ID	Number of base flow measurements 2018-2022	Number > 10 NTU	Target number*
111101030403	Lake Wedington-Illinois River	Illinois River	ARK40	21	11	6
			Savoy	48	13	12
111101030606	Lake Frances-Illinois River	Illinois River	ARK0006	19	5	5
			IR59	49	15	12

* (DEQ, 2021)

Table 4.10 shows a comparison of SWAT modeled sediment yields for Category 1 sub-watersheds to the target upland sediment yield (2.5 ton/ha/yr). Table 4.11 shows a comparison of SWAT modeled sediment instream yields to target instream yield (0.4 ton/ha/yr). Modeled upland sediment yields in the Category 1 HUC12s are all less than or equal to the target yield. However, modeled instream sediment yields exceed the target yield. This suggests that streambank and channel erosion may be higher concern nonpoint sediment sources than erosion and runoff from pastures, unpaved roads, and developed areas.

Table 4.10. Comparison of modeled sediment upland yields from recommended sub-watersheds to target sediment upland yield (2.5 ton/ha/yr), with reduction targets.

HUC12 ID Number	HUC12 Name	Modeled Upland Yield (ton/ha/yr)	Modeled yield – target yield (2.5 ton/ha/yr)	Percent reduction to meet target	Target land yield reduction
111101030102	Moores Creek	0.6	-1.9	--	0
111101030103	Lower Muddy Fork	2.3	-0.2	--	0
111101030302	Little Osage Creek	0.9	-1.6	--	0
111101030403	Lake Wedington-Illinois River	2.4	-0.1	--	0
111101030606	Lake Frances-Illinois River	2.5	0	--	0

Table 4.11. Comparison of modeled sediment instream yields from Category 1 sub-watersheds to target sediment instream yield (0.4 ton/ha/yr), with reduction targets.

HUC12 ID Number	HUC12 Name	Modeled instream Yield (ton/ha/yr)	Modeled yield – target yield (0.4 ton/ha/yr)	Percent reduction to meet target	Target instream yield reduction
111101030102	Moores Creek	2.44	2.04	84%	80%
111101030103	Lower Muddy Fork	0.45	0.05	11%	10%
111101030302	Little Osage Creek	1.03	0.63	61%	60%
111101030403	Lake Wedington-Illinois River	1.56	1.16	74%	70%
111101030606	Lake Frances-Illinois River	2.44	2.04	84%	80%

4.5.4 Nitrogen

The average of at least 10 total nitrogen measurements from water quality monitoring stations within the Category 1 HUC12 sub-watersheds were compared to the ecoregion target concentrations (Table 4.12). This is part of the approach used by DEQ to identify waterbodies impaired by nutrients (DEQ, 2021). Water quality sampling was not conducted 2018-2022 in three (3) of the Category 1 HUC12s. Therefore, it is not possible to evaluate total nitrogen concentrations from these HUC12s. The information evaluated for ranking the Upper Illinois River sub-watersheds does not indicate that nitrogen is an issue in the two (2) Illinois River Category 1 HUC12s where water quality sampling was conducted 2018-2022. However, the average total nitrogen concentrations from the Illinois River stations in these Category 1 HUC12s are a little higher than the ecoregion target concentration (Table 4.12).

Table 4.12. Comparison of available total nitrogen measurements from Category 1 HUC1s to the Ozark Highlands wadeable streams target concentration.

HUC12 ID Number	HUC12 Name	Waterbody	Water Quality Station ID	Sampling Organization	2018-2022 Average Total Nitrogen, mg/L	Percent difference from 2.28 mg/L (difference/2.28)	Reduction to meet 2.28 (difference/average)
111101030403	Lake Wedington-Illinois River	Illinois River	ARK40	DEQ	2.6	14%	12%
			Savoy	AWRC	2.5	10%	9%
			71948000	USGS	2.6	14%	12%
111101030606	Lake Frances-Illinois River	Illinois River	ARK0006	DEQ	2.8	23%	18%
			IR59	AWRC	2.6	14%	12%
			07195430	USGS	2.8	23%	18%
111101030102	Moores Creek	Moores Creek	--				
111101030103	Lower Muddy Fork	Muddy Fork	--				

Table 4.13 shows a comparison of SWAT modeled total nitrogen yields from upland sources to the target upland yield. Table 4.14 shows a comparison of SWAT modeled total nitrogen instream yields to target instream yield (7 kg/ha/yr).

Table 4.13. Comparison of modeled total nitrogen loads from Category 1 sub-watersheds to target total nitrogen load, with load reduction targets.

HUC12 ID Number	HUC12 Name	Modeled Upand Yield	Modeled yield – target yield	Percent reduction to meet target	Target land yield reduction
111101030102	Moores Creek	31.3	-6.2	--	0
111101030103	Lower Muddy Fork	34.9	-2.6	--	0
111101030302	Little Osage Creek	31.4	-6.1	--	0
111101030403	Lake Wedington-Illinois River	40.7	5	12%	10%
111101030606	Lake Frances-Illinois River	33.7	-3.8	--	0

Table 4.14. Comparison of modeled total nitrogen instream yields from Category 1 sub-watersheds to target total nitrogen instream yield, with reduction targets.

HUC12 ID Number	HUC12 Name	Modeled instream Yield (kg/ha/yr)	Modeled yield – target yield	Percent reduction to meet target	Target instream yield reduction
111101030102	Moores Creek	10.35	3.35	32%	30%
111101030103	Lower Muddy Fork	11.67	4.67	40%	40%
111101030302	Little Osage Creek	20.87	13.87	66%	65%
111101030403	Lake Wedington-Illinois River	9.88	2.88	29%	25%
111101030606	Lake Frances-Illinois River	8.23	1.23	15%	15%

4.5.5 Phosphorus

The average of at least 10 total phosphorus measurements from water quality monitoring stations within the Category 1 HUC12 were compared to the Ozark Highlands ecoregion target concentration (Table 4.15). This is part of the approach used by DEQ to identify waterbodies impaired by nutrients (DEQ, 2021). Water quality sampling was not conducted 2018-2022 in three (3) of the Category 1 HUC12s. Therefore, it is not possible to evaluate total phosphorus concentrations from these HUC12s. The average total phosphorus concentrations from the Illinois River stations in the two (2) Category 1 HUC12s where sampling was conducted 2018-2022 are a little higher than the ecoregion target concentration (Table 4.16).

Table 4.15. Comparison of mean total phosphorus concentrations from Category 1 HUC12 sub-watersheds to Ozark Highlands ecoregion target total phosphorus concentration.

HUC12 ID Number	HUC12 Name	Waterbody	Water Quality Station ID	Sampling Organization	2018-2022 Average Total Phosphorus, mg/L	Percent difference from 0.07 mg/L (difference/0.07)	Reduction to meet 0.07 (difference/ average)
111101030403	Lake Wedington-Illinois River	Illinois River	ARK40	DEQ	0.070	0	0
			Savoy	AWRC	0.21	200%	67%
			71948000	USGS	0.074	6%	5%
111101030606	Lake Frances-Illinois River	Illinois River	ARK0006	DEQ	0.067	-4%	0
			IR59	AWRC	0.17	143%	59%
			07195430	USGS	0.083	18%	16%
111101030102	Moores Creek	Moores Creek			--		
111101030103	Lower Muddy Fork	Muddy Fork			--		

Table 4.16 Comparison of total phosphorus measurements to Oklahoma water quality standard.

HUC12 ID Number	HUC12 Name	Waterbody	Water Quality Station ID	Sampling Organization	2018-2022 Average Total Phosphorus, mg/L	Percent difference from 0.037 mg/L (difference/0.037)	Reduction to meet 0.037 (difference/ average)
111101030606	Lake Frances-Illinois River	Illinois River	ARK0006	DEQ	0.067	81%	45%
			IR59	AWRC	0.17	359%	78%
			07195430	USGS	0.083	124%	55%

Table 4.17 shows a comparison of SWAT modeled total phosphorus instream yields to target instream yield (1.0 kg/ha/yr). Table 4.18 shows a comparison of SWAT modeled total phosphorus yields from Category 1 HUC12s to the target yield.

Table 4.17. Comparison of modeled total phosphorus instream yields from Category 1 sub-watersheds to target total phosphorus instream yield (1.0 kg/ha/yr), with reduction targets.

HUC12 ID Number	HUC12 Name	Modeled instream Yield (kg/ha/yr)	Modeled yield – 1.0 kg/ha/yr	Percent reduction to meet target	Target instream yield reduction
111101030102	Moores Creek	2.01	1.01	50%	50%
111101030103	Lower Muddy Fork	2.10	1.10	52%	50%
111101030302	Little Osage Creek	0.85	-0.15	--	0
111101030403	Lake Wedington-Illinois River	2.72	1.72	63%	60%
111101030606	Lake Frances-Illinois River	3.52	2.52	72%	70%

Table 4.18. Comparison of modeled total phosphorus upland yields from Category 1 sub-watersheds to target total phosphorus load (1.3 kg/ha/yr), with load reduction targets.

HUC12 ID Number	HUC12 Name	SWAT modeled phosphorus upland yield, kg/ha/yr	Difference from 1.3 kg/ha/yr	Percent reduction to reach 1.3 kg/ha/yr (difference/modeled)	Load Reduction Target
111101030102	Moores Creek	1.0	-0.3	--	0
111101030103	Lower Muddy Fork	2.8	1.5	54%	50%
111101030302	Little Osage Creek	1.4	0.1	7%	5%
111101030403	Lake Wedington-Illinois River	1.9	0.6	32%	30%
111101030606	Lake Frances-Illinois River	3.6	2.3	64%	60%

4.5.6 Summary

Table 4.19 lists the Category 1 sub-watersheds and target pollutants, with the applicable load reduction targets for this plan. For nitrogen, phosphorus, and sediment, more than one approach was used to evaluate the need for load reduction. The reduction target values presented in Table 4.19 are the largest of the percent reduction values calculated.

Table 4.19. Summary of load reduction targets for Upper White River Category 1 sub-watersheds. See notes for explanation of symbols and abbreviations.

Category 1 Sub-watersheds		Load Reduction Targets					
HUC12 ID Number	**HUC12 Name**	***E. coli***	**Chloride**	**Sediment[a]**	**Sulfate**	**Total Nitrogen[a]**	**Total Phosphorus[b]**
111101030102	Moores Creek	D	N	80%	D	30%	50%
111101030103	Lower Muddy Fork	D	N	10%	D	40%	50%
111101030302	Little Osage Creek	D	N	60%	N	65%	5%
111101030403	Lake Wedington-Illinois River	D	*	70%	10%	25%	60%
111101030606	Lake Frances-Illinois River	D	*	80%	10%	15%	70%

a = instream yield reduction target (upland reduction targets were less for all HUC12s)
b = maximum of instream and upland reduction targets
N = This pollutant will not be targeted in this sub-watershed
D = There is not enough data/information to set load reduction targets for this pollutant, but management recommendations for other pollutants will reduce this pollutant
* = Data from 2018-2022 indicate target may currently be met, however management recommendations for other pollutants will address this pollutant.

4.6 Nonpoint Pollution Sources in Category 1 Sub-Watersheds

Water quality issues and pollutant sources identified for each of the Category 1 sub-watersheds, in analyses for this plan and other studies, are discussed below.

4.6.1 Moores Creek

Pollutants of concern in the Moores Creek sub-watershed are nutrients, sediment, pathogens, and sulfate. Moores Creek in this sub-watershed is classified as impaired due to high levels of pathogens and sulfate. This sub-watershed has the third highest risk of excess nutrients and excess pathogens from the 2015 State Resource Assessment, in the Upper Illinois River watershed. SWAT model results indicate that instream sediment yield from this sub-watershed is on the high end for this watershed. Modeled instream sediment, total nitrogen, and total phosphorus yields are greater than the targets for this plan (Table 4.19). Streams in this sub-watershed are also potential habitat for the endangered Neosho Mucket mussel and the threatened Rabbitsfoot mussel and Missouri Bladderpod plant.

4.6.1.1 Moores Creek Nonpoint Sources Recommended for Management

High modeled instream sediment yield suggests that streambank and channel erosion may be the greatest source of Moores Creek sediment load. However, observations do not support this conclusion. There are two (2) streambanks on Moores Creek that were part of a recent streambank erosion study in the Illinois River watershed. Annual bank erosion rates at these sites were classified as low, and projected streambank erosion rates along Moores Creek were estimated to be moderate to low (Natural State Streams, LLC, 2021). The area lost to streambank erosion estimated by Fox (2023) for this HUC12 was one (1) of the lowest in the watershed. As a result, streambank and channel erosion will not be a targeted nonpoint source of pollutants in this sub-watershed.

Upland nonpoint pollutant sources will be targeted in this sub-watershed under this plan. The 2015 State Resource Assessment classifies the risk of streambank, gully, and sheet/rill/wind erosion in this HUC12 as above average for Arkansas, but these risks are not in the top 20 percent for the Upper Illinois River watershed (Figures 3.23-3.25). SWAT model results indicate that pasture is the source of almost half of the upland sediment load from this HUC12 (Appendix L).

Potential sources of pathogens in this sub-watershed include livestock, runoff from pastures, failing septic systems, and groundwater. Fifty-five percent of this sub-watershed was pasture in 2019 (9,152 acres), and 43 percent of the land within 50 meters of a stream (687 acres) was pasture. Based on reported cattle inventories and acres of pasture reported in Washington County for 2022, we estimate there could be over 5,000 cows pastured in this HUC12. Poultry litter was applied to pastures in this HUC12 in 2019 and 14 poultry houses were reported to be operating in the HUC12 that year (T. Wentz, Natural Resources Division, personal communication, 5/12/2022). Available information suggests that there are 210 septic systems active in this HUC12 (Appendix M). The number of failing septic systems is not known. Failing septic systems close to streams are of particular concern. However, given the prevalence of karst features in the Upper

Illinois River watershed, a failing septic system just about anywhere has the potential to contribute *E. coli* to Moores Creek. USGS estimates that groundwater accounts for approximately one-third of the flow at the mouth of Moores Creek (USGS, 2024).

SWAT model results indicate that pasture is the source of 58 percent of upland phosphorus load and 78 percent of upland nitrogen load. Pathogen sources in this sub-watershed area also potential sources of nitrogen and phosphorus. Figure 4.2 shows locations of potential nonpoint pollution sources in the Moores Creek sub-watershed.

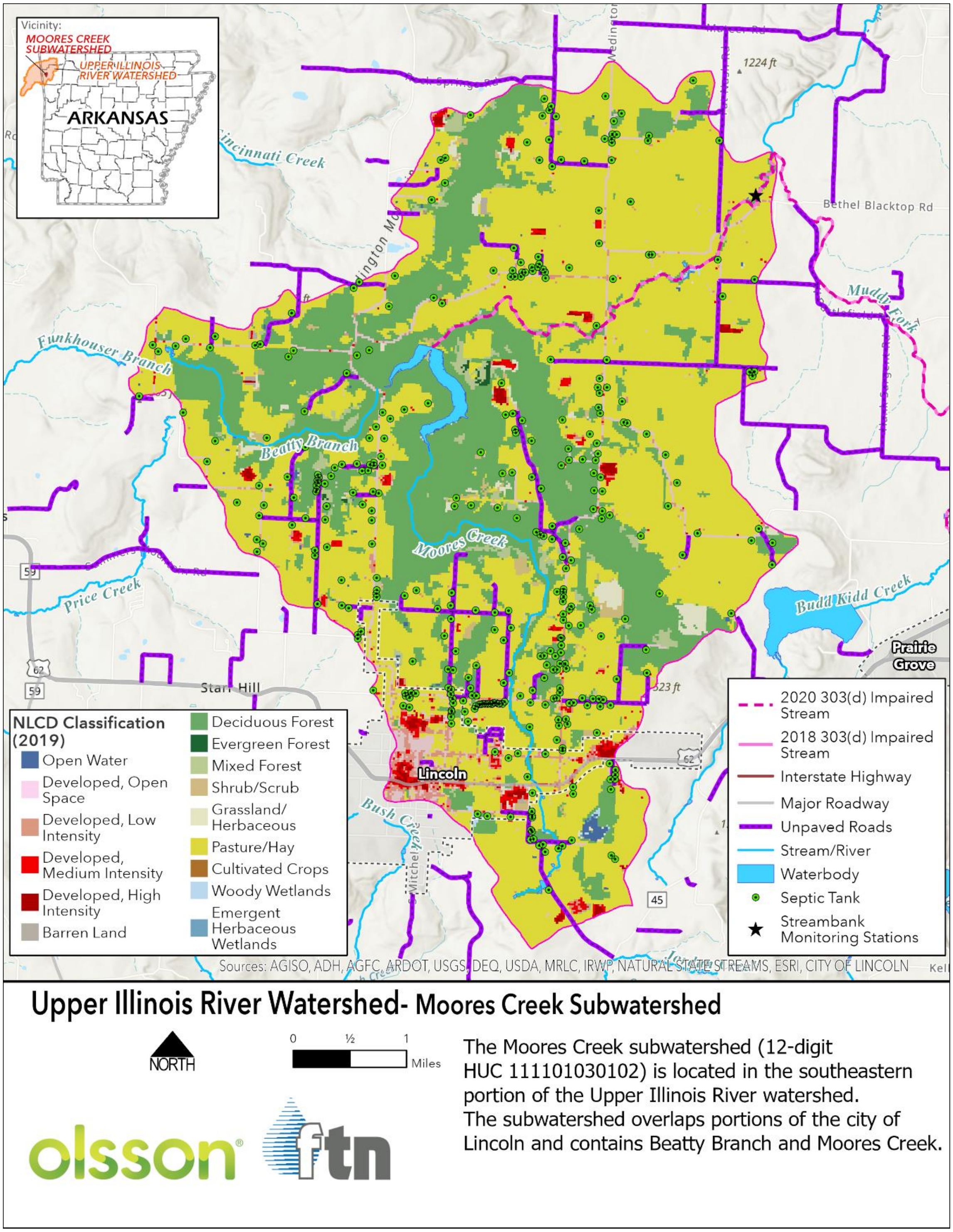

Figure 4.2 Upper Illinois River Watershed Moores Creek Subwatershed.

4.6.1.2 Plan Management Focus for Moores Creek

The suggested focus for the Moores Creek sub-watershed includes improved management of riparian areas as well as reduction of sediment and nutrient inputs from pastures and failing septic systems. In addition, prevention of groundwater contamination is recommended. Improved understanding of sources of sulfate and *E. coli* contributing to water quality impairment, and potential water quality threats to local populations of threatened and endangered species, as well as overall habitat degradation, is also suggested.

4.6.2 Lower Muddy Fork

Pollutants of concern in the Lower Muddy Fork sub-watershed are nutrients, pathogens, and sulfate. Lower Muddy Fork in this sub-watershed is classified as impaired due to high levels of sulfate and E. coli. This sub-watershed has the second highest risk of excess nutrients and excess pathogens, and risks of excess sediment and habitat degradation in the top 10 from the 2015 State Resource Assessment, in the Upper Illinois River watershed. SWAT model results indicate that instream total phosphorus yield from this sub-watershed is on the high end for the watershed. Modeled instream sediment, total nitrogen, and total phosphorus yields are greater than the targets for this plan (Table 4.19). Streams in this sub-watershed are also potential habitat for the endangered Neosho Mucket mussel and the threatened Rabbitsfoot mussel and Missouri Bladderpod plant.

4.6.2.1 Nonpoint Sources Recommended for Management

Potential sources of pathogens in this sub-watershed include livestock, runoff from pastures, failing septic systems, and groundwater. Sixty-eight percent of this sub-watershed was pasture in 2019 (9,143 acres), and 64 percent of the land within 50 meters of a stream (600 acres) was pasture. Based on reported cattle inventories and acres of pasture reported in Washington County for 2022, we estimate there could be over 5,000 cows pastured in this HUC12. Poultry litter was applied to pastures in this HUC12 in 2019 and 24 poultry houses were reported to be operating in the HUC12 that year (T. Wentz, Natural Resources Division, personal communication, 5/12/2022). Available information suggests that there are 173 septic systems active in this HUC12 (Appendix I). The number of failing septic systems is not known. Failing septic systems close to streams are of particular concern. However, given the prevalence of karst features in the upper Illinois River watershed, a failing septic system just about anywhere has the potential to contribute *E. coli* to Muddy Fork. USGS estimates that groundwater accounts for approximately one-third of the flow at the mouth of Muddy Fork (USGS, 2024).

Although sediment the sediment reduction target for sediment is rather low, field observations indicate that streambank erosion is a concern in this sub-watershed. There are two (2) streambanks on the Muddy Fork in this sub-watershed that were part of a recent streambank erosion study in the Illinois River watershed. Annual bank erosion rates at these sites were classified as very high. This study predicted that almost a mile of streambank in this sub-watershed is eroding at an average rate of over two (2) feet each year (Natural State Streams, LLC, 2021). The 2015 State Resource Assessment classifies the risk of streambank, gully, and sheet/rill/wind erosion in this HUC12 as above average for Arkansas, and risks of streambank and gully erosion are in the top 20 percent for the Upper Illinois River watershed (Figures 3.23-3.25).

SWAT model results indicate that pasture is the source of 86 percent of upland phosphorus load. Pathogen sources in this sub-watershed area also potential sources of phosphorus. Streambank erosion is also a possible source contributing to instream phosphorus load in Lower Muddy Fork. Legacy phosphorus stored in stream sediments is another potential source contributing to instream phosphorus load in this sub-watershed.

SWAT model results indicate that pasture is the source of 86 percent of upland nitrogen load. Pathogen sources in this sub-watershed area also potential sources of nitrogen. Figure 4.3. shows locations of potential nonpoint pollution sources in the Lower Muddy Fork sub-watershed.

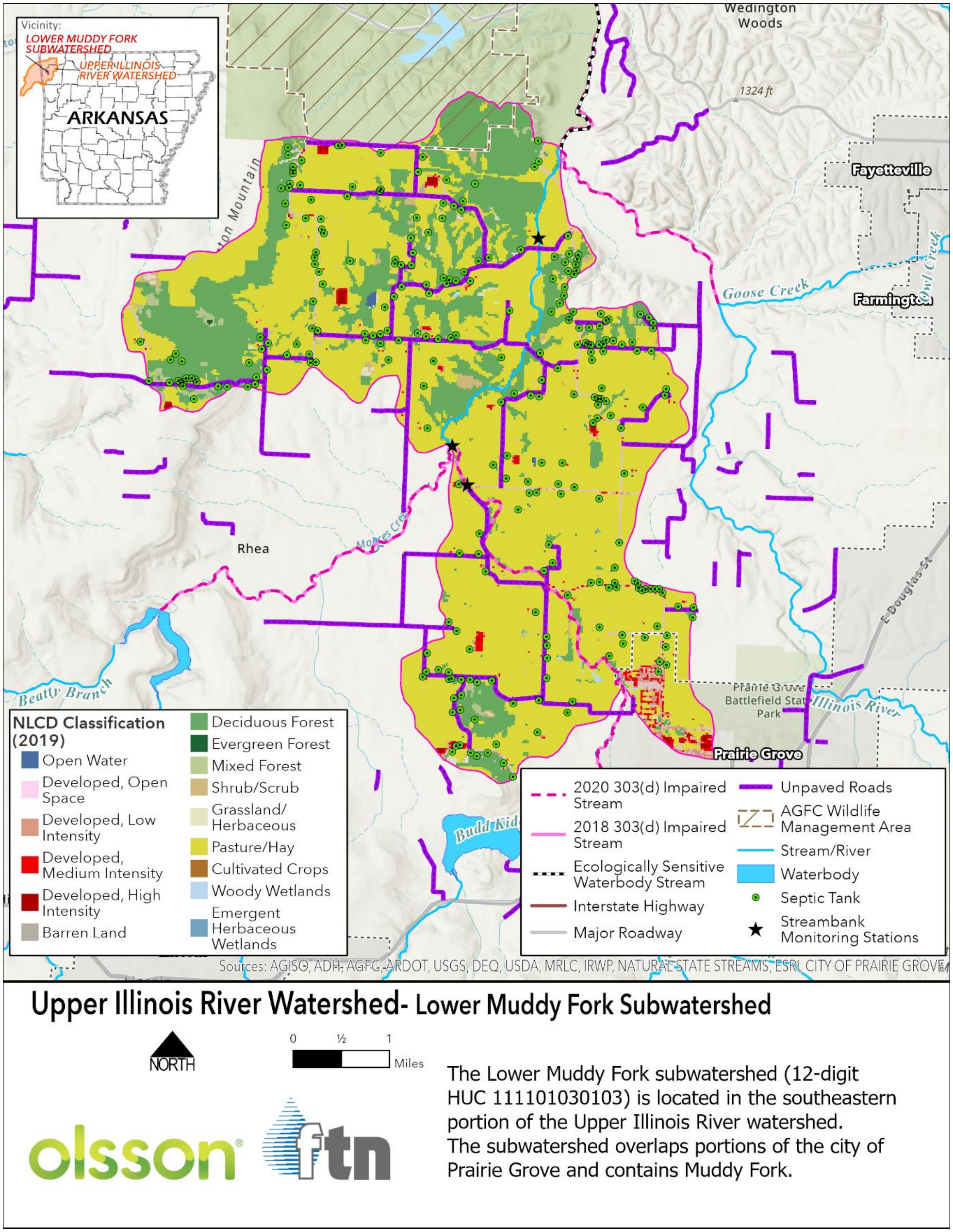

Figure 4.3 Shows locations of potential nonpoint pollution sources in Lower Muddy Fork sub-watershed.

4.6.2.2 Plan Management Focus for Lower Muddy Fork

The suggested focus for the Lower Muddy Fork sub-watershed includes improved management of riparian areas, reduction of nutrient and pathogen inputs from pastures and failing septic systems, and restoration of streambanks with excessive erosion. In addition, prevention of groundwater contamination is recommended. Improved understanding of sources of *E. coli* contributing to water quality impairment, and potential water quality threats to local populations of threatened and endangered species, as well as overall habitat degradation, is also suggested.

4.6.3 Little Osage Creek

Pollutants of concern in the Little Osage Creek sub-watershed are nutrients, sediment, and pathogens. Little Osage Creek in this sub-watershed is classified as impaired due to high levels of pathogens. This sub-watershed has the highest risk of excess nutrients and excess pathogens, and risks of excess sediment and habitat degradation in the top 10 percent from the 2015 State Resource Assessment, in the Upper Illinois River watershed. SWAT model results indicate that instream total nitrogen yield from this sub-watershed is on the high end for this watershed. Modeled instream sediment, total nitrogen, and total phosphorus yields are greater than the targets for this plan (Table 4.19). This sub-watershed includes the recharge area for Hewlitts Springs. Streams in this sub-watershed are also potential habitat for listed threatened and endangered species: Neosho Mucket, Rabbitsfoot mussel, Ozark Cavefish, and Benton County Cave Crayfish.

4.6.3.1 Nonpoint Sources Recommended for Management

Potential sources of pathogens in this HUC12 include livestock, runoff from pastures, septic systems, runoff from developed areas, and groundwater. Sixty-two percent of this sub-watershed was pasture in 2019 (18,428 acres), and 62 percent of the land within 50 meters of a stream (1,748 acres) was pasture. Poultry litter was applied to pastures in this HUC12 in 2019 and 34 poultry houses were reported to be operating in the HUC12 that year (T. Wentz, Natural Resources Division, personal communication, 5/12/2022). Based on reported cattle inventories and acres of pasture reported in Benton County for 2022, we estimate there could be around 13,000 cows pastured in this HUC12. In 2019, 25 percent of this sub-watershed was developed (7,501 acres), and 18 percent of the land within 50 meters of a stream (512 acres) was developed. Available information suggests that there are 434 septic systems active in this HUC12 (Appendix I). The number of failing septic systems is not known. Failing septic systems close to streams are of particular concern. However, given the prevalence of karst features in the upper Illinois River watershed, a failing septic system just about anywhere has the potential to contribute pathogens to Little Osage Creek. USGS estimates that groundwater accounts for approximately one-half of the flow at the mouth of Little Osage Creek (USGS, 2024).

Potential sediment sources in this sub-watershed include runoff from pastures and development, and streambank erosion. The 2015 State Resource Assessment classifies the risk of streambank, gully, and sheet/rill/wind erosion in this HUC12 as above average for Arkansas, and the streambank erosion risk is in the top 20 percent for the Upper Illinois River watershed (Figures 3.23-3.25). Fox (2023) estimated that almost 14 hectares of land was lost to streambank erosion in this sub-watershed between 2010 and 2019, the sixth largest area in the Upper Illinois River watershed.

SWAT model results indicate that pasture is the source of 51 percent of upland nitrogen load and development contributes 44 percent. Pathogen sources in this sub-watershed are also potential sources of nitrogen.

SWAT model results indicate that pasture is the source of 60 percent of upland phosphorus load, and development contributes 39 percent of the load. Pathogen sources in this sub-watershed are also potential sources of phosphorus. Streambank erosion is also a possible source contributing to instream phosphorus load in Little Osage Creek. Legacy phosphorus stored in stream sediments is another potential source contributing to instream phosphorus load in this sub-watershed. Figure 4.4 shows locations of potential nonpoint pollution sources in the Little Osage Creek sub-watershed.

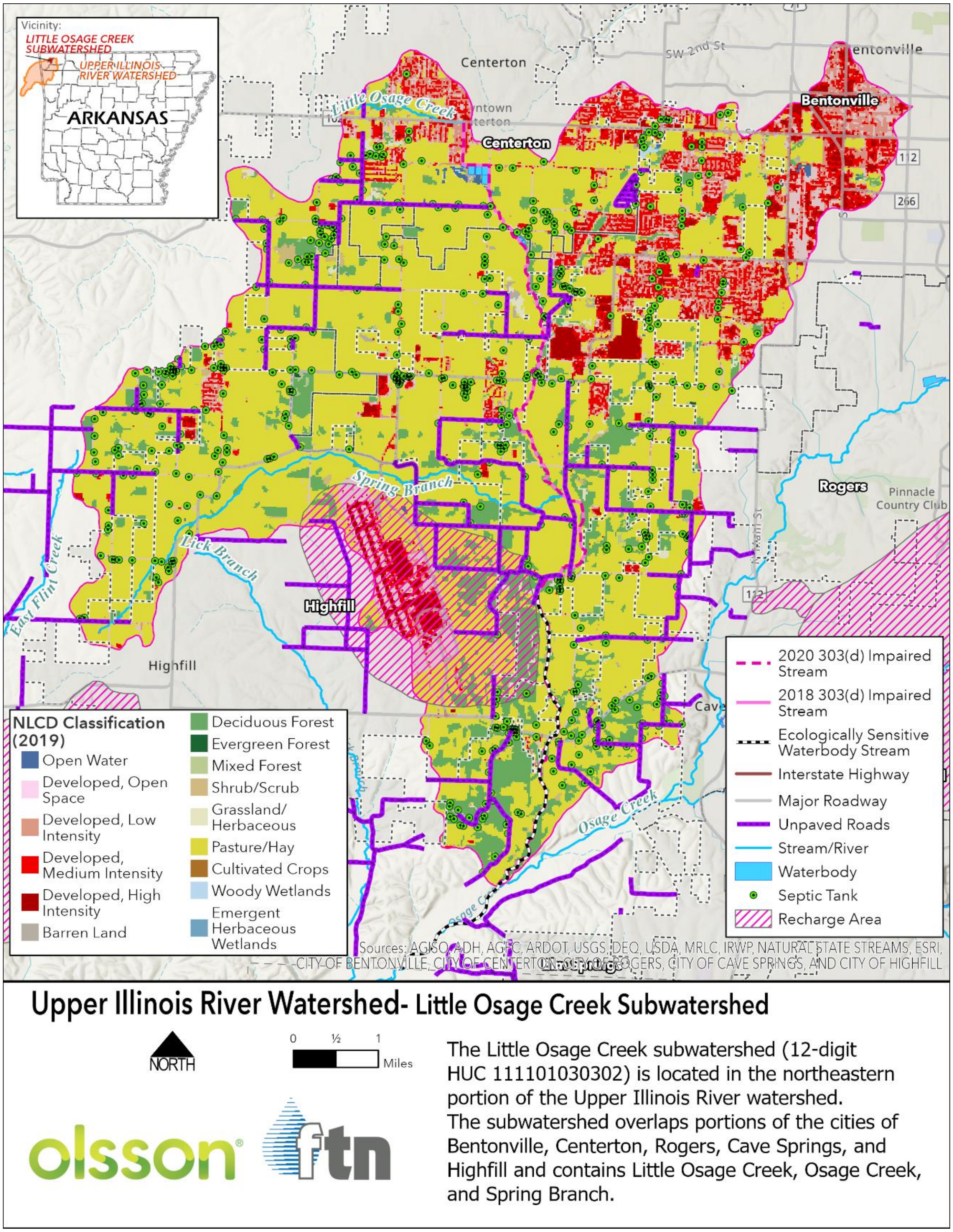

Figure 4.4. shows locations of potential nonpoint pollution sources in the Little Osage Creek sub-watershed.

4.6.3.2 Plan Management Focus for Little Osage Creek

The suggested focus for the Little Osage Creek sub-watershed includes improved management of riparian areas; reduction of nutrient and pathogen inputs from pastures, development, and failing septic systems; and restoration of streambanks with excessive erosion. In addition, prevention of groundwater contamination is recommended. Improved understanding of sources of *E. coli* contributing to water quality impairment, and potential water quality threats to local populations of threatened and endangered species, as well as overall habitat degradation, is also suggested.

4.6.4 Lake Wedington-Illinois River

Pollutants of concern in the Lake Wedington-Illinois River sub-watershed are phosphorus, sediment, pathogens, and sulfate. Lake Wedington-Illinois River in this sub-watershed is classified as impaired due to high levels of turbidity, chloride, sulfate, and pathogens. This sub-watershed has the second highest risk of excess sediment and habitat degradation from the 2015 State Resource Assessment, in the Upper Illinois River watershed. SWAT model results indicate that instream total phosphorus and sediment yields from this sub-watershed are on the high end for this watershed. Modeled instream sediment, total nitrogen, and total phosphorus yields are greater than the targets for this plan (Table 4.19). Streams in this sub-watershed are also potential habitat for listed threatened and endangered species: Neosho Mucket, Rabbitsfoot mussel, Ozark Cavefish, Benton County Cave Crayfish, and Missouri Bladderpod.

4.6.4.1 Nonpoint Sources Recommended for Management

Potential sources of pathogens in this sub-watershed include livestock, runoff from pastures, failing septic systems, and groundwater. Thirty-two percent of this sub-watershed was pasture in 2019 (5,988 acres), and 28 percent of the land within 50 meters of a stream (546 acres) was pasture. Based on reported cattle inventories and acres of pasture reported in Benton and Washington Counties for 2022, we estimate there could be over 4,000 cows pastured in this HUC12.i Poultry litter was applied to pastures in this HUC12 in 2019 and 33 poultry houses were reported to be operating in the HUC12 that year (T. Wentz, Natural Resources Division, personal communication, 5/12/2022). Available information suggests that there are 179 septic systems active in this HUC12 (Appendix I). The number of failing septic systems is not known. Failing septic systems close to streams are of particular concern. However, given the prevalence of karst features in the upper Illinois River watershed, a failing septic system just about anywhere has the potential to contribute *E. coli* to Illinois River. USGS estimates that groundwater accounts for approximately 40 percent of the flow of Illinois River just upstream of Osage Creek (USGS, 2024).

Potential nonpoint sources of sediment in this sub-watershed are runoff from pasture and streambank erosion. SWAT model results indicate that 88 percent of upland sediment load is from pasture. There are two (2) streambanks on Lake Wedington-Illinois River that were part of a recent streambank erosion study in the Illinois River watershed where average annual erosion rates were classified as “extreme”. This study predicted that almost two miles of streambank in this sub-watershed is eroding at an average rate of over two (2) feet each year (Natural State Streams, LLC, 2021).

SWAT model results indicate that pasture is the source of 75 percent of upland phosphorus load. Pathogen sources in this sub-watershed are also potential sources of phosphorus. Streambank erosion is also a possible source contributing to instream phosphorus load in Illinois River. Legacy phosphorus stored in stream sediments is another potential source contributing to instream phosphorus load in this sub-watershed.

SWAT model results indicate that pasture is the source of 94 percent of upland nitrogen load Pathogen sources in this sub-watershed are also potential sources of nitrogen. Figure 4.5 shows locations of potential nonpoint pollution sources in the Lake Wedington-Illinois River sub-watershed.

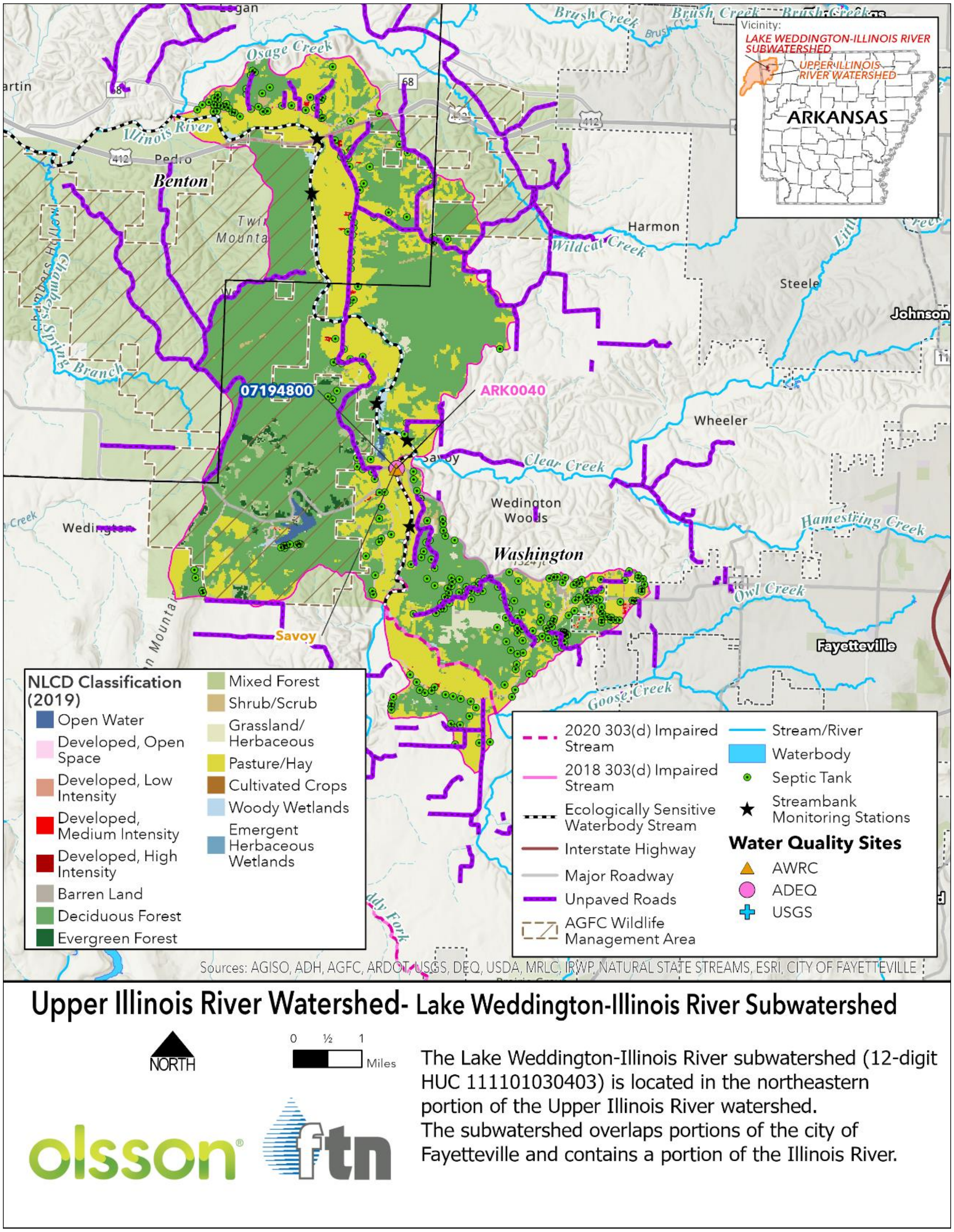

Figure 4.5. Shows locations of potential nonpoint pollution sources in the Lake Wedington-Illinois River sub-watershed.

4.6.4.2 Plan Management Focus for Lake Wedington-Illinois River

The suggested focus for the Lake Wedington-Illinois River sub-watershed includes improved management of riparian areas; reduction of nutrient and pathogen inputs from pastures and failing septic systems; and restoration of streambanks with excessive erosion. In addition, prevention of groundwater contamination is recommended. Improved understanding of sources of sulfate and *E. coli* contributing to water quality impairment, and potential water quality threats to local populations of threatened and endangered species, as well as overall habitat degradation, is also suggested.

4.6.5 Lake Frances-Illinois River

Pollutants of concern in the Lake Frances-Illinois River sub-watershed are phosphorus, sediment, pathogens, and sulfate. Lake Frances-Illinois River in this sub-watershed is classified as impaired due to high levels of chloride and sulfate. This sub-watershed has the highest risk of excess sedimentation from the 2015 State Resource Assessment, in the Upper Illinois River watershed. SWAT model results indicate that instream total phosphorus and sediment yield from this sub-watershed is on the high end for this watershed. Modeled instream sediment, total nitrogen, and total phosphorus yields are greater than the targets for this plan (Table 4.19). Streams in this sub-watershed are also potential habitat for the threatened and endangered species: Neosho Mucket, Rabbitsfoot mussel, Benton County Cave Crayfish, and Missouri Bladderpod.

4.6.5.1 Nonpoint Sources Recommended for Management

Potential nonpoint sources of sediment in the Lake Frances-Illinois River sub-watershed include pasture runoff and streambank erosion. SWAT model results indicate that pasture is the source of 85 percent of upland sediment load. Thirty-five percent of this sub-watershed was pasture in 2019 (8,916 acres), and 30 percent of the land within 50 meters of a stream was pasture (595 acres). The 2015 State Resource Assessment classifies the risk of streambank, gully, and sheet/rill/wind erosion in this HUC12 as above average for Arkansas, and these erosion risks for this sub-watershed are the highest in the Upper Illinois River watershed (Figures 3.23-3.25). There is one streambank on the Illinois River in this sub-watershed that was part of a recent streambank erosion study in the Upper Illinois River watershed. The annual average bank erosion rate at this site was classified as high. This study predicted that around three-quarters of a mile of streambank in this sub-watershed is eroding at an average rate of over two (2) feet each year (Natural State Streams, LLC, 2021). The estimated area of land in this sub-watershed lost to streambank erosion was the highest in the watershed (Fox, 2023).

Potential nonpoint sources of pathogens in this sub-watershed include livestock, runoff from pastures, failing septic systems, and groundwater. Based on reported cattle inventories and acres of pasture reported in Benton County for 2022, we estimate there could be over 6,000 cows pastured in this HUC12. Poultry litter was applied to pastures in this HUC12 in 2019 and 23 poultry houses were reported to be operating in the HUC12 that year (T. Wentz, Natural Resources

Division, personal communication, 5/12/2022). Available information suggests that there are 332 septic systems active in this HUC12 (Appendix I). The number of failing septic systems is not known. Failing septic systems close to streams are of particular concern. However, given the prevalence of karst features in the upper Illinois River watershed, a failing septic system just about anywhere has the potential to contribute phosphorus to Lake Frances-Illinois River. USGS estimates that groundwater accounts for approximately 40 percent of the flow of Illinois River just upstream of the state line (USGS, 2024).

SWAT model results indicate that pasture is the source of 94 percent of upland phosphorus load. Pathogen sources in this sub-watershed are also potential sources of phosphorus. Streambank erosion is also a possible source contributing to instream phosphorus load in Illinois River. Legacy phosphorus stored in stream sediments is another potential source contributing to instream phosphorus load in this sub-watershed.

SWAT model results indicate that pasture is the source of 84 percent of upland nitrogen load Pathogen sources in this sub-watershed are also potential sources of nitrogen. Figure 4.6 shows locations of potential nonpoint pollution sources in the Lake Frances-Illinois River sub-watershed.

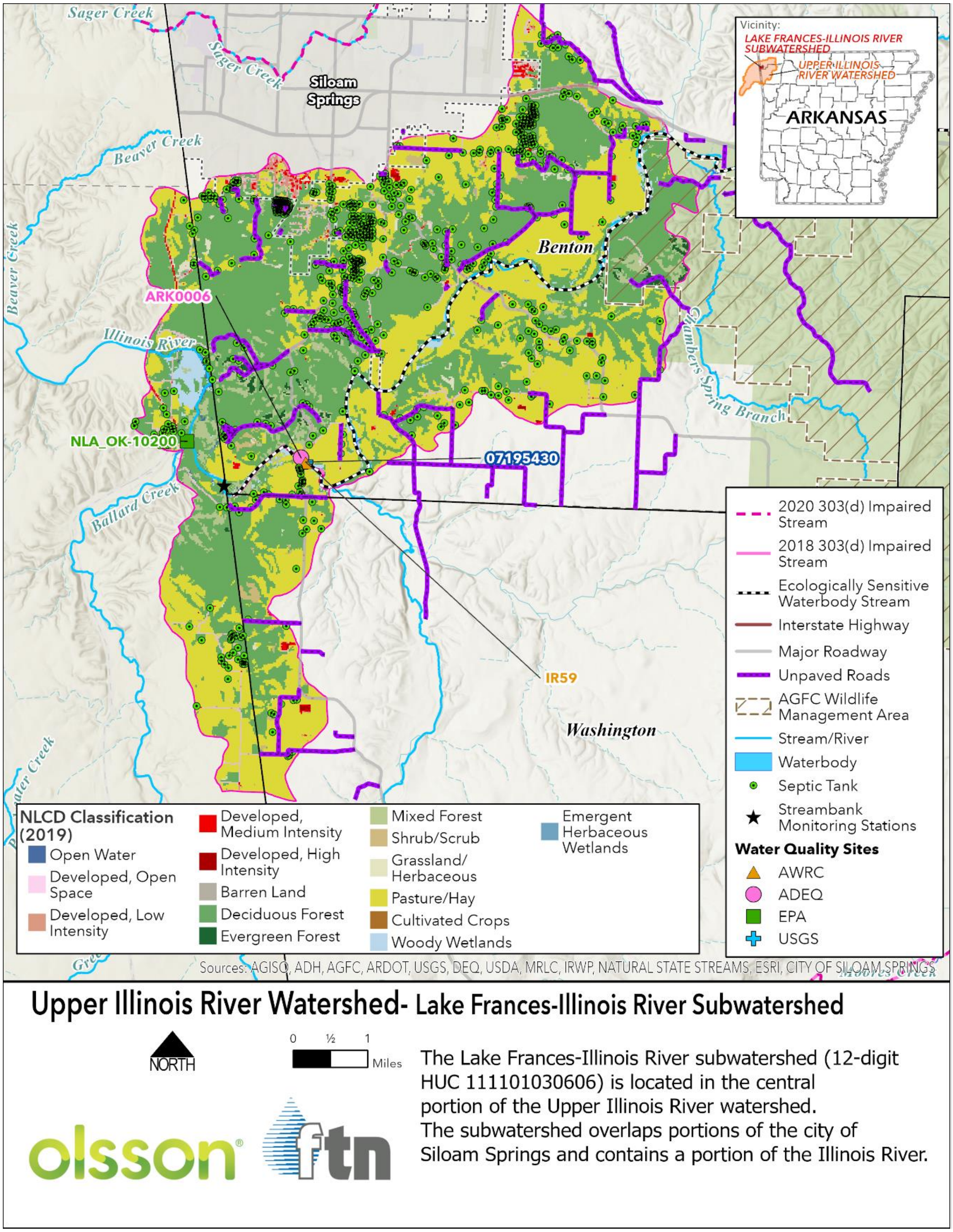

Figure 4.6. Shows locations of potential nonpoint pollution sources in the Lake Frances River sub-watershed – Illinois.

4.6.5.2 Plan Management Focus for Lake Frances-Illinois River

The suggested focus for the Lake Frances-Illinois River sub-watershed includes improved management of riparian areas; reduction of nutrient and pathogen inputs from pastures and failing septic systems; and restoration of streambanks with excessive erosion. In addition, prevention of groundwater contamination is recommended. Improved understanding of sources of sulfate contributing to water quality impairment, and potential water quality threats to local populations of threatened and endangered species is also suggested.

4.7 Management Practices

At the second public meeting for this watershed management plan, stakeholders were asked to identify management practices (BMPs) to address issues in the Upper Illinois River watershed. Table 4.20 lists the practices discussed at that meeting. These practices identified by stakeholders are applicable to the target pollutant and nonpoint sources in the Category 1 sub-watersheds.

Table 4.20. Management practices for the Upper Illinois River watershed recommended by stakeholders.

Practices for Rural Areas	Practices for Developed Areas
Streambank restoration	Rain gardens
Riparian restoration	Green streets
Conservation easements	Bioswales
Fencing to exclude cattle from streams	Permeable pavement
Poultry litter stacking sheds	Green roof
Litter export	Conservation easements
Convert excess poultry litter to biochar	Riparian buffers
	Phytoremediation
	Advanced treatment septic systems
	Recreation stewardship
	Detention pond retrofit
	Pet waste management
	Karst best management practices

These and other management practices appropriate for nonpoint sources present in the Category 1 sub-watersheds are discussed below by pollutant source. There are two (2) approaches for managing nonpoint source pollution inputs. The first is to reduce the sources of the pollutant that can end up in surface and groundwater. Examples of this approach include activities that reduce erosion, or exposure of manure or poultry litter to rainfall. The second approach is to implement measures that remove or capture pollutants in runoff. Examples of this approach include practices such as forested or grassed (herbaceous) riparian buffers and waterways that filter and capture pollutants from runoff.

4.7.1 Pasture Runoff

Nonpoint sources of pathogens and nutrients associated with pastures that could be reduced include livestock manure and applied fertilizer, including the use of poultry litter for fertilizer. The nonpoint source of sediment associated with pasture that could be reduced is field erosion, i.e. gully erosion and sheet/rill/wind erosion. Table 4.21 lists conservation practices that can reduce nutrient, pathogen, and sediment sources associated with pastures. Grazing management improves the pasture cover which helps prevent erosion. Heavy use area protection and the planting practices do the same. Pasture aeration is a practice that is recommended for the Beaver Lake watershed and could be applicable in the Upper Illinois River watershed (RTI International, 2023). Nutrient management plans help ensure that fertilizer is applied appropriately. Because the Upper Illinois River watershed is classified by the State as a Nutrient Surplus Area, all applications of fertilizer to pasture, including poultry litter, are required to be guided by a nutrient management plan prepared by a certified nutrient management planner (Arkansas Natural Resources Commission Title 22). Therefore, we assume that this practice is already in use for all pasture in the Upper Illinois River watershed.

Table 4.21 also lists the effectiveness of these practices identified through the NRCS Conservation Practice Physical Effects program (CPPE) (NRCS, 2024). Note that not all of the practices listed in Table 4.21 have been evaluated through the CPPE program. Prescribed grazing, heavy use area management, and pasture and hay planting are practices recommended by NRCS and IRWP for the Upper Illinois Rive watershed (IRWP, 2024). Land conservation, e.g., conservation easements, is a practice identified by stakeholders as appropriate for the Upper Illinois River watershed (Table 4.20).

Table 4.21. Practices that reduce pasture erosion and sources of pathogens and nutrients. Where available, degree of effectiveness identified from the CPPE is included in parentheses.

Practice	NRCS Practice Code	Pathogens	Nutrients	Erosion
Prescribed grazing and grazing management	528	Slight	Slight	Moderate to substantial
Nutrient management plans		Moderate to substantial	Substantially	-
Heavy use area protection	561	-	-	Slight to moderate
Pasture & hay planting	512	-	Slight	Moderate to substantial
Pasture aeration		-	X	-
Critical area planting	342	Slight	Slight to moderate	Substantial
Land conservation		X	X	X

A survey of producers in the Beaver Lake watershed found that only 12.5 percent of respondents don’t aerate their pastures (Popp, et al., 2021). If we assume the results of this survey are representative of conditions in Northwest Arkansas, it appears that there may not be much need for increasing the area of pasture aeration in this region. Therefore, increasing pasture aeration will not be a focus of the recommendations in this plan. However, maintaining widespread use of this practice is beneficial.

Table 4.22 lists pasture conservation practices that have been identified by CPPE as removing substantial amounts of pathogens, sediment, and/or nutrients from runoff (NRCS, 2024). Some of these practices have been funded by NRCS programs in the Upper Illinois River watershed (R. Christianson, University of Illinois, personal communication 12/7/2021). Riparian forest buffer is a practice recommended by stakeholders, including NRCS and IRWP, for the Upper Illinois River watershed (IRWP, 2024).

Table 4.22 Pasture practices that remove pathogens, sediment, and/or nutrients from runoff (NRCS 2024) and are included in the Arkansas Conservation Practice Catalog (NRCS, 2012).

Practice Name	NRCS Practice Code	Effects quantification		
		Nutrient load	Pathogen load	Sediment load
Filter strip	393	Substantial	Moderate to substantial	Substantial
Riparian forest buffer	391	Substantial	Moderate	Substantial
Riparian herbaceous buffer	390	Substantial	Moderate	Moderate to substantial
Sediment basin	350	Substantial	Slight to moderate	Moderate to substantial
Vegetated treatment area	635	Moderate to substantial	Substantial	Minor to moderate
Constructed wetland	656	Moderate to substantial	Moderate to substantial	Substantial
Grassed waterway	412	Minor to moderate	Minor	Substantial
Critical area planting	342	Minor to moderate	None	Moderate to substantial
Pasture and hay planting	512	Slight	Slight	Slight

4.7.2 Streambank Erosion

Streambank erosion is a concern in both developed and agricultural (pasture and hayland) areas. In both developed and agricultural areas there are practices widely accepted as useful for reducing streambank erosion:

- Protection or restoration of riparian buffers to natural vegetation
- Reduced hydrologic alteration
- Streambank protection
- Streambank and/or channel restoration

These practices are in use in the Upper Illinois River watershed and are recommended by NRCS and IRWP for the Upper Illinois River watershed (IRWP, 2024). Streambank restoration is a practice recommended by stakeholders during public meetings (Table 4.20). Practices that can reduce hydrologic alteration in both developed and agricultural areas are discussed in Section 4.7.6. As noted in Section 3.3.2, there are stream banks in the Upper Illinois River watershed that have been identified as priorities for streambank and channel restoration (Natural State Streams, LLC, 2021). Some of these reaches are associated with developed areas, while others are associated with agricultural areas.

Through the CPPE program, NRCS has identified practices that substantially reduce erosion of streambanks associated with agricultural lands. These practices are listed in Table 4.23. Restoration of riparian areas, and excluding cattle from streams, e.g., access control, are practices recommended at public meetings (Table 4.20).

Table 4.23. NRCS practices that reduce streambank erosion (NRCS 2024).

Practice	NRCS Practice Code	CPPE effectiveness
Access Control	472	Substantial
Stream Crossing	578	Substantial
Stream habitat improvement and management	395	Substantial
Riparian Forest Buffer	391	Moderate to substantial
Riparian Herbaceous Cover	390	Moderate to substantial
Streambank and shoreline protection	580	Moderate to substantial

4.7.3 Unpaved Roads and Road Stream Crossings

Erosion and sediment loss from unpaved roads is reduced through the application of practices as part of Environmentally Sensitive Maintenance (ESM) of unpaved roads. These practices have been developed and tested by the US Forest Service and other leaders in the road industry. Examples of ESM practices include appropriate bridge and pipe design at stream crossings, grade breaks and broad dips for drainage control, increasing the number of drainage ditch outlets, and management of roadside and streamside vegetation. Both Benton and Washington County are certified in ESM through the Arkansas Unpaved Roads Program. Therefore, this plan assumes that unpaved county roads in Benton and Washington County are being maintained using ESM. Improper maintenance of municipal unpaved roads was identified as a concern during discussion of conservation practices at one of the public meetings.

Stream road crossings, especially culverts, can act as barriers to migration of fish and mussel species of concern (Slay, Knighten, & Gallipeau, 2018). In addition, they can alter stream geomorphology and contribute to streambank and channel erosion. These effects can be reduced through thoughtful design of new crossings or modification of existing crossings. This may involve replacing culverts, converting low water crossings to a culvert crossing, or converting a culvert crossing or low water crossing to a bridge (AGFC, 2023).

4.7.4 Livestock in Streams/Riparian Areas

Practices that reduce the amount of time livestock spend in streams and riparian areas reduce pathogen, nutrient, and sediment loads to streams. Pathogens and nutrients are reduced through reducing deposition of livestock waste in streams and riparian areas. Sediment (and possibly nutrients) are reduced through reduce streambank erosion caused by livestock. Table 4.24 shows practices that are often used to control livestock access to streams. Fencing off riparian areas and providing alternate water supplies can be implemented as part of a prescribed grazing program. Excluding livestock from riparian areas can be part of riparian restoration or protection. Benefits of these practices are listed in previous sections. Alternative water supplies and fencing are practices recommended by stakeholders, including NRCS and IRWP, for the Upper Illinois River watershed (IRWP, 2024).

Table 4.24. Practices that reduce stream pollutants through reducing the time livestock spends in streams and riparian areas (NRCS 2024).

Practice	Pathogens	Nutrients	Sediment	Streambank Erosion
Watering facility	Slight to moderate	Moderate to substantial	Slight to moderate	Moderate to substantial
Access control	Slight	Slight	Moderate	Substantial
Fence	Slight to moderate	None	Slight	Slight
Stream crossing	Slight to moderate	Slight	Slight to moderate	Substantial

4.7.5 Failing Septic Systems

The number of failing septic systems acting as sources of nutrients and pathogens can be reduced. This can be through either fixing (remediating) or replacing the failing system. Teaching septic system owners how to properly maintain their systems and supporting owners in proper maintenance prevents septic systems from becoming a source of pathogens and nutrients. These practices are supported by IRWP. Advanced treatment septic systems were recommended for the Upper Illinois River watershed during one of the public meetings (Table 4.20).

4.7.6 Hydrologic Alteration

Hydrologic alteration in the Upper Illinois River watershed is believed to be at least partially the result of land use change from forest to pasture and/or development. Pasture, especially poorly managed pasture, and developed areas have different infiltration and runoff characteristics than forest. In general, infiltration is lower for pastures and developed areas, and runoff is higher. However, there are management practices that can improve infiltration and/or reduce runoff from pastures and developed areas. In some areas of the Upper Illinois River watershed care must be taken to prevent infiltrating water from contaminating groundwater (see Section 4.7.9).

Pasture management practices that can improve infiltration and reduce runoff include prescribed grazing (EPA, 2003) and pasture aeration (Popp, et al., 2021) (Adams, et al., 2021).

In developed areas, Low Impact Development and Green Infrastructure practices increase infiltration and reduce stormwater runoff, potentially restoring or maintaining the natural hydrologic function of developed watersheds (EPA, 2023). Examples of these practices that are suggested by IRWP for the Upper Illinois River watershed include rain gardens, permeable pavement, retrofitting of stormwater detention basins, bioswales, rain barrels, and green roofs (IRWP, 2024). Rain gardens, green streets, bioswales, permeable pavement, and green roofs were identified at one of the public meetings as practices applicable in the Upper Illinois River watershed. Many of these practices have already been successfully implemented in the Upper Illinois River watershed.

USACE modeling confirmed that addition of runoff detention capacity can reduce flood levels during flood events. Modeled restoration of riparian buffers reduced stream velocities (flow rate), during flood events, which results in less streambank erosion. In some locations addition of riparian buffers reduced flood levels, however, in other locations flood levels increased due to the slower flow rate (Hart, Howe and Blankenship 2023).

4.7.7 Development Runoff

Several municipalities and Benton and Washington Counties in the Upper Illinois River watershed are subject to federal stormwater regulations intended to reduce nonpoint source pollution from development. These regulations require the regulated entities to develop plans to reduce sources of stormwater pollution, including erosion at construction sites, illicit wastewater discharges to storm sewers, pet waste, trash, car washing, vehicle leaks, dumping into storm drains, materials stored outside, and combined sewer overflow incidents. Thus, the only management practice recommended in this plan for addressing these nonpoint pollution sources associated with development is to continue to implement the existing stormwater management plans that apply in the Upper Illinois River watershed.

Nutrient management plans, and fertilizer application guidelines, training, and certification required in this Nutrient Surplus Area are practices that help reduce improper fertilizer application. Improper fertilizer application may also contribute sulfate to runoff. This plan recommends and supports continued use of these practices.

Reducing the amount of runoff from developed areas, by using LID and Green Infrastructure practices (Section 4.7.6), also reduces pollutant loads to surface waters. However, some LID and Green Infrastructure practices that encourage water infiltration have the potential to increase pollutant inputs to groundwater. This is an important consideration in the Upper Illinois River watershed. Many LID and Green Infrastructure practices can remove nutrients and other chemicals, pathogens, and sediment from stormwater runoff from developed areas. Examples of such practices that are suggested by IRWP (and other stakeholders) for the Upper Illinois River watershed are detention pond retrofits, rain gardens, bioswales, and green streets (IRWP, 2024). Other examples include media filters, hydrodynamic separators, conservation or restoration of riparian buffers, and grassed waterways.

4.7.8 Poultry Operations

The primary nonpoint source of nutrients and pathogens at poultry operations that can be reduced is poultry litter stored in the open. Management practices that can reduce this source include storing litter outside for only short periods, transport or transfer of litter off-site, and use of Waste Storage Facilities. Practices that can remove nutrients and pathogens from poultry operation runoff include filter strips, grassed waterways, and vegetated treatment areas. Table 4.25 lists selected practices appropriate for poultry feeding operations and their CPPE effectiveness. Most of these practices have been funded by NRCS programs in the Upper Illinois River watershed (R. Christianson, University of Illinois, personal communication 12/7/2021). Waste storage facilities, e.g., stacking sheds, were suggested as an appropriate and useful management practice at one of the public meetings (Table 4.20).

Table 4.25. Selected practices appropriate for poultry feeding operations and their pollutant reduction effectiveness.

Practice	Pathogens	Nutrients
Animal mortality facility	Slight to moderate	Slight to moderate
Amendments for treatment of agriculture waste	Slight to moderate	Slight to moderate
Roof runoff structure	Slight to moderate	Slight to moderate
Waste storage facility	Slight to moderate	Moderate to substantial
Composting facility	Slight to moderate	Slight to moderate
Filter strip	Moderate to substantial	Substantial
Vegetated treatment area	Substantial	Moderate to substantial
Grassed waterway	Slight	Slight to moderate

Between 2008 and 2020 NRCS funded over 950 projects implementing Amendment for Treatment of Agricultural Waste (R. Christianson, University of Illinois, personal communication

12/7/2021). Therefore, we assume this is a practice already widely used that does not need to be a focus for implementation under this plan.

4.7.9 Groundwater

Groundwater pollutant contributions are reduced by preventing the pollutants from entering the groundwater. However, it should be noted that groundwater trace studies have shown that groundwater can carry pollutants across hydrologic boundaries, i.e., outside of a river basin. The NRCS conservation practice standard for sinkhole treatment recommends the use of riparian buffers and/or filter strip practices, possibly with fencing, to prevent transfer of pollutants to groundwater (NRCS, 2021). US Fish and Wildlife Service also recommends buffers around karst features, and losing streams, in the Upper Illinois River watershed (P. Ardapple-Kindberg, USFWS, personal communication 8/22/2023). Table 4.26 lists selected practices that have been identified by CPPE as effective for reducing the transport of nutrients and/or pathogens to groundwater. Table 4.27 lists other agricultural conservation practices identified in Section 4.7.1, 4.7.4, and 4.7.8 with their effect identified by CPPE on transport of nutrients and pathogens to groundwater. Practices highlighted in yellow have the potential to increase transport of nutrients and/or pathogens to groundwater and are not recommended for the Upper Illinois River watershed. Practices that reduce groundwater contamination from developed areas include appropriately designing, installing, and maintaining septic systems; repairing or replacing failing septic systems; fixing vehicle leaks, and detecting and fixing leaks in municipal wastewater collection infrastructure.

Table 4.26. Practices that reduce transport of pathogens and nutrients to groundwater (NRCS, 2024).

Practice	CPPE reported efficiency	
	Pathogens	Nutrients
Nutrient management plans	Moderate to substantial	Substantial
Forested riparian buffer	Slight	Substantial
Herbaceous riparian buffer	Slight to moderate	Substantial
Filter strip	Slight	Slight
Fence	Neutral	Slight
Critical area planting	Slight	Slight

Table 4.27. Impacts of other agricultural conservation practices on transport of nutrients and pathogens to groundwater (NRCS, 2024).

Practice Name	NRCS Practice Code	Effects quantification	
		Nutrient load	Pathogen load
Constructed wetland	656	Slight improvement	Slight improvement
Critical area planting	342	Slight improvement	Slight improvement
Filter strip	393	Slight improvement	Slight improvement
Grassed waterway	412	No effect	No effect
Heavy use area protection	561	No effect	No effect
Land conservation		--	--
Nutrient management	590	Substantial improvement	Moderate to substantial improvement
Pasture and hay planting	512	No effect	No effect
Pasture aeration		--	--
Prescribed grazing and grazing management	528	Slight improvement	Slight improvement
Sediment basin	350	Slight worsening	Slight worsening
Vegetated treatment area	635	Slight to moderate worsening	No effect
Constructed wetland	656	Slight improvement	Moderate improvement
Grassed waterway	412	No effect	No effect
Watering facility	614	No effect	slight improvement
Access control	472	Slight improvement	Slight improvement
Stream crossing	578	No effect	Slight to moderate improvement
Animal mortality facility	316	Slight to moderate improvement	Slight to moderate improvement
Amendments for treatment of agriculture waste	591	Slight to moderate improvement	Slight to moderate improvement
Roof runoff structure	558	Slight to moderate improvement	No effect
Waste storage facility	313	Slight to moderate improvement	Slight to moderate improvement
Composting facility	317	Slight to moderate improvement	Slight to moderate improvement

4.7.10 Sediment

Reducing inputs of pathogens and nutrient-laden sediment can help reduce their availability from sediment storage. Once pathogens and phosphorus are in waterbody sediments, it can be almost impossible to control release of pathogens and phosphorus from them. Chemical treatment of sediments to enhance binding of phosphorus has been used in ponds and reservoirs, with variable success. This is not an approach that is useful in river systems. Holistic, integrated practices that work to restore ecological function of watersheds, including stream restoration, have been recommended by some researchers as an approach that is more likely to be effective for reducing sediment pathogens and legacy phosphorus, and/or their effects (Jarvie, et al., 2013) (MacKenzie, Auger, Beitollahpour, & Gharabaghi, 2024).

4.8 Meeting Load Reduction Goals

Information has been published on the effectiveness of many of the BMPs identified in Section 4.7 for reducing selected pollutants in surface waters, including *E. Coli*, sediment, and nutrients. This information was used to estimate reductions of these parameters when appropriate BMPs are implemented. Table 4.28 lists ranges of estimated potential load reductions from implementing BMPs in the Category 1 sub-watersheds. *E. coli* reductions are included in Table 4.28 for information purposes even though no *E. coli* reduction targets are set in this plan. The assumptions and calculations used to develop these load reduction estimates are provided in Appendix M. Potential load reductions were calculated for only some of the many possible BMPs. Note that BMPs must be properly installed, operated, and maintained to achieve reported pollutant reduction efficiencies.

Table 4.28. Estimated potential nutrient, sediment, and E. coli load reductions from implementing example BMPs in the Category 1 sub-watersheds.

Subwatershed	Total phosphorus (reduction target)	Total nitrogen (reduction target)	Sediment (reduction target)	*E. Coli*
Moores Creek	8%-31%	5%-30% (30%)	0-29%	0-90%
Lower Muddy Fork Creek	1%-50% (50%)	1%-35% (40%)	0-53% (10%)	0-90%
Lake Wedington-Illinois River	3%-26% (60%)	1%-33% (25%)	24%-53% (70%)	0-90%
Little Osage Creek	0-35% (5%)	1%-26% (65%)	0-39% (60%)	0-90%
Lake Frances-Illinois River	3%-33% (70%)	1%-30% (15%)	24%-51% (80%)	0-90%

Bold text indicates the parameter is a targeted pollutant in the sub-watershed.
Light text indicates that the parameter is a concern in the sub-watershed but is not specifically targeted for management under this plan.

Olsson did not find information about the effectiveness of BMPs for reducing sulfate in runoff. Therefore, there are no calculations of the potential for reducing sulfate levels as a result of implementing BMPs. It is expected that practices that filter runoff or reduce the amount of stormwater runoff would also reduce the sulfate load from stormwater runoff.

4.9 Summary

Nonpoint source pollution concerns and management goals have been identified. Five (5) Category 1 HUC12 sub-watersheds have been identified in which to focus water quality improvement efforts under this plan. Pollutants targeted for reduction are nutrients, *E. coli*, sulfate, and sediment. Load reduction targets have been determined for nutrients and sediment for all five (5) Category 1 sub-watersheds, and reduction targets have been determined for sulfate for two (2) Category 1 sub-watersheds. Potential sources of nutrient, E. Coli, sulfate, and sediment loads have been identified, along with BMPs to reduce loads from these sources. A variety of practices addressing multiple nonpoint pollution sources will need to be implemented to achieve load reduction targets. Management summaries for each of the Category 1 sub-watersheds are provided below.

- **Moores Creek:** BMPs that reduce nonpoint source pollution from pasture, livestock, and poultry operations are encouraged, as well as restoration and protection of riparian areas.

- **Lower Muddy Fork:** BMPs that reduce nonpoint source pollution from pasture, livestock, and poultry operations are encouraged. Streambank stabilization or restoration is also encouraged for streambanks in this sub-watershed where high rates of erosion have been documented or predicted.

- **Lake Wedington-Illinois River:** BMPs that reduce nonpoint source pollution from pasture, livestock, and poultry operations are encouraged. Streambank stabilization or restoration is also encouraged for streambanks in this sub-watershed where high rates of erosion have been documented or predicted.

- **Little Osage Creek:** BMPs that reduce nonpoint source pollution from pasture, livestock, and poultry operations are encouraged. Low impact development practices are encouraged for developed areas in this sub-watershed. Practices that encourage infiltration should be avoided in the spring recharge area. Karst-compatible practices are encouraged in the recharge area. Streambank stabilization or restoration is encouraged for streambanks in this sub-watershed where there are high rates of erosion.

- **Lake Frances-Illinois River:** BMPs that reduce nonpoint source pollution from pasture, livestock, and poultry operations are encouraged. Low impact development practices are encouraged for developed areas in this sub-watershed. Streambank stabilization or restoration is encouraged for streambanks in this sub-watershed where high rates of erosion have been documented or predicted.

5. IMPLEMENTATION STRATEGY

The implementation strategy for the Upper Illinois River watershed management plan includes several elements and follows the adaptive management process. These elements are described in this section. In addition to implementing practices to manage unregulated nonpoint pollution sources, the implementation strategy includes:

- Information and education activities for watershed stakeholders
- An implementation lead to coordinate voluntary activities in Category 1 sub-watersheds
- Water quality and biological monitoring to document current conditions and any changes resulting from voluntary nonpoint source pollution management activities
- Criteria for evaluating progress
- Regular evaluations of progress toward plan goals
- Updates to the plan to accommodate changes in the watershed and/or in understanding of the watershed
- A proposed implementation schedule with milestones

5.1 Information and Education

Watershed management is fundamentally a social activity (Thornton & Laurin, 2005). While technical solutions to problems are necessary for effective watershed management, they are not sufficient. Decisions on how to protect and improve water quality, and implement BMPs, are ultimately based on the socioeconomic perceptions, beliefs, and values of landowners and stakeholders about how these technical solutions will affect them. The Information and Education objectives of this watershed plan, therefore, include the following:

- Increase local landowner and public awareness of the need for, and the benefits of, watershed restoration and protection practices
- Increase stakeholder support and participation in watershed management activities for water quality protection and improvement
- Improve stakeholder understanding of how water quality and environmental improvements contribute to increased economic and social capital in communities

5.1.1 Existing Outreach and Education in the Upper Illinois River Watershed

There are several organizations and partnerships active in the Upper Illinois River watershed that have outreach and education programs in place that can accomplish the Information and Education objectives of this plan (Table 5.1). The IRWP is active throughout the watershed and is focused on its mission “to improve the integrity of the Illinois River Watershed through public education, outreach, and implementation of conservation and restoration practices throughout the watershed.” Additionally, the University of Arkansas Division of Agriculture Cooperative Extension Service and Northwest Arkansas Regional Planning Commission (NWARPC) are partnering with seventeen NWA cities, Washington and Benton counties, and the University of Arkansas on a regional stormwater management approach with a focus on stormwater quality through the NWA Urban Stormwater Education Program.

Table 5.1. Examples of Outreach and Education projects and programs in the Upper Illinois River watershed.

Project Title (Lead Organization)	Start year	End year	Type of Project/funding source
Implementing Green Infrastructure Elements for Enhanced Water Quality in the Illinois River Watershed (IRWP)	2015	2025	CWA 319 Nonpoint Source Program
Connecting NPS Management to Receiving Streams through BMP Education and Demonstration (UAEX)	2015	2018	CWA 319 Nonpoint Source Program
North Arkansas Quail Focal Landscape Project (NRCS, AGFC)	2018	2021	Regional Conservation Partnership Program (RCPP)
Growing Conservation in the Illinois River Watershed Project (NRCS, ADA Division of Forestry, AGFC)	2018	2019	Regional Conservation Partnership Program (RCPP)
Western AR/SE OK Woodland Restoration: A Joint Chief's Landscape Restoration Partnership Project (NRCS - USFS)	2018	2021	USDA-NRCS
IRWP Programs-Landowner Services Technical Assistance Educational materials on streambank restoration, riparian buffers, land conservation, residential LID, commercial/industrial LID and related topics mailed to landowners: 5162 Number of field tours: 9 Number of attendees at field tours: 239 Conservation plans prepared: 12	2016	Ongoing	USDA-NRCS
Unpaved Roads BMP Demonstration Project for the Illinois River Watershed (IRWP)	2019	2021	CWA 319 Nonpoint Source Program
NPS Pollution Prevention through Direct Outreach and Digital Media (Washington County Cooperative Extension Service)	2019	2021	CWA 319 Nonpoint Source Program
Northwest Arkansas Low Impact Development (NWA LID) 2020 Conference (IRWP)	2020	2022	CWA 319 Nonpoint Source Program
IRWP Programs-Youth Education Labs/Activities: Nature Hike, Bug Kick, Macroinvertebrates & Water Quality, Enviroscape, Groundwater Pollution & Aquifers, Erosion, Tragedy/Success of the Commons, Nature Journaling, Watershed Modeling, Incredible Journey of a Water Molecule (project WET)	2022	Ongoing	American Electric Power Foundation, sponsors
IRWP Programs – Community Outreach Litter Removal		Ongoing	Sponsorships

Other examples of other Upper Illinois River watershed stakeholder groups with active education and outreach programs within this watershed are listed in Table 5 2.

Table 5.2. Upper Illinois River watershed stakeholder groups and outreach programs.

Stakeholder Groups	Organizations with Information and Education Programs for the Stakeholders
Agriculture producers	NRCS; University of Arkansas Division of Agriculture; County Conservation Districts; Arkansas Grazing Lands Coalition; Arkansas Cattlemen’s Association; Arkansas Farm Bureau; Agriculture Council of Arkansas; AGFC; Arkansas Resource Conservation and Development Council (ARCDC); National Center for Appropriate Technology (NCAT); IRWP; Arkansas Land Trust; Watershed Conservation Resource Center (WCRC); Arkansas Water Resources Center (AWRC)
Recreationists and other tourists	USFWS; USACE; AGFC; Audubon Arkansas; The Nature Conservancy; Arkansas Department of Parks, Heritage, and Tourism; Chambers of Commerce; IRWP; The Ozark Society Highlands chapter; IRWP
Landowners and residents	Rural Water Associations; NRCS; University of Arkansas Division of Agriculture; County Conservation Districts; AGFC; Arkansas Natural Heritage Commission; The Nature Conservancy; Arkansas Master Naturalists; ARCDC; USACE; USFWS; Arkansas Department of Health; Washington/Benton County Extension; IRWP; Beaver Water District; Arkansas Land Trust; WCRC
Local and county governments	Arkansas Economic Development Commission; Natural Resources Division; ARCDC; Arkansas Farm Bureau; Washington/Benton County Extension; IRWP; WCRC
Concessioners, guides, vendors, hostelers, restaurants	Arkansas Economic Development Commission; Arkansas Department of Parks, Heritage, and Tourism; AGFC; USACE; IRWP
Teachers	AGFC; DEQ; Arkansas Farm Bureau; Arkansas Wildlife Federation; IRWP; Beaver Water District; Washington/Benton County Extension; The Ozark Society; Northwest Arkansas Master Naturalists

5.1.2 Proposed Information and Education Activity

Quantifying the ecosystem services of the Upper Illinois River watershed is proposed as an additional information and education activity. Ecosystem services are the benefits that people derive from ecosystems, encompassing both direct and indirect contributions to human well-being (Millennium Ecosystem Assessment, 2005; Kumar, 2010).

According to the Millennium Ecosystem Assessment, ecosystem services are categorized into four (4) types:

- **Provisioning Services:** These include essential resources such as food, water, timber, and fiber
- **Regulating Services:** These affect climate, flood control, disease regulation, waste management, and water quality
- **Cultural Services:** These provide recreational, aesthetic, and spiritual benefits
- **Supporting Services:** These encompass processes like soil formation, nutrient cycling, pollination, and photosynthesis

While only provisioning services typically have market value, as determined in the marketplace where goods and services are bought and sold, ecosystem services offer many more benefits and values beyond just provisioning.

A set of standard terms about economic values for ecosystem services has been developed based on the physical relationship between ecosystems and human use (National Research Council, 2004). These values are categorized as follows:

- **Use Values:** These can be further divided into consumptive, non-consumptive, and indirect use.
  - **Consumptive Uses:** Examples include water withdrawals for drinking or irrigation, which are market-based provisioning services.
  - **Non-Consumptive Uses:** These include activities like boating, recreational fishing, or health benefits from clean water.
  - **Indirect Uses:** These encompass services such as providing habitat for birds and birdwatching, hunting areas, or spawning grounds for fish.
- **Non-Use Values:** These are not directly tied to human use but still hold value.
  - **Option Values:** The value people place on the potential future use of an ecosystem, even if they do not use it now.
  - **Bequest Values:** The desire to ensure that resources are available for future generations.
  - **Altruistic Values:** The wish for resources to be available for others in the present.

Economists have developed methods to quantify many of non-consumptive, indirect, and non-use ecosystem services (see Table 5.3). These methods can be applied to estimate the value of services provided by the Upper Illinois River and its tributaries. By quantifying and presenting the value of these ecosystem services, we may enhance local interest in protecting and improving these ecosystems.

Table 5.3. Monetary valuation methods for ecosystem goods and services.

Market Place Method – value based on ecosystem goods and services bought and sold in commercial markets	Productivity Method – value based on products or services that contribute to the production of commercially marketed goods
Hedonic Pricing Method – value based on services that directly affect market price of another good (e.g., streamside vs non-streamside property)	**Travel Cost Method** – value associated with ecosystem used for recreation and willingness of people to pay to travel to the site
Damage Cost Avoided/Replacement Cost Method – value based on cost of avoiding damages from lost services or cost of replacing services (e.g., drinking water treatment costs)	**Contingent Valuation Method** – value based on asking people their willingness to pay (WTP) for specific ecosystem services based on scenario (most widely used method for estimating nonuse values)
Contingent Choice Method – value based on asking people to make trade-offs among choices of services or characteristics. Does not ask for WTP, but infers value from trade-offs	**Benefit Transfer Method** – value based on transferring existing benefit estimates to similar location, issue, or use.

Ecosystem services can be quantified using several established frameworks and tools. Notable frameworks include those proposed by Grizzetti et al. (2016) and Ready (2016), which offer foundational approaches for this process. Additionally, practical tools such as those assessed by Bagstad et al. (2013) and the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) models can be employed.

InVEST, developed by the Natural Capital Project, is a suite of open-source models designed to assess and value ecosystem services. The Natural Capital Project is a collaborative initiative involving the University of Minnesota, The Nature Conservancy, Stanford University, World Wildlife Fund, and the Stockholm Resilience Centre (more information is available at Natural Capital Project).

For the initial quantification of ecosystem services in one of the Category 1 sub-watersheds, we propose using the DPSIR model framework (Bradley & Yee, 2015). This model helps illustrate the connections between various factors affecting ecosystem services:

- **Drivers (D):** Underlying causes or motivations for changes
- **Pressures (P):** Direct effects or stressors imposed on the ecosystem

- **Status (S):** Current condition or state of the ecosystem
- **Impacts (I):** Consequences of changes in ecosystem status on human well-being
- **Responses (R):** Actions and strategies implemented to address or mitigate impacts

Using the DPSIR framework will aid in understanding how changes in ecosystem services affect human well-being in the Upper Illinois River sub-watersheds. For example, a 2013 study by UA Department of Agricultural and Biological Engineering in the Little Osage Creek (Category 1 sub-watershed) evaluated the impact of land use change on ecosystem services at the field and watershed level using the InVEST model. This type of analysis is useful for stakeholders wanting to balance ecosystem services in a changing environment (Mansoor Leh, 2013). For instance, ecosystem services provided by agricultural production under various management schemes could mitigate those lost by urbanization. The tools could also quantify changes in ecosystem services under BMP scenarios in both urban and agricultural settings. The voluntary practices and activities outlined in Section 4.7 represent a set of responses aimed at addressing these impacts. The set of ecosystem services considered for initial valuation, along with the proposed valuation method, is shown in Table 5.4.

Table 5.4. Freshwater ecosystem services of the Upper Illinois River Watershed, type of value and applied valuation methods. The classification of ecosystem services has been developed for fresh and transitional water (Reynaud & Lanzanova, 2017).

Ecosystem services	Category	Value type	Valuation method[a]	Examples of economic good provided
Raw (biotic) materials	Provisioning	Direct	MP, RC	Algae as fertilizers
Water for non-drinking purposes	Provisioning	Direct	MP, PF	Water for industrial or agricultural uses
Raw materials for energy	Provisioning	Direct	RC	Wood from riparian zones
Water purification	Regulation	Indirect	RC, CV	Excess nitrogen removal by microorganisms, solids and nutrients removed by vegetation
Erosion prevention	Regulation	Indirect	RC	Vegetation controlling soil erosion
Flood protection	Regulation	Indirect	RC, CV	Vegetation increasing infiltration capacity of soils
Maintaining populations and habitats	Regulation	Indirect	RC	Habitats for threatened and endangered species, and species of conservation concern
Pest and disease control	Regulation	Indirect	RC, CV	Natural predation of diseases and parasites
Soil formation	Regulation	Indirect	RC	Rich soil formation in flood plains
Carbon sequestration	Regulation	Indirect	RC, MP	Carbon accumulation in sediments
Local climate regulation	Regulation	Indirect	RC, MP	Maintenance of temperature patterns
Recreation	Cultural	Direct	CV, TC, DC, HP	Recreational fishing, sightseeing
Recreational boating/swimming	Cultural	Direct	MP, TC, CV	Canoeing, kayaking, rafting, tubing, swimming
Intellectual and aesthetic appreciation	Cultural	Non-use	CV, DC	Matter for research, artistic representation
Spiritual and symbolic appreciation	Cultural	Non-use	CV, TC, DC	Sense of being
Raw abiotic materials	Extra abiotic	Direct	PF, MP	Extraction of sand, gravel, crushed stone

a: contingent valuation (CV), choice experiment (CE), hedonic price (HP), market price (MP), production function (PF), replacement cost (RC), travel costs (TC)

5.2 Implementation Lead

The greatest effectiveness in implementing watershed management plans and enhancing water quality is often achieved through locally led watershed groups or teams. Empirical evidence supports the effectiveness of nonprofit watershed groups in providing public goods (Grant & Langpap, 2018). In economics, a public good is defined as a commodity or service that is available to all individuals, and one person's use does not reduce its availability to others.

Grant and Langpap (2018) reviewed data from 2,150 watersheds across the lower United States from 1996 to 2008. During this period, the number of watershed groups increased from 500 to 1,500. Their findings indicated that the presence and activities of these groups led to improvements in water quality, specifically a reduction in DO deficiency, which means an increase in DO concentrations in water bodies. Additionally, donations to watershed groups were linked to reduced DO deficiency.

IRWP has committed to leading implementation of the Upper Illinois River Watershed Management Plan. IRWP is dedicated to integrating new technology, leveraging tools and techniques from various industries, and implementing innovative approaches to education and outreach. There are several stakeholders active in this watershed with whom IRWP will work. This includes Arkansas Water Resources Center (AWRC), Watershed Conservation Resource Center (WCRC), and others. Table 5.5 lists possible partners associated with the Category 1 sub-watersheds for this plan.

Table 5.5. Potential stakeholder partners for IRWP in the Upper Illinois River Category 1 sub-watersheds.

Category 1 sub-watershed	Potential stakeholder partners
Moores Creek	AWRC, cattle farmers, poultry producers, Washington County, NWA Regional Planning Commission, Beaver Water District, municipalities, University of Arkansas, NWA Land Trust, local conservation districts
Lower Muddy Fork	AWRC, City of Prairie Grove, cattle farmers, poultry producers, Washington County, NWA Regional Planning Commission, WCRC, Beaver Water District, University of Arkansas, NWA Land Trust, local conservation districts
Little Osage Creek	IRWP, City of Bentonville, City of Centerton, City of Rogers cattle farmers, poultry producers, Benton County, NWA Regional Planning Commission, Beaver Water District, developers, AWRC, NWA Regional Airport, University of Arkansas, local conservation districts
Lake Wedington – Illinois River	IRWP, Beaver Water District, Arkansas Game and Fish, cattle farmers, poultry producers, Washington County, WCRC, AWRC, City of Siloam Springs, USDA Forest Service, University of Arkansas, NWA Land Trust, local conservation districts
Lake Frances – Illinois River	IRWP, Beaver Water District, Arkansas Game and Fish, cattle farmers, poultry producers, Washington County, WCRC, AWRC, NWA Land Trust, local conservation districts

5.3 Implement Nonpoint Source Pollution BMPs

Section 4.7 outlines best management practices (BMPs) for addressing nonpoint source pollution in the Upper Illinois River watershed and Category 1 sub-watersheds. Sections 4.3 and 4.6 detail the focus areas for management. It is important to note that there is no legal obligation for landowners, operators, or stakeholders to implement the practices listed in Section 4.7. These practices are suggested as voluntary measures for those interested in enhancing or safeguarding water quality in the watershed.

Implementing these BMPs can not only help protect water quality but also potentially increase the value and returns of the property where they are applied, provided they are properly installed, operated, and maintained. While the practices listed are generally accepted within the watershed and recommended by stakeholders, they are not exhaustive. Other effective practices that are not listed could also contribute to improving or protecting water quality and habitat.

For those seeking support in implementing these BMPs, including installation, operation, and maintenance, Section 6 provides information on programs that offer technical and financial assistance.

5.3.1 Existing Implementation of Practices in the Watershed

Many of the BMPs listed in Section 4.7 are already in use in the Upper Illinois River watershed and the Category 1 sub-watersheds. Figures 5.1 and 5.2 summarize the practices implemented in the Upper Illinois River watershed through the NRCS Environmental Quality Incentives Program (EQIP) and Conservation Stewardship Program (CSP) programs during the period from 2018 to 2020 (R. Christianson, University of Illinois, personal communication 12/7/2021).

The 2022 Census of Agriculture provides data on implementation of selected conservation practices at the county level. This data for the counties associated with the Upper Illinois River watershed is detailed in Table 5.6. Additionally, the USDA Farm Services Agency (FSA) reports the annual acres enrolled in the Conservation Reserve Program (CRP) by county (FSA 2022). The CRP enrollment data for 2022 in the counties within which the Upper Illinois River watershed is located is also included in Table 5.6.

Table 5.7 lists the specific practices utilized on CRP acreage in 2022 while Table 5.8 provides examples of past conservation projects funded by other sources that involved BMPs.

Table 5.6. Extent of conservation practices by county reported in the 2022 Census of Agriculture (USDA National Agricultural Statistics Service 2022) and by FSA (FSA 2020).

Practices		Extent in	
		Benton County	Washington County
Prescribed grazing	2022	269 operations	367 operations
Conservation Reserve Program	2001-2019	43 acres	97 acres

Table 5.7. Acreage enrolled in CRP practices by county reported by FSA in 2022 (FSA 2022).

CRP Practices (acres)	County	
	Benton	Washington
Native grass plantings	32	--
Riparian buffers	11	97
TOTAL	**43**	**97**

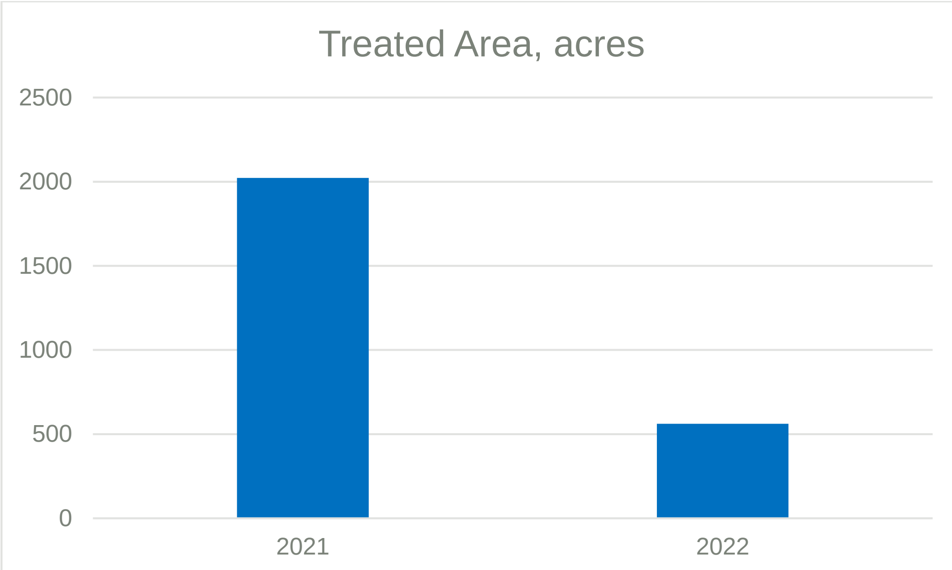

Figure 5.1. Summary of area treated by BMPs implemented through NRCS EQIP and CSP programs 2018-2022 in Upper Illinois River watershed.

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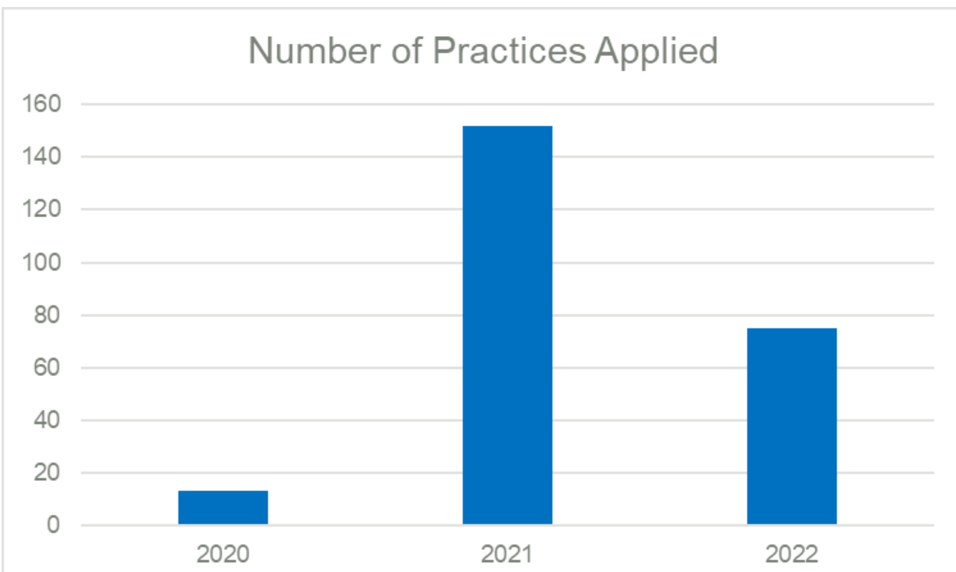

Figure 5.2. Number of BMPs implemented in Upper Illinois River watershed through EQIP and CSP programs 2018-2020.

The practices applied in 2020 were for farmstead energy management plans and improvements, fencing, and constructed wetlands and are not included in the treated area in Figure 5.1.

Table 5.8 Examples of BMPs installed through funded projects.

Project Title (Lead Organization)	Start year	End year	BMPs	Type of Project/funding source	Project #
Illinois River Assistance and Stabilization (AGFC)	2017	2018	Landowner assistance; bank stabilization		
North Arkansas Quail Focal Landscape Project (NRCS; AGFC)	2018	2021	BMP implementation; Education & outreach	RCPP	
Growing Conservation in the Illinois River Watershed Project (NRCS, ADA Division of Forestry, AGFC)	2018	2019	BMP implementation; Education & outreach	RCPP	
Western AR/SE OK Woodland Restoration: A Joint Chief's Landscape Restoration Partnership Project (NRC - USFS)	2018	2021	BMP implementation; Education & outreach		
Grassland Restoration and Riparian Buffer Project (FSA)	2019	2034	Conversion of cropland to grassland; riparian buffer	CRP	
Unpaved Roads BMP Demonstration Project for the Illinois River Watershed (IRWP)	2019	2021	BMP implementation and education demonstrations	CWA 319 Nonpoint Source Program	319 Project # 19-800
Water Quality Monitoring in the Upper Illinois River and Upper White River Watersheds (AWRC)	2019	2022	BMP Effectiveness Monitoring	CWA 319 Nonpoint Source Program	319 Project # 19-1100
EQIP Conservation Practices for Water Quality Improvement (NRCS)	2021	2026	Cover crops, conservation tillage, and nutrient management systems	EQIP	
Demonstrating Cool Season Forage Cover Crops and a Vegetation Barrier to Reduce Sediment and Nutrient Loss from Grazing Lands (NRCS - UAEX)	2021	2022	Nutrient Management; Cover Crops		
Implementation of Green Infrastructure Practices to Improve Water Quality in the Illinois River Watershed (IRWP)	2022	2025	Detention basin retrofits, rain gardens, bioswales, permeable pavement, vegetated roofs, and green-designed streets.	CWA 319 Nonpoint Source Program	319 Project # 22-100
Enhancement and Establishment of River, Riparian, and Wetland Restoration in Northwest Arkansas (WCRC)	2022	2026	Enhance 5,000 feet of river and riparian areas and 3 acres of wetlands at existing restoration sites	CWA 319 Nonpoint Source Program	319 Project # 22-300
Wetlands Restoration Program (FSA)	2023	2038	Restore wetlands	CRP	
Streamside Buffer Restoration (NRCS)	2024	2029	Vegetative buffers along streams EQIP		
IRWP Programs – Riparian Restoration Program	2018	Ongoing	Streambank stabilization, riparian revegetation, native riparian establishment, alternative watering facilities, exclusion fencing, native prairie establishment and management *56 Conservation Plans have been prepared, waitlist of applications* *5 field tours including riparian workshops, pasture walks, and wetland tour* *21.9 miles of streambank/riparian vegetation restored/protected* *1,923 acres serviced by alternative water facilities* *94,071 linear ft of fencing for rotational grazing and livestock exclusion*	Natural Resources Division, Walton Family Foundation, Arbor Day Foundation, sponsors	

Table 5.2 Examples of BMPs installed through funded projects (continued).

Project Title (Lead Organization)	Start year	End year	BMPs	Type of Project/funding source	Project #
IRWP Programs – Septic Tank Remediation Program	2021	2024	Nutrient Management; Septic tank repair or replacement *82 projects as of October 2024* *$1.1 million committed, with a waitlist of funding needs beyond*	Natural Resources Division Clean Water Revolving Loan Funds	
IRWP Programs – Blue Cities, Blue Neighborhoods	2021	Ongoing	Urban stormwater management, native plants, detention pond retrofits, neighborhood natural areas, residential LID *Prioritization Index for Neighborhoods in major cities in NWA* *4 Green Infrastructure Master Plans developed* *3 of 4 sites moving forward with BMPs*	Walton Family Foundation	
IRWP Programs – Green Infrastructure Program	2015	Ongoing	Riparian revegetation, rain gardens, bioswales, native plants, stormwater management, urban stormwater, rain barrels, Pre-Post site water quality analysis *13 projects in 2023 - 2024, totaling 30 BMPs, 2 rain garden workshops*	CWA 319 Nonpoint Source Program	319 Project # 15-800
IRWP Rain Garden Project	2011	Ongoing	Installation of rain gardens: *74,228 SF Impervious area treated* *16,874 SF Rain gardens installed* *4,458 Native Plants in the ground*	CWA 319 Nonpoint Source Program	
IRWP Programs – Landowner Services Technical Assistance	2016	Ongoing	Streambank Erosion, Riparian Buffers, Rotational Grazing, Land conservation *Educational materials on streambank restoration, riparian buffers, land conservation, residential LID, commercial/industrial LID and related topics mailed to landowners: 5162* *Number of field tours: 9* *Number of attendees at field tours: 239* *Conservation plans prepared: 12*	USDA-NRCS	
IRWP Programs – Recreation Stewardship		Ongoing	Conservation-Based Recreation Master Planning	Benton County ARP	
IRWP Programs – Community Outreach		Ongoing	*Since 2022:* *48 miles of streams where litter was removed* *900 bags of trash and recycling*	Sponsorships	

5.3.2 Planned Implementation Projects

As shown in Section 5.3.1, the Upper Illinois River watershed has a history of implementing BMPs aimed at improving water quality and ecosystem health. Building upon these efforts, several new and ongoing projects will further enhance watershed management. Table 5.9 lists examples of planned projects.

Table 5.9. Examples of active and planned projects for implementation of BMPs in the Upper Illinois River watershed.

Project Title	Activity Description
IRWP Programs-Septic Tank Remediation Program	• Onsite wastewater repair or replacement
Implementing Green Infrastructure Elements for Enhanced Water Quality In the Illinois River Watershed (IRWP)	• Education/Information • GI BMP implementation
IRWP Programs-Green Infrastructure Program	• Riparian revegetation • Rain gardens • Bioswales • Native plants • Stormwater management • Pre-Post site water quality analysis
Water Quality Monitoring in the Upper Illinois River Watershed and Upper White River Basin (AWRC)	• Water Quality Assessment/Monitoring
EQIP Conservation Practices for Water Quality Improvement (NRCS)	• Cover crops • conservation tillage • nutrient management systems
Enhancement and Establishment of River, Riparian, and Wetland Restoration in Northwest Arkansas (WCRC)	• Enhance river and riparian areas • Enhance wetlands at existing restoration sites
Streamside Buffer Restoration (NRCS)	• Vegetative buffers along streams
Grassland Restoration and Riparian Buffer Project (FSA)	• Conversion of cropland to grassland • Riparian buffer
Wetlands Restoration Program (FSA)	• Restore wetlands

Table 5.9. Examples of active and planned projects for implementation of BMPs in the Upper Illinois River watershed (continued).

Project Title	Activity Description
IRWP Programs-Riparian Restoration Program	• Streambank stabilization • Riparian revegetation • Native riparian establishment • Wetland establishment and management • Alternative watering facilities • Exclusion fencing • Native prairie establishment and management
IRWP Programs-WQ Monitoring	• EcoAssessment, • Streambank Erosion Inventory Study
IRWP Programs-Blue Cities, Blue Neighborhoods	• Stormwater management • Native plants • Detention pond retrofits • Neighborhood natural areas • Residential LID
IRWP Programs-Landowner Services	• Streambank Erosion • Riparian Buffers • Rotational Grazing • Land conservation
IRWP Programs-Youth Education	• Education: Labs/Activities: Nature Hike, Bug Kick, Macroinvertebrates & Water Quality, Enviroscape, Groundwater Pollution & Aquifers, Erosion, Tragedy/Success of the Commons, Nature Journaling, Watershed Modeling, Incredible Journey of a Water Molecule (project WET)
IRWP Programs-Community Outreach	• Litter Cleanups
IRWP Programs-Recreation Stewardship	• Conservation-Based Recreation Master Planning
CPRG Green Networks initiative	• Restore streams and riparian areas • Preserve and protect critical green infrastructure

5.3.3 Barriers to BMP Implementation

As part of the second public meeting for updating the Illinois River watershed management plans, stakeholders were asked to identify conditions or situations in the Illinois River watershed that make it difficult to implement recommended BMPs, i.e., barriers to BMP implementation. Table 5.10 lists barriers discussed during the public meeting, as well as some options for addressing these barriers that were proposed. The need for funding and education were mentioned most frequently as barriers to implementation.

Table 5.10. Barriers to BMP implementation identified by stakeholders at May 2023 public meeting.

BMP	Barriers	Options
Stream/streambank restoration	• Cost for restoration – materials and labor • Obtaining Section 404 permits from USACE can be expensive • Can be washed out by floods if not properly installed and expensive to redo	Enroll restored streams in mitigation bank to offset cost
Riparian restoration/protection	• Expensive • Loss of land for production • Current municipal, county codes don't adequately protect riparian/floodplain areas	• Enroll restored riparian wetlands in mitigation bank to offset costs • Change or update municipal and county building codes to better protect floodplains and riparian areas
Conservation easements	• Not well understood • Concerns about restricting what heirs can do with property • Concerns about limiting sale price of property • Expensive, costs associated with donation and maintenance on landowner	• Pay for conservation easements using government source water protection funds • Additional sources of funding to offset landowner costs.
Fencing to exclude cattle from streams	• Fencing damage/loss during flood events • Loss of land for production • Expense of providing alternative water sources	• Virtual fencing • Enroll excluded land in NRCS conservation programs • Monetary assistance programs for practices
Poultry litter export	• Cost of transportation	• Organize transport direct to user, i.e., move litter only once
Green infrastructure/low impact development	• Cities required paved areas as part of development • Cities don't incentivize pervious pavement and other alternatives	• Chang or update municipal and county building codes to allow and/or incentivize green infrastructure and low impact development

5.4 Monitoring

Monitoring is an essential element of adaptive watershed management. The objectives of the ongoing and proposed monitoring programs and special studies in the Upper Illinois River watershed include:

- Determine compliance with state water quality standards
- Characterize current water quality conditions and patterns
- Characterize water quality trends and impacts
- Identify sources of pollutants

For all water quality monitoring, both existing and proposed, it is recommended that the frequency and timing of sampling ensure that the data that meet DEQ data requirements for the biennial assessment of streams and lakes, as outlined in the 2022 Assessment Methodology (DEQ, 2021).

5.4.1 Existing/Planned Monitoring Programs

To effectively manage and improve water quality in the Upper Illinois River Watershed, several existing and planned monitoring programs are in place. These programs are essential for collecting comprehensive data on water quality, stream conditions, and habitat health, which supports the goals of the watershed-based plan. Below is an overview of these programs:

Arkansas Department of Energy and Environment – DEQ

- **Ambient Water Quality Monitoring:** DEQ conducts routine sampling of streams and lakes across the watershed to assess water quality. Parameters include nutrients, bacteria, and physical and chemical indicators.
- **Biological Monitoring:** DEQ performs biological assessments to evaluate the health of aquatic ecosystems, including macroinvertebrate and fish surveys.
- **Comprehensive Data:** Provides a broad understanding of water quality conditions and trends
- **Impairment Identification:** Helps identify impaired water bodies and track improvements over time

U.S. Geological Survey (USGS):

- **Routine Sampling:** USGS operates established sampling stations in streams to collect data on water quality parameters such as flow rates, temperature, and concentrations of various substances
- **Long-Term Monitoring:** Maintains continuous monitoring stations that provide daily data on critical parameters, enabling trend analysis and detection of changes over time

Arkansas Water Resources Center (AWRC)

- **Water Quality Monitoring:** Conducts comprehensive water quality monitoring and data analysis, including various flow events. Measured parameters include nitrate-nitrogen, chloride, sulfate, total phosphorus, total nitrogen, turbidity, and conductivity.
- **Targeted Monitoring:** Focuses on specific contaminants and parameters of concern
- **Data Analysis:** Provides detailed analysis and interpretation of water quality data to inform management practices

Illinois River Watershed Partnership (IRWP)

- **Water Quality Monitoring:** IRWP monitors various water quality parameters to assess the condition of the watershed. This includes collecting data on nutrient levels, sediment, and other indicators.
- **Streambank Erosion Inventory Study:** Evaluates streambank erosion to identify areas at risk and guide restoration efforts
- **Integrated Monitoring:** Combines water quality and erosion data to provide a holistic view of watershed health
- **Ecological Assessment:** Stream habitat assessment, macroinvertebrate sampling, and land use change analysis to characterize stream health
- **BMP Monitoring:** Supports data collection for baseline and effectiveness evaluation of BMP implementation in the watershed

Integration and Coordination

These monitoring programs are crucial for the successful implementation of the watershed-based plan. Coordination among DEQ, USGS, AWRC, and IRWP ensures that data collected is comprehensive, accurate, and used effectively to address water quality issues.

Key Integration Points

- **Data Sharing**: Programs should share data and findings to avoid duplication of efforts and enhance overall understanding of watershed conditions.
- **Collaborative Analysis**: Joint analysis of data from different programs can provide more robust insights and support more effective management strategies.
- **Reporting**: Regular reporting and communication of monitoring results to stakeholders will support transparency and foster community engagement.

By leveraging the strengths of these existing and planned monitoring programs, the Upper Illinois River Watershed can achieve its water quality and habitat improvement goals, ensuring a healthier and more sustainable watershed. **Error! Reference source not found.**14 shows examples of ANRC CWA 319 Nonpoint Source Program monitoring projects in the Upper Illinois River watershed from 2015-2025.

Table 5.11. CWA 319 NPS water quality monitoring projects in the Upper Illinois River watershed.

Project Title (Lead Organization)	Start year	End year
Water Quality Monitoring in the Upper Illinois River Watershed and Upper White River Basin (AWRC)	2015	2025
Partner's Lake Nuisance Algal Growth (AWRC, IRWP)	2017	2018
Ecological Evaluation of Priority Subwatersheds in the Illinois River Watershed (IRWP, AGFC)	2017	2019
Clear Creek Bacteria Sampling (AWRC)	2023	2025
Water Quality Monitoring (IRWP) *Streambank Erosion Assessment, Ecological Assessment*	2017	Ongoing

5.4.2 Proposed Monitoring Studies

The proposed monitoring studies address key water quality and habitat data gaps in the Illinois River Watershed, focusing on Category 1 sub-watersheds. These studies will help characterize water quality conditions, identify pollution sources, and assess habitat conditions to guide effective management and restoration efforts.

- **Characterize water quality conditions** and trends along Moores Creek, Lower Muddy Fork, and Little Osage Creek sampling a full suite of parameters, including *E. coli*. Collect samples at a frequency adequate to evaluate whether water quality standards are being met, and utilize DEQ standard methods for water quality analysis.
- **Identify sulfate** sources in Illinois River Category 1 sub-watersheds. Measure sulfate concentrations and related indicators such as total dissolved solids and conductivity. Employ isotopic analysis and flow tracing techniques to identify and quantify sulfate sources, including contributions from agricultural runoff, stormwater runoff from developed areas, industrial discharges, or natural sources, especially during significant runoff events.
- **Conduct Little Osage Creek streambank erosion inventory** using field surveys, aerial imagery, and geospatial analysis to document areas of streambank erosion. Generate detailed maps showing erosion-prone areas and severity and identify high-priority areas for streambank stabilization and restoration efforts.
- **Assess habitat conditions** including streambank stability, riparian vegetation cover, and in-stream habitat quality. Develop habitat quality rating based on assessment and identify key areas needing conservation or restoration to improve overall habitat conditions.
- ***E. coli* sampling** at existing, active, water quality sampling locations, including springs, at a variety of hydrologic conditions, and a frequency adequate to evaluate whether water quality standards are being met.

5.5 Evaluation

It is recommended that the implementation of this plan be evaluated approximately every seven (7) years. Therefore, the first evaluation of this plan would occur in 2031. This evaluation will be carried out by IRWP. Performance measures for this evaluation are detailed below.

If the criteria outlined in Section 5.6 are not met, the management approaches, scientific knowledge, and stakeholder opinions in the Category 1 sub-watersheds will be re-evaluated. Partners and stakeholders involved in managing water quality and nonpoint sources will review and adjust management elements as necessary.

It is important to recognize that significant improvements in in-stream water quality resulting from management measures may take more than five (5) years, or even decades, to become apparent (Meals, Dressing, & Davenport, 2010). The time required to observe meaningful changes in water quality partly depends on the proximity of water quality measurement sites to the locations where management activities are implemented. Researchers have suggested that legacy phosphorus in

Upper Illinois River watershed streams is preventing reduction of instream phosphorus despite improved wastewater treatment and nutrient management (Jarvie, et al., 2012) (Jarvie, et al., 2013).

5.6 Performance Measures

Performance measures evaluate the effectiveness of the watershed management plan by considering three (3) key elements: program inputs, outputs, and outcomes. For a robust evaluation of water quality management and BMP implementation, identified performance measures for information/education, monitoring, and BMP implementation are provided in this section.

5.6.1 Inputs

Inputs include the resources, assistance programs, and stakeholder participation essential for implementing the water quality management plan. Measuring inputs helps gauge the support and resources allocated towards achieving the plan's objectives. Indicators that measure this component of the plan implementation are listed in **Error! Reference source not found.**5. The stakeholders and organizations that participate in implementation of this plan should provide IRWP with annual totals for these input indicators for the period 2024 through 2029 by February 2030.

Table 5.12. Indicators of inputs for implementation of this watershed management plan.

Implementation Task	Activity	Indicators
Monitoring	Agency monitoring programs	• Resources spent on monitoring in Upper Illinois River watershed • Hours and number of personnel involved
	Stream Teams	• Number of inquiries • Number of teams formed • Number of participants on teams • Hours and number of AGFC personnel involved
	Special studies	• Resources spent on special studies • Hours and number of personnel involved
Information/Education	Conferences	• Resources conferences (e.g. Arkansas Grazing Lands Coalition) • Hours and number of personnel involved
	Events	• Hours and number of people involved in organizing events (field days, festivals, lake and river clean-ups) • Cost
	Community Presentations	• Hours and number of people involved in putting on presentations • Cost
	K-12 Education Programs	• Hours and number of people involved in developing and managing educational programs (e.g., IRWP mobile learning labs) • Cost
	Interest Groups	• Number of website posts/updates/newsletters • Hours and number of people involved • Cost
	Social media, Webinars	• Number of posts, videos, et cetera • Hours and number of people creating content • Cost
Implement BMPs	Assistance Programs	• Resources distributed to Upper Illinois River watershed • Hours and number of people assisting stakeholders • Number of stakeholders requesting assistance
	Implementation projects	• Number of partnerships formed • Number of sub-watersheds with projects and/or studies • Number of BMPs implemented through partnerships

5.6.2 Outputs

Outputs are the direct products or results from implementing the plan. They include the formation of partnerships, implementation of BMPs, information and education, and monitoring and special studies. Indicators for measuring these outputs are listed in **Error! Reference source not found.**16. Stakeholders and organizations that participate in implementation of this plan should provide the IRWP with annual totals for these indicators for the period 2024 through 2029 by February 2030.

Table 5.13. Indicators of outputs of implementation of this watershed management plan.

Implementation Task	Activity	Indicators
Monitoring	Agency monitoring programs	• Number of active water quality monitoring stations • Number of stations sampled • Number of water quality parameter measurements collected • Number of sampling events • Number of biological surveys
	Stream Teams	• Number of active teams • Number of streams monitored • Number of active water quality monitoring stations • Number of stations sampled • Number of water quality parameters measured • Number of sampling events • Number of invertebrate surveys
	Special studies	• Number of studies completed • Number of sub-watersheds studied • Study results reported
Information/Education	Conferences	• Number of conferences • Number of attendees
	Events	• Number of events in watershed • Number of events outside watershed where watershed information presented • Number of attendees
	Community Presentations	• Number of presentations • Number of attendees
	K-12 Education Programs	• Number of programs • Number of attendees
	Interest Groups	• Number of meetings • Number of attendees • Number of website visits • Number of newsletters distributed

	Social media, Webinars	• Number of webinar attendees • Number of shares, likes, comments on content

Table 5.13. Indicators of outputs of implementation of this watershed management plan (continued).

Implementation Task	Activity	Indicators
Implement BMPs	Assistance Programs	• Number/amount of BMPs implemented • Number of contracts/projects started and finished
	Implementation projects	• Number of partnerships formed • Number of sub-watersheds with implementation projects and/or studies • Number of projects and studies organized through partnerships • Number/amount of BMPs implemented through partnerships

5.6.3 Outcomes

Outcomes reflect the long-term effects of implementing BMPs and managing water quality. The watershed management plan for the Upper Illinois River watershed is designed to achieve several key outcomes, including water quality assessment in all Category 1 sub-watersheds, improved water quality and aquatic habitats, and increased community awareness and engagement with water quality and aquatic habitat concerns within the watershed.

The long-term objectives of this watershed plan are that waterbodies in the Upper Illinois River watershed will meet established water quality criteria and fulfill their designated uses. Additionally, the plan aims to reduce nutrient loads and support the survival of threatened and endangered species.

Progress will be measured using the following indicators:

- **Primary Indicators:**
  - *E. coli* concentrations
  - Turbidity levels
  - Total nitrogen and total phosphorus concentrations
  - pH levels
  - Sulfate concentrations
  - Condition of threatened and endangered species populations
  - Extent of threatened and endangered species populations
- **Secondary Indicators:**
  - Dissolved oxygen (DO) concentrations

- Biochemical oxygen demand (BOD)
- Total suspended solids (TSS) concentrations
- Condition of fish and macroinvertebrate communities

These parameters, currently monitored at various locations, will help evaluate the effectiveness of nonpoint source pollution management efforts. The plan aims for incremental progress over the next four (4) to six (6) years, targeting reductions in *E. coli*, pH, turbidity, sulfate, total nitrogen, and total phosphorus levels. It also seeks to maintain or increase populations of threatened and endangered species and document stakeholder activities that contribute to improved water quality and quality of life in the watershed.

DEQ assesses water bodies in the Upper Illinois River watershed every two (2) years to produce the Arkansas Integrated Water Quality Assessment Report, which includes the 303(d) list of impaired water bodies. This assessment will help evaluate progress towards the plan’s goals, including the delisting of impaired water bodies and preventing the addition of new impairments.

Implementation of this plan will be considered successful by 2030 if:

- At least one implementation project or proposed study is initiated in a Category 1 sub-watershed
- At least one water body is removed from the Arkansas impaired waters list
- Sufficient water quality data is collected from all Category 1 sub-watersheds for the DEQ biennial assessment
- No new water quality impairments are identified due to unregulated nonpoint pollution sources

5.7 Update Watershed Management Plan

A comprehensive update of this watershed management plan will be initiated in 2031 by IRWP.

This update will consider and address the following information:

- Results of the evaluation of the implementation of this plan, described in Section 5.5
- Relevant information about the Upper Illinois River system and how it works, nonpoint source BMPs, and pollutant sources in the watershed that has been developed since 2023
- Changes in water quality related issues in the watershed
- Changes in water quality management assistance programs
- Changes in land use, industry, population, and/or economy in the watershed

As part of the update process, a summary of changes in the watershed since the completion of the previous management plan will be prepared. This summary will be presented at public stakeholder meetings, where stakeholders will have the opportunity to provide input on potential adjustments to management strategies and goals. These discussions may focus on enhancing water quality in different sub-watersheds or addressing new concerns.

Following the public meetings, an updated version of the watershed management plan will be drafted based on the evaluation results, stakeholder feedback, and any other relevant information. This draft will be presented at additional public meetings for further input. The final version of the updated plan will incorporate stakeholder comments and be prepared for implementation.

5.8 Implementation Schedule

The successful implementation of the Upper Illinois River Watershed Management Plan relies on a well-defined framework of schedules and milestones. This section provides an overview of the timelines and milestones associated with the ongoing and planned activities aimed at achieving the watershed's management goals.

The schedule follows an adaptive management process, which involves several key steps:

- **Implementation:** Practices are put into action according to the plan
- **Monitoring:** Results are documented through ongoing monitoring
- **Evaluation:** Results are assessed against the goals and criteria outlined in the plan.
- **Modification:** Based on the evaluation, the plan is updated to address any changes in regulations, available assistance programs, understanding of the watershed, or management priorities

This adaptive approach ensures that the management plan remains effective and responsive to new information and changing conditions. A schedule for implementing the elements of this watershed management plan described previously is summarized in Table 5.14.

Table 5.14. Proposed implementation schedule for Upper Illinois River watershed management plan.

Activity	Action	Lead	Start	Anticipated Completion	2029 Milestones	Indicator	Long-Term Goal
BMP Implementation	**Streambank Restoration**	IRWP, Local Partners, WCRC	Ongoing	Expected to continue indefinitely	2 new projects to restore streambanks and reduce erosion	Progress reports; sediment load measurements; habitat quality assessments	Stabilize streambanks in Category 1 sub-watersheds; achieve significant reduction in streambank erosion
BMP Implementation	**Nutrient Management Practices**	IRWP, NRCS, Conservation Districts	Ongoing	Expected to continue indefinitely	Compliance with nutrient management plans; total phosphorus monitoring showing decreasing trend	Phosphorus levels in water; land use changes; farmer participation rates	Implement practices in Category 1 sub-watersheds; reduction in phosphorus loading; meet total phosphorus water quality standards at OK border
BMP Implementation	**Riparian Buffer Installation**	IRWP, Local Conservation Groups	Ongoing	Expected to continue indefinitely	Increased riparian buffer acreage along Category 1 sub-watershed streams	Buffer acreage; water quality data; maintenance of buffer areas	Establish riparian buffers along major streams in UIRW; improvement in water quality concerns
BMP Implementation	**Invasive Species Management**	Local Agencies, IRWP, WCRC	Ongoing	Expected to continue indefinitely	Re-establish native plants and remove invasive species in new projects	Area treated; reduction in invasive species populations	Control and reduce spread in invasive species in critical areas
BMP Implementation	**Habitat Restoration Projects**	IRWP, Local Conservationists, WCRC	Ongoing	Expected to continue indefinitely	At least one wetland and one upland area identified for habitat restoration	Acres restored; species diversity assessments; habitat condition surveys	Significantly increase in biodiversity
BMP Implementation	**Agricultural Best Management Practices (BMPs)**	IRWP, Extension Services, NRCS, Conservation Districts	Ongoing	Expected to continue indefinitely	Promote and implement sustainable practices on 5 new farms	Soil health indicators; number of farms adopting practices; nutrient levels in runoff	Increase in sustainable practices in IRWP (acres of no-till, etc.); Soil health improvement; decrease nutrients in runoff
BMP Implementation	**Wetland Restoration**	IRWP, Local Conservationists	2018	2028	Restore 50 acres of wetlands; enhance flood storage capacity	Acres of wetlands restored; flood storage capacity	Restore wetlands in Category 1 sub-watersheds; significant flood storage improvement; Protect existing wetlands
BMP Implementation	**Green Infrastructure Program**	IRWP, local partners	2022	Expected to continue indefinitely	30 new projects identified and selected; at least one rain garden workshop per year	Number of projects funded; Number of BMPs implemented; Number of workshops	GI implemented on all new development projects
BMP Implementation	**Blue Cities, Blue Neighborhoods**	IRWP, Local communities/partners	2021	Expected to continue indefinitely	4 Green Infrastructure Master Plans developed in identified priority areas	Number of Green Infrastructure Master Plans developed; Number of projects funded; Number of BMPs implemented	Green Infrastructure Master Plans for priority neighborhoods in each major city in NWA
BMP Implementation	**Septic Tank Remediation Program**	IRWP, Natural Resources Division	2021	Funded through 2024, Extension recommended	List of remediation/replacement projects identified; funding committed for identified projects	Number of loans/projects	Repair/Replacement of all failing septic systems in UIRW

Table 5.14. Proposed implementation schedule for Upper Illinois River watershed management plan (continued).

Activity	Action	Lead	Start	Anticipated Completion	2029 Milestones	Indicator	Long-Term Goal
Evaluation	**State Biennial Water Quality Assessment (DEQ)**	DEQ	1980s	Expected to continue indefinitely	EPA approved final impaired waters lists for 2024 and 2026	Attaining and non-attaining waterbodies in the Upper Illinois River watershed	All water quality criteria met in all monitored waterbodies in the Upper Illinois River watershed
Evaluation	**Track implementation of BMPs in Upper Illinois River watershed**	IRWP	2025	Expected to continue indefinitely	Information for 2024 – 2028 compiled	Amount of BMPs implemented	All water quality criteria met in monitored waterbodies, reduce pollutant loads to waterbodies
Evaluation	**Track education and outreach**	IRWP	2024	2028	Information for 2024 – 2028 compiled	Number of events, number of documents, number of people attending or reached	All water quality criteria met in monitored waterbodies, threatened and endangered species stable
Evaluation	**Track monitoring**	IRWP	2024	2028	Information for 2024 – 2028 compiled	number of sampling locations, number of sampling events, parameters analyzed, species surveyed	All water quality criteria met in monitored waterbodies, threatened and endangered species stable
Evaluation	**Evaluation of watershed management plan**	State Agency	2028	2028	Data needed for evaluation compiled	Evaluation completed, Evaluation made public	All water quality criteria met in monitored waterbodies, threatened and endangered species stable
Monitoring	**Ambient Surface Water Quality Monitoring**	DEQ, USGS	Prior to 1990	Expected to continue indefinitely	Five additional years of water quality data collected at existing stations	Number of sampling events; Number of sampling locations	Identify and track changes in water quality; Assess water quality relative to water quality standards
Monitoring	**Stream Team Water Quality Sampling and Aquatic Invertebrate Surveys**	IRWP, AGFC	2012	Expected to continue indefinitely	At least 2 active stream teams per county in the UIRW	Number of participants; Number of sampling events per year	Stream Teams participating on every major stream in UIRW
Monitoring	**DEQ Fish Surveys**	DEQ	2012	Expected to continue indefinitely	At least one fish survey	Number of locations surveyed; Number of sampling events	Assess biohabitats
Monitoring	**Water Quality Monitoring in the Upper Illinois River Watershed and Upper White River Basin**	AWRC	Ongoing	Expected to continue indefinitely	Add Moores Creek and Muddy Fork as sampling locations	Number of monitoring sites; number of sampling events; water quality reports; trend analysis	Establish comprehensive water monitoring network, including high flow events; identify priority NPS pollution areas; Remove streams from 303(d) List
Monitoring	**Clear Creek Bacteria Sampling**	AWRC	2023	2024	Water quality report for Clear Creek	Clear Creek evaluated	Water quality criteria met in Clear Creek

Table 5.14. Proposed implementation schedule for Upper Illinois River watershed management plan (continued).

Activity	Action	Lead	Start	Anticipated Completion	2029 Milestones	Indicator	Long-Term Goal
Outreach and Education	**Community Education and Outreach**	IRWP, Local Agencies	Ongoing	Expected to continue indefinitely	Conduct at least 2 workshops per year; Identify any additional key stakeholders for BMPs	Attendance at workshops; surveys on community awareness	Conduct quarterly workshops for stakeholders in various topics of watershed management
Outreach and Education	**Youth Education**	IRWP	2011	Expected to continue indefinitely	Conduct at least monthly Mobile Learning Labs and field trips per year.	Number of students educated	Watershed education be part of general youth education in NWA
Outreach and Education	**Poultry and Livestock Producer Training**	IRWP, Local Agencies, Extension Services	Ongoing	Expected to continue indefinitely	At least one training workshop each year	Number of workshops and attendees	Each producer attended at least one workshop; All producers following active nutrient management plan
Outreach and Education	**Landowner Services Technical Assistance (education materials, field tours)**	IRWP, NRCS	2016	Expected to continue indefinitely	At least two field tours per year, 2 new conservation plans	Number of materials produced, number of field tours, number of attendees, number of conservation plans implemented	20 conservation plans prepared: scheduled field tours of sites each year
Special Studies	**Water Quality Monitoring Expansion**	State Agencies, IRWP, AWRC	2025	Expected to continue indefinitely	Expand monitoring to at least 1 Category 1 sub-watershed that has been identified as needing additional monitoring	Number of monitoring sites; number of sampling events; water quality reports; trend analysis	Sustained monitoring network on all major streams in the UIRW; establish comprehensive water quality database
Special Studies	**Identify sulfate sources in Category 1 sub-watersheds**	State Agencies, AWRC	2025	2028	Measure sulfate concentrations monthly in Category 1 sub-watersheds; employ isotopic analysis and flow tracing techniques to identify and quantify sulfate sources	Number of sampling locations, number of sampling events, monitoring report,	Identify sources of sulfate in category 1 sub-watersheds and BMPs to address sources
Special Studies	**Little Osage Creek Streambank Erosion Inventory**	State Agencies, Local Partners	2026	2029	Conduct streambank erosion inventory using field survey, aerial imagery, and geospatial analysis to document areas of streambank erosion.	Miles of streambank surveyed, maps of erosion-prone areas, erosion rates calculated	Inventory of Little Osage Creek streambanks, erosion rates, and high-priority areas identified. BMPs and special projects in place to restore identified streambanks.
Update plan	**Public meetings**	State Agency, IRWP	2027	2028	Begin planning public meetings	number of meetings, number of attendees	stakeholder input to water and water quality management
Update plan	**Update watershed management plan**	State Agency, IRWP	2028	2030	Initiate preparations for update	updated watershed management plan complete and accepted by EPA, focus sub-watersheds identified, stakeholders involved	Maintain watershed management plan as a living document that reflects stakeholder interest and concerns related to protecting and improving water quality in the Upper Illinois River watershed

6. IMPLEMENTATION COSTS, BENEFITS, AND AVAILABLE ASSISTANCE

This section characterizes costs and benefits associated with implementation of the Upper Illinois River watershed management plan and identifies potential sources of technical and financial assistance for implementing this plan.

6.1 Implementation Cost Estimates

Estimates of costs for implementing activities identified in this watershed management plan are provided below. Actual costs may differ from these estimates.

6.1.1 Existing Monitoring

The costs of existing routine water quality and biological monitoring in the Upper Illinois River watershed are included in agency budgets.

6.1.2 Proposed Special Studies

The cost of collecting water quality data in Category 1 sub-watersheds without recent data will depend on who conducts the sampling and analysis. The cost of sample analysis by a commercial laboratory for DEQ standard parameters was estimated to be around $800 per sample in 2023. EQIP fiscal year 2024, 75 percent reimbursements (non-HU) for installing edge of field monitoring systems (practice 201) range from $24,000.00 to $29,000.00, with another $4,000.00 to $30,000.00 a year to collect and analyze data (NRCS, 2023).

6.1.3 Nonpoint Source Pollution Management

The cost of implementing BMPs to reduce nonpoint source pollution can be variable, depending on materials markets and site conditions (e.g., slope, soil type). Tables 6.1 through 6.5 provide examples of estimated potential relative costs for implementation of selected BMPs in the Category 1 sub-watersheds of Upper Illinois River to achieve load reduction targets. Note that the estimated costs in Table 6.1 through 6.5 have been rounded to two (2) significant digits. Appendix N provides a detailed description of how these costs were calculated.

Table 6.1. Estimated costs for implementing practices in the Moores Creek sub-watershed.

Practice	Units to Implement	Cost per Unit	Maximum Cost	Potential Reduction			
				Total Nitrogen	Total Phosphorus	Sediment	*E. coli*
Prescribed grazing	6,578 acres	$40/acre	$260,000.00	8%	8%	15%	60%
Access control fence	91,206 feet	$4.00/foot	$360,000.00	8%	8%	25%	40%
Access control stream crossing	27 crossings	$3,000/crossing	$81,000.00	8%	8%	25%	40%
Watering facility	55 facilities	$1,200.00/facility	$66,000.00	8%	8%	15%	70%
Pasture and hay planting	1,000 acres	$400.00/acre	$400,000.00	8%	8%	29%	30%
Roof runoff structure	14 structures	$7,000.00/house	$98,000.00	12%	8%	20%	0%
Waste storage	4 facilities	$19,000.00/facility	$76,000.00	12%	8%	0%	90%
Filter strip	1.2 acres	$250.00/acre	$300.00	12%	28%	25%	0%
Grassed waterway	4 acres	$2,000.00/acre	$8,000.00	20%	14%	15%	0%
Restore riparian buffer (forest)	225 acres	$800.00/acre	$180,000.00	27%	19%	29%	55%
Restore riparian buffer (herbaceous)	225 acres	$200.00/acre	$63,000.00	27%	19%	29%	55%

Table 6.2. Estimated costs for implementing practices in the Lower Muddy Fork sub-watershed.

Practice	Units to Implement	Cost per Unit	Maximum Cost	Potential Reduction			
				Total Nitrogen	Total Phosphorus	Sediment	*E. coli*
Prescribed grazing	6,279 acres	$40.00/acre	$250,000.00	9%	13%	26%	60%
Access control fence	79,723 feet	$4.00/foot	$320,000.00	9%	13%	44%	40%
Access control stream crossing	24 crossings	$3,000.00/crossing	$72,000.00	9%	13%	44%	40%
Watering facility	48 facilities	$1,200.00/facility	$58,000.00	9%	13%	26%	70%
Pasture and hay planting	2,000 acres	$400.00/acre	$800,000.00	9%	13%	53%	30%
Roof runoff structure	24 houses	$7,000.00/house	$170,000.00	13%	13%	35%	0%
Waste storage	6 facilities	$19,000.00/facility	$110,000.00	13%	13%	0%	90%
Filter strip	1.8 acres	$250.00/acre	$450.00	13%	43%	44%	60%
Grassed waterway	6 acres	$2,000.00/acre	$12,000.00	22%	22%	26%	0%
Restore riparian buffer (forest)	192 acres	$800.00/acre	$150,000.00	30%	30%	53%	55%
Restore riparian buffer (herbaceous)	192 acres	$200.00/acre	$54,000.00	30%	30%	53%	55%
Streambank protection	4,910 feet	$160.00/foot	$780,000.00	1%	3%	24%	--
Streambank or stream restoration	4,910 feet	$3,000.00/foot	$15,000,000.00	3%	12%	30%	--
Remediate failing septic systems	5 systems	$11,000.00/system	$55,000.00	1%	1%	0%	90%

Table 6.3. Estimated costs for implementing practices in the Little Osage Creek sub-watershed.

Practice	Units to Implement	Cost per Unit	Maximum Cost	Potential Reduction			
				Total Nitrogen	Total Phosphorus	Sediment	*E. coli*
Prescribed grazing	13,863 acres	$40.00/acre	$550,000.00	5%	9%	15%	60%
Access control fence	231,952 feet	$4.00/foot	$930,000.00	5%	9%	25%	40%
Access control stream crossing	70 crossings	$3,000.00/crossing	$210,000.00	5%	9%	25%	40%
Watering facility	141 facilities	$1,200.00/facility	$170,000.00	5%	9%	15%	70%
Pasture and hay planting	6,000 acres	$400.00/acre	$2,400,000.00	5%	9%	29%	30%
Roof runoff structure	34 houses	$7,000.00/house	$240,000.00	8%	9%	20%	0%
Waste storage	9 facilities	$19,000.00/facility	$170,000.00	8%	9%	0%	90%
Filter strip	2.7 acres	$250.00/acre	$680.00	8%	30%	25%	60%
Grassed waterway	9 acres	$2,000.00/acre	$18,000.00	13%	15%	15%	0%
Restore riparian buffer (forest)	678 acres	$800.00/acre	$540,000.00	18%	21%	29%	55%
Restore riparian buffer (herbaceous)	678 acres	$200.00/acre	$190,000.00	18%	21%	29%	55%
Streambank protection	15,312 feet	$160.00/foot	$2,400,000.00	1%	3%	24%	--
Streambank or stream restoration	15,312 feet	$3,000.00/foot	$43,000,000.00	3%	12%	30%	--
Remediate failing septic systems	12 systems	$11,000.00/system	$130,000.00	11%	35%	0%	90%
Permeable pavement	2,964,000 square feet	$94.50/square foot	$280,000,000	26%	23%	29%	0
Rain garden	731,000 square feet	$365.87/square foot	$270,000,000	11%	0	29%	40%

Table 6.4. Estimated costs for implementing practices in the Lake Wedington-Illinois River sub-watershed.

Practice	Units to Implement	Cost per Unit	Maximum Cost	Potential Reduction			
				Total Nitrogen	Total Phosphorus	Sediment	*E. coli*
Prescribed grazing	4,186 acres	$40.00/acre	$170,000.00	26%	11%	9%	60%
Access control fence	72,505 feet	$4.00/foot	$290,000.00	44%	11%	9%	40%
Access control stream crossing	22 crossings	$3,000.00/crossing	$66,000.00	44%	11%	9%	40%
Watering facility	44 facilities	$1,200.00/facility	$53,000.00	26%	11%	9%	70%
Pasture and hay planting	1,000 acres	$400.00/acre	$400,000.00	26%	19%	24%	0%
Roof runoff structure	33 houses	$7,000.00/house	$230,000.00	24%	3%	1%	0%
Waste storage	8 facilities	$19,000.00/facility	$150,000.00	44%	38%	14%	60%
Filter strip	2.4 acres	$250.00/acre	$600.00	0%	0%	0%	0%
Grassed waterway	8 acres	$2,000.00/acre	$16,000.00	30%	12%	3%	0%
Restore riparian buffer (forest)	186 acres	$800.00/acre	$150,000.00	53%	26%	33%	55%
Restore riparian buffer (herbaceous)	186 acres	$200.00/acre	$52,000.00	53%	26%	33%	55%
Streambank protection	10,402feet	$160.00/foot	$1,700,000.00	53%	11%	9%	30%
Streambank or stream restoration	10,402feet	$3,000.00/foot	$31,000,000.00	35%	11%	14%	0%
Remediate failing septic systems	4 systems	$11,000.00/system	$44,000.00	0%	18%	1%	90%

Table 6.5. Estimated costs for implementing practices in the Lake Frances-Illinois River sub-watershed.

Practice	Units to Implement	Cost per Unit	Maximum Cost	Potential Reduction			
				Total Nitrogen	Total Phosphorus	Sediment	*E. coli*
Prescribed grazing	6,795 acres	$40.00/acre	$270,000.00	26%	14%	9%	60%
Access control fence	79,067 feet	$4.00/foot	$320,000.00	43%	14%	9%	40%
Access control stream crossing	24 crossings	$3,000.00/crossing	$72,000.00	43%	14%	9%	40%
Watering facility	48 facilities	$1,200.00/facility	$58,000.00	26%	14%	9%	70%
Pasture and hay planting	1,000 acres	$400.00/acre	$400,000.00	26%	24%	21%	0%
Roof runoff structure	23 houses	$7,000.00/house	$160,000.00	24%	3%	1%	0%
Waste storage	8 facilities	$19,000.00/facility	$110,000.00	43%	47%	13%	60%
Filter strip	1.8 acres	$250.00/acre	$450.00	0%	0%	0%	0%
Grassed waterway	6 acres	$2,000.00/acre	$12,000.00	30%	12%	3%	0%
Restore riparian buffer (forest)	209 acres	$800.00/acre	$170,000.00	51%	33%	30%	55%
Restore riparian buffer (herbaceous)	209 acres	$200.00/acre	$58,000.00	51%	33%	30%	55%
Streambank protection	4,118 feet	$160.00/foot	$660,000.00	51%	14%	9%	30%
Streambank or stream restoration	4,118 feet	$3,000.00/foot	$12,000,000.00	34%	14%	13%	0%
Remediate failing septic systems	2 systems	$11,000.00/system	$22,000.00	0%	18%	1%	90%

6.2 Benefits

While there are costs associated with implementing BMPs, as noted in Section 6.1.3, there are also benefits. These include direct economic benefits to the individuals and organizations implementing BMPs, as well as benefits that are more difficult to quantify economically to the individual or community implementing practices, as well as to society.

BMPs recommended for the Upper Illinois River watershed are expected to improve the health of ecosystems and their ability to provide services. In some cases, this can result in economic benefits that can be quantified relatively easily. In other cases, the benefits are more difficult to quantify economically. Examples of economic and non-material benefits of recommended BMPs are provided below.

6.2.1 Economic Benefits

While not all ecosystem services improved by BMPs have directly marketable economic value, there have been assessments of economic benefits of a number of practices. Economic benefits from pasture management BMPs can occur due to improved livestock production; reduced need for inputs such as fertilizer, pesticides, fuel, and labor; and additional opportunities for income -producing activities, such as hunting leases. Table 6.6 summarizes economic benefits associated with the BMPs recommended for Upper Illinois River watershed. Note that economic benefits have been associated with most, but not all, of the recommended practices. Much of the information in this table is based on NRCS cost-benefit worksheets (NRCS, n.d.). Other information sources include studies by NRCS and other researchers (NRCS 2006, Zeckoski, Benham and Lunsford 2012).

One (1) economic concern with stream exclusion fencing is damage to fences from debris carried by floods, requiring repeated maintenance or replacement. Virtual fencing for cattle is an alternative method of controlling cattle that is generating a lot of interest and shows good potential on large-scale cattle operations (Smith Thomas 2021) (US Department of Agriculture, n.d.). Use of this technology would eliminate the cost of replacing stream-side fences damaged by flooding.

Table 6.6. Summary of economic benefits associated with recommended BMPs for the Upper Illinois River watershed.

Practices	Increased Cattle Production	Decreased Pesticide Use/Cost	Decreased Damage/Land and/or Soil Loss	Reduced Maintenance Cost	Increased Property Value
Access control	x	x	x	x	x
Amendments for treatment of agriculture waste				x	x
Animal mortality facility				x	x
Composting facility					x
Critical area planting		x	x	x	x
Heavy use area protection			x	x	x
Karst sinkhole treatment	x			x	x
Pasture & hay planting			x		
Prescribed grazing and grazing management	x	x	x	x	x
Roof runoff structure			x	x	x
Livestock stream crossing	x		x	x	x
Waste storage facility				x	x
Watering facility	x		x		x
Constructed wetland		x	x	x	x
Filter strip		x	x	x	x
Grassed waterway			x	x	x
Land conservation		x	x	x	x
Restore riparian buffer		x	x	x	x
Stream crossing restoration			x	x	
Stream habitat improvement and management			x	x	x
Stream restoration			x	x	x
Streambank protection			x	x	x
Green streets			x	x	x
Low impact development/green infrastructure			x	x	
Septic system remediation					x
Rain gardens			x	x	x
Retrofit detention basins			x	x	
Permeable pavement			X	x	
Bioswale			x	x	X
Green roof			X		x
Rain barrel			x		

6.2.2 Other Benefits

BMPs also improve ecosystem services in ways that do not translate well into direct economic benefits. Table 6.7 lists examples of ecosystem service provided by BMPs recommended for the Upper Illinois River watershed. Specific BMPs proposed for the Upper Illinois River Category 1 sub-watersheds are listed in Table 6.8 along with the non-material environmental benefits that accrue from the implementation of these practices. Much of the information in this table is based on NRCS cost-benefit worksheets (NRCS, n.d.). Other information sources include studies by NRCS and other researchers (NRCS 2006, Zeckoski, Benham and Lunsford 2012).

Table 6.7. Examples of ecosystem service benefits associated with BMPs recommended for Upper Illinois River watershed that don't translate well into direct economic benefits.

Ecosystem service benefit	Description of how practice results in benefit
Erosion control	Practice reduces erosion.
Aquatic habitat	Practice provides or improves habitat for aquatic animals, e.g., by reducing water temperature, providing structure or organic matter inputs, or restoring more natural hydrology.
Nutrient cycling	Practice reduces nutrient losses from fields or encourages chemical transformation to non-bioavailable forms.
Carbon storage	Practice increases soil organic matter and vegetation growth that increase removal of greenhouse gases from atmosphere and regulate climate.
Soil health	Practice adds organic matter to soils, increases infiltration, reduces compaction, and improves soil structure and soil health.
Water purification	Practice increases water filtering through soils and vegetative/organic debris, or water contaminants are stored in plant matter.
Wildlife habitat	Practice increases or improves habitat for pollinators and other beneficial insects, sport birds, sport game, and other wildlife.
Flood regulation	Practice increases water infiltration, reduces stormwater runoff volume

Table 6.8. Ecosystem service benefits of BMPs proposed for Upper Illinois River watershed.

Practices	Erosion control	Aquatic habitat	Nutrient cycling	Carbon storage	Soil health	Water purification	Wildlife habitat	Flood regulation
Access control	x	x	x	x	x	x	x	x
Amendments for treatment of agriculture waste			x		x			
Animal mortality facility								
Composting facility			x	x	x			
Critical area planting	x	x	x	x	x	x	x	x
Heavy use area protection	x				x	x		
karst sinkhole treatment	x					x		
Pasture & hay planting	x		x	x	x	x	x	x
Prescribed grazing and grazing management	x	x	x	x	x	x	x	x
Roof runoff structure					x			
Livestock Stream Crossing		x						
Waste storage facility					x			
Watering facility	x	x			x			x
Constructed wetland	x	x	x	x		x	x	x
Filter strip	x		x	x	x	x	x	x
Grassed waterway	x		x	x	x	x	x	
Land conservation	x		x	x	x	x	x	x
Restore Riparian Buffer	x	x	x	x	x	x	x	x
stream crossing restoration	x	X						

Table 6.8. Ecosystem service benefits of BMPs proposed for Upper Illinois River watershed (continued).

Practices	Erosion control	Aquatic habitat	Nutrient cycling	Carbon storage	Soil health	Water purification	Wildlife habitat	Flood regulation
Stream habitat improvement and management		X						
Stream restoration		X	x					
Streambank protection	x	X						
Green streets	x		x	x		x		x
Low impact development/green infrastructure	x		x	x		x		x
Septic system remediation								
Rain gardens	x		x	x	x	x	x	x
Retrofit detention basins	x		x	x	x	x	x	x
Permeable pavement						x		X
Bioswale	x		x	x		x	X	x
Green roof			x	x		x	X	x
Rain barrel								

6.3 Technical Assistance

This section describes programs that can provide technical assistance for implementation of the activities recommended in this plan. The programs described here are examples. This is not intended to be a complete listing of all available programs that can provide technical assistance.

6.3.1 Monitoring

Agencies and universities conducting water quality monitoring generally have their own technical resources. Technical assistance for volunteer water quality monitoring programs is available through the AGFC Stream Habitat Program (see Stream Habitat Program • Arkansas Game & Fish Commission (agfc.com)). IRWP also offers training for volunteer water quality monitoring through its Water Quality Monitors program (see Water Quality Monitoring at IRWP — Illinois River Watershed Partnership).

6.3.2 Information and Education

Information for and assistance with education and outreach activities is available through the Arkansas Environmental Education Association (Project WET), AGFC (Project WILD), IRWP (Youth Education — Illinois River Watershed Partnership (irwp.org), Arkansas Cooperative Extension Service, and others. Resources are also available from EPA through the Nonpoint Source Outreach Toolbox (http://cfpub.epa.gov/npstbx/index.html).

Arkansas Cooperative Extension Service implements stormwater education programs required by municipal storm runoff NPDES permits in Northwest Arkansas (UofA Cooperative Extension Service 2018). Information and education sources related to public education about urban stormwater are available on the Arkansas Cooperative Extension Service website, https://www.uaex.uada.edu/environment-nature/water/stormwater/default.aspx.

The Arkansas Cooperative Extension Service and Natural Resources Division together implement the Arkansas Watershed Steward Program. This program includes training that outreach professionals and educators can use to educate and recruit residents to play more active roles in watershed management and their communities.

6.3.3 Implementing BMPs

There are agencies and organizations that provide technical assistance for installing, operating, and maintaining BMPs identified for the Category 1 sub-watersheds. Examples are summarized in Table 6.9 and discussed below.

Table 6.9. Examples of technical assistance available for BMPs recommended for the Upper Illinois River watershed.

Practices	AR Department of Agriculture Forestry Division	AR Game and Fish Commission	Cooperative Extension Service	County Conservation Districts	EPA	Farm Services Agency	NRCS	National Sustainable Agriculture Information Service	Sustainable Agriculture Education Programs	US Fish and Wildlife Service	USDA Wildlife Services	IRWP	Northwest Arkansas Land Trust
Access control			X	X			X	X					
Amendments for treatment of agriculture waste			X	X			X						
Animal mortality facility			X	X			X						
Composting facility			X	X			X						
Critical area planting				X			X						
Heavy use area protection			X	X			X						
Karst sinkhole treatment				X			X						
Pasture & hay planting				X			X						
Prescribed grazing and grazing management			X	X			X	X	X			X	
Roof runoff structure				X			X						
Livestock stream crossing		X		X			X			X			
Waste storage facility				X			X						
Watering facility				X			X	?	?				
Constructed wetland		?	?	X	X		X			?		?	?
Filter strip			?	X	X	X	X						
Grassed waterway			X	X	X		X	?	?				
Land conservation		?				X	X	X		X			X
Restore riparian buffer	X	X	X	X		X	X	X		X		X	X
Stream crossing restoration		X		X			X			X			
Stream habitat improvement and management		X	X	X	X		X			X		X	?
Stream restoration					X					X		X	?
Streambank protection		X		X			X						
Green streets			X		X							X	
Lined waterway or outlet			X		X							X	
Low impact development/green infrastructure			X		X							?	
Septic system maintenance			X		X							X	

Table 6.9. Examples of technical assistance available for BMPs recommended for the Upper Illinois River watershed (continued).

Practices	AR Department of Agriculture Forestry Division	AR Game and Fish Commission	Cooperative Extension Service	County Conservation Districts	EPA	Farm Services Agency	NRCS	National Sustainable Agriculture Information Service	Sustainable Agriculture Education Programs	US Fish and Wildlife Service	USDA Wildlife Services	IRWP	Northwest Arkansas Land Trust
Rain gardens			X		X							X	
Retrofit detention basins					X							X	
Permeable pavement			X		X							X	
Bioswale			X		X							X	
Green roof					X							X	
Rain barrel			X		X							X	

6.3.3.1 County Conservation Districts

Conservation Districts for the counties in the Upper Illinois River watershed are active in nonpoint source management within the watershed. They work with NRCS to provide technical support to landowners, including information and guidance about BMPs for protecting soil and water resources, including benefits, costs, installation, operation, and maintenance. Conservation districts employee water quality technicians supported through the Arkansas Department of Agriculture’s Natural Resources Division to write nutrient management plans at no cost to the producer. Conservation districts can also support producers participation voluntary cost-share programs through the Natural Resources Division Title X cost-share program.

6.3.3.2 U of A Division of Agriculture

The UofA Cooperative Extension Service provides technical assistance through a range of programs and services including testing of manure, hay, soil, and water; assistance with cropland, pasture, and livestock management; and field days and on-farm demonstrations. Cooperative Extension Service also maintains an extensive library of up-to-date, research-based fact sheets, applied research publications, and manuals and guidelines that address both agricultural and urban BMPs. The experiment station and Discovery Farm programs of the UofA Division of Agriculture generate, interpret, and distribute information and technology useful to farmers in Arkansas. Arkansas Cooperative Extension Service is also partnering with Natural Resources Division to provide training in water quality management through the Arkansas Watershed Steward Program.

6.3.3.3 Arkansas Game and Fish Commission

Through the AGFC Private Lands Division, Private Lands Biologists can provide technical assistance to volunteer landowners and tenants with managing their lands to improve both upland and aquatic wildlife habitat, in working pastures and haylands, farm ponds, and in set-aside areas like riparian areas. Management actions that improve wildlife habitat usually also reduce nonpoint source pollution and improve water quality.

Through the Stream Habitat Program, AGFC can provide technical assistance to riparian landowners and stream users in planning, designing, and implementing streambank stabilization and riparian restoration projects to reduce erosion, and sediment and turbidity in streams. AGFC can also assist landowners with identifying and obtaining necessary permits and identifying additional potential sources of financial assistance. These programs are available to non-agriculture landowners (E. Powers, AGFC, personal communication, 9/20/2022).

6.3.3.4 USDA Natural Resources Conservation Service and Farm Services Agency

The NRCS offers several programs to help landowners address natural resources concerns related to poultry, livestock, and pasture management. NRCS conservationists and specialists at county field service centers can work with producers on resource assessments of pastures and fields, designing practices, developing management plans, and can provide guidance on implementation, and maintenance of implemented practices. Technical assistance is available for a variety of cropland and pasture practices through the NRCS County Service Centers, through NRCS programs such as Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP) (NRCS, 2022b). FSA also provides technical assistance for planning and implementing habitat improvement on Conservation Reserve Program (CRP) lands (FSA, 2021b).

6.3.3.5 Sustainable Agriculture Education Programs

The Sustainable Agriculture Research and Education program (SARE) and National Sustainable Agriculture Information Service (ATTRA) (both funded by USDA) support farmers, researchers, and educators exploring practices that improve farm stewardship and profitability, and the vigor of farm communities. These programs emphasize outreach and distribution of the results of program research. This information is available from websites and includes a variety of print and electronic materials appropriate for producers (http://www.southernsare.org/About-Us, www.attra.ncat.org). On-site technical assistance is also available from ATTRA (ATTRA, 2018).

6.3.3.6 US Environmental Protection Agency

The EPA website provides access to information on a variety of water quality subjects, including management measures for agriculture, unpaved roads, and developed areas. Specific information sources available through the EPA website include the Watershed Academy (https://www.epa.gov/watershedacademy/online-training-watershed-management), Nonpoint Source Pollution page (https://www.epa.gov/nps), and Green Infrastructure section (https://www.epa.gov/green-infrastructure).

6.3.3.7 US Fish and Wildlife Service

Through its Partners for Fish and Wildlife program, the USFWS provides technical assistance to private landowners for projects to protect, improve, or restore native habitats. Assistance is available for designing, installing, and maintaining habitat-enhancing projects, including restoration of riparian habitats, wetlands, and native grasslands, and removal of stream barriers. The USFWS can also assist with locating funding for implementation.

6.3.3.8 Illinois River Watershed Partnership (IRWP)

IRWP provides free technical assistance to landowners in partnership with the NRCS through its Landowner Services program. Through this program assistance is available with both agricultural and green infrastructure practices, and land conservation. In addition, IRWP can assist landowners in working with NRCS and with locating funding assistance sources for implementation. IRWP is dedicated to integrating new technology, leveraging tools and techniques from various industries, and implementing innovative approaches to education and outreach.

6.3.3.9 Northwest Arkansas Land Trust

The Northwest Arkansas Land Trust works with landowners to develop and implement conservation plans for undeveloped land in Northwest Arkansas. Benton and Washington County, Arkansas in the Trust's core service area.

6.4 Financial Assistance

This section describes programs that can provide financial assistance for implementation of the activities recommended in this plan. The programs described here are examples. This is not intended to be a complete listing of all available programs that can provide funding assistance.

6.4.1 Monitoring

DEQ, Natural Resources Division, and USGS have funded water quality monitoring projects in the Upper Illinois River watershed. USGS flow and/or water quality monitoring sites could be added in the watershed if a local entity would provide funds. The USGS 104b grant program funds water research projects of the Arkansas Water Resources Center.

SARE grants are available to support agricultural research, which could include water quality and/or biological monitoring. SARE funded 11 research grants totaling over $1 million in Arkansas 2019-2024 (Sustainable Agriculture Research and Education, 2024).

The AGFC Stream Habitat program has supported water quality monitoring by Stream Teams in the Upper Illinois River watershed. This program can provide funding for volunteer monitoring programs through mini grants. State Wildlife Grant funding from AGFC can be used for biological surveys. In 2019, federal funds totaling $597,556 were distributed as State Wildlife Grants in Arkansas (https://www.agfc.com/en/wildlife-management/awap/state-wildlife-grants/).

Natural Resources Division can assist with funding water quality monitoring projects through the 319 Program. In fiscal year 2022, Natural Resources Division allocated approximately 55% of Nonpoint Source Program federal funds to monitoring projects (Natural Resources Division, 2023a).

NRCS EQIP and RCCP programs can fund monitoring of water quality (practice 201), prescribed grazing (practice 219), soil organic carbon (practice 221), habitats for rare or declining species (practice 643), wetland habitat (practice 644), and upland habitat (practice 645) (NRCS, 2023).

6.4.2 Information and Education

AGFC offers Wildlife Education Grants funded through fines collected from violations of Arkansas game laws (https://www.agfc.com/en/education/classroom/conservation-education-grants/). For the 2023- 2024 school year, a combined amount of over $17,000.00 was available for Wildlife Education Grants in Benton and Washington counties (AGFC, 2023).

Projects funded through the Natural Resources Division Nonpoint Source Pollution Management Program (Section 319[h] funds) usually include an education and outreach component. In 2021, approximately $400,000 were spent on outreach projects in Arkansas through the 319 Grant Program (Natural Resources Division, 2022).

SARE offers Research and Education grants. From2019-2024, SARE funded five education only grants totaling over $200,000 in Arkansas (Sustainable Agriculture Research and Education, 2024).

Projects funded through NRCS and Farm Services Agency cost-share and easement programs are often used as demonstrations in NRCS and Conservation District outreach and education programs.

The EPA provides grants for environmental education (https://www.epa.gov/education/grants).

There are several private foundations that fund education, which may include environmental education. Examples include the Arkansas Environmental Educators Association and the Walton Family Foundation. In addition, organizations can often find local businesses or organizations to sponsor information and education activities, such as painting storm drains, festivals, and clean-up days.

6.4.3 Implementing BMPs

Over the years, funding has been provided for implementation of BMPs in the Upper Illinois River watershed. There are several agencies and programs that offer financial assistance for implementation of nonpoint source pollution BMPs recommended for the Category 1 sub-watersheds and throughout the Upper Illinois River watershed. The majority of these are grant programs, many of which require matching funds from the grant recipient. In addition, there are low interest loan programs and at least one tax incentive program that address practices that reduce nonpoint source pollution. Table 6.10 lists BMPs for the Category 1 sub-watersheds along with examples of funding sources. It is notable that many federal assistance programs are seeing reductions in available funds. However, it is also notable that use of many of these BMPs can improve the bottom line for producers or communities (see Section 6.2), providing an incentive for implementation even without financial assistance.

Table 6.10. Examples of sources of financial assistance available for BMPs recommended in the Upper Illinois River watershed.

Agency/Organization	AR Department of Agriculture Natural Resources Division				AR Game and Fish Commission		Farm Services Agency	IRWP			Northwest Arkansas Land Trust	NRCS			US Fish and Wildlife Service
Program	Nonpoint Source Grant Program (Section 319 and Infrastructure funds)	State Revolving Loan Fund	Agriculture Water Quality Loan Program	Arkansas Wetland and Riparian Zones Tax Credit Program	Acres for Wildlife	Stream Habitat Program	Conservation Reserve Programs	Green Infrastructure Program	Riparian Restoration Program	Septic Tank Remediation Program	Northwest Arkansas Land Trust	Conservation Stewardship Program	Environmental Quality Incentive Program	Regional Conservation Partnership Program	Partners for Fish and Wildlife
Eligible recipients	Cities, counties, organizations	Communities, utilities	Individuals	Individuals	Individuals	Individuals	individuals	counties, communities, companies, organizations, schools	landowners (agricultural and residential), businesses, HOAs, municipalities	homeowners	individuals	Individuals	Individuals	Individuals, communities, organizations	Individuals, organizations
Focus area within Upper Illinois River watershed	All	All	Agricultural land	Wetlands and riparian zones	Pastures	Streams & rivers & adjacent land	agricultural land	highly visible locations in developed areas	all	all	undeveloped land	Agriculture and forest lands	Agriculture and forest lands	Agriculture and forest lands	Wetlands, prairies, habitat for species of concern

Table 6.10. Examples of sources of financial assistance available for BMPs recommended in the Upper Illinois River watershed (continued).

Program	Nonpoint Source Grant Program (Section 319 and	State Revolving Loan Fund	Agriculture Water Quality Loan Program	Arkansas Wetland and Riparian Zones Tax Credit Program	Acres for Wildlife	Stream Habitat Program	Conservation Reserve Programs	Green Infrastructure Program	Riparian Restoration Program	Septic Tank Remediation Program	northwest Arkansas Land Trust	Conservation Stewardship Program	Environmental Quality Incentive Program	Regional Conservation Partnership Program	Partners for Fish and Wildlife
Funding Vehicle	cost share	low interest loan	low interest loan	tax credit			Rent, 50% cost share	50% cost-share	75% cost-share	zero-interest loan grant	purchase	cost share	cost share	cost share	cost share
Practice															
Access control	X		X			?		X	X			X	X	X	X
Amendments for treatment of agriculture waste	X												X	X	
Animal mortality facility	X												X	X	
Composting facility	X												X	X	
Critical area planting	X				X								X	X	
Heavy use area protection	X												X	X	
Karst sinkhole treatment	X												X	X	
Pasture & hay planting	X				X								X	X	X
Prescribed grazing and grazing management	X		X						X			X	X	X	
Roof runoff structure	X												X	X	
Livestock stream crossing	X				X				X				X	X	X
Waste storage facility	X		X										X	X	
Watering facility	X		X						X			X	X	X	X
Constructed wetland	X			?	?								X	X	?
Filter strip	X						X					X	X	X	
Grassed waterway	X												X	X	
Land conservation					X		X				X		X	X	X
Restore riparian buffer	X			X	X	X	X	X	X			X	X	X	X
Stream crossing restoration	X				X								X	X	
Stream habitat improvement and management	X			X	X								X	X	X
Stream restoration	X			X		X								X	X
Streambank protection	X			X	X	X			X			X	X	X	X
Green streets	X							X							
Lined waterway or outlet	X												X		
Low impact development/green infrastructure	X							X							
Septic system maintenance										X					
Rain gardens	X							X							
Retrofit detention basins	X							X	X						
Permeable pavement	X							X							
Bioswale	X							X							
Green roof	X							X							
Rain barrel															

6.4.3.1 USDA NRCS

As shown in Table 6.6 there are NRCS programs active in Arkansas that provide funding assistance for development and installation of nonpoint source pollution BMPs that are applicable to the Category 1 sub-watersheds of the Upper Illinois River. Benton County is a focus area for Bobwhite Quail under the Environmental Quality Incentive Program (EQIP) Working Lands for Wildlife Initiative. Information about NRCS financial assistance programs, including application deadlines, cost-share requirements, and funding caps, is available online (https://www.nrcs.usda.gov/conservation-basics/conservation-by-state/arkansas) or from a local USDA service center, local conservation district, or local cooperative extension agents.

During the period 2008-2020 NRCS provided around $1,000,000.00 in funding assistance to producers in the Upper Illinois River watershed through EQIP, Conservation Stewardship Program, and Regional Conservation Partnership Program (Christianson 2021). Table 6.9 shows funding provided to individuals in Arkansas through NRCS programs active in the Upper Illinois River watershed during the 2021 fiscal year (Arkansas NRCS 2021). Table 6.9 also shows the 2023 fiscal year national budget for NRCS conservation programs that can provide funding assistance in the Little Red River watershed.

Table 6.11. Funding provided to individuals in Arkansas through NRCS programs during the 2022 fiscal year (Sullivan, 2023) and 2024 fiscal year national budgets for selected NRCS conservation programs (USDA, 2023)

Program	FY2022 Funds Distributed in Arkansas, millions of dollars	FY2024 National Budget, millions of dollars
Agricultural Conservation Easement Program	$13.9	$424
Conservation Stewardship Program	$30	$943
Environmental Quality Incentives Program	$57	$1,910
Regional Conservation Partnership Program	$3.2	$283

6.4.3.2 Farm Service Agency

The FSA administers the CRP. Through this land conservation program, landowners receive yearly rental payments for land enrolled in the program. CRP land contracts typically are for 10 to 15 years. Marginal pasture and pasture along streams that can be used for establishment of riparian buffers can be eligible for CRP enrollment. In addition to rental payments, the FSA may pay up to 50 percent of eligible costs for establishing vegetation on eligible lands, and an additional cost share for Climate-Smart practices that reduce greenhouse gases or increase carbon sequestration (FSA 2022a). Additional financial incentives are available in Arkansas for conservation easements through the FSA CLEAR30, State Acres for Wildlife Enhancement, and Farmable Wetlands Program (FSA 2022b, FSA 2022c, FSA 2022d). The fiscal year 2024 national budget for CRP is $1,676 million (USDA, 2023).

6.4.3.3 US Fish and Wildlife Service

The USFWS Partners for Fish and Wildlife program can provide funding assistance to individuals for installing nonpoint source BMPs. Funding from this program may require cost-share (USFWS, 2022b). The 2024 fiscal year national budget for the Partners for Fish and Wildlife program is $79,717 million (USFWS, 2023).

6.4.3.4 Arkansas Department of Agriculture - Natural Resources Division

Natural Resources Division manages the Arkansas Section 319 grant program. This program provides cost-share grants to non-profit groups, organizations, communities, and academic institutions for projects related to reduction, control, or abatement of nonpoint source pollution. Eligible projects can include implementation of BMPs on pastures as well as stormwater management and low impact development practices in developed areas. Organizations seeking grants must be capable of implementing projects and are typically required to provide a minimum of 43% non-federal matching contributions. Through the Natural Resources Division Title X program, conservation districts can distribute Section 319 grant funds to individuals. In 2021, around $2.25 million in federal funds were spent on implementing BMPs in Arkansas through the Clean Water Act Section 319 grant program (Natural Resources Division, 2023). The 2024 fiscal year national budget for the Section 319 grant program is $189 million (EPA, 2023).

The Natural Resources Division manages the state Agriculture Water Quality Loan Program and State Revolving Loan Funds. Through the Agriculture Water Quality Loan Program landowners can borrow up to $250,000.00 at a low interest rate to implement BMPs to reduce NPS (NRD, 2021b). Communities and utilities can borrow money from the State Revolving Loan Fund at a low interest rate to fund improvements to drinking water and wastewater systems and infrastructure, BMPs that protect drinking water sources, and projects that use or promote green approaches and facilitate compliance with the Clean Water Act (Natural Resources Division 2023b, Natural Resources Division 2022c).

Funds for wetland and riparian area restoration projects are available through the Arkansas Wetland & Riparian Zones Tax Credit Program. Through this program, landowners can receive up to $50,000.00 in tax credits, up to $5,000 per year over 10 years, as reimbursement for the expenses of wetland or riparian restoration projects.

6.4.3.5 Arkansas Game and Fish Commission (AGFC)

The AGFC has programs that can provide financial assistance with implementation of BMPs. The Acres for Wildlife program can provide up to $5,000 to landowners to assist with establishment of plantings for wildlife habitat. Stream Habitat program funds can be used to provide up to $5,000.00 to private landowners to assist with streambank stabilization or riparian restoration projects (https://www.agfc.com/en/education/onthewater/streamteam/habitat-restoration/). In addition, AGFC can help landowners identify and apply for other state and federal funding incentives for implementation of BMPs that reduce nonpoint source pollution (J. Sheehan, AGFC, personal communication, 2/24/2023).

6.4.3.6 Illinois River Watershed Partnership (IRWP)

IRWP has programs that can provide financial assistance to individuals and communities with implementation of BMPs. The IRWP Green Infrastructure Program is a cost-share program that can fund up to 50 percent of project costs of installing green infrastructure practices. The goal of this program is to install 30 practices in at least 12 high visibility locations in the Upper Illinois River watershed (IRWP, 2023). In 2023 approximately $760,000.00 was disbursed by IRWP for natural infrastructure projects (IRWP, 2024).

The IRWP Riparian Restoration Program is a cost-share program that can provide up to 75 percent of project costs to agricultural and residential landowners, as well as businesses, homeowner associations, and municipalities. This program has $2.8 million available to fund 20 miles of water quality improvements in the watershed (IRWP, 2023).

The Septic Tank Remediation Program assists homeowners with the cost of repairing or replacing septic systems designated as failing by the Arkansas Department of Health local county health unit. Funding assistance is provided as a combination of low interest loan and non-repayable grant (IRWP, 2023). Between 2020 and 2023 IRWP disbursed $839,290.00 through the Septic Tank Remediation Program. This program was funded at least through 2024 (IRWP, 2024).

6.4.3.7 Northwest Arkansas Land Trust

One (1) option for land conservation through the Northwest Arkansas Land Trust is purchase of land. Donation of land to the trust can provide tax benefits (Northwest Arkansas Land Trust, 2022).

6.5 Non-Monetary Assistance with Implementing BMPs

Agencies, organizations, and individuals can support implementation of nonpoint source BMPs in ways other than providing funds or technical assistance. One way is through offering free or low-cost materials. For example, the Arkansas Forestry Commission, Arkansas Urban Forestry Council, and National Arbor Day Foundation provide low-cost or free tree seedlings.

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[1] Cow+calf inventories were divided by the reported acres of permanent pasture. This value of average number of cows+calves per acre of pasture was multiplied by the acreage of pasture and hayland for this HUC12 from the 2019 NLCD to get an estimate of the number of cows and calves in the HUC12.

UPPER ILLINOIS RIVER WATERSHED MANAGEMENT PLAN

Little Rock, Arkansas

October 2024

Olsson Project No. 024-01220

APPENDIX A
SUMMARIES OF PUBLIC MEETING ATTENDEES

The following tables show the number and type of stakeholders that attended each stakeholder meeting for the update of the Illinois River Watershed Management Plan. The fourth stakeholder meeting was held in two locations on consecutive days. The same information was presented and discussed at both meetings. The meeting schedule was as follows:

- First Stakeholder Meeting – October 11,2022
- Second Stakeholder Meeting – May 18, 2023
- Third Stakeholder Meeting – August 10, 2023
- Fourth Stakeholder Meeting – June 25 and 26, 2024

First Stakeholder Meeting – October 11, 2022

Organization / Category	Number of attendees
Arkansas Game and Fish Commission	1
Arkansas Dept. of Agriculture Natural Resources Division	3
Interested citizens	1
FTN Associates	3
Oklahoma Conservation Commission	3
Save the Illinois River (STIR)	2
Cherokee County RWD12	1
Journalists	3
BioX Design	1
Grand River Dam Authority (USACE)	3
Oklahoma Rural Water Association	1
Citizens Advocating a Safe Environment (CASE)	2
Jacobs/WRRF	1
Breweries	2
Oklahoma Water Resources Board	1
Arkansas Department of Health	1
OK Foods	1
Camp/Canoe Operators	2
Illinois River Watershed Partnership	1
Edgewater Coaching and Consulting	1
Tyson	1
Conservation Coalition of Oklahoma Foundation	1

Second Stakeholder Meeting –May 18, 2023

Organization / Category	Number of attendees
Arkansas Game and Fish Commission	1
Arkansas Dept. of Agriculture Natural Resources Division	2
Interested citizens	12
FTN Associates	4
Oklahoma Conservation Commission	3
Save the Illinois River (STIR)	5
Cherokee County	1
Journalists	4
Attorneys	3
Bio x Design	1
Grand River Dam Authority	1
Oklahoma Rural Water Association	1
Citizens Advocating a Safe Environment (CASE)	1
Jacobs/City of Fayetteville	1
OK Foods	1
Illinois River Watershed Partnership	4
Oklahoma Energy & Environment	1
Oklahoma Department of Agriculture, Food, and Forestry (ODAFF)	1
Tahlequah Public Works	1
Carbon Chicken Project	1
Ozark Society	1
Emerald Solutions	1
SHV Tahlequah	1
USDA Natural Resources Conservation Service	5
Oklahoma Department of Wildlife Conservation (ODWC)	1
Oklahoma Onsite Wastewater Association (OOWA)	1
City of Siloam Springs	1
Northwest Arkansas Land Trust	2
US Army Corps of Engineers	2

City of Bentonville	2
University of Arkansas Cooperative Extension Service	1
Benton County Quorum Court	1
H2Ozarks	1
Watershed Conservation Resource Center	1
NWAR PC	1
Crafton Tull	1
AEMS (OK)	1
Oklahoma Farm Bureau	1
WCCD	1
City of Tontitown	1
Cherokee Nation	1
Food Recycling Solutions	1
Tulsa Metro Utility Authority	1
Fiddlers Bend?	1
Southwestern Power Company (SWEPCO)	1

Third Stakeholder Meeting – August 10, 2023

Organization / Category	Number of attendees
Arkansas Department of Agriculture Natural Resources Division	3
Arkansas Department of Energy and Environment Division of Environmental Quality (DEQ)	2
Arkansas Farm Bureau	1
Attorneys	1
Beaver Water District	1
BioX Design	1
Breweries	1
Camp/Canoe Operators	1
Carbon Chicken Project	2
Cherokee Nation Environmental Programs	1
City of Bentonville	2
City of Fayetteville	2

City of Springdale	1
City of Tahlequah Public Works	1
City of Tontitown	2
Crafton Tull	1
Emerald Solutions	1
EnviroScapes	1
Envision Group	1
Freese and Nichols	1
FTN Associates	3
Grand River Dam Authority	1
Halff	1
Illinois River Watershed Partnership (IRWP)	6
Interested citizens	13
Jacobs/City of Fayetteville	1
Journalists	1
NCAT (National Center for Appropriate Technology)	1
Northwest Arkansas Regional Planning Commission (NWARPC)	2
OERI	1
Oklahoma Conservation Commission (OCC)	4
Oklahoma Department of Agriculture, Food, and Forestry (ODAFF)	4
Oklahoma Energy & Environment (OEE)	2
Oklahoma Rural Water Association (ORWA)	1
Save the Illinois River (STIR)	1
SG Municipal	1
Tyson	1
University of Arkansas Cooperative Extension Service	2
US Environmental Protection Agency Region 6	3
US Fish and Wildlife Service (USFWS)	1
US Geological Survey (USGS)	1
USDA Natural Resources Conservation Service (NRCS)	1
Watershed Conservation Resource Center (WCRC)	2

Fourth Stakeholder Meeting 1 – June 25, 2024, Tahlequah, Oklahoma

Organization / Category	Number of attendees
Arkansas Department of Agriculture Natural Resources Division	2
The Nature Conservancy	1
Carollo Engineers	1
Political candidates/campaigns	3
Golf course	2
Landowner	6
Resident	4
Cherokee Nation	2
City of Tahlequah Public Works	1
Freese and Nichols	1
Olsson FTN	2
Grand River Dam Authority	3
Illinois River Watershed Partnership (IRWP)	1
Journalists	2
Oklahoma Conservation Commission (OCC)	5
Oklahoma Department of Agriculture, Food, and Forestry (ODAFF)	1
Save the Illinois River (STIR)	4
Arkansas Department of Energy and Environment	2
US Environmental Protection Agency Region 6	2
US Fish and Wildlife Service (USFWS)	1

Fourth Stakeholder Meeting 2 – June 26, 2024, Cave Springs, Arkansas

Organization / Category	Number of attendees
Arkansas Department of Agriculture Natural Resources Division	2
Arkansas Department of Energy and Environment Division of Environmental Quality (DEQ)	2
Buffalo River Watershed Alliance	1
Conservation Coalition of Oklahoma	1
WEI	1
Ozark Ecological Restoration, Inc.	1
Ozark Society	1
Savanna Springs, LLC	2
Benton County	1
Trailblazers	1
The Nature Conservancy	2
Oklahoma Department of Environmental Quality (ODEQ)	3
City of Springdale	2
Political candidates/campaigns	1
City of Rogers	1
Northwest Arkansas Regional Planning Commission	1
Crafton Tull	1
Olsson FTN	2
Grand River Dam Authority	1
SWEPCO	1
Illinois River Watershed Partnership (IRWP)	4
Interested citizens	3
Journalists	1
Oklahoma Conservation Commission (OCC)	3
Tyson	1
University of Arkansas Cooperative Extension Service	1
USDA Natural Resources Conservation Service (NRCS)	1

APPENDIX B
DEMOGRAPHICS BY HUC12

HUC12 Number 11110103-	Population (2022)	White (%)	Black or African American alone (%)	American Indian and Alaska Native alone (%)	Asian alone (%)	Native Hawaiian and Other Pacific Islander alone (%)	Some Other Race alone (%)	Two or More Races (%)	Male (%)	Male 0-5 yrs (%)	Male 5-14 yrs (%)	Male 15-24 yrs (%)	Male 25-34 yrs (%)	Male 35-44 yrs (%)	Male 45-54 yrs (%)	Male 55+ yrs (%)	Female (%)	Female 0-5 yrs (%)	Female 5-14 yrs (%)	Female 15-24 yrs (%)	Female 25-34 yrs (%)	Female 35-44 yrs (%)	Female 45-54 yrs (%)	Female 55+ yrs (%)	No schooling completed (%)	Regular high school diploma (%)	Associate's degree (%)	Bachelor's degree (%)	Master's degree (%)	Doctorate degree (%)	Average Median Household Income (2022 inflation-adjusted dollars)
-0101	5,573	78%	0%	1%	1%	0%	2%	19%	50%	6%	8%	5%	7%	5%	7%	12%	50%	2%	10%	4%	8%	6%	11%	10%	0%	19%	9%	10%	2%	0%	64,900
-0102	1,975	80%	0%	0%	2%	0%	3%	15%	51%	3%	6%	9%	8%	5%	10%	11%	49%	4%	8%	6%	5%	8%	5%	13%	1%	25%	5%	7%	2%	0%	53,600
-0103	972	79%	0%	0%	0%	0%	2%	18%	52%	7%	3%	8%	6%	3%	14%	11%	49%	4%	7%	4%	6%	9%	7%	11%	1%	18%	6%	10%	2%	0%	54,900
-0201	33,671	80%	4%	0%	4%	0%	2%	9%	48%	3%	5%	10%	9%	7%	4%	10%	52%	3%	6%	10%	8%	7%	5%	13%	0%	10%	5%	19%	11%	3%	71,800
-0202	35,066	55%	4%	2%	5%	4%	13%	17%	51%	4%	7%	8%	6%	7%	8%	10%	49%	3%	8%	7%	8%	7%	5%	10%	2%	13%	4%	10%	6%	1%	71,000
-0203	21,011	78%	5%	1%	2%	0%	3%	11%	53%	4%	5%	11%	14%	7%	3%	8%	47%	3%	4%	10%	11%	5%	5%	10%	1%	10%	3%	18%	11%	2%	66,000
-0204	7,025	77%	2%	0%	2%	1%	5%	12%	50%	4%	8%	4%	7%	7%	6%	14%	50%	2%	6%	10%	5%	8%	7%	12%	1%	12%	3%	16%	8%	2%	86,400
-0301	46,444	52%	3%	1%	2%	10%	12%	20%	51%	4%	9%	8%	8%	8%	5%	8%	49%	4%	8%	7%	8%	6%	6%	10%	2%	14%	3%	10%	4%	0%	74,000
-0302	31,803	63%	4%	0%	17%	0%	3%	13%	52%	4%	8%	6%	12%	10%	6%	5%	48%	3%	9%	5%	10%	9%	5%	7%	0%	12%	5%	17%	12%	1%	97,500
-0303	71,765	69%	2%	1%	4%	1%	4%	19%	50%	4%	8%	7%	8%	7%	6%	9%	50%	3%	7%	7%	8%	7%	6%	12%	1%	16%	4%	15%	6%	1%	81,400
-0304	19,458	65%	1%	1%	2%	3%	11%	17%	51%	3%	8%	9%	6%	8%	6%	12%	49%	4%	7%	6%	7%	6%	6%	13%	2%	14%	4%	13%	5%	1%	72,200
-0305	4,998	76%	1%	0%	2%	2%	9%	11%	54%	3%	6%	10%	5%	7%	10%	14%	46%	4%	8%	3%	5%	6%	6%	14%	0%	23%	4%	12%	5%	1%	80,100
-0401	3,110	88%	2%	2%	1%	0%	0%	7%	50%	2%	7%	6%	7%	7%	7%	15%	50%	2%	7%	6%	6%	6%	9%	16%	1%	23%	6%	12%	4%	1%	71,000
-0402	19,454	82%	2%	2%	1%	0%	4%	9%	50%	4%	8%	6%	9%	8%	5%	10%	50%	3%	6%	10%	8%	6%	5%	12%	1%	15%	5%	13%	7%	1%	75,700
-0403	1,850	76%	0%	1%	1%	0%	9%	13%	55%	4%	7%	4%	4%	10%	7%	18%	45%	3%	3%	4%	7%	8%	4%	14%	0%	18%	4%	15%	9%	0%	82,700
-0501	4,870	76%	0%	3%	2%	0%	1%	16%	49%	4%	4%	7%	8%	6%	5%	15%	51%	3%	9%	7%	7%	5%	7%	13%	0%	20%	5%	13%	2%	0%	67,700
-0502	15,325	64%	1%	5%	4%	0%	5%	21%	47%	3%	7%	9%	7%	5%	5%	12%	53%	5%	7%	10%	8%	4%	5%	15%	3%	15%	3%	11%	3%	0%	64,900
-0503	3,752	71%	1%	6%	2%	2%	2%	18%	48%	3%	6%	6%	7%	6%	6%	15%	52%	3%	8%	6%	7%	6%	7%	14%	0%	22%	4%	12%	2%	0%	69,100
-0601	1,422	77%	0%	1%	3%	0%	0%	19%	53%	2%	5%	10%	5%	7%	10%	15%	47%	3%	8%	3%	3%	7%	7%	16%	0%	30%	3%	16%	3%	1%	60,000
-0602	541	66%	0%	1%	9%	0%	5%	18%	52%	3%	5%	7%	8%	5%	9%	15%	48%	2%	7%	3%	4%	5%	8%	19%	2%	27%	8%	10%	3%	1%	65,100
-0603	824	54%	0%	1%	17%	0%	8%	19%	52%	5%	5%	8%	9%	3%	11%	11%	48%	3%	7%	4%	7%	3%	11%	13%	3%	27%	3%	8%	3%	1%	65,100
-0604	2,123	68%	0%	6%	5%	0%	4%	17%	49%	3%	7%	8%	8%	5%	7%	12%	51%	3%	9%	5%	6%	6%	6%	15%	1%	28%	2%	5%	2%	0%	53,700
-0606	4,709	69%	1%	4%	2%	0%	8%	15%	50%	5%	6%	10%	7%	5%	5%	12%	50%	4%	9%	5%	10%	4%	5%	12%	5%	21%	2%	11%	3%	0%	59,800
-0701	1,677	70%	0%	2%	0%	1%	3%	24%	48%	3%	4%	10%	7%	5%	6%	13%	52%	4%	8%	4%	7%	7%	6%	17%	0%	25%	3%	9%	3%	0%	70,000
-0702	779	60%	0%	14%	3%	1%	6%	16%	49%	5%	5%	7%	5%	5%	5%	16%	51%	3%	6%	6%	8%	5%	5%	20%	0%	28%	2%	8%	4%	0%	48,100
-0703	613	68%	0%	0%	0%	3%	1%	27%	46%	2%	0%	8%	10%	5%	2%	19%	55%	9%	5%	3%	8%	3%	4%	22%	0%	24%	2%	15%	4%	0%	-*

* No data available for median household income for this block group from ACS 2022.

ArcGIS Pro was used to determine socioeconomic information about the Upper Illinois River watershed organized by HUC12. The following data sources and references were utilized:

American Community Survey (ACS) 2022: This survey provides detailed demographic and socioeconomic data, including population, gender distribution, age, educational attainment, and median household income. The ACS 2022 data (US Census Bureau, 2022) was employed to gather this information for census blocks.

Census Blocks and HUC12 Boundaries: The geographic boundaries of census blocks were intersected with HUC12 boundaries to ensure accurate data aggregation. ArcGIS Pro facilitated this spatial analysis, enabling the extraction and summarization of ACS data for each HUC12 watershed unit.

Reference: U.S. Census Bureau. (2022). *American Community Survey 2022 5-Year Estimates*. Retrieved from https://www.census.gov/programs-surveys/acs.

APPENDIX C
LAND USE INFORMATION BY HUC12

HUC12 Number 11110103-	Open Water	Developed, Open Space	Developed, Low Intensity	Developed, Medium Intensity	Developed, High Intensity	Barren Land	Deciduous Forest	Evergreen Forest	Mixed Forest	Shrub/Scrub	Herbaceous	Hay/Pasture	Woody Wetlands	Emergent Herbaceous Wetlands	Total Area (hectare)
-0101	1.6%	5.7%	2.7%	1.4%	0.5%	0.1%	40.6%	0.4%	3.8%	0.7%	0.4%	41.9%	0.2%	0.0%	7,208
-0102	0.7%	4.6%	2.0%	1.3%	0.6%	0.1%	29.2%	0.1%	1.4%	0.6%	0.9%	58.3%	0.1%	0.0%	6,357
-0103	0.1%	4.3%	1.3%	1.0%	0.3%	0.0%	22.6%	0.0%	0.8%	0.5%	0.3%	68.4%	0.2%	0.0%	5,409
-0201	0.2%	17.2%	26.2%	17.1%	6.1%	0.1%	11.7%	0.5%	3.5%	0.1%	0.2%	17.0%	0.0%	0.0%	4,350
-0202	1.2%	9.9%	14.2%	14.2%	4.6%	0.5%	17.8%	0.1%	1.4%	0.4%	1.1%	34.7%	0.1%	0.0%	5,850
-0203	0.1%	11.3%	13.7%	12.0%	2.0%	1.0%	26.4%	0.0%	1.7%	0.6%	1.0%	30.2%	0.0%	0.0%	3,839
-0204	0.2%	8.1%	3.0%	1.8%	0.5%	0.5%	37.6%	0.2%	1.1%	0.6%	1.1%	45.2%	0.1%	0.0%	5,868
-0301	0.1%	10.3%	16.3%	14.9%	5.9%	1.1%	10.7%	0.0%	0.5%	0.3%	1.0%	38.9%	0.0%	0.0%	9,469
-0302	0.2%	8.1%	6.4%	7.7%	2.9%	0.2%	11.8%	0.0%	0.2%	0.4%	0.5%	61.6%	0.0%	0.0%	12,113
-0303	0.1%	12.9%	17.7%	16.6%	7.1%	0.2%	11.4%	0.0%	0.8%	0.2%	0.6%	32.3%	0.0%	0.0%	12,053
-0304	1.0%	9.1%	11.7%	10.0%	4.0%	0.1%	13.3%	0.0%	0.5%	0.3%	0.4%	49.6%	0.1%	0.0%	6,129
-0305	0.1%	4.9%	1.2%	0.8%	0.2%	0.2%	34.2%	0.1%	0.5%	1.1%	1.1%	55.3%	0.4%	0.0%	13,649
-0401	0.1%	4.0%	1.0%	0.5%	0.1%	0.0%	53.0%	0.4%	3.9%	1.0%	1.2%	34.7%	0.1%	0.0%	9,591
-0402	0.1%	8.0%	5.4%	4.1%	0.7%	0.1%	23.2%	0.1%	1.3%	0.2%	0.3%	56.4%	0.3%	0.0%	11,360
-0403	0.6%	3.4%	0.8%	0.5%	0.0%	0.1%	58.8%	1.0%	1.7%	0.8%	1.6%	29.5%	1.1%	0.1%	8,232
-0501	0.4%	7.5%	3.2%	2.0%	0.8%	0.2%	27.0%	0.0%	1.0%	1.8%	2.1%	53.8%	0.2%	0.0%	7,587
-0502	0.1%	9.8%	9.9%	8.1%	4.0%	0.1%	16.1%	0.0%	0.7%	0.7%	0.8%	49.7%	0.0%	0.0%	5,615
-0503	1.9%	4.4%	1.7%	1.0%	0.5%	0.5%	29.7%	0.0%	0.3%	0.6%	1.0%	58.4%	0.1%	0.0%	9,938
-0601	0.1%	3.6%	1.1%	1.0%	0.3%	0.1%	50.0%	0.7%	2.9%	0.8%	0.6%	38.1%	0.5%	0.0%	7,924
-0602	0.1%	3.4%	0.7%	0.7%	0.5%	0.1%	26.3%	0.6%	1.4%	1.3%	0.5%	64.4%	0.0%	0.0%	6,033
-0603	0.1%	3.8%	0.9%	0.8%	0.3%	0.2%	32.6%	0.0%	0.9%	0.9%	1.0%	58.5%	0.0%	0.0%	6,471
-0604	0.1%	4.4%	1.8%	1.2%	0.8%	0.1%	23.5%	0.1%	2.4%	0.4%	1.3%	63.8%	0.2%	0.0%	7,138
-0606	0.8%	5.1%	1.6%	0.8%	0.1%	0.1%	45.9%	0.6%	3.6%	0.5%	0.5%	38.6%	1.6%	0.1%	9,342
-0701	0.1%	4.0%	0.8%	0.4%	0.2%	0.1%	46.6%	0.3%	3.4%	0.9%	0.9%	42.1%	0.1%	0.0%	10,639
-0702	0.1%	4.3%	0.6%	0.4%	0.2%	0.1%	44.6%	1.2%	6.1%	1.3%	1.8%	39.3%	0.2%	0.1%	7,337
-0703	0.0%	3.3%	0.3%	0.2%	0.0%	0.0%	63.7%	0.7%	4.2%	1.0%	0.9%	25.2%	0.3%	0.0%	6,301

APPENDIX D
INVENTORY OF HISTORICAL WATER QUALITY MONITORING IN THE UPPER ILLINOIS RIVER WATERSHED

Table D.1. Surface water monitoring historic inventory (Water Quality Portal retrieval August 2024, https://www.waterqualitydata.us/, and AWRC MSC reports).

Entity	Station ID	Station Description	Start Year	End Year	Number of Sampling Events
Arkansas Department of Environmental Quality	ARK0006	Illinois River south of Siloam Springs, Arkansas	1992	2022	285
	ARK0006A	Illinois River near Siloam Springs, Arkansas	1990	1998	113
	ARK0006B	Illinois River on Fisher Ford Rd/CR2 3 miles SE of Siloam Springs	2022	2024	23
	ARK0007	Barren Fork on SR59 N of Dutch Mills, Arkansas	1990	2006	119
	ARK0007A	Barren Fork on SR45 E of Dutch Mills, Arkansas	1998	2024	285
	ARK0010C	Clear Creek at Hwy. 112 Bridge	1994	2024	342
	ARK0026B	Spring Creek BL Springdale, Arkansas	2023	2024	14
	ARK0040	Illinois River on SR16 W of Savoy, Arkansas	1990	2024	409
	ARK0041	Osage Creek near Elm Springs, Arkansas	1990	2013	297
	ARK0078	Flint Creek at Highway 59	2023	2024	11
	ARK0082	Osage Creek at Logan, Arkansas	2008	2024	166
	ARK0141	Cincinnati Creek near Cincinnati, Arkansas on SR244	1998	2024	283
	ARK0155	Osage Creek at SR264/Healing Springs Road.	2005	2007	18
	ARK0204	Unnamed Tributary to Brush Creek directly upstream of confluence with Brush Creek	2017	2018	15
	ARK0252	Cincinnati Creek bridge on County Road 7/Cincinnati Road in Cincinnati, Arkansas	2023	2024	14
	ARK0253	Evansville Creek bridge on Hwy 59, North of Evansville, Arkanas	2023	2024	14
	LARK009A	SWEPCO Lake - north of Siloam Springs, Arkansas - midpoint of dam	1994	2012	6
	LARK012A	Bobb Kidd Lake - W. of Prairie Grove, midpoint of dam	1994	2024	26
	LARK014A	Lake Elmdale - Southeast of Elm Springs Arkansas	1994	2024	11
	LARK015A	Lake Fayetteville - W. of spillway above boat docks.	1994	2023	39
	LARK018A	Lake Wedington - pt. on trans. parallel to dam	1994	2016	23
	LARK038	Siloam Springs Lake	2012	2024	6
	LARK039	Lincoln Lake	2012	2024	4

Entity	Station ID	Station Description	Start Year	End Year	Number of Sampling Events
	MUD0002B	Mud Creek N of Fayetteville on N Front Street	2023	2024	14
	OSC0004	Osage Creek on County Road. Approx 1 Mi. West of Hwy 112. Ark68b	2014	2024	100
Arkansas Water Resources Center	Ballard	Ballard Creek at County Road 76	2009	2015	250
	Baron	Baron Fork at Dutch Mills, Arkansas	2009	2022	533
	FC12	Flint Creek at Springtown, Arkansas	2009	2015	271
	FCWSS	Flint Creek near West Siloam Springs,	2009	2015	271
	IR59	Illinois River South of Siloam Springs, Arkansas	2000	2022	535
	Mud	Mud Creek at Gregg Street near Johnson, Arkansas	2015	2022	259
	NC	Niokaska Creek at Township St. Fayetteville, Arkansas	2011	2015	173
	OC112	Osage Creek at Highway 112 near Cave Springs, Arkansas	2015	2022	253
	Osage	Osage Creek near Elm Springs, Arkansas	2009	2022	534
	Sager	Sager Creek at Siloam Springs, Arkansas	2011	2018	325
	Savoy	Illinois River at Savoy, Arkansas	2009	2022	536
	Spring	Spring Creek at Highway 112 near Springdale, Arkansas	2012	2022	408
Cherokee Nation (Oklahoma)	FC1	Flint Creek 1	2006	2008	137
Cherokee Nation (Tribal)	FC1	Flint Creek 1	2006	2022	77
GBMc & Associates	SC-0	Sager Creek - 0	2014	2014	8
	SC-1	Sager Creek - 1	2014	2014	11
GLEON Lake Observer (Volunteer)	Partners Lake Spillway	Partners Lake (formerly Lake Keith) Spillway	2015	2015	2
North American Lake Management Society	F49018	Lake Fayetteville, Washington County, Arkansas	2002	2020	21
Oklahoma Conservation Commission	OK121700-05-0170T	Baron Fork: State Line	2014	2015	110
OWRB Streams Monitoring	OKIO6594-48	Evansville Creek	2007	2009	33
USGS Arkansas	07194735	Illinois River near Hogeye, Arkansas	2012	2012	1

Entity	Station ID	Station Description	Start Year	End Year	Number of Sampling Events
Water Science Center	07194746	Illinois R Site 1 at Hwy 62 near Prairie Grove, Arkansas	1978	1981	30
	07194749	Illinois River Site 2 At Bridge W Of Walnut Grove, Arkansas	1978	1981	28
	07194753	Illinois River Site 3 At Bridge N of Viney Grove, Arkansas	1978	1981	8
	07194756	Illinois River Site 3a At Mouth near Viney Grove, Arkansas	1979	1981	3
	07194758	Goose Creek near Farmington, Arkansas	2011	2011	1
	07194759	Goose Creek Site 4 near Viney Grove, Arkansas	1978	1981	5
	07194760	Illinois River near Viney Grove, Arkansas	1978	2007	56
	07194763	Tributary Site 5a near Elkhorn Springs, Arkansas	1981	1981	3
	07194766	Illinois River Site 6 near Elkhorn Springs, Arkansas	1978	1981	4
	07194767	Illinois River Site 6a near Elkhorn Springs, Arkansas	1979	1979	1
	07194771	Prairie Grove Lake Near Prairie Grove, Arkansas	1989	1990	53
	07194777	Bob Kidd Lake near Prairie Grove, Arkansas	1989	1990	75
	07194780	Muddy Fork Site 7 At County Road Bridge near Prairie Grove, Arkansas	1978	1981	32
	07194781	Muddy Fork Site 9 Near Prairie Grove, Arkansas	1978	1981	32
	07194783	Muddy Fork Site 10 at Bridge Near Viney Grove, Arkansas	1978	1981	16
	07194787	Muddy Fork Site 11 near Rhea, Arkansas	1978	1981	11
	07194788	Muddy Fork Site 11a near Rhea, Arkansas	1979	1981	4
	071947882	Lincoln Lake On Moores Creek near Lincoln, Arkansas	1989	1990	56
	071947884	Lincoln Lake (Beatty Branch Arm) near Lincoln, Aransas	1989	1990	77
	071947887	Moores Creek Site 12 near Rhea, Arkansas	1978	1981	8
	071947888	Moores Creek northeast of Rhea, Arkansas	2011	2011	1
	071947889	Muddy Fork Site 12a near Rhea, Arkansas	1979	1981	4
	071947893	Muddy Fork Trib Site 13 near Viney Grove, Arkansas	1978	1981	8
	071947894	Muddy Fork Site 14 At Br SW of Weaver Hill, Arkansas	1978	1981	12
	071947895	Muddy Fork Site 14a West of Weaver Hill, Arkansas	1979	1979	1

Entity	Station ID	Station Description	Start Year	End Year	Number of Sampling Events
	071947898	Unnamed Trib Site 14b at Weaver Hill, Arkansas	1979	1979	1
	071947899	Muddy Fork Site 15 at Weaver Hill, Arkansas	1978	1981	32
	07194790	Muddy Fork Illinois River near Savoy, Arkansas	1978	1988	20
	07194791	Illinois River Site 17a near Savoy, Arkansas	1978	1979	3
	07194792	Illinois River Site 17b near Savoy, Arkansas	1978	1981	4
	07194793	Illinois River Site 17c near Savoy, Arkansas	1978	1981	4
	071947945	Lake Wedington near Savoy	1971	1972	7
	07194795	Lake Wedington near Savoy	1971	1972	7
	07194796	Lake Wedington near Savoy	1971	1972	7
	07194798	Illinois River Trib Site 18 near Savoy, Arkansas	1978	1978	1
	07194800	Illinois River at Savoy, Arkansas	1968	2023	499
	07194802	Clear Creek on Hylton Rd near Springdale, Arkansas	2010	2011	2
	07194803	Clear Creek on Hwy 265 near Springdale, Arkansas	2010	2011	4
	071948095	Mud Creek near Johnson, Arkansas	2011	2024	63
	07194810	Clear Creek at Johnson, Arkansas	1986	1994	91
	07194811	Hamestring Creek near Wheeler, Arkansas	2011	2011	1
	07194812	Clear Creek near Johnson, Arkansas	2011	2011	1
	07194813	Clear Creek on Hwy 112 Bridge near Tontitown, Arkansas	1993	1994	10
	07194820	Clear Creek Site 20 at Savoy, Arkansas	1978	1986	18
	07194821	Illinois River Site 21 West of Savoy, Arkansas	1978	1981	4
	07194822	Illinois River Site 22 Northwest of Savoy, Arkansas	1978	1979	5
	07194823	Illinois River Site 23 near Savoy, Arkansas	1978	1979	5
	07194824	Illinois River Site 24 near Savoy, Arkansas	1978	1981	10
	07194825	Unnamed Trib to Illinois River Site 25 near Robinson, Arkansas	1979	1981	2
	07194826	Illinois River Site 26 near Robinson, Arkansas	1978	1981	3
	07194827	Illinois River Site 27 South of Robinson, Arkansas	1978	1981	3

Entity	Station ID	Station Description	Start Year	End Year	Number of Sampling Events
	07194828	Illinois River Site 28 SW of Robinson, AR	1978	1981	2
	07194829	Illinois River Site 29 at Robinson, Arkansas	1978	1981	3
	071948297	Illinois River Site 30 West of Robinson, Arkansas	1978	1981	3
	07194831	Illinois R Site 31a near Robinson, Arkansas	1979	1981	2
	07194854	Osage Creek Site 32 near Rogers, Arkansas	1978	1981	37
	07194855	Osage Creek Site 34 near Rogers, Arkansas	1978	1981	35
	07194877	Osage Creek Site 36 near Rogers, Arkansas	1979	1981	2
	07194879	Unnamed Trib to Osage Cr Site 36a Near Cave Springs, Arkansas	1978	1979	3
	07194880	Osage Creek near Cave Springs, Arkansas	1978	2021	80
	07194885	Osage Creek Site 38 near Cave Springs, AR	1978	1981	37
	07194887	Osage Creek northwest of Cave Springs, Arkansas	2011	2011	1
	07194890	Osage Creek at Cave Springs, Arkansas	1978	1981	35
	07194900	Osage Creek Site 39a Southwest of Cave Springs, Arkansas	1981	1981	3
	07194903	Osage Creek Site 39b near Cave Springs, Arkansas	1979	1981	2
	07194905	Spring Creek at Park Street at Springdale, Arkansas	2009	2011	8
	07194906	Spring Creek at Sanders Ave at Springdale, Arkansas	2009	2021	74
	071949063	Spring Creek upstream from I-540 near Springdale, Arkansas	2011	2011	1
	07194907	Spring Creek Site 40 near Springdale, Arkansas	1978	1981	36
	07194908	Spring Creek at N. 40 Street at Springdale, Arkansas	1979	2011	14
	07194909	Spring Creek Site 42 near Springdale, Arkansas	1978	1981	35
	07194911	Spring Creek Site 43 near Elm Springs, Arkansas	1978	1981	35
	07194916	Puppy Creek Site 44 near Elm Springs, Arkansas	1978	1981	7
	07194919	Spring Creek Site 44a near Elm Springs, Arkansas	1979	1979	2
	07194920	Spring Creek Site 45 near Elm Springs, Arkansas	1979	1981	3

Entity	Station ID	Station Description	Start Year	End Year	Number of Sampling Events
	07194921	Spring Creek near Elm Springs, Arkansas	1979	1979	1
	07194928	Cross Creek Site 46 near Elm Springs, Arkansas	1978	1981	7
	07194929	Spring Creek Site 46a near Elm Springs, Arkansas	1979	1979	1
	07194931	Spring Creek Site 47 near Elm Springs, Arkansas	1978	1981	33
	07194933	Spring Creek at Hwy 112 near Springdale, Arkansas	1978	2024	147
	07194937	Osage Creek Site 49 near Healing Springs, Arkansas	1978	1981	17
	07194945	Little Osage Creek near Osage Mills, Arkansas	2011	2011	1
	07194947	Little Osage Creek at Healing Springs, Arkansas	1994	2006	5
	07194950	Little Osage Creek near Healing Springs, Arkansas	1978	1988	10
	07195000	Osage Creek near Elm Springs, Arkansas	1951	2023	494
	07195003	Osage Creek Site 52 near Tontitown, Arkansas	1978	1981	7
	07195020	Lick Branch Site 53 near Healing Springs, Arkansas	1978	1978	1
	07195023	Osage Creek Site 53a near Tontitown, Arkansas	1978	1981	3
	07195050	Brush Cr on Har-Ber Ave. near Springdale, Arkansas	2010	2011	4
	07195210	Brush Creek Site 54 near Tontitown, Arkansas	1978	1981	4
	07195219	Osage Creek Site 55 near Robinson, Arkansas	1978	1981	17
	07195223	Wildcat Creek near Robinson, Arkansas	2011	2011	1
	07195226	Wildcat Branch Site 55a near Robinson, Arkansas	1978	1981	6
	07195229	Osage Creek Site 56 near Robinson, Arkansas	1978	1981	5
	07195340	Galey Hollow Site 57 at Logan, Arkansas	1981	1981	3
	07195350	Osage Creek at Logan, Arkansas	1978	1986	29
	07195356	Osage Creek Site 60 near Pedro, Arkansas	1978	1981	28
	07195357	Illinois River Site 60a near Pedro, Arkansas	1979	1981	2
	07195359	Illinois River Trib Site 61 near Pedro, Arkansas	1978	1981	6
	07195362	Illinois River Site 62 near Pedro, Arkansas	1978	1981	4

Entity	Station ID	Station Description	Start Year	End Year	Number of Sampling Events
	07195366	Illinois River Site 63 South of Gallatin, Arkansas	1978	1981	25
	07195368	Illinois River Site 64 near Gallatin, Arkansas	1978	1981	14
	07195372	Chambers Hollow at Mouth Site 65 near Gallatin, Arkansas	1978	1981	4
	07195374	Illinois River Site 65a near Gum Springs, Arkansas	1979	1981	3
	07195383	Illinois River Site 67 near Gum Springs, Arkansas	1978	1981	15
	07195390	Illinois River Site 69 near Gum Springs, Arkansas	1978	1978	2
	07195392	Illinois River Site 70 Southeast of Gum Springs, Arkansas	1978	1978	3
	07195394	Illinois River Site 71 South of Gum Springs, Arkansas	1978	1978	2
	07195400	Illinois River at Hwy. 16 near Siloam Springs Arkansas	1978	1994	155
	07195406	Illinois River Site 73 SE of Siloam Springs, Arkansas	1978	1978	1
	07195409	Illinois River Site 74 near Siloam Springs, Arkansas	1978	1981	11
	07195413	Illinois River Site 75 near Siloam Springs, Arkansas	1978	1978	2
	07195416	Illinois River Site 76 near Siloam Springs, Arkansas	1978	1978	3
	07195425	Wedington Creek near Cincinnati, Arkansas	2011	2011	1
	07195427	Cincinnati Creek near Cincinnati, Arkansas	2011	2011	1
	07195428	Cincinnati Creek near Siloam Springs, Arkansas	1978	1981	4
	07195430	Illinois River South of Siloam Springs, Arkansas	1972	2023	386
	07195436	Illinois River Site 79 near Siloam Springs, Arkansas	1978	1978	2
	07195452	Ballard Creek near Summers, Arkansas	2011	2011	1
	07195686	North Fork Flint Creek near Springtown, Arkansas	1994	1996	3
	07195696	East Fork Flint Creek near Springtown, Arkansas	1994	1996	3
	07195800	Flint Creek at Springtown, Arkansas	1975	1996	38
	07195820	Flint Creek near Gentry, Arkansas	2011	2011	1
	07195850	Flint Creek North of Siloam Springs, Arkansas	1972	1981	127
	07195862	Sager Creek above Siloam Springs, Arkansas.	1993	1994	8

Entity	Station ID	Station Description	Start Year	End Year	Number of Sampling Events
	07196880	Baron Fork near Morrow, Arkansas	2012	2012	1
	07196890	Fly Creek near Morrow, Arkansas	2012	2012	1
	07196900	Baron Fork at Dutch Mills, Arkansas	1959	2023	533
	07196940	Evansville Creek near Evansville, Arkansas	2012	2012	1
	07196950	Evansville Creek at Evansville, Arkansas	1958	1988	16
	360516094063400	Mud Creek South of Hwy 45 at Fayetteville, Arkansas	2004	2011	6
	360534094063900	Mud Creek at Hwy 45 at Fayetteville, Arkansas	2006	2011	4
	360538094065500	Mud Creek at Township Road at Fayetteville, Arkansas	2004	2011	6
	360619094071200	Mud Creek at Old Wire Road at Fayetteville, Arkansas	2004	2011	6
	360651094071900	Mud Creek at Sweetbriar Park at Fayetteville, Arkansas	2006	2011	4
	361248094094200	Spring Creek at Silent Grove Road near Springdale, Arkansas	2004	2006	2
	361254094100200	Spring Creek downstream of WWTP near Springdale, Arkansas	2006	2006	1
	361301094102400	Spring Creek at North 40th St near Springdale, Arkansas	2004	2006	2
	361326094113100	Spring Creek at 56th Street near Springdale, Arkansas	2006	2006	1
	361438094141900	Spring Creek at Highway 112 near Cave Springs, Arkansas	2004	2006	2
	361556094141600	Osage Creek at Highway 264 at Cave Springs, Arkansas	2004	2004	1
	361823094122700	Osage Creek near County Road 51 near Rogers, Arkansas	2004	2004	1
USGS Oklahoma Water Science Center	07194830	Illinois River Near Pedro, Arkansas	1996	2000	142
	07195455	Ballard Creek near Westville, Oklahoma	1991	1992	7

Table D.2. Historical inventory of groundwater and spring water quality sampling in the Upper Illinois River watershed (Water Quality Portal retrieval August 2024).

Entity	Station ID	Station Description	Start Year	End Year	Number of Sampling Events
Arkansas Department of Environmental Quality	ARK0006	Illinois River south of Siloam Springs, Arkansas	1992	2022	285
	ARK0199	Cave Spring at mouth of Cave Springs Cave	2017	2018	14
	ARK0202	Logan Spring at mouth of Logan Cave	2017	2018	15
USGS Arkansas Water Science Center	07194735	Illinois River near Hogeye, Arkansas	2012	2012	1
	071949065	Stultz Spr at Pump Station Road at Springdale, Arkansas	2011	2011	1
	07195351	Logan Spring Site 59 at Logan, Arkansas	1978	1981	4
	07195388	Shinn Spring Site 68 near Gum Springs, Arkansas	1981	1981	3
	354630094252301	well SP-6	1993	1993	1
	355438094213401	14N32W10BBB1	2015	2023	2
	355834094280801	AR-WA-13	1994	1994	1
	355901094181401	15N31W17BBD1	1953	1953	1
	360045094233401	15N32W05ADA1	1959	1959	1
	360129094172801	AR-WA-25	1994	1994	1
	360313094215701	AR-WA-39	1994	1994	1
	360425094093901	16N30W09DAC1SP	2007	2007	1
	360435094275501	AR-WA-26	1994	1994	1
	360536094105701	UA WREC 6	2015	2015	1
	360618094225701	ARWA-REF3	1995	1995	1
	360811094120901	AR WA 106	1994	1994	1
	360819094115001	AR WA 111	1994	1994	1
	360829094135801	AR WA 101	1994	1994	1
	360832094113601	AR WA 109	1994	1994	1
	360839094102801	AR-WA-30	1994	1994	1
	360846094104801	17n30w16adc1sp	1994	2007	2
	360903094142501	AR WA 102	1994	1994	1
	360905094173401	AR-WA-10	1994	1994	1
	360914094122501	17N30W08CCD1	2007	2007	1
	360946094042701	17N29W09ABD1	1995	1995	1
	360946094133101	AR WA 104	1994	1994	1

Entity	Station ID	Station Description	Start Year	End Year	Number of Sampling Events
	360946094133102	AR WA 103	1994	1994	1
	360954094191501	17N31W07ADC1	1968	1968	1
	360957094153201	AR WA 105	1994	1994	1
	361008094115701	AR WA 107	1994	1994	1
	361038094140001	17N31W01ACD1	1968	1968	1
	361156094192101	AR-WA-6	1994	1994	1
	361202094112801	AR-WA-29	1994	1994	1
	361221094140501	AR-WA-28	1994	2007	3
	361221094140502	AR WA 28B	1994	1994	1
	361311094264501	18N33W24DBD1	1994	1994	1
	361430094125701	18N30W07DCC1	1994	1994	1
	361454094095301	18N30W10BDD1	1954	1954	1
	361459094323201	18N33W07CAB1	1993	1993	1
	361529094223901	18N32W10BAA1	1994	1994	1
	361529094224901	18N32W10BAB1	1994	1994	1
	361529094241201	18N32W09BBB1	1994	1994	1
	361529094241202	18N32W09BBB2	1994	1994	1
	361529094241203	18N32W10BBB3	1994	1994	1
	361529094244301	19N32W08ABB1	1994	1994	1
	361529094244302	AR BE 135	1994	1994	1
	361536094275801	18N33W02DCC1	1994	1994	1
	361540094130701	18N30W01DBB1SP	1996	2017	6
	361542094245101	19N32W05CDA1	1994	1994	1
	361545094251501	18N32W05CC1SP	1993	1996	4
	361546094193501	19N31W31BDC1	1993	1993	1
	361547094251401	18N32W05CBC3	1995	1996	3
	361547094251403	18N32W05CBC2	1995	1995	1
	361605094241201	19N32W04BCB1	1994	1994	1
	361617094245401	18N32W05BAB1	1995	1996	3
	361618094245501	18N32W05BAB2	1995	1995	2
	361619094201101	18N32WS01AAB1	2007	2007	1
	361630094253201	19N32W31DDC1	1994	1994	1
	361631094240601	19N32W33CCB1	1995	1996	3
	361631094240602	Kinser Shallow	1995	1996	2
	361634094244101	19N32W32DCB1	1994	1994	1
	361642094225001	19N32W34CAB1	1994	1994	1
	361649094242901	19N32W32DBA1	1995	1996	3
	361650094235401	19N32W33CAB1	1994	1994	1
	361718094224101	19N32W27CDC1	1994	1994	1

Entity	Station ID	Station Description	Start Year	End Year	Number of Sampling Events
	361729094242501	19N32W29DDB1	1994	1994	1
	361732094254501	19N32W30DBC1	1994	1994	1
	361733094143301	19N31W26ADD1	1994	1994	1
	361745094234901	19N32W28BDC2	1995	1996	3
	361745094234902	19N32W28BDC1	1995	2000	4
	361745094234903	Dillahunty North Well	1995	1996	3
	361756094234201	19N32W28BDA1	1994	1994	1
	361759094223701	19N32W27BAD1--AR-BE-131	1994	1994	1
	361801094175801	19N31W29ABA1	1994	2007	2
	361804094233601	19N32W28ABB2	1995	1996	3
	361804094233602	19N32W28ABB1	1995	1996	3
	361809094233001	19N32W21DCD1SP	1994	1994	1
	361819094232301	19N32W21DCB1	1994	1994	1
	361819094232302	19N32W21DCA1	1994	1994	1
	361907094130501	19N30W18CAC1	1994	1994	1
USGS Kansas Water Science Center	361025094253501	17N 32W 06DDD 01 Davis Well, Gallatin, Arkansas	2007	2007	1
USGS Oklahoma Water Science Center	345403094271301	05N-27E-16 DDC 1 ML #01 Site 1	1977	1979	28

APPENDIX E
CHARACTERIZATION OF CURRENT SURFACE WATER QUALITY IN UPPER ILLINOIS RIVER

Introduction

Measurements of selected parameters of concern that were collected during the period 2018-2022 by Arkansas Department of Environmental Quality (DEQ), Arkansas Water Resources Center (AWRC), and United States Geological Survey (USGS) are summarized below. The data used for this summary were downloaded in July 2022 from the Water Quality Portal (WQP). Parameters examined in this section include those related to current assessed water quality impairments: bacteria, pH, turbidity, total suspended solids (TSS), suspended sediment concentration (SSC), temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), nutrients (total nitrogen and phosphorus), and minerals (chloride, sulfate). When a measurement was reported as not detected or less than the detectable limit, the Kaplan Meier (KM) method has been used in analyses through EPA's ProUCL tool (USEPA, 2022). There are 35 water quality monitoring stations in the Upper Illinois River Watershed at 24 locations (Figure 1).

When multiple results are reported for the same sample date and depth, a single value was derived by averaging the reported values. This average value was used in analyses. This appendix includes several box and whisker graphs. Box and whisker graphs show the range and distribution of values. They show the minimum and maximum values as well as the 25^{th} percentile, median or 50th percentile, and 75th percentile. Figure 2 illustrates the elements of the box and whisker graphs in this appendix. Note that the interquartile range is equal to the 75^{th} percentile value minus the 25^{th} percentile value. Only stations with at least 10 samples were graphed.

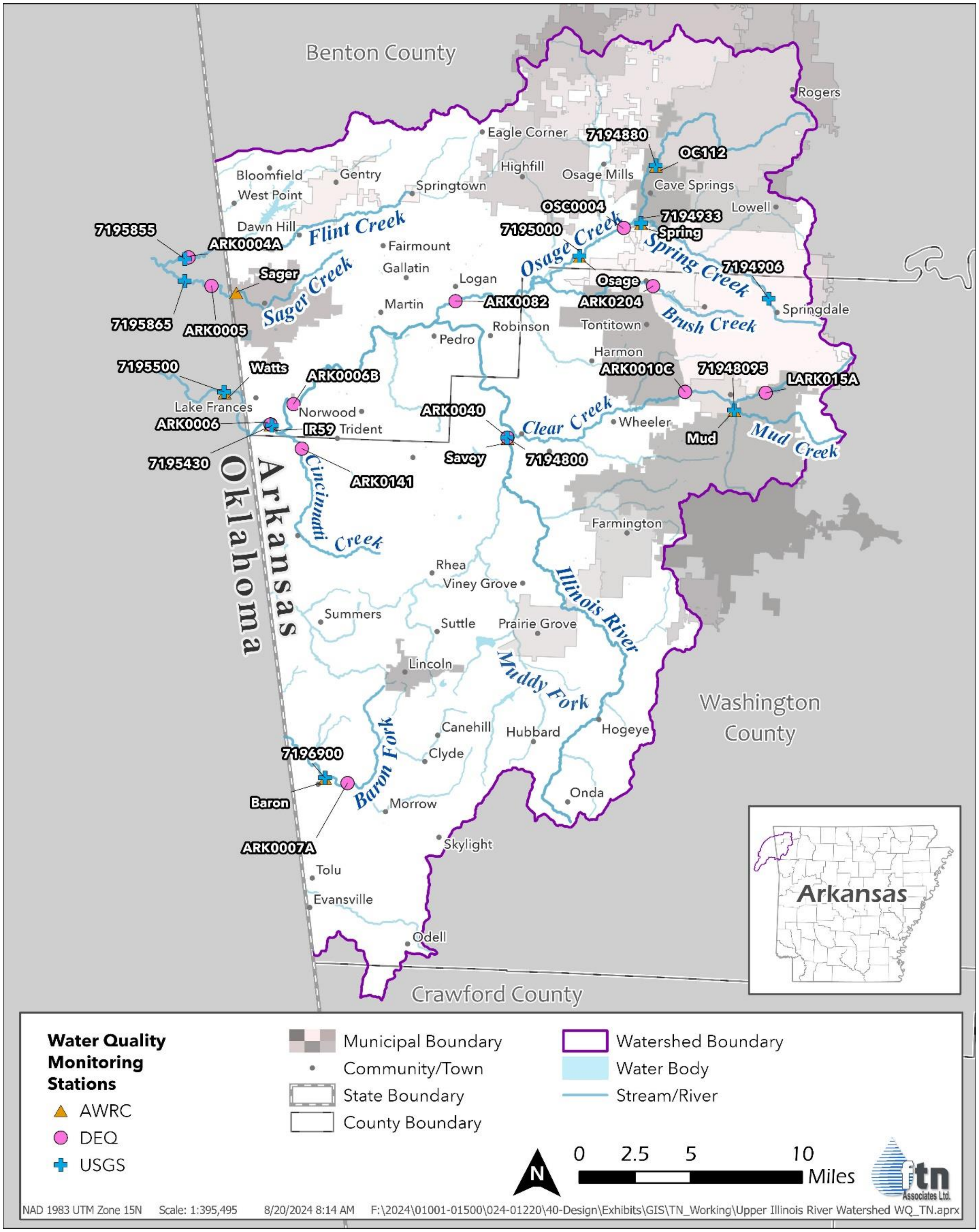

Figure 1: Water quality monitoring stations in the Upper Illinois River Watershed sampled from 2018-2022.

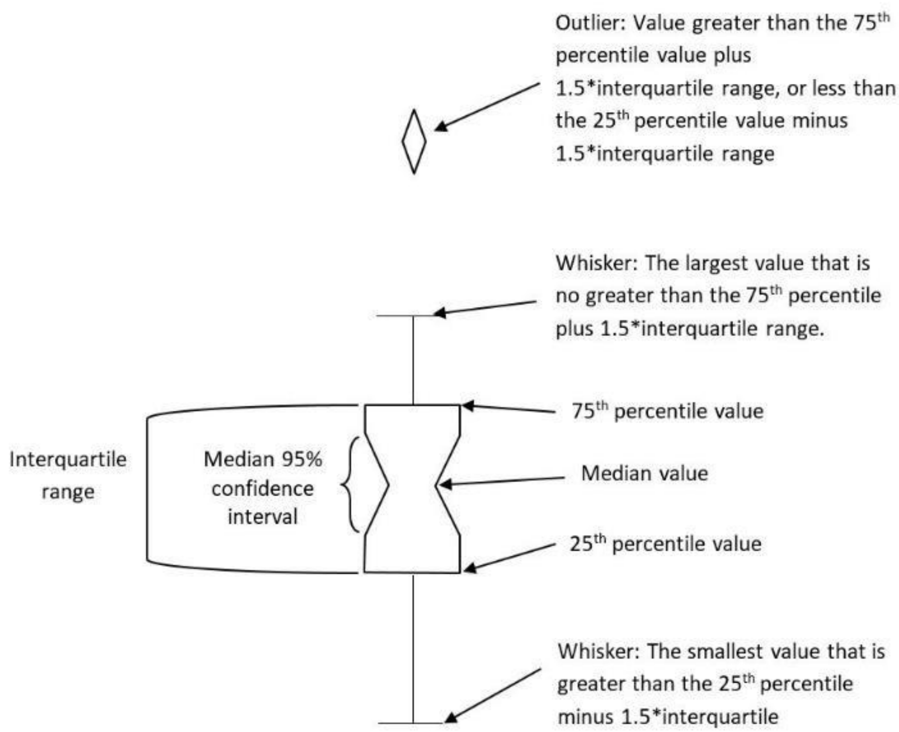

Figure 2: Elements of box and whisker graphs.

Bacteria Indicator of Pathogens

Bacteria and viruses in water have the potential to infect people who come into contact with the water, making them sick. Historically, water borne pathogens from human and animal waste were responsible for a significant number of human deaths (e.g., typhoid fever). *Escherichia coli* (*E. coli*) is a group of bacteria that is present in human and animal waste. Certain types of *E. coli* can make people sick, but primarily *E. coli* are monitored as an indicator of the presence of human or animal waste. The presence of *E. coli* above certain levels indicates contamination by human or animal wastes, and the possible presence of other water borne pathogens that could make people sick. Thus, *E. coli* are used as “pathogen indicator bacteria”.

The tables below list summary statistics for *E. coli* measurements in the watershed during the period 2018-2022. Note that *E. coli* measurements were only collected at eight stations by USGS during 2018-2022. Locations where more than 25 percent of at least eight (8) individual *E. coli* measurements exceed the criteria may be classified as impaired (APCEC, 2022). DEQ Rule 2 specifies separate criteria for primary and secondary contact season for *E. coli*. Primary contact season is defined as May 1 through September 30 and secondary contact season is year-round. The stream reaches classified as impaired due to high *E. coli* levels on the final 2018 and draft 2020 and 2022 303(d) Lists are highlighted in the tables below.

Primary Contact Season *E. coli*

Table 1 shows the primary contact season (May – September) summary statistics for stream stations. DEQ has six stream assessment units listed as impaired for *E. coli* on the approved 2018 303(d) list (DEQ, 2019); however, only USGS reported *E. coli* from 2018-2022. The stations listed below are not on *E. coli* impaired stream segments, even though there are measurements that are above the individual sample criterion.

Table 1: Summary statistics for primary contact season (May -September) stream *E. coli* measurements during 2018-2022 (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID	Stream ID+	Number of measures	Minimum Value, col/100mL	25th Percentile, cfu/100mL	Median, cfu/100mL	Mean, cfu/100mL	75th Percentile, cfu/100mL	Maximum Value, cfu/100mL	Criteria, cfu/100mL	Number of Values > Criteria	Percentage of Values > Criteria*
USGS	07194800	IR	10	45	78	210	277	433	800	410	3	30%
USGS	071948095	MC	10	46	168	280	746	1175	2300	410	4	40%
USGS	07194880	OC	1	19000	19000	19000	19000	19000	19000	410	1	-*
USGS	07194933	SC	3	25	46	66	110	153	240	410	0	-*
USGS	07195000	OC	10	44	74	129	2019	318	18000	410	2	20%
USGS	07195430	IR	9	38	92	150	352	280	1900	410	1	11%
USGS	07195500	IR	16	20	58	496	2890	2400	21000	410	8	50%
USGS	07196900	BF	9	50	100	160	174	280	300	410	0	0%

+ IR = Illinois River, MC = Mud Creek, OC = Osage Creek, SC = Spring Creek, BF = Baron Fork
* DEQ requires at least 8 samples to evaluate attainment of the Primary Contact *E. coli* criteria (APCEC, 2022).

Figure 3 shows a box and whisker plot of primary contact season *E. coli* measurements in the Upper Illinois River watershed from 2018-2022. Only stations with at least eight measurements were graphed. Because there is so much variation in the measurements, and so few of them, median *E. coli* levels at these stations are not statistically significantly different.

The red line is at 410 cfu/100mL, the primary contact season criterion for streams. The highest median *E. coli* value occurs on the main stem of the Illinois River near Watts, OK (07195500). The median *E. coli* in the Illinois River at Watts is higher than the median value at AR State Road 59 crossing east of the border (07195430). This could be because only 9 data measurements were taken at SR59 crossing and 16 measurements at Watts. More data is needed for a good assessment. Illinois River at Watts (07195500) is the only station with a median value above the 410 cfu/100mL criterion.

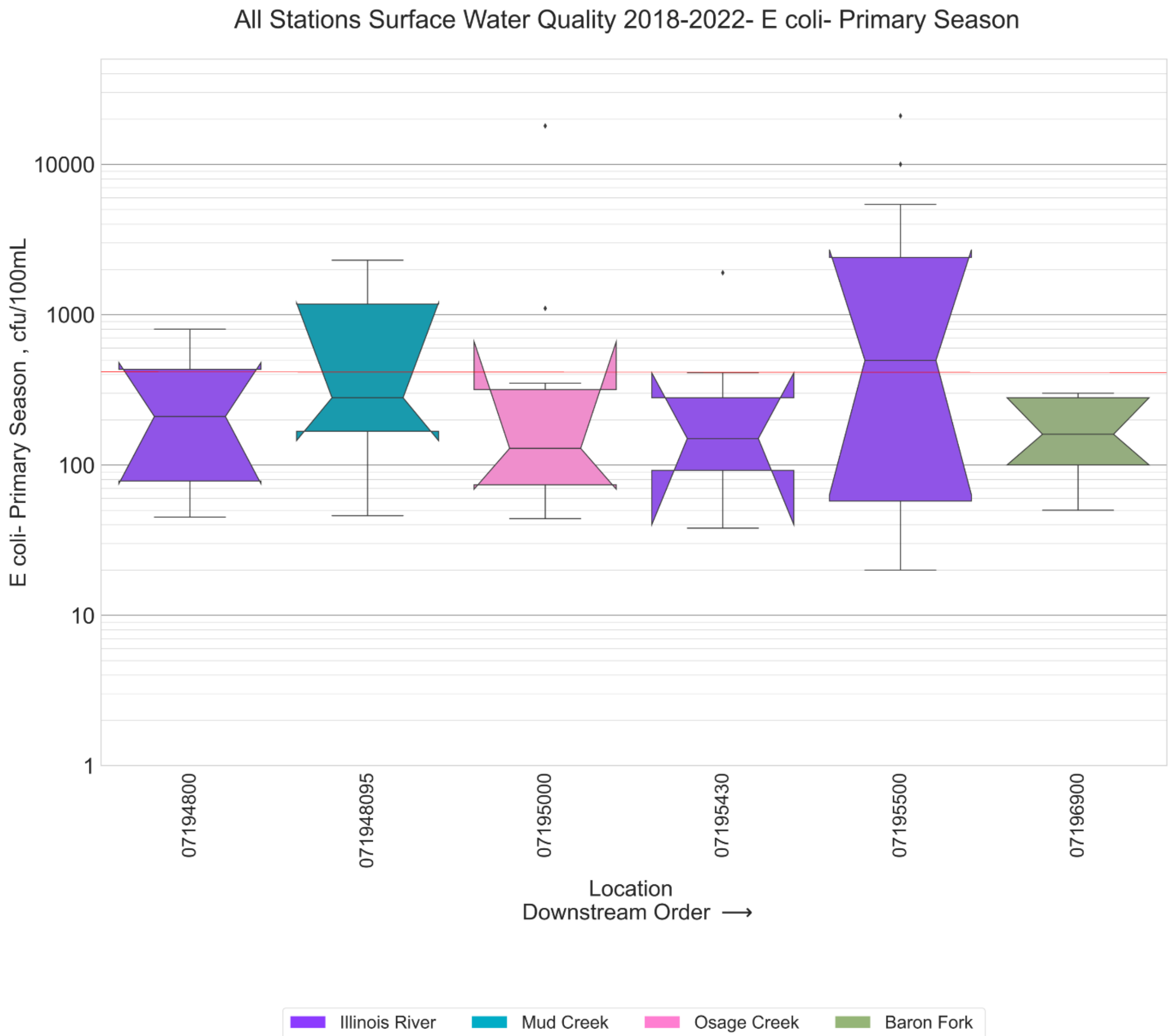

Figure 3: Box and whisker graph of *E. coli* measurements from stream stations with more than 8 values in the primary contact season from 2018-2022.

Secondary Contact Season *E. coli*

Table 2 shows the secondary contact season (year-round) summary statistics for stream stations, thus, all the data collected from 2018-2022 was used. Criterion for secondary contact season are greater than for primary contact: 2,050 cfu/100mL for stream stations. As with primary contact season, DEQ requires at least eight samples to evaluate attainment for secondary contact *E. coli* criterion. There are several stations where *E. coli* measurements at times exceed the secondary contact *E. coli* criterion.

Table 2: Summary statistics for secondary contact season (year-round) stream *E. coli* measurements during 2018-2022 (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID	Stream ID+	Number of measures*	Minimum Value, col/100mL	25th Percentile, cfu/100mL	Median, cfu/100mL	Mean, cfu/100mL	75th Percentile, cfu/100mL	Maximum Value, cfu/100mL	Criterion, cfu/100mL	Number of Values > Criterion	Percentage of Values > Criterion
USGS	07194800	IR	18	3	74	89	189	218	800	2050	0	0%
USGS	071948095	MC	23	17	82	180	1651	1150	13000	2050	4	17%
USGS	07194880	OC	6	4000	5738	9500	11442	17500	21000	2050	6	-*
USGS	07194933	SC	5	20	23	25	75	66	240	2050	0	-*
USGS	07195000	OC	20	12	46	75	1086	175	18000	2050	1	5%
USGS	07195430	IR	17	1	38	47	200	150	1900	2050	0	0%
USGS	07195500#	IR	51	10	41	570	2761	2900	26000	2050	15	29%
USGS	07196900	BF	17	10	50	100	127	160	300	2050	0	0%

+ IR = Illinois River, MC = Mud Creek, OC = Osage Creek, SC = Spring Creek, BF = Baron Fork
* DEQ requires at least 8 samples to evaluate attainment of the Secondary Contact *E. coli* criterion (APCEC, 2022).
# This station is located in Oklahoma, on a stream reach Oklahoma lists as impaired due to *E. coli* levels.

Figure 4 shows a box and whisker plot of secondary contact season *E. coli* measurements in the Upper Illinois River watershed from 2018-2022. Only stations with at least eight measurements were graphed. Because there is so much variation in the measurements, and so few of them at most of the stations, median *E. coli* levels at these stations are not statistically significantly different.

The red line is at 2050 cfu/100mL, the secondary contact season criterion for streams. The highest median *E. coli* value occurs again at station 07195500 (Illinois River at Watts, OK). Median values for the other stream stations are well below the secondary contact season criterion. *E. coli* increases quite a bit around the OK/AR border. However, only 17 measurements were taken from Illinois River at SR59 crossing (07195430) and 51 measurements at Watts. Illinois River at Watts (07195500) had fifteen measurements above the 2050 cfu/100mL criterion, and SR59 (07195430) had none.

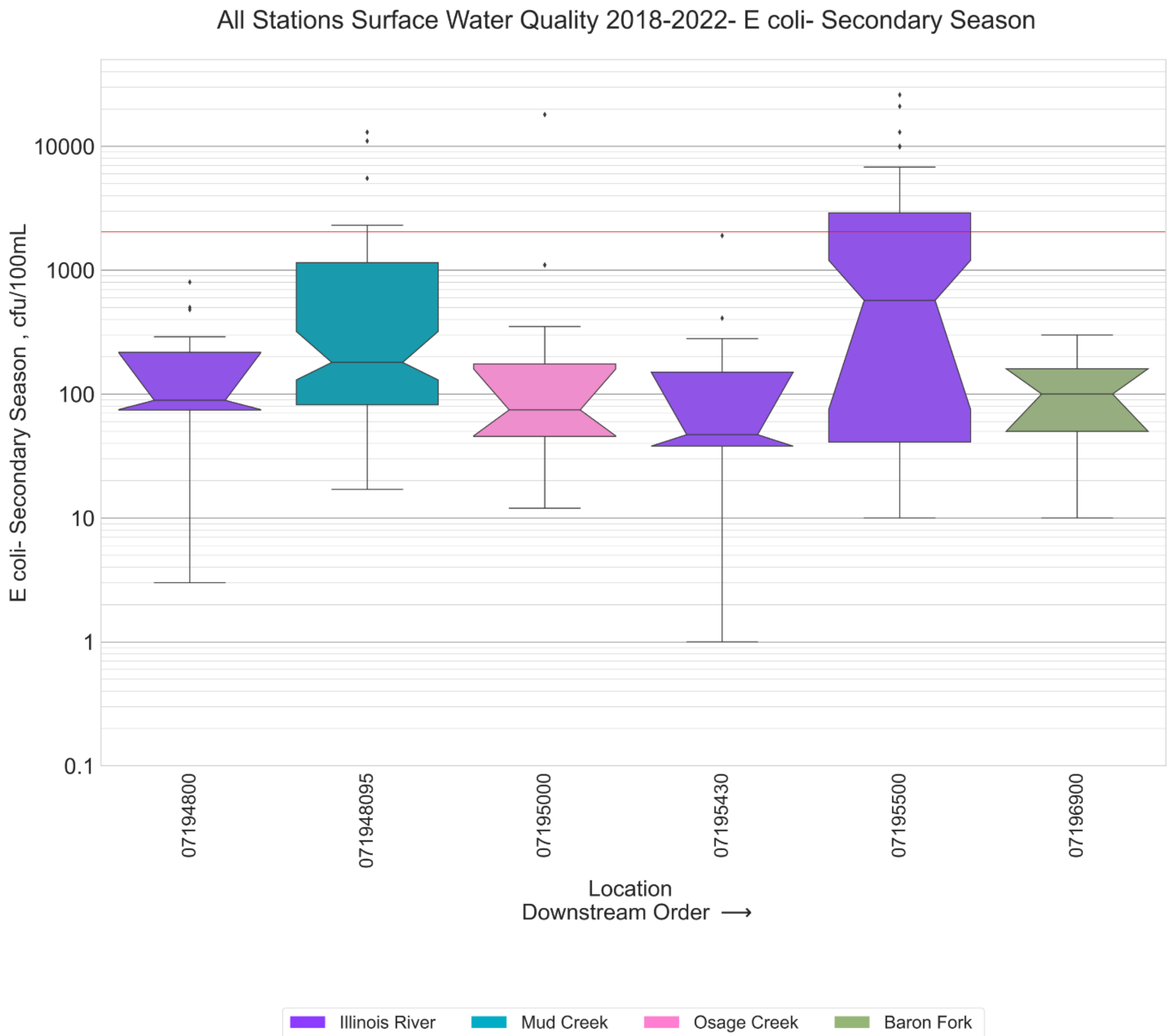

Figure 4: Box and whisker graph of *E. coli* measurements from stream stations with more than 8 values in the secondary contact season (year-round) from 2018-2022.

pH

When water is too acidic or too alkaline creatures and plants living in the water can be negatively affected. People who come into contact with water that is too acidic or too alkaline may experience skin reactions or skin damage.

Summary statistics for stream measurements from the period 2018-2022 are provided in The Upper Illinois River watershed does not have any stream segments listed as impaired for pH. To determine pH impairment of water quality DEQ requires at least 10 measurements. Locations where more than 10 percent of at least 10 measurements that do not meet pH criterion (between 6 and 9 standard units) may be classified as impaired by DEQ (DEQ 2019). None of the measurements reported for 2018-2022 at any station were outside the pH criterion.

Table **3**. Lake Fayetteville is listed as impaired for pH on 2018 and 2020 303(d) lists (DEQ, 2019; DEQ, 2023), however the maximum pH reported from 2018-2022 by DEQ was 8.99 mg/L. The Upper Illinois River watershed does not have any stream segments listed as impaired for pH. To determine pH impairment of water quality DEQ requires at least 10 measurements. Locations where more than 10 percent of at least 10 measurements that do not meet pH criterion (between 6 and 9 standard units) may be classified as impaired by DEQ (DEQ 2019). None of the measurements reported for 2018-2022 at any station were outside the pH criterion.

Table 3: Summary statistics for stream pH measurements from stations in Upper Illinois River watershed during 2018-2022 (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID#	Stream ID+	Number of measures*	Minimum Value, su^	25th Percentile, su	Median, su	Mean, su	75th Percentile, su	Maximum Value, su
DEQ	ARK0040[a]	IR	52	7.21	7.79	7.87	7.90	8.04	8.37
USGS	07194800[a]	IR	20	7.45	7.75	7.98	7.94	8.06	8.35
DEQ	LARK015A	LF	12	7.33	7.68	8.31	8.23	8.56	8.99
USGS	071948095	MC	24	7.18	7.73	7.93	7.89	8.06	8.40
DEQ	ARK0010C	CC	53	7.17	7.60	7.74	7.72	7.83	8.16
USGS	07194880	OC	9	7.30	7.40	7.45	7.48	7.55	7.73
DEQ	ARK0199	SCS	9	6.90	7.04	7.07	7.11	7.19	7.48
USGS	07194906	SC	4	7.15	7.45	7.68	7.59	7.81	7.85
USGS	07194933	SC	27	7.50	7.85	8.00	8.00	8.10	8.50
DEQ	OSC0004	OC	53	7.04	7.75	7.84	7.83	7.91	8.35
USGS	07195000	OC	20	7.65	7.84	7.93	7.96	8.06	8.45
DEQ	ARK0204	BC	9	6.24	6.80	6.86	6.90	6.88	7.94
DEQ	ARK0202	LS	9	6.92	7.10	7.45	7.39	7.54	7.89
DEQ	ARK0082	OC	54	7.14	7.89	8.03	8.07	8.24	8.85
DEQ	ARK0006B	IR	8	7.76	7.89	8.01	8.05	8.22	8.36
DEQ	ARK0141	CnC	50	7.21	7.69	7.83	7.87	8.07	8.50
DEQ	ARK0006[b]	IR	45	7.13	7.88	7.98	7.98	8.07	8.73
USGS	07195430[b]	IR	20	7.70	7.80	7.90	7.94	8.01	8.50
USGS	07195500	IR	64	6.50	7.58	7.80	7.73	7.90	8.80
DEQ	ARK0004A[c]	FC	50	7.16	7.76	7.88	7.94	8.11	8.82
USGS	07195855[c]	FC	29	6.80	7.50	7.70	7.75	7.90	8.90
DEQ	ARK0005	SG	49	7.09	7.75	7.89	7.93	8.02	8.96
USGS	07195865	SG	30	7.20	7.60	7.75	7.78	7.98	8.50
DEQ	ARK0007A	BF	54	6.28	7.57	7.70	7.66	7.86	8.30
USGS	07196900	BF	20	7.60	7.74	7.85	7.87	7.90	8.55

Stations in this table with the same superscript letter are at the same location.
+ IR = Illinois River, LF = Lake Fayetteville, MC = Mud Creek, CC = Clear Creek, OC = Osage Creek, SCS = Spring at Cave Springs, SC = Spring Creek, BC = Brush Creek, LS = Logan Spring, CnC = Cincinnati Creek, FC = Flint Creek, SG = Sager Creek, BF = Baron Fork
* DEQ requires at least 10 samples to evaluate pH criterion attainment (APCEC, 2022).
^su = standard unit

Indicates stations are located on assessment units are listed as impaired due to pH on the approved 2018 303(d) List and on the Draft 2020 303(d) List.

Figure 5 below shows a box and whisker graph of pH measurements from monitoring stations in the Upper Illinois River watershed. The graphed stations all show median pH values between 7.5 and 8.0. The highest median pH is from Lake Fayetteville, possibly as a result of algal productivity. There isn't much variation in pH thoughout the watershed. Median pH in Osage Creek increases from upstream to downstream. In the Illinois River, median pH declines significantly between stations ARK0006/07195430 and 07195500. Median pH values measured by DEQ and USGS at the same location on Flint Creek are statistically significantly different. At other locations where pH is measured by more than one entity, the median values are not statistically significantly different.

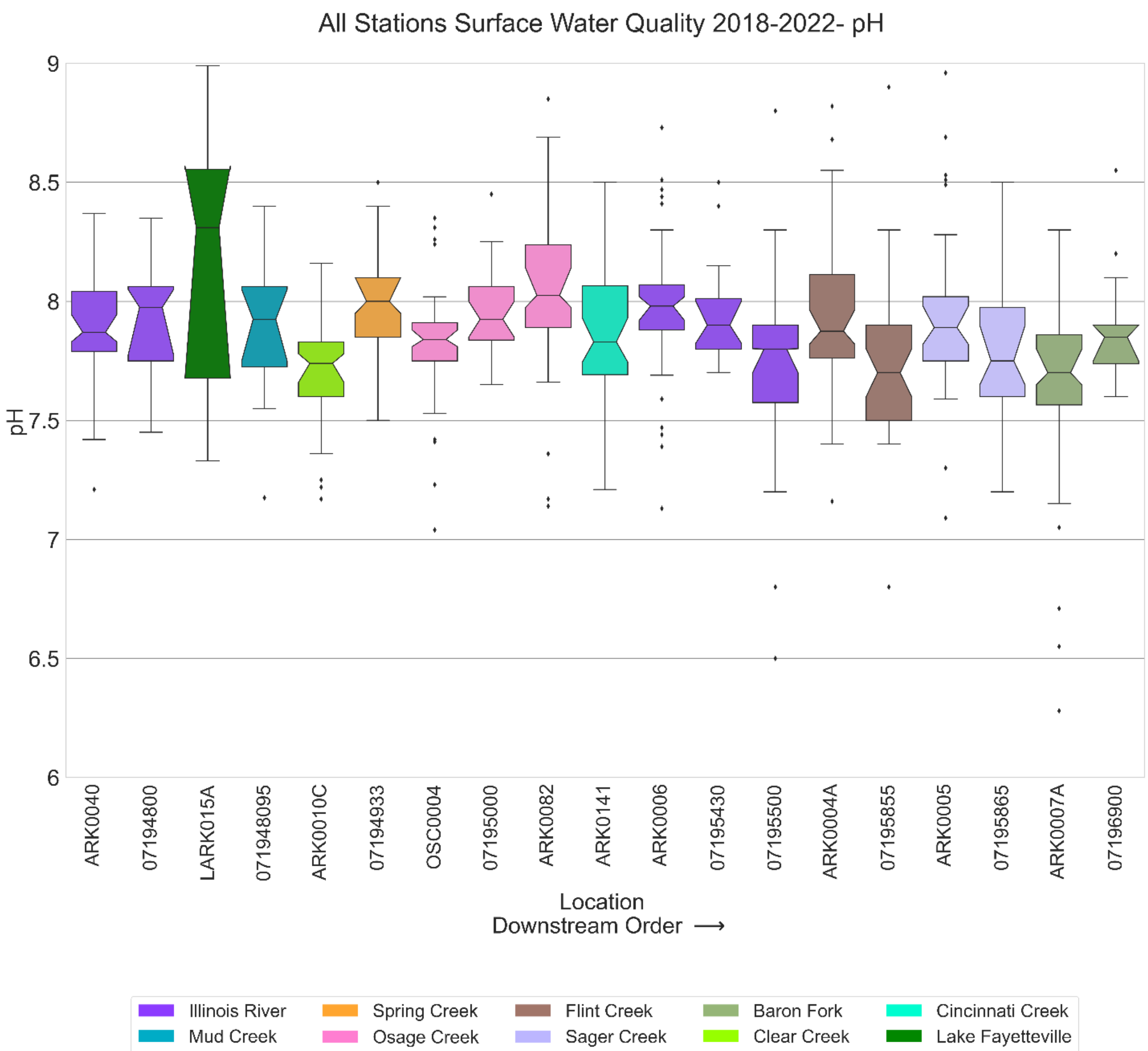

Figure 5: Box and whisker graph of pH measurements from stations in the Upper Illinois River watershed with more than 10 values from 2018-2022. Stations ARK0040 and 07194800 as well as ARK0006 and 07195430 on the Illinois River are at the same location. The two Flint Creek stations are also at the same location.

Sediment Parameters

AWRC, DEQ, and USGS all measure indicators of sediment water quality issues. The three (3) indicators that are monitored in the Upper Illinois River watershed are turbidity, total suspended solids (TSS), and suspended sediment concentration (SSC). All three (3) organizations monitor turbidity, AWRC and DEQ report TSS, and USGS reports SSC.

Sediment or other solids suspended in water can make it difficult for fish to catch prey, reducing their ability to eat. Sediment deposited in streams can change the stream habitat and impact water quality, making it unsuitable for some aquatic species currently or historically present in the stream. Sediment deposited in reservoirs reduces their capacity to store water. Arkansas water quality standards include numeric criteria for turbidity, but not TSS or SSC (APCEC, 2022). However, turbidity cannot be converted to a load, so DEQ collects TSS concentration measurements to calculate loads. Measurements of turbidity are often strongly correlated with TSS and/or SSC.

Turbidity

Turbidity is measured by how much light can pass through a water sample. A higher turbidity value means less light can pass through the water, which impacts visibility for aquatic species and aquatic plant photosynthesis. Both suspended and dissolved material in water can contribute to turbidity.

To determine stream turbidity impairment, DEQ requires at least 24 measurements. Locations where more than 25 percent of at least 24 measurements do not meet turbidity criteria may be classified as impaired (APCEC, 2022). Arkansas water quality regulations include separate numeric criterion for Storm Flow (year-round) and Base Flow conditions (June - October).

Storm Flow Turbidity Summary Statistics

Table 4 lists summary statistics for turbidity measurements from streams in the Upper Illinois River watershed during the period 2018-2022. Included in these tables is a listing of the applicable DEQ Storm Flow (year-round) turbidity numeric water quality criteria based on the ecoregion the station is located within. The number and percentage of measurements that exceed the applicable criterion are also shown in these tables.

The station with the lowest median storm flow turbidity (with at least 24 measurements) is on Cincinnati Creek (ARK0141). The stations with the highest median storm flow turbidity (with at least 24 measurements) are on the Illinois River at Savoy (ARK0040) and at Watts (AWRC Watts).

Table 4: Summary statistics (NTU) for storm flow (year-round) turbidity measurements during 2018-2022 (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID#	Stream ID+	Number of measures*	Minimum Value, NTU	25th Percentile, NTU	Median, NTU	Mean, NTU	75th Percentile, NTU	Maximum Value, NTU	Criterion, NTU	Number of Values > Criterion	Percentage of Values > Criterion
AWRC	Savoy[a]	IR	124	1.40	5.38	7.63	56.95	63.30	409.00	17	39	31%
DEQ	ARK0040[a]	IR	52	1.48	5.23	8.38	11.61	13.15	93.40	17	8	-*
DEQ	LARK015A	LF	12	5.97	7.43	11.20	10.07	12.25	15.50	17	0	-*
AWRC	Mud	MC	128	0.90	1.90	2.88	34.87	28.68	396.00	17	42	33%
DEQ	ARK0010C	CC	50	0.85	1.89	2.62	4.25	3.93	29.90	17	3	6%
AWRC	OC112	OC	126	0.45	1.60	2.50	26.82	18.35	385.00	17	33	26%
DEQ	ARK0199	SCS	6	0.28	0.43	0.64	0.71	0.93	1.31	17	0	-*
AWRC	Spring	SC	126	0.60	1.40	2.40	40.83	20.68	942.00	17	35	28%
USGS	07194933	SC	9	2.60	3.00	85.00	200.40	150.00	865.00	17	6	-*
DEQ	OSC0004	OC	50	0.77	1.94	2.81	5.84	4.97	60.00	17	4	8%
AWRC	Osage	OC	123	0.50	1.60	2.70	35.68	29.18	396.70	17	36	29%
DEQ	ARK0204	BC	7	0.44	0.72	0.99	1.66	2.55	3.63	17	0	-*
DEQ	ARK0202	LS	7	0.28	0.52	0.57	0.82	1.04	1.80	17	0	-*
DEQ	ARK0082	OC	54	0.96	2.46	3.47	6.33	5.39	83.80	17	3	6%
DEQ	ARK0006B	IR	8	6.41	7.85	11.09	11.35	13.95	18.50	17	1	-*
DEQ	ARK0141	CnC	48	0.16	0.63	0.88	1.61	1.40	16.30	17	0	0%
AWRC	IR59[b]	IR	127	0.40	4.35	6.70	62.78	74.20	695.00	17	41	32%
DEQ	ARK0006[b]	IR	43	0.73	4.30	5.54	7.93	9.34	38.60	17	5	12%
AWRC	Watts	IR	128	0.90	6.88	10.15	69.30	98.98	842.00	17	43	34%
USGS	07195500	IR	3	7.50	13.75	20.00	27.17	37.00	54.00	17	2	-*
DEQ	ARK0004A	FC	48	0.74	1.52	1.84	2.46	2.38	18.20	17	1	2%
USGS	07195855	FC	6	2.40	2.68	2.90	3.05	3.20	4.20	17	0	-*
AWRC	Sager	SG	33	0.70	1.30	1.90	16.07	5.00	124.00	17	6	18%
DEQ	ARK0005	SG	47	0.48	0.96	1.24	3.82	2.46	81.30	17	2	4%
USGS	07195865	SG	1	2.20	2.20	2.20	2.20	2.20	2.20	17	0	-*
DEQ	ARK0007A	BF	54	0.89	1.98	2.84	4.68	4.12	52.10	17^	2	4%
AWRC	Baron	BF	124	0.40	1.64	2.70	32.77	20.18	592.00	17^	32	26%

Stations in this table with the same superscript letter are at the same location.
+ IR = Illinois River, LF = Lake Fayetteville, MC = Mud Creek, CC = Clear Creek, OC = Osage Creek, SCS = Spring at Cave Springs, SC = Spring Creek, BC = Brush Creek, LS = Logan Spring, CnC = Cincinnati Creek, FC = Flint Creek, SG = Sager Creek, BF = Baron Fork
* DEQ requires at least 24 samples to evaluate storm flow turbidity criterion attainment (APCEC, 2022).
^ DEQ has proposed updating the ecoregion boundaries. If approved, this station would change ecoregions.
Indicates stations are located on assessment units listed as impaired due to high turbidity on the Arkansas Draft 2022 303(d) List.

Figure 6 shows the box and whisker graph of storm flow turbidity stations with at least 10 measurements from 2018-2022. The criteria for Arkansas water quality attainment requires at least 24 measurements, but any station with at least 10 measurements is graphed for this analysis. AWRC-Savoy and ARK0040 are located at the same location, as well as AWRC-IR59 and ARK0006, on the Illinois River.

DEQ sampled water quality monthly, USGS sampled quarterly, and AWRC monitored more often to collect better information around hydrologic events. At some locations, AWRC monitoring data have a higher median turbidity than DEQ or USGS data sets at the same location. Comparing just AWRC data sets, median turbidity values measured at different locations in the Illinois River are not statistically significantly different from each other. Interesting that the median turbidity value in Lake Fayetteville is statistically significantly higher than the median value for Clear Creek downstream, and for the Mud Creek station.

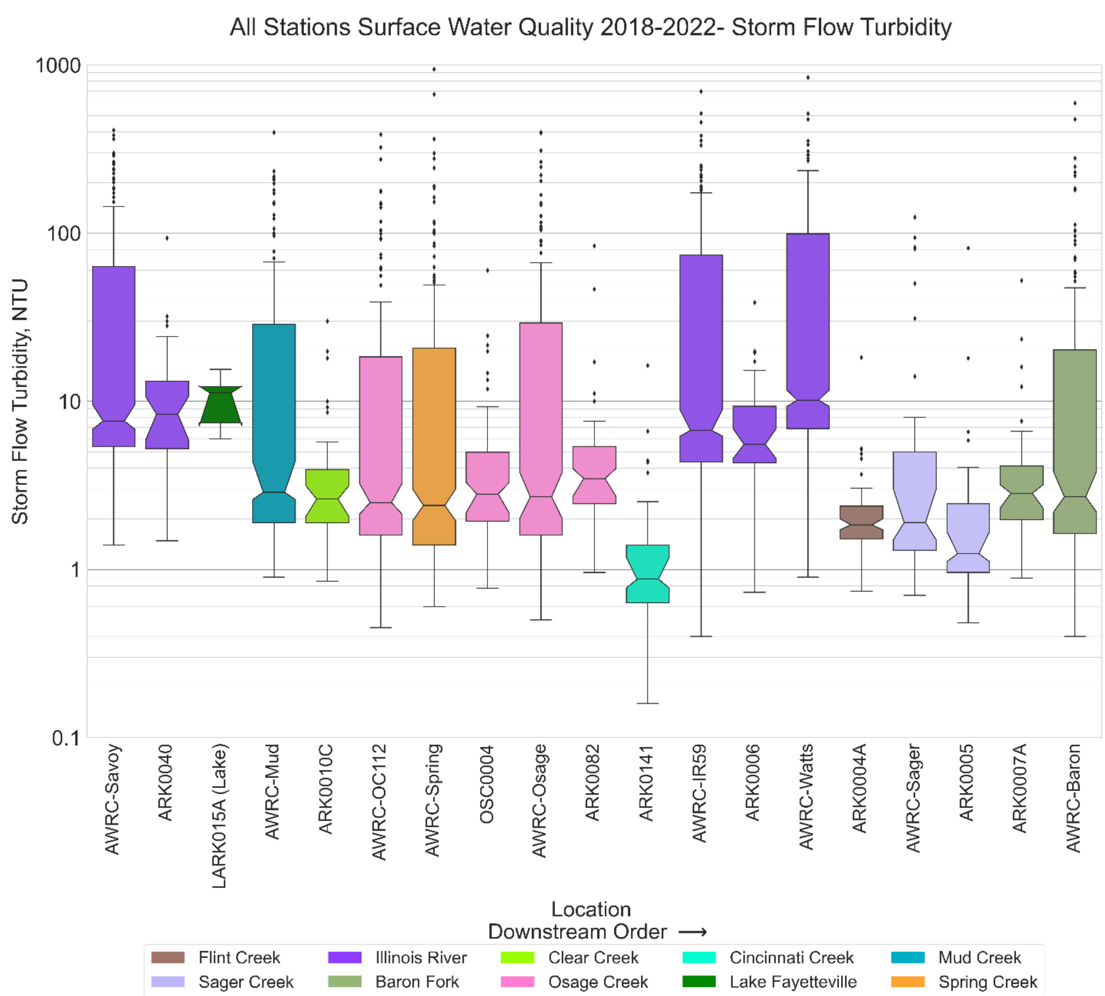

Figure 6: Box and whisker graph of storm flow turbidity measurements with more than 10 values from 2018-2022. Note that all of these stations are in the Ozark Highlands ecoregion. AWRC-Savoy and ARK0040 are located at the same location as well as AWRC-IR59 and ARK0006 on the Illinois River.

Base Flow Turbidity Summary Statistics

Separate numeric criteria are used to evaluate surface water turbidity levels during Base Flow conditions (June 1- October 31). In natural systems, Base Flow conditions are usually characterized by reduced runoff and slower flows, which results in lower turbidity levels. Thus, Base Flow turbidity criteria are lower than the Storm Flow criteria (APCEC, 2022). Median Base Flow turbidity was significantly less than Storm Flow turbidity at each station.

Table 5 lists summary statistics for Base Flow turbidity measurements from streams in the Upper Illinois River watershed during the period 2018-2022. Included in the table are the applicable Base Flow turbidity numeric water quality criteria based on the ecoregion of the station. The number and percentage of measurements that exceed the applicable criteria are also shown in these tables. The values should not exceed the Base Flow criteria in more than 20 percent of samples during Base Flow period (DEQ 2022). The numeric criterion for Boston Mountain ecoregion and for Ozark Highlands ecoregion is 10 NTU, and 25 NTU for lake stations.

Table 5: Summary statistics (NTU) for base flow (June-October) turbidity measurements during 2018-2022 (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID#	Stream ID+	Number of measures^	Minimum Value, NTU	25th Percentile, NTU	Median, NTU	Mean, NTU	75th Percentile, NTU	Maximum Value, NTU	Criteria, NTU	Number of Values > Criteria	Percentage of Values > Criteria
AWRC	Savoy[a]	IR	48	3.10	5.55	7.00	33.84	11.53	288.50	10	13	27%
DEQ	ARK0040[a]	IR	21	5.87	8.43	10.50	13.87	17.70	31.90	10	11	-*
DEQ	LARK015A	LF	5	11.20	11.60	12.20	12.02	12.40	12.70	25	0	-*
AWRC	Mud	MC	49	1.00	1.80	2.70	23.52	5.40	210.00	10	12	24%
DEQ	ARK0010C	CC	22	1.68	2.18	3.14	5.94	4.57	29.90	10	3	-*
AWRC	OC112	OC	48	0.45	1.68	2.40	12.13	5.08	147.60	10	10	21%
DEQ	ARK0199	SCS	3	0.39	0.56	0.73	0.81	1.02	1.31	10	0	-*
AWRC	Spring	SC	48	0.70	1.40	2.00	17.76	4.28	297.80	10	9	19%
USGS	07194933	SC	5	2.80	3.00	80.33	56.23	85.00	110.00	10	3	-*
DEQ	OSC0004	OC	22	1.38	2.76	3.34	7.21	5.55	60.00	10	3	-*
AWRC	Osage	OC	48	0.80	1.58	1.90	16.97	5.28	146.80	10	11	23%
DEQ	ARK0204	BC	3	0.57	2.01	3.45	2.55	3.54	3.63	10	0	-*
DEQ	ARK0202	LS	3	0.47	0.52	0.56	0.59	0.66	0.75	10	0	-*
DEQ	ARK0082	OC	23	1.92	2.52	3.67	9.99	6.73	83.80	10	3	-*
DEQ	ARK0006B	IR	4	7.60	7.85	10.62	11.83	14.60	18.50	10	2	-*
DEQ	ARK0141	CnC	23	0.36	0.60	0.82	2.07	1.64	16.30	10	1	-*
AWRC	IR59[b]	IR	49	1.93	4.50	6.20	28.28	16.20	245.00	10	15	31%
DEQ	ARK0006[b]	IR	19	3.02	4.90	6.12	9.59	9.88	38.60	10	5	-*
AWRC	Watts	IR	49	4.10	7.80	10.10	32.43	16.50	278.00	10	25	51%
USGS	07195500	IR	2	7.50	19.13	30.75	30.75	42.38	54.00	10	1	-*
DEQ	ARK0004A	FC	22	1.36	1.74	1.91	2.99	2.60	18.20	10	1	-*
USGS	07195855	FC	3	2.60	2.75	2.90	2.80	2.90	2.90	10	0	-*
AWRC	Sager	SG	16	0.85	1.25	1.85	7.67	4.55	50.10	10	3	-*
DEQ	ARK0005	SG	22	0.71	0.95	1.14	6.02	2.41	81.30	10	2	-*
DEQ	ARK0007A	BF	23	1.51	2.67	3.80	7.18	5.49	52.10	10	3	-*
AWRC	Baron	BF	48	0.75	1.79	2.48	21.38	4.23	592.00	10	7	15%

Stations in this table with the same superscript letter are at the same location.

+ IR = Illinois River, LF = Lake Fayetteville, MC = Mud Creek, CC = Clear Creek, OC = Osage Creek, SCS = Spring at Cave Springs, SC = Spring Creek, BC = Brush Creek, LS = Logan Spring, CnC = Cincinnati Creek, FC = Flint Creek, SG = Sager Creek, BF = Baron Fork

* DEQ requires at least 24 samples to evaluate storm flow turbidity criteria attainment (APCEC, 2022).

Indicates stations are located on assessment units listed as impaired due to high turbidity on the Draft 2020 303(d) List but are proposed as delisted on the Draft 2020 303(d) List.

Figure 7 shows the box and whisker graph of base flow turbidity stations with at least 10 measurements from 2018-2022. The criteria for Arkansas water quality attainment requires at least 24 measurements, but any station with at least 10 measurements is graphed for this analysis. AWRC-Savoy and ARK0040 are located at the same location, as well as AWRC-IR59 and ARK0006, on the Illinois River. DEQ sampled water quality on a monthly, ambient basis and AWRC monitored more often to collect better information around storm events.

The main stem of the Illinois River has higher median turbidity than the tributary streams. Illinois River median base flow turbidity values are statistically significantly different than median values for most of the tributary streams. Cincinnati Creek has the lowest turbidity during the base flow season.

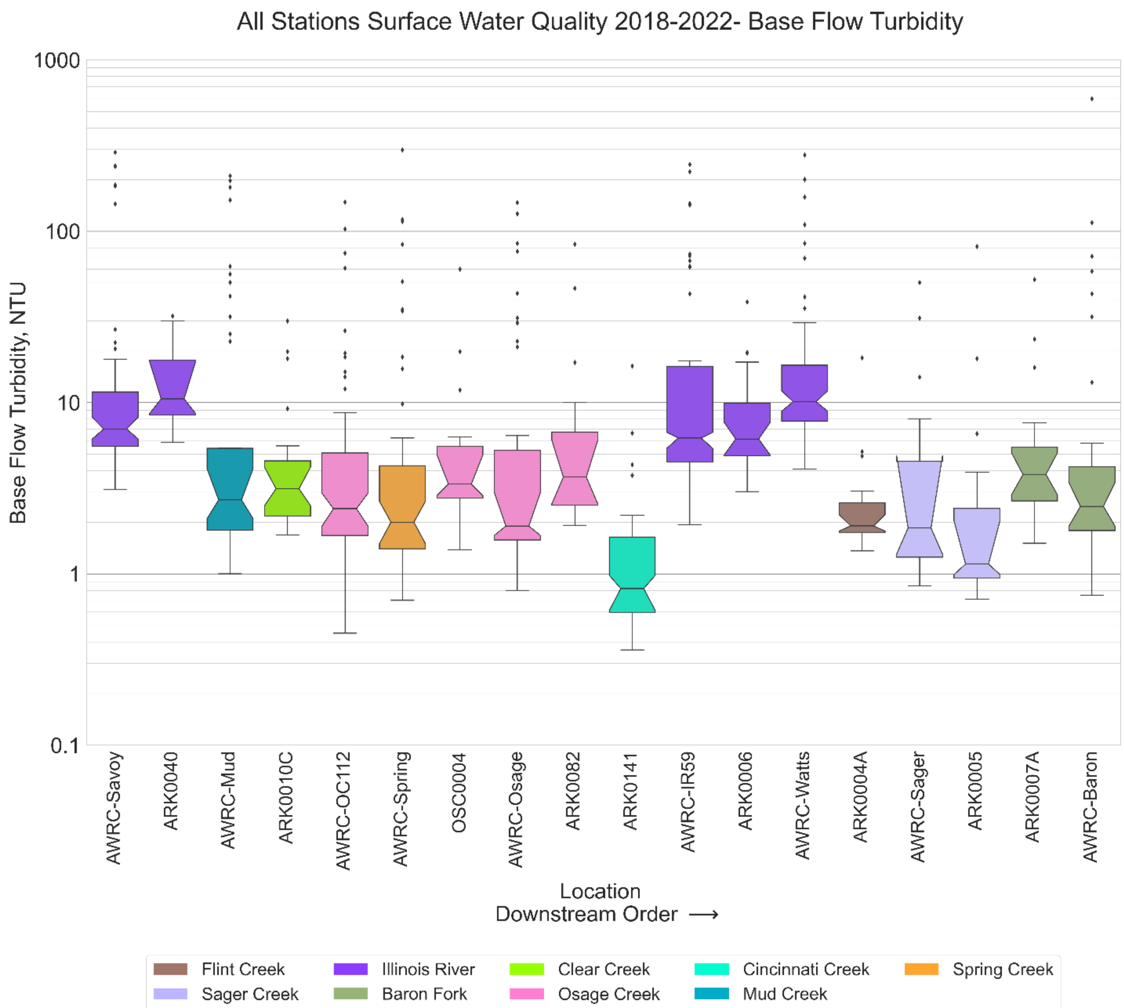

Figure 7: Box and whisker graph of base flow turbidity measurements with more than 10 values from 2018-2022. AWRC-Savoy and ARK0040 are located at the same location as well as AWRC-IR59 and ARK0006 on the Illinois River.

Total Suspended Solids

Total Suspended Solids (TSS) is a measure of solid material that can be filtered out of a water sample. This solid material can include organic debris as well as inorganic material such as soil particles. Sediment and other particles in the water provide attachment places for pollutants such as nutrients, metals, bacteria, and organic compounds. Table 6 shows summary statistics for reported TSS measurements from the Upper Illinois River watershed from the period 2018-2022 collected by DEQ and AWRC. AWRC has significantly more measurements over the five-year period than DEQ. AWRC's monitoring program collects samples that represent storm events as well as ambient conditions throughout the year.

Table 6: Summary statistics for stream TSS measurements in the White River to Lake Sequoyah during 2018-2022 (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID#	Stream ID+	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
AWRC	Savoy[a]	IR	124	0.5	5.8	8.6	75.1	74.8	632.7
DEQ	ARK0040[a]	IR	44	2.0	3.9	5.6	9.7	8.8	121.0
DEQ	LARK015A	LF	12	3.0	5.8	6.8	6.6	8.0	10.5
AWRC	Mud	MC	128	0.0	1.4	2.4	46.1	25.6	749.6
DEQ	ARK0010C	CC	15	1.0	2.0	2.5	6.3	4.6	31.2
AWRC	OC112	OC	126	0.1	2.5	3.4	33.8	14.4	633.1
DEQ	ARK0199	SCS	1	1.0	1.0	1.0	1.0	1.0	1.0
AWRC	Spring	SC	126	0.0	2.0	3.3	58.4	26.6	1822.0
DEQ	OSC0004	OC	28	2.0	2.3	3.3	5.0	4.3	30.0
AWRC	Osage	OC	123	0.0	2.0	3.1	50.2	36.4	603.4
DEQ	ARK0204	BC	5	1.0	1.5	1.5	3.7	6.5	7.8
DEQ	ARK0082	OC	38	1.0	2.6	3.3	6.1	5.0	56.0
DEQ	ARK0006B	IR	8	3.5	4.6	6.6	7.0	8.6	12.2
DEQ	ARK0141	CnC	1	1.0	1.0	1.0	1.0	1.0	1.0
AWRC	IR59[b]	IR	127	0.0	5.1	8.1	82.1	90.4	941.2
DEQ	ARK0006[b]	IR	33	1.0	3.3	4.0	6.4	6.8	43.2
AWRC	Watts	IR	128	0.4	7.6	10.7	88.7	126.5	1001.0
DEQ	ARK0004A	FC	14	1.5	2.1	2.5	2.7	2.9	6.5
AWRC	Sager	SG	33	0.0	1.0	1.5	17.0	4.5	144.2
DEQ	ARK0005	SG	10	1.0	2.1	2.5	11.9	3.4	94.8
DEQ	ARK0007A	BF	15	1.0	2.1	2.5	5.0	3.3	38.5
AWRC	Baron	BF	124	0.2	1.4	2.7	34.1	7.7	802.5

Stations in this table with the same superscript letter are at the same location.
+ IR = Illinois River, LF = Lake Fayetteville, MC = Mud Creek, CC = Clear Creek, OC = Osage Creek, SCS = Spring at Cave Springs, SC = Spring Creek, BC = Brush Creek, CnC = Cincinnati Creek, FC = Flint Creek, SG = Sager Creek, BF = Baron Fork

Figure 8 shows the box and whisker graph of TSS concentrations measured at stations in the Upper Illinois River Watershed with more than 10 measurements during the period 2018-2022. The AWRC stations show the statistical range of TSS concentrations that encompass baseflows and storm events in the watershed. Higher flow events correspond to much higher TSS, which is illustrated by looking at stations AWRC-Savoy and DEQ station ARK0040 located at the same location. Though the median TSS at these stations is only 3.0 mg/L different, the maximum concentrations are significantly different. At locations where both AWRC and DEQ collect TSS measurements, median TSS values for the AWRC data sets are statistically significantly higher than median values for the DEQ data sets. The highest median TSS concentration is at AWRC-Watts on the Illinois River at the state line and the lowest median TSS concentration is at Sager Creek (AWRC-Sager) at the state line. Comparing just AWRC stations, median TSS values for the Illinois River stations are statistically significantly higher than median TSS values for the tributary stations. Median TSS values at the AWRC Illinois River stations are not statistically significantly different from each other, suggesting that TSS levels in the Illinois River do not change significantly between Savoy and Watts. As with turbidity, the median Lake Fayetteville TSS concentration is statistically significantly higher than the median TSS concentrations at the downstream Clear Creek and Mud Creek stations.

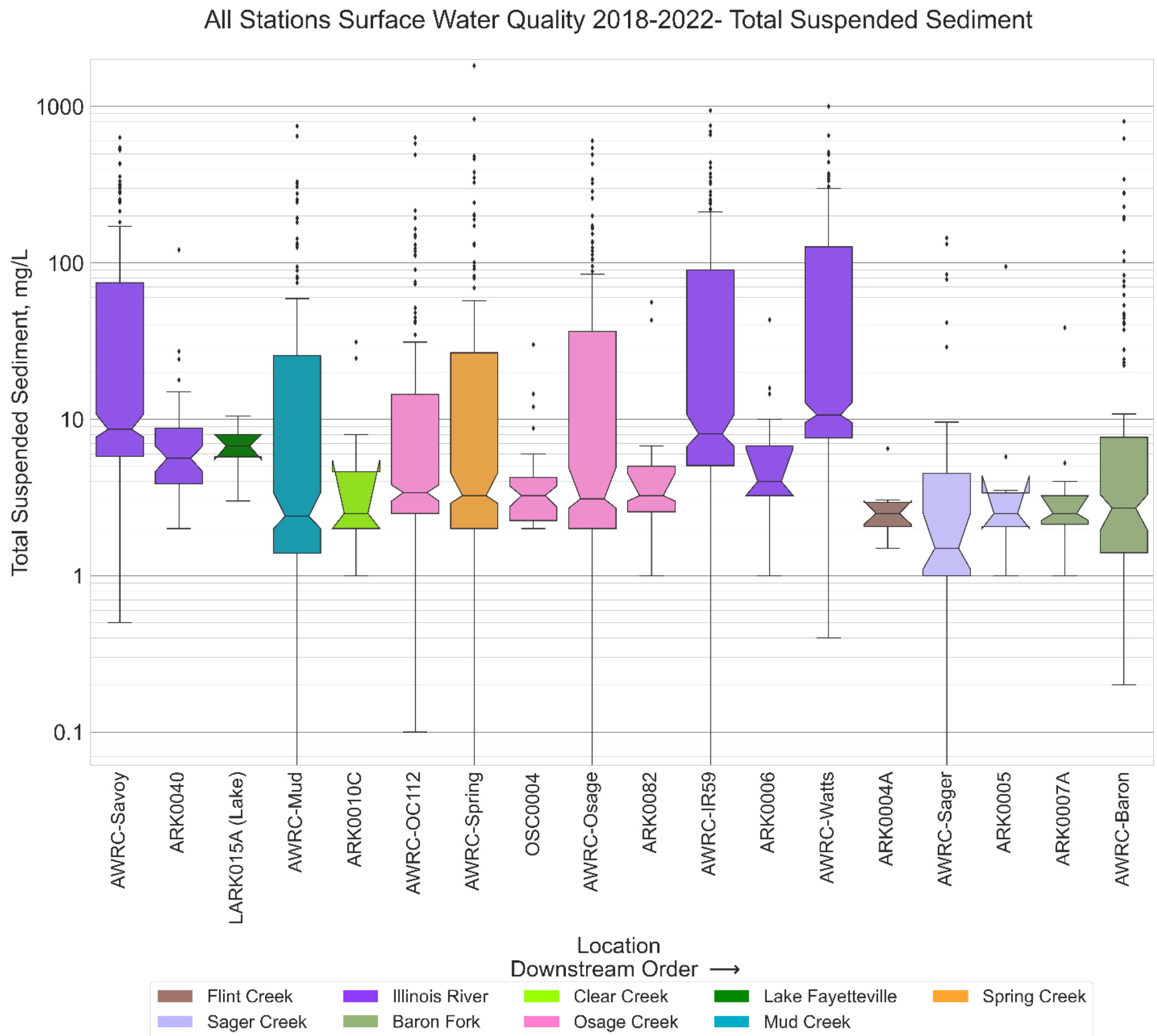

Figure 8: Box and whisker graph of TSS measurements with more than 10 values from 2018-2022. AWRC-Savoy and ARK0040 are located at the same location as well as AWRC-IR59 and ARK0006 on the Illinois River.

Suspended Sediment Concentration

The USGS measures suspended sediment concentrations (SSC) in the Upper Illinois River watershed instead of TSS. Table 7 lists summary statistics for available SSC measurements that were collected during the period 2018-2022. Stations reported less than detection limit values (<1.0 mg/L), so the Kaplan Meier (KM) method was used for general statistics to estimate average and percentile values.

Table 7: Summary statistics for SSC measurements from Upper Illinois River watershed streams, 2018-2022 (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID#	Stream ID+	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	KM Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
USGS	07194800	IR	20	3.0	6.0	9.5	23.8	11.5	307.0
USGS	071948095	MC	22	<1.0	2.3	6.0	65.9	22.5	539.5
USGS	07194880	OC	9	52.0	177.0	214.5	237.9	333.5	499.0
USGS	07194906	SC	4	23.0	54.5	261.1	317.6	524.2	725.0
USGS	07194933	SC	24	<1.0	2.0	5.0	192.3	8.0	2635.0
USGS	07195000	OC	20	<1.0	2.0	4.0	14.3	6.5	160.0
USGS	07195430	IR	19	<1.0	6.0	8.0	54.8	11.0	821.0
USGS	07195500	IR	60	<1.0	11.0	22.5	121.5	104.3	1110.0
USGS	07195855	FC	26	<1.0	2.0	4.0	4.9	5.0	21.0
USGS	07195865	SG	21	<1.0	1.0	2.0	2.4	3.0	5.0
USGS	07196900	BF	19	<1.0	3.5	4.0	5.2	5.5	23.0

+ IR = Illinois River, MC = Mud Creek, OC = Osage Creek, SC = Spring Creek, FC = Flint Creek, SG = Sager Creek, BF = Baron Fork

Figure 9 shows the box and whisker graph of SSC concentrations measured at stations in the Upper Illinois River Watershed with more than 10 measurements during the period 2018-2022. Like TSS above, the station at Watts on the Illinois River reports the highest median and maximum SSC concentrations and the Sager Creek station reports the lowest median SSC concentration. The median SCC concentration at Watts is statistically significantly higher than the median concentrations at the other USGS stations.

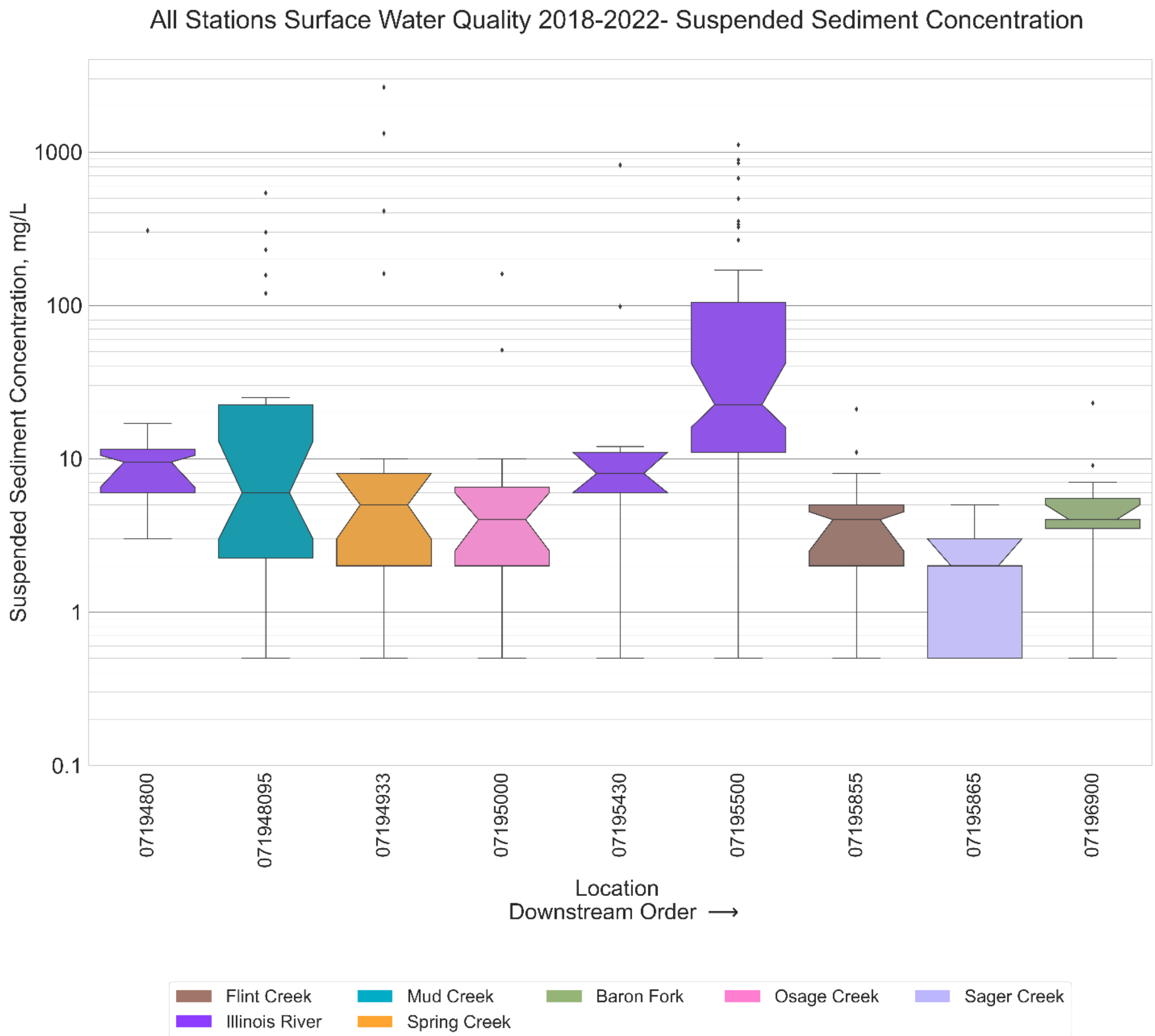

Figure 9: Box and whisker graph of SSC measurements with more than 10 values from 2018-2022.

Water Temperature

Water temperature can affect fish and other aquatic creatures living in waterbodies, as well as water chemistry. Criteria for impairment is found in Arkansas Pollution Control and Ecology Commission Section 2.502 of Rule 2, regulations for water quality standards of surface waters (APCEC, 2022). To determine stream temperature impairment, DEQ requires at least 10 measurements. The Upper Illinois Watershed falls within two (2) ecoregions, the Boston Mountains (31ºC) and Ozark Highlands (29ºC). Lakes and reservoirs have a temperature criterion of 32ºC regardless of ecoregion. The criteria used for each station are from the Regulation 2 ecoregion boundaries; however, the Baron Fork stations are subject to criterion change if the proposed changes to regulatory ecoregion boundaries are approved. Locations where more than 10 percent of measurements exceed the criterion temperature may be classified as impaired. There are no stream segments listed as impaired for temperature on the approved 2018 303(d) list nor the draft 2020 or 2022 303(d) lists (DEQ, 2019; DEQ, 2023).

Table 8 list summary statistics for stream and reservoir temperature measurements from the period 2018-2022. Statistics for LARK015A (Lake Fayetteville) were calculated using only measurements from the epilimnion (less than 6 feet). There are three locations where DEQ and USGS monitor temperature at the same location.

Table 8: Summary statistics for water temperature measurements from stations in the Illinois River from 2018-2022 (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID#	Stream ID+	Number of measures^	Minimum Value, deg C	25th Percentile, deg C	Median, deg C	Mean, deg C	75th Percentile, deg C	Maximum Value, deg C	Criteria, deg C	Number of Values > Criteria	Percentage of Values > Criteria
DEQ	ARK0040[a]	IR	52	5.50	9.98	16.55	16.53	23.30	28.30	29	0	0%
USGS	07194800[a]	IR	20	6.50	10.68	16.75	17.07	23.60	28.00	29	0	0%
DEQ	LARK015A	LF	11	5.75	15.15	20.40	18.25	24.00	26.60	32	0	0%
USGS	071948095	MC	24	4.30	10.00	16.35	15.65	22.30	24.10	29	0	0%
DEQ	ARK0010C	CC	52	5.00	10.68	15.10	15.41	21.68	29.20	29	1	2%
USGS	07194880	OC	9	11.20	14.50	15.30	15.94	18.40	20.10	29	0	-*
DEQ	ARK0199	SCS	9	14.70	14.80	14.90	15.03	15.30	15.70	29	0	-*
USGS	07194906	SC	3	13.60	15.55	17.50	16.97	18.65	19.80	29	0	-*
USGS	07194933	SC	27	8.70	12.75	15.13	16.84	21.30	25.40	29	0	0%
DEQ	OSC0004	OC	53	7.00	11.30	15.00	15.98	21.70	28.00	29	0	0%
USGS	07195000	OC	20	8.60	10.45	16.05	16.24	21.70	25.40	29	0	0%
DEQ	ARK0204	BC	9	8.40	13.20	16.20	14.76	16.50	17.90	29	0	-*
DEQ	ARK0202	LS	9	12.20	14.20	14.90	14.77	15.40	16.60	29	0	-*
DEQ	ARK0082	OC	54	6.80	11.18	17.25	17.29	23.85	28.00	29	0	0%
DEQ	ARK0006B	IR	8	12.80	18.38	24.00	22.03	25.48	29.20	29	1	-*
DEQ	ARK0141	CnC	50	5.40	11.53	17.35	17.40	23.68	26.60	29	0	0%
DEQ	ARK0006[b]	IR	45	5.50	10.10	15.60	16.51	23.70	26.90	29	0	0%
USGS	07195430[b]	IR	20	6.40	10.50	17.45	17.15	24.30	26.50	29	0	0%
USGS	07195500	IR	64	6.10	11.30	14.80	15.93	20.30	28.60	29	0	0%
DEQ	ARK0004A[c]	FC	50	7.30	11.53	18.25	18.19	25.15	29.20	29	1	2%
USGS	07195855[c]	FC	27	7.20	10.70	14.90	16.10	21.05	26.40	29	0	0%
DEQ	ARK0005	SG	49	8.50	11.60	18.10	18.22	24.30	28.70	29	0	0%
USGS	07195865	SG	29	8.00	11.30	14.50	15.90	19.90	25.70	29	0	0%
DEQ	ARK0007A	BF	54	4.50	10.25	16.50	16.36	22.98	26.90	29^	0	0%
USGS	07196900	BF	20	4.30	10.23	16.00	16.49	24.23	29.10	29^	1	5%

Stations in this table with the same superscript letter are at the same location.

+ IR = Illinois River, LF = Lake Fayetteville, MC = Mud Creek, CC = Clear Creek, OC = Osage Creek, SCS = Spring at Cave Springs, SC = Spring Creek, BC = Brush Creek, LS = Logan Spring, CnC = Cincinnati Creek, FC = Flint Creek, SG = Sager Creek, BF = Baron Fork

* DEQ requires at least 10 samples to evaluate attainment of temperature criteria (DEQ 2022).

^ DEQ has proposed updating the ecoregion boundaries. If approved, this station would change ecoregions.

Figure 10 illustrates the temperature statistics from 19 stations with at least 10 measurements from 2018-2022. Lake Fayetteville has the highest median temperature, which is to be expected. Of the stream stations, DEQ's Flint Creek station (ARK0004A) has the highest median temperature, though it is not significantly different from the median values for the other stream stations in the watershed. Interestingly, the USGS station at the same location on Flint Creek as ARK0004A (07195855) has the second lowest median temperature in the watershed. DEQ monitors water quality monthly and USGS takes quarterly measurements, so DEQ stations have more measurments than USGS stations.

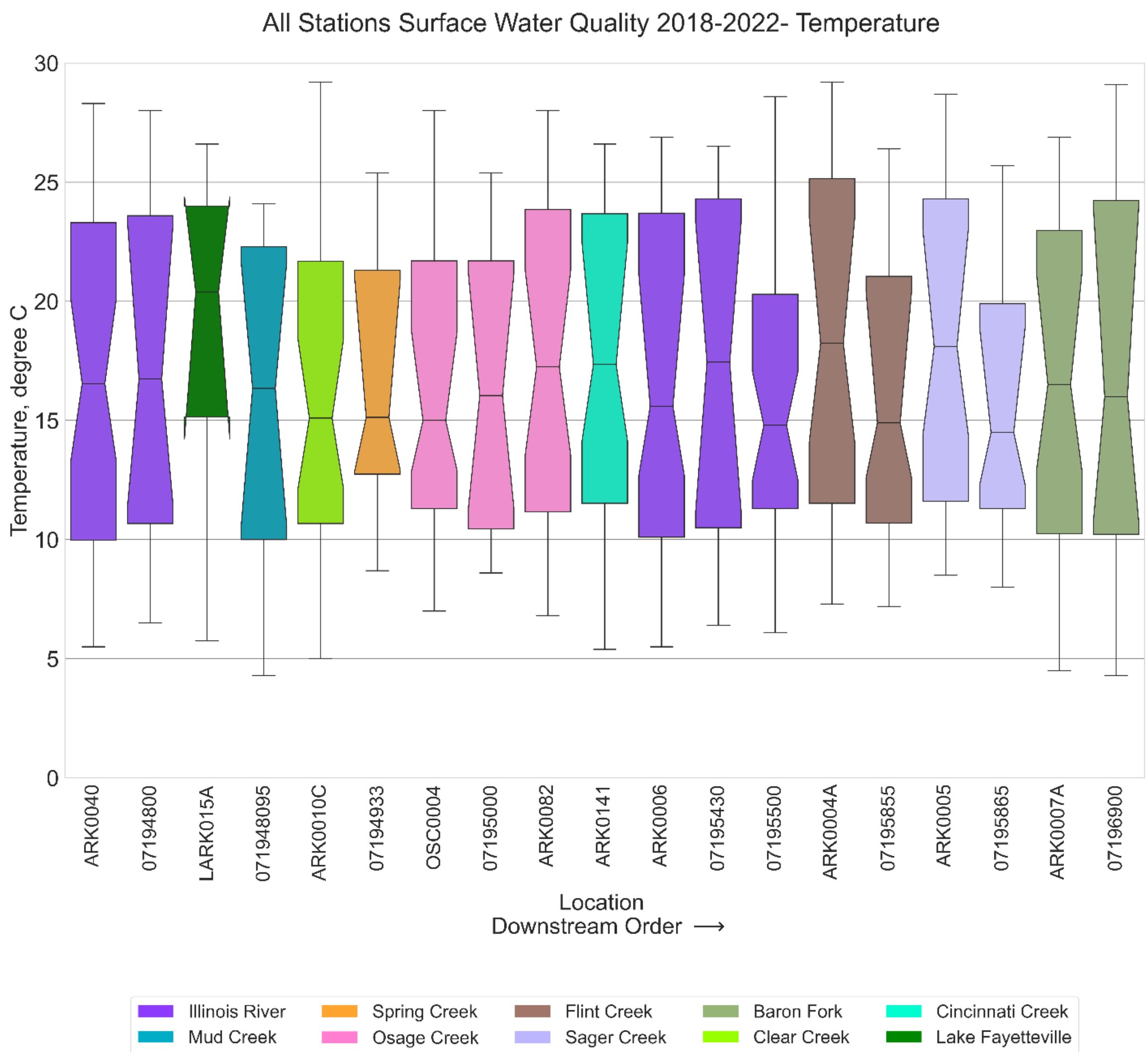

Figure 10: Box and whisker graph of temperature measurements with more than 10 values from 2018-2022. ARK0040 and 07194800 are at the same location on the Illinois River as well as ARK0006 and 07195430. The Flint Creek stations are also at the location.

Dissolved Oxygen

Dissolved oxygen (DO) in water is used by fish and other aquatic creatures and plants living in waterbodies. Dissolved oxygen is evaluated based on two seasons: primary and critical. Primary season and critical season criteria are based on water temperature and minimum flows for the season, as well as ecoregion and watershed area (APCEC, 2022).

APCEC Rule 2.505 defines separate numeric criteria that are used to evaluate stream DO conditions during the Primary Season (when water temperature is 22°C or less, usually mid-September to mid-May), and during the Critical Season (when water temperature is greater than 22°C, usually mid-May to mid-September). Seasonal DO conditions are discussed in two subsections below. To determine DO impairment of stream water quality, DEQ requires at least 10 measurements over two primary or critical seasons. To determine DO impairment of reservoir water quality, DEQ requires at least 10 measurements over at least three years. Locations where more than 10 percent of at least 10 measurements do not meet DO criteria may be classified as impaired (DEQ 2019).

Primary Season DO

The Primary Season for DO water quality criteria is characterized by lower water temperatures (less than 22ºC) and higher flows. DO concentrations are usually naturally higher during this season. Over 70 percent of samples taken from 2018-2022 are categorized as primary season DO due to stream water temperatures typically being below 22ºC. Additionally, at water temperature less than or equal to 10ºC or during March, April and May when discharge is greater than 15cfs, the primary season DO standard is 6.5 mg/L (APCEC, 2022). All stations listed below met this criterion from 2018-2022. Table 9 lists summary statistics for stream DO measurements from the Primary Season (temperatures less than 22ºC) in 2018-2022. Included in the table are the listings of the number and percentage of Primary Season DO measurements that are less than the criteria that apply (6 mg/L for Ozark Highlands ecoregions; 5 mg/L for reservoirs).

Table 9: Summary statistics for Primary Season DO measurements in the Upper Illinois River watershed from 2018-2022 (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID[#]	Stream ID[+]	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L	Criteria, mg/L	Number of Values < Criteria	Percentage of Values < Criteria
DEQ	ARK0040[a]	IR	37	7.21	9.95	10.60	10.80	12.00	14.00	6	0	0%
USGS	07194800[a]	IR	13	8.00	9.70	10.40	10.72	12.00	14.80	6	0	0%
DEQ	LARK015A	LF	8	9.35	9.55	10.60	10.80	11.45	13.40	5	0	-*
USGS	071948095	MC	17	6.00	8.50	10.20	10.30	12.20	13.80	6	1	6%
DEQ	ARK0010C	CC	39	7.49	9.09	10.30	10.34	11.75	13.20	6	0	0%
USGS	07194880	OC	9	7.90	8.10	8.60	8.68	9.00	9.90	6	0	-*
DEQ	ARK0199	SCS	9	9.13	9.39	9.43	9.72	9.92	10.70	6	0	-*
USGS	07194906	SC	3	8.20	8.25	8.30	8.27	8.30	8.30	6	0	-*
USGS	07194933	SC	21	7.50	8.40	10.00	10.06	11.30	14.50	6	0	0%
DEQ	OSC0004	OC	40	7.17	8.81	10.05	9.96	11.20	12.80	6	0	0%
USGS	07195000	OC	15	7.70	9.35	9.70	10.35	11.60	14.70	6	0	0%
DEQ	ARK0204	BC	9	4.74	7.31	9.77	8.68	10.50	12.00	6	2	-*
DEQ	ARK0202	LS	9	7.34	9.30	9.56	9.19	9.65	9.70	6	0	-*
DEQ	ARK0082	OC	36	7.09	10.20	11.00	11.08	12.53	15.50	6	0	0%
DEQ	ARK0006B	IR	3	9.63	9.64	9.64	9.96	10.12	10.60	6	0	-*
DEQ	ARK0141	CnC	31	7.52	9.93	10.90	10.90	12.10	13.20	6	0	0%
DEQ	ARK0006[b]	IR	31	7.71	9.99	10.70	10.97	11.95	13.80	6	0	0%
USGS	07195430[b]	IR	13	8.00	9.60	10.10	10.52	10.90	15.30	6	0	0%
USGS	07195500	IR	51	7.30	9.50	10.30	10.19	10.90	12.50	6	0	0%
DEQ	ARK0004A[c]	FC	32	7.77	10.28	11.20	11.15	12.00	16.00	6	0	0%
USGS	07195855[c]	FC	23	6.20	8.50	10.20	10.06	11.00	14.70	6	0	0%
DEQ	ARK0005	SG	31	8.16	9.64	10.70	10.90	11.80	15.40	6	0	0%
USGS	07195865	SG	23	6.80	8.30	10.10	9.96	11.50	14.10	6	0	0%
DEQ	ARK0007A	BF	37	7.28	10.00	11.10	10.86	12.10	13.50	6^	0	0%
USGS	07196900	BF	12	6.80	8.98	9.70	10.29	11.55	14.10	6^	0	0%

Stations in this table with the same superscript letter are at the same location.
+ IR = Illinois River, LF = Lake Fayetteville, MC = Mud Creek, CC = Clear Creek, OC = Osage Creek, SCS = Spring at Cave Springs, SC = Spring Creek, BC = Brush Creek, LS = Logan Spring, CnC = Cincinnati Creek, FC = Flint Creek, SG = Sager Creek, BF = Baron Fork
* DEQ requires at least 10 samples for assessment.
^ DEQ has proposed updating the ecoregion boundaries. If approved, this station would change ecoregions; however, the criteria for Boston Mountain and Ozark Highland ecoregion Primary Season DO is the same at 6 mg/L.

Indicates stations are located on assessment units listed as impaired due to low Primary Season DO on the Draft 2020 and Draft 2022 303(d) Lists.

Figure 11 shows the box and whisker graph of Primary Season DO measurements from stations in the Upper Illinois River watershed with at least 10 Primary Season measurements during 2018-2022. The median Illinois River DO concentration does not change much from upstream to downstream (~10.5 to 10.3 mg/L). The highest median DO concentration is on Osage Creek (ARK0082), and the lowest graphed median DO concentration is shared between Osage Creek USGS station (07195000) and the USGS Baron Fork station (07196900). None of the graphed stations had measurements below the 6 mg/L standard; however, the Brush Creek monitoring station (ARK0204) had two of nine measurements below the 6 mg/L standard from 2018-2022 and is listed as impaired for Primary Season DO in the Draft 2020 303(d) list (DEQ, 2023).

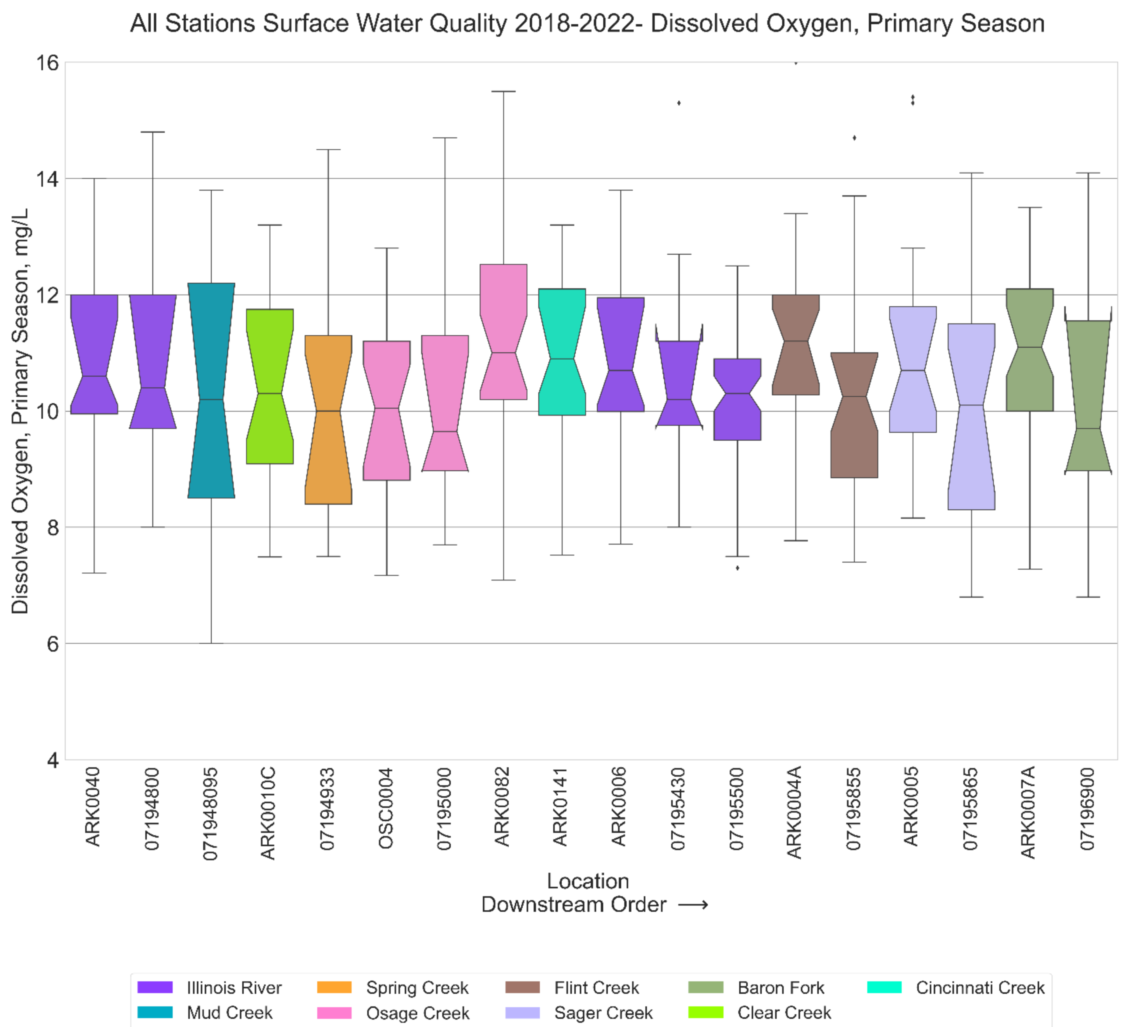

Figure 11: Box and whisker graph of Primary Season DO measurements from Illinois River watershed stations and its tributaries with more than 10 values from 2018-2022. ARK0040 and 07194800 are at the same location on the Illinois River as well as ARK0006 and 07195430. The Flint Creek stations are also at the location.

Critical Season DO

The Critical Season for DO water quality criteria is characterized by higher temperatures (greater than 22^{o}C) and lower flows. DO concentrations naturally tend to be lower during this season. Table 10 lists summary statistics for DO measurements from the Critical Season, 2018-2022. The Baron Fork has a stream assessment unit listed as impaired for Critical Season DO by DEQ (highlighted in the table below) on the Draft 2020 and Draft 2022 303(d) Lists. All the stations listed below are in the Ozark Highlands ecoregion, so 5 mg/L was used as the DO criterion. However, DEQ has proposed a change in ecoregion boundary, which would impact the Baron Fork monitoring stations and move them to the Boston Mountains ecoregion. The Critical Season DO criterion for watersheds greater than 10mi^2 in the Boston Mountain ecoregion is 6 mg/L.

Table 10: Summary statistics for Critical Season DO measurements in the Upper Illinois River watershed from 2018-2022 (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID#	Stream ID+	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L	Criteria, mg/L	Number of Values < Criteria	Percentage of Values < Criteria
DEQ	ARK0040[a]	IR	16	6.36	7.68	8.03	8.05	8.59	9.13	5	0	0%
USGS	07194800[a]	IR	7	6.90	7.45	7.90	7.99	8.35	9.50	5	0	-*
DEQ	LARK015A	LF	4	9.17	9.79	11.15	11.09	12.45	12.90	5	0	-*
USGS	071948095	MC	5	4.80	6.70	7.40	6.88	7.50	8.00	5	1	-*
DEQ	ARK0010C	CC	13	6.24	7.26	7.62	8.10	8.74	10.20	5	0	0%
USGS	07194933	SC	6	5.80	7.55	8.35	8.30	9.30	10.40	5	0	-*
DEQ	OSC0004	OC	13	6.59	7.03	8.35	8.18	8.93	10.60	5	0	0%
USGS	07195000	OC	5	5.60	7.50	7.85	7.81	8.30	9.80	5	0	-*
DEQ	ARK0082	OC	19	6.75	8.41	8.58	8.68	9.03	10.10	5	0	0%
DEQ	ARK0006B	IR	5	7.16	8.58	8.70	8.83	9.77	9.92	5	0	-*
DEQ	ARK0141	CnC	20	5.65	6.85	7.23	7.46	7.87	9.67	5	0	0%
DEQ	ARK0006[b]	IR	15	5.20	7.82	8.07	7.97	8.66	9.29	5	0	0%
USGS	07195430[b]	IR	7	6.20	6.85	7.90	7.63	8.40	8.80	5	0	-*
USGS	07195500	IR	13	7.10	7.40	7.90	7.95	8.50	9.00	5	0	0%
DEQ	ARK0004A[c]	FC	19	7.50	8.13	8.49	8.40	8.67	9.40	5	0	0%
USGS	07195855[c]	FC	5	6.90	7.00	8.40	8.24	8.90	10.00	5	0	-*
DEQ	ARK0005	SG	19	7.11	8.30	8.67	8.60	8.97	10.10	5	0	0%
USGS	07195865	SG	6	6.40	7.93	8.05	8.13	8.63	9.60	5	0	-*
DEQ	ARK0007A	BF	18	5.93	6.89	7.47	7.47	8.23	9.02	5^	0	0%
USGS	07196900	BF	8	5.00	6.83	7.95	7.90	9.40	10.00	5^	1	-*

Stations in this table with the same superscript letter are at the same location.
+ IR = Illinois River, LF = Lake Fayetteville, MC = Mud Creek, CC = Clear Creek, OC = Osage Creek, SC = Spring Creek, CnC = Cincinnati Creek, FC = Flint Creek, SG = Sager Creek, BF = Baron Fork
* DEQ requires at least 10 samples for assessment.
^ DEQ has proposed updating the ecoregion boundaries. If approved, this station would change ecoregions; the criteria for Boston Mountain ecoregion Critical Season DO is 6 mg/L.

Indicates stations are located on assessment units listed as impaired due to low Critical Season DO on the Draft 2020 and Draft 2022 303(d) Lists.

Figure 12 below shows a box and whisker graph of Critical Season DO measurements from stations with at least 10 Critical Season measurements during 2018-2022. The lowest median stream Critical Season DO concentration was from Cincinnati Creek (ARK0141). The highest graphed median DO concentration during Critical Season was measured on Sager Creek (ARK0005). Overall, there is not a lot of variability in DO concentration throughout the watershed.

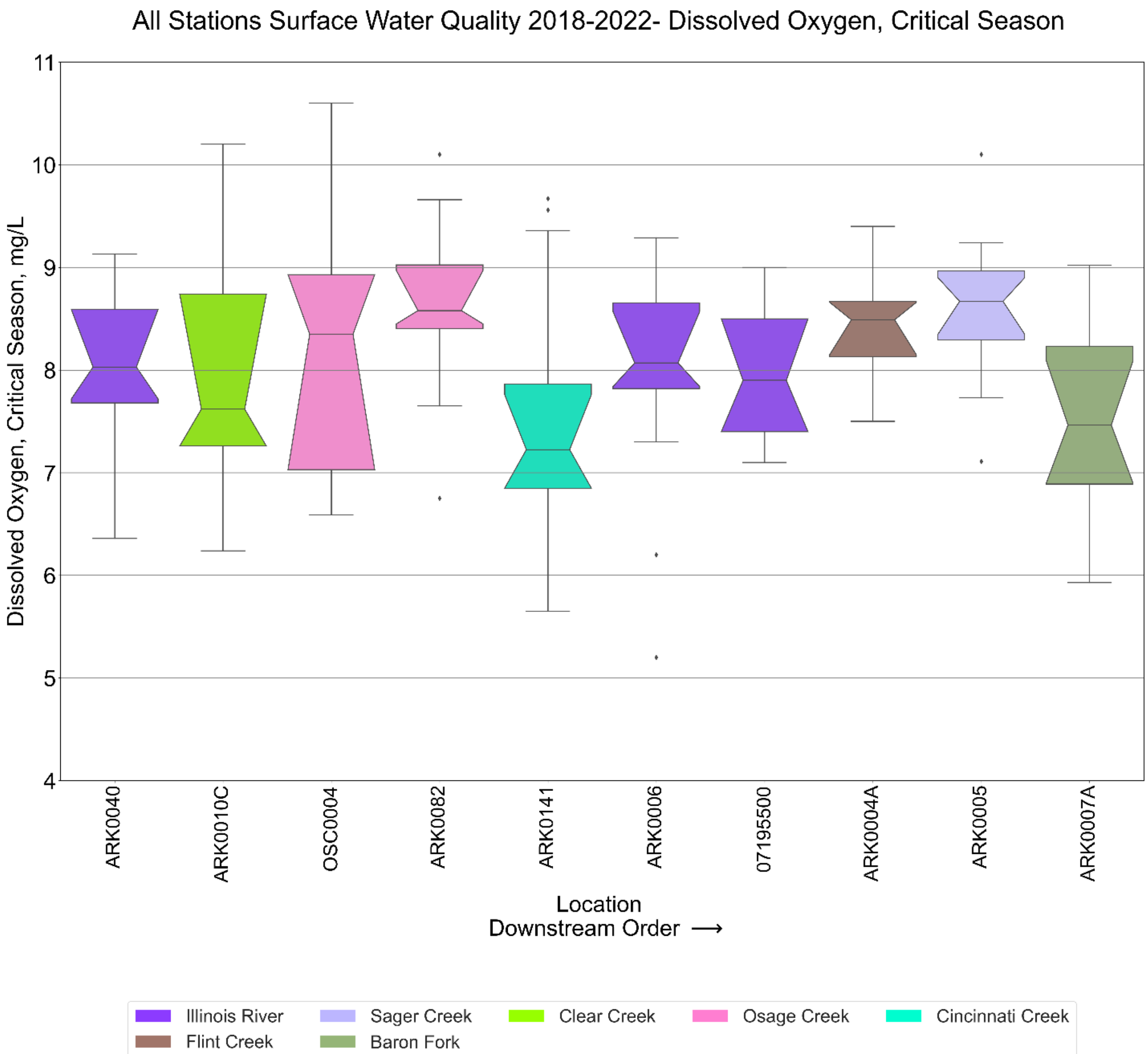

Figure 12: Box and whisker graph of Critical Season DO measurements from Upper Illinois River watershed stations and its tributaries with more than 10 values from 2018-2022. ARK0006 and 07195500 are at the same location on the Illinois River.

Percent DO Saturation

Water temperature affects the ability of water to dissolve oxygen. More oxygen can be dissolved in cooler water than in warmer water, i.e., higher maximum DO concentrations are possible in cooler water than in warmer water. Percent DO saturation compares the measured DO concentration to the maximum possible DO concentration at the measured water temperature. Percent DO saturation values greater than 100 percent can occur during algae blooms.

Table 11: Summary statistics for stream percent DO saturation measurements from 2018-2022 (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID	Stream ID+	Number of measures	Minimum Value, %	25th Percentile, %	Median, %	Mean, %	75th Percentile, %	Maximum Value, %
USGS	07194800	IR	20	83	94	101	102	113	122
USGS	071948095	MC	19	59	88	92	93	106	116
USGS	07194880	OC	9	85	87	91	90	93	95
USGS	07194906	SC	3	84	87	89	89	92	95
USGS	07194933	SC	27	73	90	98	102	116	128
USGS	07195000	OC	20	71	91	95	100	112	128
USGS	07195430	IR	20	77	94	99	99	104	125
USGS	07195500	IR	61	83	99	100	99	102	114
USGS	07195855	FC	26	73	90	100	100	102	128
USGS	07195865	SG	27	79	89	100	99	107	125
USGS	07196900	BF	20	59	83	93	96	108	132

+ IR = Illinois River, MC = Mud Creek, OC = Osage Creek, SC = Spring Creek, FC = Flint Creek, SG = Sager Creek, BF = Baron Fork

Percent DO Saturation values range from 59 percent to 132 percent, both of these being measured in the Baron Fork (07196900). Figure 11 below illustrates the summary statistics of the percent DO saturation throughout the watershed. Median percent DO saturation is at or above 100 percent on the main stem of the Illinois River, Flint Creek, and Sager Creek, although these stations do not have the highest maximum percent DO saturation values. All stations except one Osage Creek station (07194880) and a Spring Creek station in Springdale (07194906 – only 3 measurements taken in March, April, and May) experience maximum percent DO saturation above 100 percent, with the Baron Fork (proposed as impaired for DO on Draft 2020 and 2022 303(d) Lists) with the greatest range of values (59 percent to 132 percent).

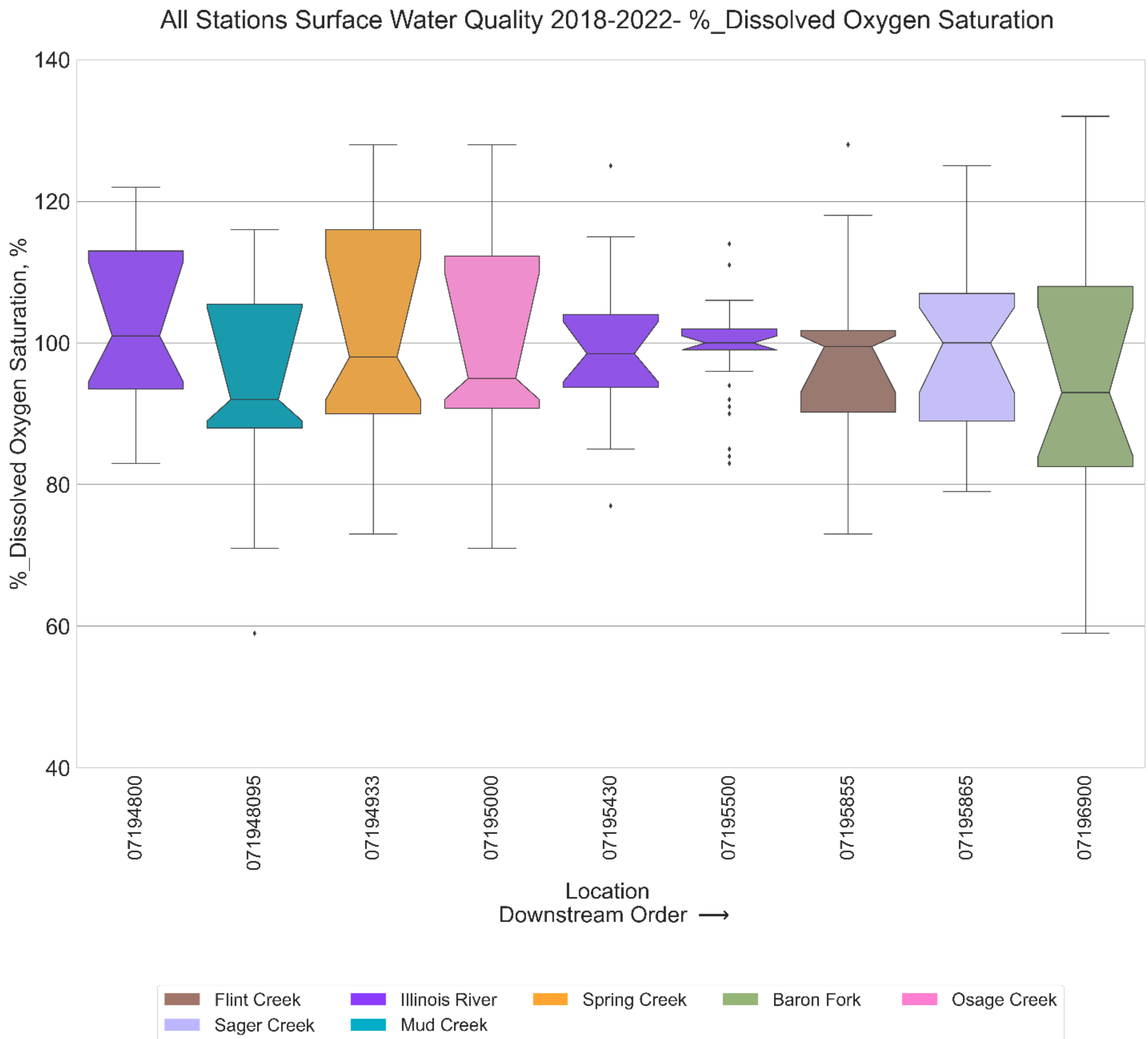

Figure 13: Box and whisker graph of percent dissolved oxygen saturation from stations with at least 10 measurements from 2018-2022.

Biochemical Oxygen Demand

Biochemical Oxygen Demand (BOD) represents the amount of DO needed by aerobic microorganisms to decompose organic matter in a water sample at a specific water temperature. It is an indicator of the level of organic matter pollution in water, and the likelihood that adequate DO levels can be maintained. BOD was measured at only one DEQ station in the Upper Illinois River watershed during 2018-2022, ARK0005 (Sager Creek at Beaver Springs Road, OK). Half of the measurements were below the detectable limit of 0.2 mg/L; therefore, the Kaplan Meier Method (KM) was used to estimate statistics, including percentiles and average, using measurements below the detectable limit (<0.2 mg/L) (Table 12). There is no numeric water quality criterion for BOD in Arkansas.

The maximum value of 2.32 mg/L was measured in late January in 2020. The next highest measurement is 0.98 mg/L in March of 2020.

Table 12: Summary statistics using Kaplan Meier method for BOD values from 2018-2022 at ADEQ station Sager Creek near Beaver Springs Road, Oklahoma.

Station ID	Stream ID+	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	KM Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
ARK0005	SG	44	<0.20	<0.20	0.21	0.39	0.47	2.32

+ SG = Sager Creek

Phosphorus

Phosphorus is a nutrient and is not harmful to humans or animals itself. However, it can stimulate algal growth in surface waters. Excessive algal growth has the potential to create conditions that are a nuisance or harmful to humans, aquatic organisms, or livestock, including low DO levels. There are no numeric water quality standards for total phosphorus (TP) that apply in the Arkansas (APCEC, 2022); however, the EPA and DEQ have used Oklahoma's standard at the state line for reference (0.037 mg/L). EPA has proposed seven new listings in the Upper Illinois River watershed as impaired due to phosphorus on the main stem Illinois River, Osage Creek, and Spring Creek. Additionally, Arkansas is a nutrient reduction target state for the Gulf of Mexico Hypoxia Task Force (Alexander, et al., 2008). Therefore, phosphorus levels are a concern in all Arkansas watersheds.

Stations reported values less than the detection limit for TP, so the Kaplan Meier (KM) method was used for general statistics. The Illinois River, Flint Creek, and Baron Fork Creek are designated as Scenic Rivers in Oklahoma. Historically, Oklahoma used a 30-day geometric mean to determine compliance with Oklahoma water quality standard of 0.037 mg/L total phosphorus (ODEQ, 2023). The five (5) year geometric mean is reported in the table below for 2018-2022. Oklahoma updated its standard in 2023 to use the rolling six-month arithmetic average for total phosphorus not to be exceeded more than three (3) times per five (5) year period (ODEQ, 2023), so both the KM arithmetic mean and the geometric mean are compared to the Oklahoma phosphorus standard of 0.037 mg/L.

Table 13: Summary statistics for total phosphorus measurements in the Upper Illinois River watershed from 2018-2022 (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID[#]	Stream ID[+]	Number of measures*	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	KM Mean, mg/L	Geometric Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L	Criterion, mg/L	KM mean above 0.037 mg/L	Geometric mean above 0.037 mg/L
AWRC	Savoy[a]	IR	124	0.010	0.042	0.069	0.210	0.096	0.262	1.080	0.037	Y	Y
DEQ	ARK0040[a]	IR	49	0.030	0.050	0.060	0.070	0.065	0.080	0.170	0.037	Y	Y
USGS	07194800[a]	IR	19	<0.020	0.035	0.050	0.074	0.051	0.070	0.520	0.037	Y	Y
DEQ	LARK015A	LF	10	0.030	0.033	0.040	0.040	0.039	0.040	0.060	0.037	Y	Y
AWRC	Mud[b]	MC	121	<0.001	0.012	0.022	0.088	0.031	0.105	0.767	0.037	Y	N
USGS	071948095[b]	MC	24	0.007	0.012	0.022	0.095	0.033	0.059	0.555	0.037	Y	N
DEQ	ARK0010C	CC	40	0.020	0.028	0.030	0.036	0.033	0.040	0.110	0.037	N	N
AWRC	OC112[c]	OC	126	<0.009	0.040	0.060	0.100	0.071	0.103	0.682	0.037	Y	Y
USGS	07194880[c]	OC	9	0.136	0.215	0.337	0.328	0.297	0.393	0.598	0.037	Y	Y
DEQ	ARK0199	SCS	6	0.038	0.040	0.040	0.042	0.041	0.041	0.050	0.037	Y	Y
USGS	07194906	SC	4	0.139	0.213	0.367	0.368	0.315	0.523	0.599	0.037	Y	Y
AWRC	Spring[d]	SC	126	0.045	0.085	0.113	0.172	0.134	0.192	1.235	0.037	Y	Y
USGS	07194933[d]	SC	25	0.060	0.105	0.177	0.255	0.183	0.276	1.288	0.037	Y	Y
DEQ	OSC0004	OC	49	0.050	0.070	0.080	0.092	0.088	0.110	0.220	0.037	Y	Y
AWRC	Osage[e]	OC	122	0.032	0.054	0.072	0.136	0.095	0.152	0.715	0.037	Y	Y
USGS	07195000[e]	OC	20	0.040	0.048	0.065	0.094	0.073	0.090	0.480	0.037	Y	Y
DEQ	ARK0204	BC	6	0.030	0.031	0.033	0.034	0.034	0.039	0.040	0.037	N	N
DEQ	ARK0202	LS	7	0.035	0.039	0.040	0.040	0.040	0.040	0.044	0.037	Y	Y
DEQ	ARK0082	OC	54	0.030	0.060	0.070	0.070	0.067	0.080	0.170	0.037	Y	Y
DEQ	ARK0006B	IR	8	0.050	0.060	0.070	0.065	0.065	0.070	0.070	0.037	Y	Y
DEQ	ARK0141	CnC	48	0.040	0.070	0.090	0.091	0.086	0.100	0.270	0.037	Y	Y
AWRC	IR59[f]	IR	126	0.006	0.046	0.060	0.168	0.088	0.244	0.956	0.037	Y	Y
DEQ	ARK0006[f]	IR	40	0.030	0.050	0.060	0.067	0.063	0.080	0.120	0.037	Y	Y
USGS	07195430[f]	IR	19	0.030	0.040	0.050	0.083	0.056	0.060	0.580	0.037	Y	Y
AWRC	Watts[g]	IR	128	0.006	0.051	0.066	0.181	0.092	0.261	0.936	0.037	Y	Y
USGS	07195500[g]	IR	61	0.024	0.059	0.081	0.190	0.108	0.208	1.140	0.037	Y	Y
DEQ	ARK0004A[h]	FC	45	0.020	0.040	0.050	0.050	0.047	0.060	0.090	0.037	Y	Y
USGS	07195855[h]	FC	30	0.017	0.027	0.036	0.037	0.035	0.045	0.062	0.037	N	N
AWRC	Sager	SG	33	0.003	0.042	0.051	0.150	0.061	0.083	1.213	0.037	Y	Y
DEQ	ARK0005	SG	47	<0.070	0.100	0.160	0.218	0.174	0.265	0.940	0.037	Y	Y
USGS	07195865	SG	30	0.082	0.118	0.199	0.229	0.193	0.271	0.663	0.037	Y	Y
DEQ	ARK0007A	BF	51	0.020	0.030	0.040	0.054	0.045	0.060	0.380	0.037	Y	Y
AWRC	Baron[i]	BF	123	<0.001	0.021	0.033	0.128	0.048	0.102	1.498	0.037	Y	Y
USGS	07196900[i]	BF	15	<0.020	0.030	0.030	0.032	0.031	0.040	0.050	0.037	N	N

Stations in this table with the same superscript letter are at the same location.
+ IR = Illinois River, LF = Lake Fayetteville, MC = Mud Creek, CC = Clear Creek, OC = Osage Creek, SCS = Spring at Cave Springs, SC = Spring Creek, BC = Brush Creek, LS = Logan Spring, CnC = Cincinnati Creek, FC = Flint Creek, SG = Sager Creek, BF = Baron Fork

Indicates stations are located on assessment units proposed as impaired by EPA for the Draft 2020 303(d) list due to high phosphorus.

Figure 14 shows the summary statistics for 28 stations with at least 10 total phosphorus measurements in the watershed from 2018-2022. The red line indicates the 0.037 mg/L TP standard at the Oklahoma state line. The Illinois River, Flint Creek, Sager Creek, and Baron Fork Creek all cross the Oklahoma border. Stations with the same superscript letter are at the same location.

DEQ sampled water quality monthly, USGS monitored on a quarterly basis, and AWRC monitored more often to collect better information around hydrologic events. AWRC data typically have a larger interquartile range than data collected by others at the same location.

The lowest median TP was measured on Mud Creek by AWRC and USGS (AWRC-Mud, 0701948095). The median and geometric mean of Mud Creek TP data are below 0.037 mg/L, but the KM mean is above 0.037 mg/L. The Clear Creek station downstream (ARK0010C) has a higher median TP, but all three statistics (median, KM mean, geometric mean) are all below 0.037 mg/L.

The highest median TP measurements are at the USGS stations on Sager Creek (07195865) and Spring Creek (07194933). AWRC also took measurements at the same location on Spring Creek. Although the AWRC station has a lower median TP value (and 100 more measurements from 2018-2022), Spring Creek still has the second highest overall median TP. DEQ also measures TP at Sager Creek upstream of the USGS station 07195865 (DEQ-ARK0005) and reported high TP values on Sager Creek. Median TP concentrations measured in Sager Creek downstream of the Oklahoma border by DEQ and USGS are statistically significantly higher than the median of TP concentrations at the AWRC Sager Creek station upstream of the border. Median TP concentration measured in Spring Creek and in Sager Creek downstream of the Oklahoma border are statistically significantly higher than median TP concentrations measured elsewhere.

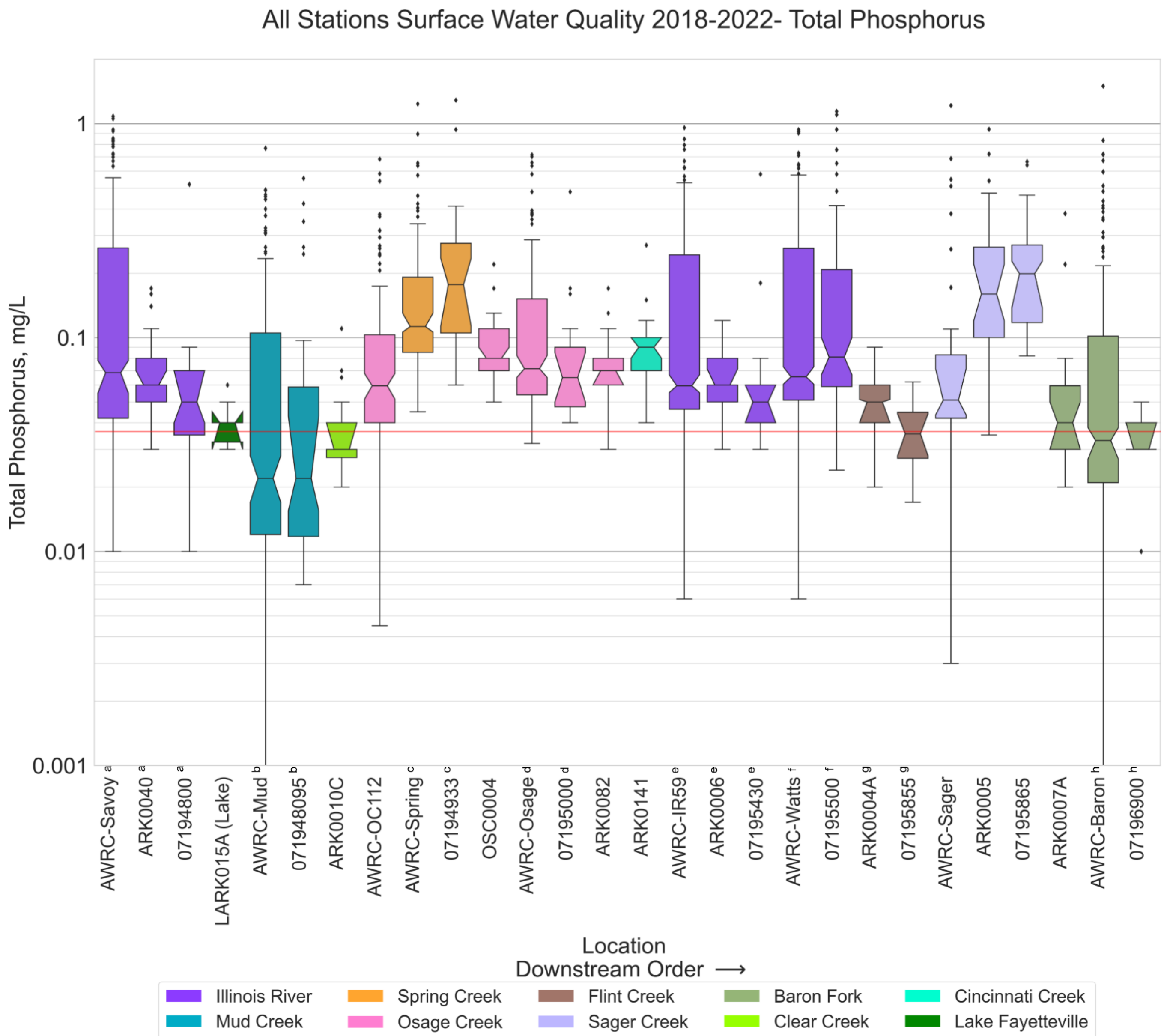

Figure 14: Box and whisker graph of total phosphorus from stations with at least 10 measurements from 2018-2022.

The rolling six (6) month average of TP measurements was calculated for each station in the watershed. Table 14 reports the number of measurements used to calculate the rolling average that exceed 0.037 mg/L. The highlighted rows indicate the station is located on an assessment unit that has a proposed TP impairment. Stations with the same superscript letter are at the same location. Most stations maintained a rolling six (6) month average above 0.037 mg/L during 2018-2022.

Table 14: Number of six-month rolling average TP values greater than 0.037 mg/L in the Upper Illinois River watershed from 2018-2022 (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID[#]	Stream ID[+]	Criterion, mg/L	Number of values above criterion	Total number of measurements	Percent exceedance
AWRC	Savoy[a]	IR	0.037	119	124	96%
DEQ	ARK0040[a]	IR	0.037	48	49	98%
USGS	07194800[a]	IR	0.037	18	19	95%
DEQ	LARK015A	LF	0.037	6	10	60%
AWRC	Mud[b]	MC	0.037	114	121	94%
USGS	071948095[b]	MC	0.037	14	24	58%
DEQ	ARK0010C	CC	0.037	16	40	40%
AWRC	OC112	OC	0.037	126	126	100%
USGS	07194880	OC	0.037	9	9	100%
DEQ	ARK0199	SCS	0.037	6	6	100%
USGS	07194906	SC	0.037	4	4	100%
AWRC	Spring[c]	SC	0.037	126	126	100%
USGS	07194933[c]	SC	0.037	25	25	100%
DEQ	OSC0004	OC	0.037	49	49	100%
AWRC	Osage[d]	OC	0.037	122	122	100%
USGS	07195000[d]	OC	0.037	20	20	100%
DEQ	ARK0204	BC	0.037	0	6	0%
DEQ	ARK0202	LS	0.037	5	7	71%
DEQ	ARK0082	OC	0.037	54	54	100%
DEQ	ARK0006B	IR	0.037	8	8	100%
DEQ	ARK0141	CnC	0.037	48	48	100%
AWRC	IR59[e]	IR	0.037	121	126	96%
DEQ	ARK0006[e]	IR	0.037	40	40	100%
USGS	07195430[e]	IR	0.037	15	19	79%
AWRC	Watts[f]	IR	0.037	123	128	96%
USGS	07195500[f]	IR	0.037	60	61	98%
DEQ	ARK0004A[g]	FC	0.037	45	45	100%
USGS	07195855[g]	FC	0.037	13	30	43%
AWRC	Sager	SG	0.037	28	33	85%
DEQ	ARK0005	SG	0.037	47	47	100%
USGS	07195865	SG	0.037	30	30	100%
DEQ	ARK0007A	BF	0.037	43	51	84%
AWRC	Baron[h]	BF	0.037	118	123	96%
USGS	07196900[h]	BF	0.037	4	15	27%

Nitrogen

Nitrogen is a nutrient and can stimulate algal growth. Excessive algal growth has the potential to create conditions that are a nuisance or harmful to humans, aquatic organisms, or livestock, including low DO levels. The only numeric water quality standards for nitrogen that are specified in the Arkansas Water Quality Standards are the criteria for ammonia nitrogen, which are dependent on temperature and pH (APCEC, 2022). Additionally, DEQ uses the numeric value of 10 mg/L nitrate nitrogen as a maximum allowable in-stream value for maintaining the designated use of domestic water supply. Therefore, ammonia nitrogen and nitrate + nitrite nitrogen measurements are evaluated in subsections below. In addition, total nitrogen (TN) measurements are evaluated.

There are no numeric water quality standards for total nitrogen that apply in the Upper Illinois River watershed (APCEC, 2022). Sager Creek has been identified as impaired due to ammonia nitrogen on the draft 2020 303(d) List (DEQ, 2023). No other impairments due to nitrogen have been identified in the Upper Illinois River watershed (DEQ 2020). Thus, nonpoint sources of nutrients have not been identified specifically as contributing to water quality impairments in this watershed. However, Arkansas is a nutrient reduction target state for the Gulf of Mexico Hypoxia Task Force. Therefore, nitrate and total nitrogen levels are a concern in all Arkansas watersheds.

Ammonia Nitrogen

Under certain conditions of pH and temperature, ammonia can be toxic to aquatic life. Ammonia can also reduce dissolved oxygen concentrations in water through bacterial conversion of ammonia to nitrate and encouraging excessive algal or plant growth. Sager Creek has been identified as impaired for aquatic life support due to ammonia nitrogen on the draft 2020 303(d) List (DEQ, 2023), but is not listed on the draft 2022 303(d) List.

Almost all ammonia nitrogen measurements are reported as less than the detection limit. The detection limit for DEQ is 0.03 mg/L. The Kaplan Meier (KM) Method was used to estimate summary statistics using EPA’s ProUCL tool (USEPA, 2022). The highest reported ammonia nitrogen concentration during 2018-2022 occurred at Sager Creek (ARK0005). Lake Fayetteville (LARK015A) had 50 percent of measurements within the detectable range, with a maximum value of 0.5 mg/L reported. Since most of the measurements are less than the detectable range, ammonia is not graphed.

Table 15: Summary statistics for measurements from 2018-2022 for ammonia nitrogen (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID	Stream ID+	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	KM Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
DEQ	ARK0040	IR	52	<0.03	<0.03	<0.03	0.04	0.03	0.14
DEQ	LARK015A	LF	12	<0.03	<0.03	0.04	0.12	0.13	0.50
DEQ	ARK0010C	CC	51	<0.03	<0.03	<0.03	<0.03	<0.03	0.10
DEQ	ARK0199	SCS	7	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
DEQ	OSC0004	OC	51	<0.03	<0.03	<0.03	0.04	<0.03	0.17
DEQ	ARK0204	BC	8	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
DEQ	ARK0202	LS	8	<0.03	<0.03	<0.03	<0.03	<0.03	0.04
DEQ	ARK0082	OC	54	<0.03	<0.03	<0.03	<0.03	<0.03	0.04
DEQ	ARK0006B	IR	8	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
DEQ	ARK0141	CnC	48	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
DEQ	ARK0006	IR	43	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
DEQ	ARK0004A	FC	48	<0.03	<0.03	<0.03	<0.03	<0.03	0.04
DEQ	ARK0005	SG	47	<0.03	<0.03	<0.03	<0.03	<0.03	0.91
DEQ	ARK0007A	BF	54	<0.03	<0.03	<0.03	<0.03	<0.03	0.12

+ IR = Illinois River, LF = Lake Fayetteville, CC = Clear Creek, SCS = Spring at Cave Springs, OC = Osage Creek, BC = Brush Creek, LS = Logan Spring, CnC = Cincinnati Creek, FC = Flint Creek, SG = Sager Creek, BF = Baron Fork

Indicates stations are located on assessment units proposed as impaired by EPA due to high ammonia nitrogen on the Draft 2020 303(d) List. This station is not currently listed on the draft 2022 303(d) List.

Nitrate + Nitrite Nitrogen

Table 16 lists summary statistics for nitrate + nitrite nitrogen measurements from the Upper Illinois River watershed during 2018-2022. Almost all measurements are below the 10 mg/L drinking water criterion, except one measurement on Cincinnati Creek. The highest nitrate + nitrite nitrogen value was 13.2 mg/L.

Table 16: Summary statistics for measurements from 2018-2022 for nitrate + nitrite (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID	Stream ID+	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	KM Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
DEQ	ARK0040	IR	49	1.4	1.9	2.3	2.2	2.6	3.5
DEQ	LARK015A	LF	9	0.2	0.5	0.6	0.6	0.8	1.1
DEQ	ARK0010C	CC	48	0.5	1.3	1.5	1.4	1.6	2.6
DEQ	ARK0199	SCS	4	5.4	5.5	5.5	5.6	5.7	6.0
DEQ	OSC0004	OC	48	1.4	2.9	3.2	3.2	3.5	3.9
DEQ	ARK0204	BC	5	2.8	2.8	3.0	3.2	3.2	4.2
DEQ	ARK0202	LS	5	4.9	5.3	5.5	5.4	5.5	5.9
DEQ	ARK0082	OC	50	2.2	2.9	3.2	3.2	3.6	4.1
DEQ	ARK0006B	IR	8	2.0	2.2	2.4	2.4	2.5	3.3
DEQ	ARK0141	CnC	46	1.8	2.6	3.5	3.5	3.9	13.2
DEQ	ARK0006	IR	41	1.6	2.2	2.5	2.5	2.8	3.5
DEQ	ARK0004A	FC	46	0.6	1.4	2.2	2.2	2.9	3.9
DEQ	ARK0005	SG	45	2.7	3.4	4.1	4.3	4.9	7.5
DEQ	ARK0007A	BF	51	0.5	1.2	1.8	1.7	2.1	3.4

+ IR = Illinois River, LF = Lake Fayetteville, CC = Clear Creek, SCS = Spring at Cave Springs, OC = Osage Creek, BC = Brush Creek, LS = Logan Spring, CnC = Cincinnati Creek, FC = Flint Creek, SG = Sager Creek, BF = Baron Fork

Figure 15 is the box and whisker plots of stations with at least 10 measurements from 2018-2022. The graphed station with the highest median is on Sager Creek (ARK0005). The median nitrate+nitrite for Sage Creek is statistically significantly higher than the median values for the other graphed stations. Clear Creek (ARK0010C) has the lowest median nitrate+nitrite concentration and the smallest variance of the graphed stations.

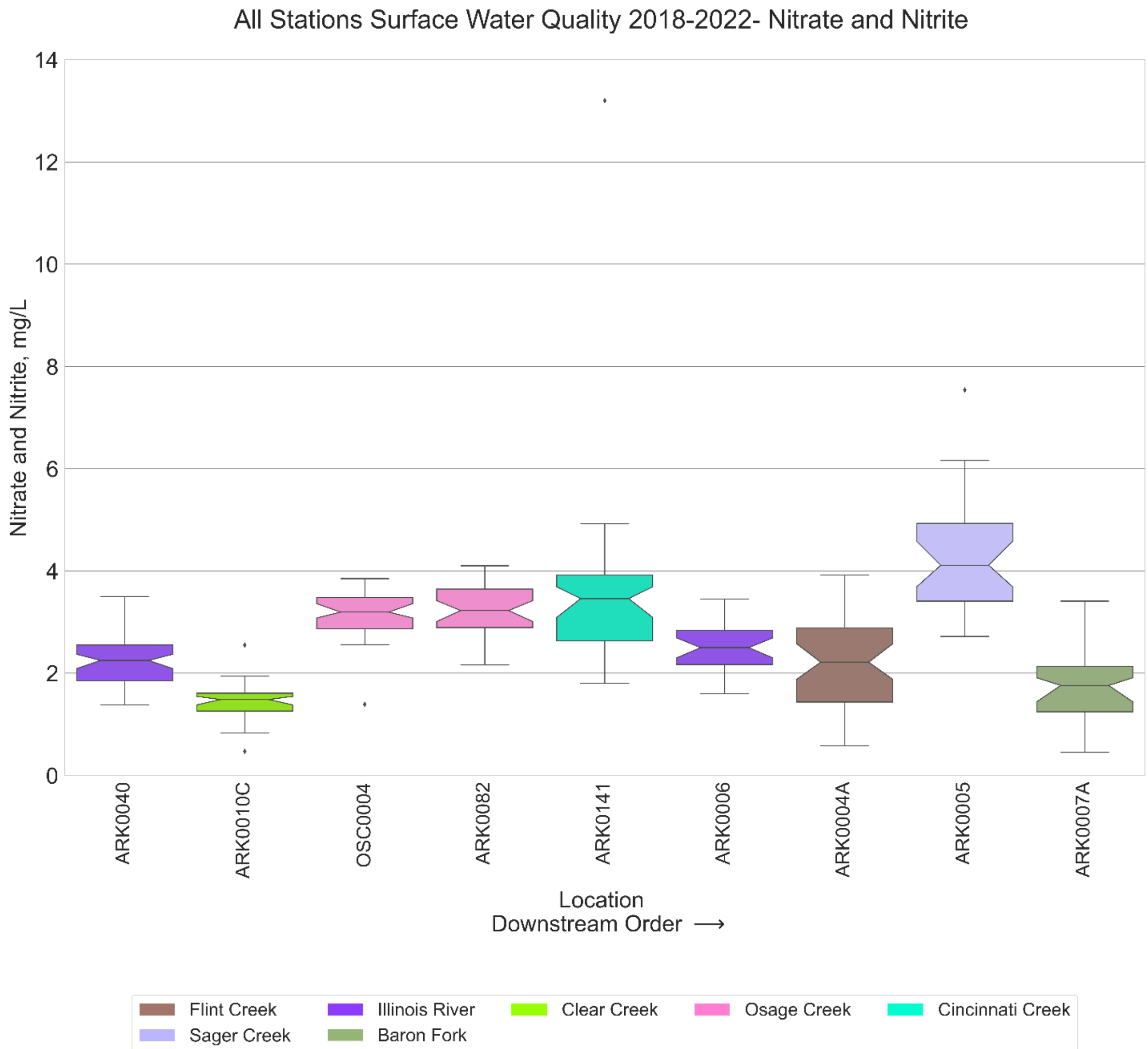

Figure 15: Box and whisker graph of nitrate + nitrite from stations with at least 10 measurements from 2018-2022.

Total Nitrogen

Total nitrogen (TN) is the sum of all forms of nitrogen (ammonia, nitrate, nitrite, organic nitrogen). Nitrogen is an essential nutrient for the support of aquatic plants and algae, which provide food and habitat for various aquatic organisms. However, elevated levels of nitrogen can cause eutrophication, characterized by excessive algal growth, and harmful algal blooms (HABs), which may produce toxins harmful to humans and animals. These blooms can also result in hypoxia, a condition of low dissolved oxygen, which can stress or kill aquatic life (EPA, 2021).

Table 17 lists the summary statistics for total nitrogen measured from 2018-2022. The highest maximum TN measurements are from AWRC stations on Osage Creek. Sager Creek has the highest median TN measured by USGS and DEQ on an ambient basis. Both of these Sager Creek stations (ARK0005, 07195865) report median TN values over 4.4 mg/L. AWRC-Mud station reports the lowest minimum TN value of 0.28 mg/L.

Table 17: Summary statistics for measurements from 2018-2022 for total nitrogen (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID#	Stream ID+	Number of measures*	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	KM Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
AWRC	Savoy[a]	IR	124	0.54	2.06	2.42	2.48	2.93	4.41
DEQ	ARK0040[a]	IR	47	1.73	2.20	2.52	2.58	2.94	3.75
USGS	07194800[a]	IR	20	1.80	2.40	2.60	2.65	2.98	3.50
DEQ	LARK015A	LF	12	0.84	1.21	1.25	1.25	1.30	1.59
AWRC	Mud[b]	MC	128	0.28	0.73	0.92	0.99	1.15	2.93
USGS	071948095[b]	MC	24	0.48	0.79	0.92	1.08	1.25	2.70
DEQ	ARK0010C	CC	47	1.02	1.50	1.66	1.65	1.83	2.14
AWRC	OC112[c]	OC	126	0.73	1.72	2.92	2.85	3.62	11.61
USGS	07194880[c]	OC	9	1.30	1.70	1.70	2.00	2.25	2.90
USGS	07194906	SC	4	1.40	1.48	1.58	1.66	1.76	2.10
AWRC	Spring[d]	SC	126	1.20	2.53	3.26	3.18	3.84	5.33
USGS	07194933[d]	SC	26	0.89	3.21	3.58	3.47	3.98	5.30
DEQ	OSC0004	OC	46	1.89	3.24	3.56	3.51	3.87	4.25
AWRC	Osage[e]	OC	123	1.24	2.56	3.69	3.60	4.11	20.89
USGS	07195000[e]	OC	20	2.10	3.63	3.85	3.99	4.40	6.00
DEQ	ARK0204	BC	3	2.99	3.01	3.03	3.02	3.04	3.05
DEQ	ARK0082	OC	49	2.46	3.09	3.37	3.45	3.72	4.90
DEQ	ARK0006B	IR	8	2.13	2.44	2.61	2.66	2.75	3.49
DEQ	ARK0141	CnC	45	1.99	2.80	3.71	3.58	4.09	5.45
AWRC	IR59[f]	IR	127	0.78	2.18	2.60	2.60	3.02	4.05
DEQ	ARK0006[f]	IR	40	1.91	2.42	2.75	2.76	3.10	4.14
USGS	07195430[f]	IR	20	1.90	2.58	2.80	2.79	3.03	3.80
AWRC	Watts[g]	IR	128	0.63	2.16	2.61	2.59	2.97	4.11
USGS	07195500[g]	IR	61	0.67	2.30	2.60	2.70	3.10	4.00
DEQ	ARK0004A[h]	FC	45	0.75	1.67	2.58	2.42	3.15	3.90
USGS	07195855[h]	FC	29	0.61	2.10	2.80	2.52	3.10	3.70
AWRC	Sager	SG	33	0.30	2.00	2.24	2.29	2.87	3.51
DEQ	ARK0005	SG	44	2.94	3.89	4.47	4.82	5.54	8.50
USGS	07195865	SG	30	1.10	3.98	4.60	4.89	5.65	10.00
DEQ	ARK0007A	BF	49	0.76	1.44	1.91	1.98	2.34	3.64
AWRC	Baron[i]	BF	124	0.36	1.34	1.78	1.82	2.26	4.32
USGS	07196900[i]	BF	20	0.30	1.44	1.85	1.84	2.18	4.20

Stations in this table with the same superscript letter are at the same location.
+ IR = Illinois River, LF = Lake Fayetteville, MC = Mud Creek, CC = Clear Creek, OC = Osage Creek, SCS = Spring at Cave Springs, SC = Spring Creek, BC = Brush Creek, LS = Logan Spring, CnC = Cincinnati Creek, FC = Flint Creek, SG = Sager Creek, BF = Baron Fork

Figure 16 shows the box and whiskers graphs of TN from stations with at least ten measurements from 2018-2022. Sager Creek downstream of the Oklahoma border has the highest median TN in the watershed. The median TN values at this location are statistically significantly higher than median TN values at the other graphed locations, including Sager Creek upstream of the Oklahoma border. Spring Creek, Osage Creek, and Cincinnati Creek stations have median TN over 3.0 mg/L, which are statistically significantly higher than median TN values for the Illinois River. The Illinois River mainstem maintains median TN between 2.0 and 3.0 mg/L even downstream of the confluence of Osage Creek and Cincinnati Creek. The stations on Mud Creek are the only stations with a median TN below 1.0 mg/L. These median values are statistically significantly lower than median TN values at the other graphed stations.

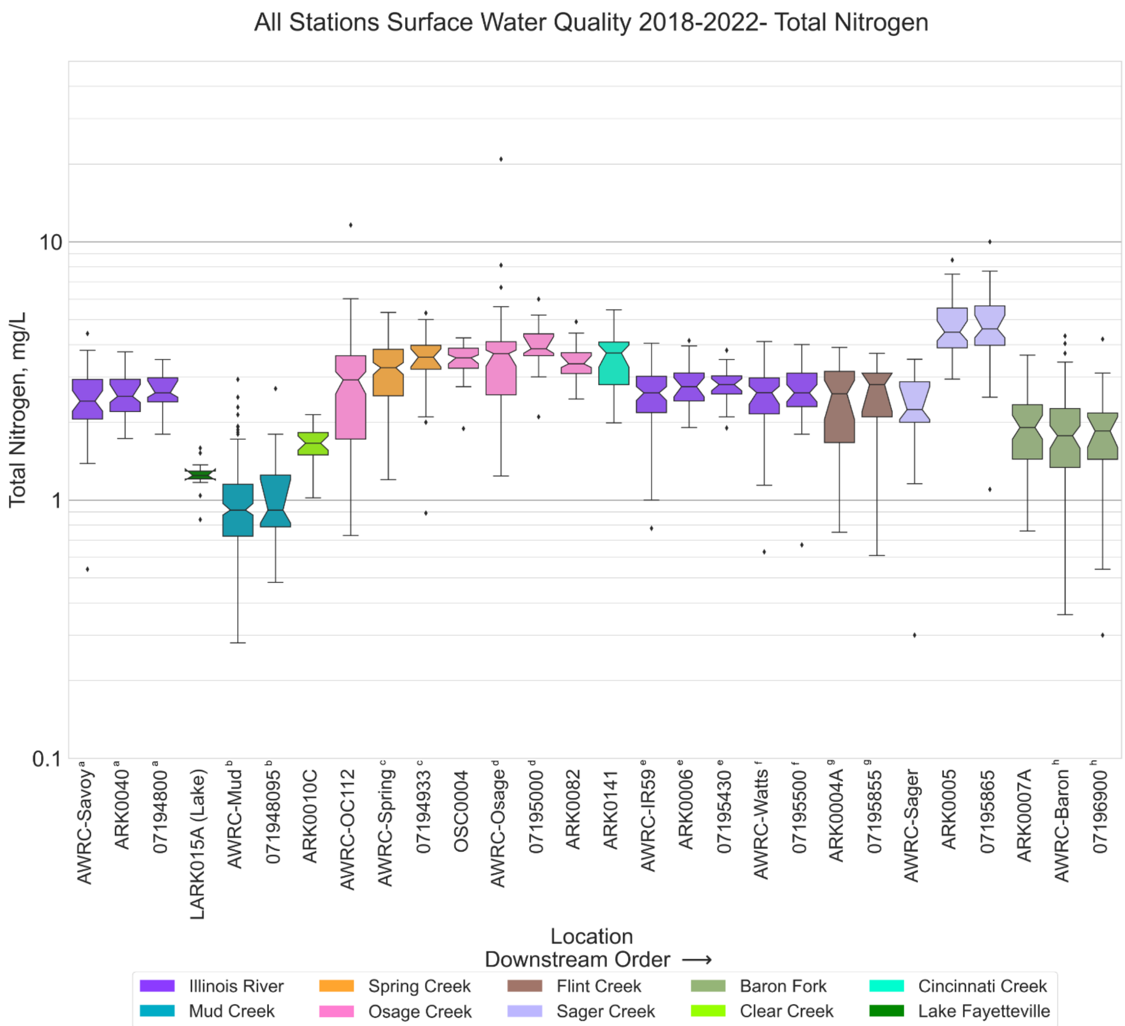

Figure 16: Box and whisker graph of total nitrogen from stations with at least 10 measurements from 2018-2022. Stations with the same superscript letter are at the same location.

Minerals

This section characterizes levels of chloride, sulfate, and total dissolved solids (TDS) in the Upper Illinois River watershed. Monitoring mineral levels is essential for ensuring water quality and safety for consumption, as well as the suitability of water for industrial and agricultural uses.

Stream specific minerals criteria have been set for the Illinois River in the watershed (Table 18). DEQ requires at least ten measurements over two years for site-specific mineral impairment assessment and uses a 25 percent exceedance rate. All other waterbodies will use the appropriate ecoregion numeric reference value. DEQ uses the same assessment methodology criteria for non-site specific mineral quality (DEQ, 2018). All the stations in the Upper Illinois River watershed are located in the Ozark Highlands ecoregion. EPA has proposed new ecoregion boundaries. If these are approved, the monitoring stations on the Baron Fork would change to the Boston Mountains ecoregion. There are significant differences in mineral water quality standards used in the Ozark Highlands and Boston Mountains ecoregions. Research found that TDS and sulfate were significantly greater in the Ozark Highlands than the Boston Mountains ecoregion (Scott & Haggard, 2021). Table 18 shows the numeric criteria for minerals in the watershed that were used for this analysis.

Table 18: Mineral standards for chloride, sulfate, and TDS for Upper Illinois River watershed from Rule 2.511 (APCEC, 2022).

Site Specification	Mineral Quality Values (mg/L)			Standard
	Chloride	Sulfate	TDS	
Illinois River	20	20	300	Not to exceed
Ozark Highlands	13	17	240	>1/3 higher or >15 mg/L, whichever is greater
Boston Mountains	13	9	85	>1/3 higher or >15 mg/L, whichever is greater
Any waterbody	250	250	500	Not to exceed

Chloride

Chloride is a major component of dissolved solids in water. Elevated concentrations of chloride in streams can be toxic to some aquatic life. Additionally, the presence of chloride increases the potential corrosivity of the water affecting water infrastructure. Table 19 below shows the summary statistics of chloride monitoring in the Upper Illinois River watershed 2018-2022.

Several stations had greater than 25 percent of chloride measurements above the Ozark Highlands ecoregion reference value raised by 1/3, 17.3 mg/L. The highest maximum chloride value was recorded at AWRC-Mud station, 64.31 mg/L. The median chloride value at AWRC-Mud is 10.34 mg/L, below the 13 mg/L reference value for Ozark Highlands. Spring Creek had the highest median chloride value, 29.75 mg/L (07195000), and Lake Fayetteville had the lowest median chloride value (with at least 10 measurements) at 5.19 mg/L.

The Illinois River has a site-specific criterion of 20 mg/L for chloride. All the stations on the Illinois River mainstem had less than 25 percent of their measurements exceed the 20 mg/L criterion. The rows highlighted in Table 19: Summary statistics for measurements from 2018-2022 for chloride (stations listed in downstream order, first row is farthest upstream station). (some are at the same location) are listed on the 2018 303(d) List (DEQ, 2019) for chloride but are not listed on the draft 2020 303(d) List (DEQ, 2023).

Table 19: Summary statistics for measurements from 2018-2022 for chloride (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID#	Stream ID+	Number of measures*	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	KM Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L	Criteria, mg/L	Number of Values > Criteria	Percentage of Values > Criteria
AWRC	Savoy[a]	IR	124	1.37	5.50	9.33	10.40	15.82	22.75	20	8	6%
DEQ	ARK0040[a]	IR	52	5.56	7.36	9.27	10.75	13.60	22.00	20	2	4%
USGS	07194800[a]	IR	20	3.28	8.70	11.35	12.47	16.13	21.00	20	2	10%
DEQ	LARK015A	LF	12	2.39	3.60	5.19	4.72	5.52	6.29	17.3	0	0%
AWRC	Mud[b]	MC	128	1.43	6.76	10.34	10.69	12.68	64.31	17.3	10	8%
USGS	071948095[b]	MC	24	1.97	8.82	10.30	10.06	12.93	19.00	17.3	1	4%
DEQ	ARK0010C	CC	51	3.59	7.99	8.76	8.81	9.62	18.70	17.3	1	2%
AWRC	OC112[c]	OC	126	2.32	10.94	19.47	21.17	32.37	52.70	17.3	75	60%
USGS	07194880[c]	OC	9	1.73	3.21	3.64	7.37	6.88	27.05	17.3	1	-*
DEQ	ARK0199	SCS	6	6.83	7.67	7.76	7.69	7.93	8.14	17.3	0	-*
USGS	07194906	SC	4	1.53	1.89	2.33	4.84	5.28	13.20	17.3	0	-*
AWRC	Spring[d]	SC	126	2.16	15.63	24.96	27.56	39.51	62.76	17.3	89	71%
USGS	07194933[d]	SC	26	1.71	19.73	29.75	28.46	39.40	55.10	17.3	20	77%
DEQ	OSC0004	OC	51	10.60	19.25	25.10	25.59	32.10	41.50	17.3	41	80%
AWRC	Osage[e]	OC	123	2.38	12.79	19.10	20.48	29.09	46.79	17.3	71	58%
USGS	07195000[e]	OC	20	10.30	17.80	26.40	23.61	28.48	36.00	17.3	16	80%
DEQ	ARK0204	BC	7	6.07	7.06	7.32	7.18	7.43	7.89	17.3	0	-*
DEQ	ARK0202	LS	7	5.03	6.07	7.47	6.89	7.73	8.11	17.3	0	-*
DEQ	ARK0082	OC	54	9.45	12.45	15.20	16.35	20.08	27.60	17.3	18	33%
DEQ	ARK0006B	IR	8	8.53	9.50	13.00	12.77	14.40	18.70	20	0	-*
DEQ	ARK0141	CnC	48	5.81	7.36	8.67	8.48	9.57	10.90	17.3	0	0%
AWRC	IR59[f]	IR	127	0.66	7.39	10.68	11.44	15.73	26.85	20	7	6%
DEQ	ARK0006[f]	IR	43	6.78	8.93	12.00	12.54	15.50	21.90	20	2	5%
USGS	07195430[f]	IR	20	5.21	10.83	12.95	13.38	16.48	19.10	20	0	0%
AWRC	Watts	IR	128	1.88	7.00	10.54	11.28	15.61	25.13	20	6	5%
DEQ	ARK0004A	FC	48	6.08	7.78	8.37	8.37	9.11	10.90	17.3	0	0%
AWRC	Sager	SG	33	1.51	7.81	10.00	9.52	12.20	18.45	17.3	1	3%
DEQ	ARK0005	SG	47	13.50	19.00	22.90	27.20	33.30	57.80	17.3	40	85%
DEQ	ARK0007A	BF	54	3.67	4.88	6.01	6.52	7.81	12.10	17.3	0	0%
AWRC	Baron[g]	BF	124	1.08	3.90	5.45	5.62	7.31	11.64	17.3	0	0%
USGS	07196900[g]	BF	20	4.53	5.13	6.41	6.56	7.93	9.15	17.3	0	0%

*DEQ requires at least 10 measurements over two years and uses a 25 percent exceedance rate for assessment.

Stations in this table with the same superscript letter are at the same location.

+ IR = Illinois River, LF = Lake Fayetteville, MC = Mud Creek, CC = Clear Creek, OC = Osage Creek, SCS = Spring at Cave Springs, SC = Spring Creek, BC = Brush Creek, LS = Logan Spring, CnC = Cincinnati Creek, FC = Flint Creek, SG = Sager Creek, BF = Baron Fork

Indicates stations are located on assessment units classified as impaired due to high chloride on the approved 2018 303(d) List. These assessment units have been proposed as delisted on the draft 2020 303(d) List.

Figure 17 shows the box and whisker graph of chloride from stations with at least ten measurements over two years. Median chloride concentrations Spring Creek stations, all but one Osage Creek station , and the DEQ station on Sager Creek downstream of the Oklahoma border are statistically significantly higher than median chloride values for the other tributaries and the Illinois River. The Spring Creek and upper Osage Creek stations are located near highly urbanized areas in the watershed.

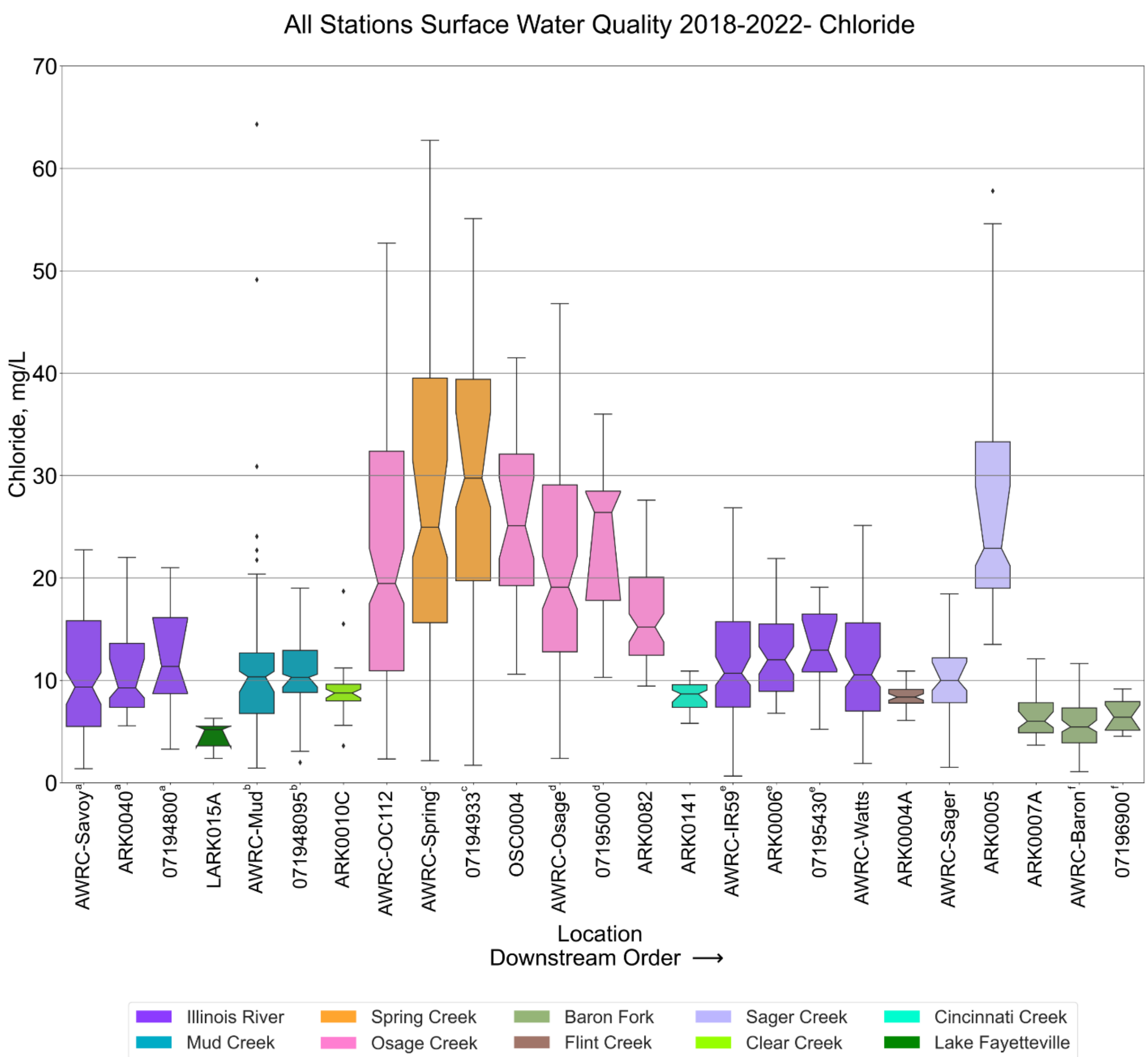

Figure 17: Box and whisker graph of chloride from stations with at least 10 measurements from 2018-2022. Stations with the same superscript letter are at the same location.

Sulfate

Sulfate is the most common form of sulfur, an essential plant nutrient, in well-oxygenated natural waters. However, at very high concentrations sulfates can be toxic to cattle and affect water pH and solubility of metals and other substances (Arizona, 2007). Sulfates can originate from various natural sources, such as mineral weathering and biological processes, as well as from anthropogenic sources, such as agricultural and urban runoff.

Table 20 below shows the summary statistics of sulfate monitoring the Upper Illinois River watershed from 2018-2022. The highlighted stations are located on stream reaches listed as impaired due to high sulfate concentrations on the 2018 303(d) List and the draft 2020 and 2022 303(d) Lists (DEQ, 2019; DEQ, 2022; DEQ, 2023). All the Illinois River stations with at least ten samples have over 25 percent of the measurements exceeding the 20 mg/L criterion. AWRC-Savoy reported 42 percent of samples were in exceedance, though the median concentration is 19.18 mg/L for this station.

AWRC-Spring on Spring Creek reported 82 percent of sulfate measurements were in greater than of 1/3 higher than the Ozark Highlands ecoregion criterion; 22.7 mg/L. AWRC-Spring had the highest maximum sulfate concentration at 97.47 mg/L and the highest median concentration of 59.81 mg/L. Osage Creek downstream of Spring Creek confluence also reports high sulfate concentrations, with 80 percent of samples greater than 22.7 mg/L at OSC0004 station. Clear Creek, Cincinnati Creek, and Flint Creek reported no samples in exceedance of the Ozark Highlands ecoregion reference criterion.

Table 20: Summary statistics for sulfate measurements from 2018-2022 (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID[#]	Stream ID[+]	Number of measures*	Minimum Value, mg/L	25^{th} Percentile, mg/L	Median, mg/L	KM Mean, mg/L	75^{th} Percentile, mg/L	Maximum Value, mg/L	Criteria, mg/L	Number of Values > Criteria	Percentage of Values > Criteria
AWRC	Savoy[a]	IR	33	6.17	16.31	19.18	18.55	21.82	25.68	20	14	42%
DEQ	ARK0040[a]	IR	52	12.30	15.28	17.45	17.75	20.70	26.60	20	15	29%
USGS	07194800[a]	IR	20	6.59	16.35	18.20	18.08	21.00	23.90	20	7	35%
DEQ	LARK015A	LF	12	4.34	4.82	5.24	5.96	6.99	8.92	22.7	0	0%
AWRC	Mud[b]	MC	34	5.79	18.46	28.48	28.14	32.64	109.60	22.7	24	71%
USGS	071948095[b]	MC	24	5.53	18.10	25.00	22.91	29.13	34.10	22.7	16	67%
DEQ	ARK0010C	CC	49	8.46	10.90	12.80	13.45	16.10	19.60	22.7	0	0%
AWRC	OC112[c]	OC	33	3.27	16.25	25.01	24.01	34.62	46.78	22.7	17	52%
USGS	07194880[c]	OC	9	2.31	2.89	3.50	5.25	6.59	14.40	22.7	0	-*
USGS	07194906	SC	4	2.28	3.46	3.88	5.78	6.19	13.10	22.7	0	-*
AWRC	Spring[d]	SC	33	5.12	40.86	59.81	53.13	71.56	97.47	22.7	27	82%
USGS	07194933[d]	SC	26	2.80	29.28	44.60	43.41	60.18	84.40	22.7	20	77%
DEQ	OSC0004	OC	50	16.30	24.43	33.35	35.33	44.58	72.10	22.7	40	80%
AWRC	Osage[e]	OC	33	4.00	23.52	31.93	30.35	38.44	57.56	22.7	25	76%
USGS	07195000[e]	OC	20	13.50	20.83	29.60	28.29	33.75	44.70	22.7	14	70%
DEQ	ARK0204	BC	7	3.79	4.14	4.18	4.34	4.61	4.92	22.7	0	-*
DEQ	ARK0082	OC	54	11.10	14.63	18.90	19.89	23.38	39.40	22.7	16	30%
DEQ	ARK0006B	IR	8	11.20	11.58	16.15	15.51	17.70	21.90	20	1	-*
DEQ	ARK0141	CnC	48	5.96	6.99	8.80	8.90	10.65	12.70	22.7	0	0%
AWRC	IR59[f]	IR	36	7.21	13.69	18.16	17.69	22.26	36.82	20	14	39%
DEQ	ARK0006[f]	IR	43	9.38	12.85	15.30	16.29	19.55	28.90	20	11	26%
USGS	07195430[f]	IR	20	7.55	12.58	15.40	15.74	18.28	23.10	20	4	20%
AWRC	Watts	IR	36	5.08	13.11	17.87	17.17	20.86	35.52	20	12	33%
DEQ	ARK0004A	FC	48	6.70	8.97	10.10	10.46	11.55	16.20	22.7	0	0%
AWRC	Sager	SG	33	2.23	8.55	9.68	9.72	11.72	21.50	22.7	0	0%
DEQ	ARK0005	SG	47	12.10	17.65	20.40	22.40	23.95	44.00	22.7	16	34%
DEQ	ARK0007A	BF	54	13.40	15.90	16.90	19.02	21.53	32.90	22.7	11	20%
AWRC	Baron[g]	BF	33	6.34	15.03	16.29	17.84	21.89	32.68	22.7	8	24%
USGS	07196900[g]	BF	20	12.80	15.10	17.05	18.55	20.38	34.30	22.7	5	25%

*DEQ requires at least 10 measurements over two years and uses a 25 percent exceedance rate for assessment.
Stations in this table with the same superscript letter are at the same location.
+ IR = Illinois River, LF = Lake Fayetteville, MC = Mud Creek, CC = Clear Creek, OC = Osage Creek, SCS = Spring at Cave Springs, SC = Spring Creek, BC = Brush Creek, LS = Logan Spring, CnC = Cincinnati Creek, FC = Flint Creek, SG = Sager Creek, BF = Baron Fork

Indicates stations are located on assessment units classified as impaired due to high sulfate on the approved 2018 303(d) List and proposed as impaired on the draft 2020 303(d) List and the draft 2022 303(d) List.

Figure 18 shows the box and whisker graph of sulfate data from stations with at least ten measurements over two (2) years. Median sulfate concentrations in Osage Creek increase downstream of the Spring Creek confluence but decrease to below 20 mg/L at the farthest downstream station. Both Spring Creek and Osage Creek originate in the highly urbanized portion of the watershed. Mud Creek and Sager Creek also have median concentrations above the 17 mg/L reference value for the Ozark Highlands ecoregion. The median sulfate concentration for Sager Creek downstream of the Oklahoma border is statistically significantly higher than the median sulfate concentration for Sager Creek upstream of the border.

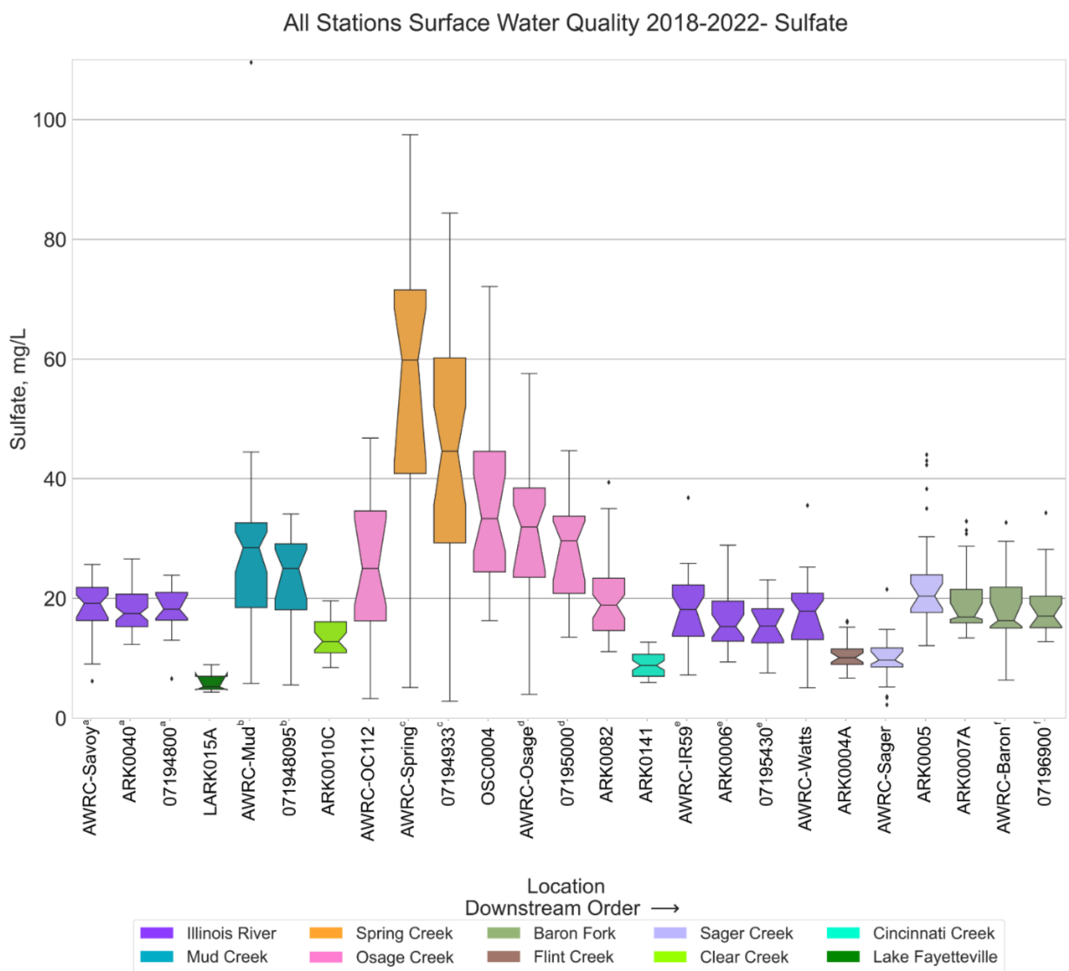

Figure 18: Box and whisker graph of sulfate concentrations from stations with at least 10 measurements from 2018-2022. Stations with the same superscript letter are at the same location.

Total Dissolved Solids

TDS is a measure of the organic and inorganic compounds dissolved in water. Common compounds dissolved in water include calcium, magnesium, chloride, nitrate, bicarbonate and sulfate (USGS, 2019). The concentration of TDS affects the water balance in the cells of aquatic organisms. High levels of TDS can affect water taste, and very high TDS levels can be detrimental to health. EPA recommends a maximum contaminant level (MCL) of 500 mg/L for TDS as a secondary drinking water standard. No stations in the Upper Illinois River watershed are on the approved or draft 303(d) lists for TDS impairment.

Spring Creek reported the highest TDS concentration and 69 percent of measurements at USGS station 07194933 are greater than the 240 mg/L Ozark Highlands reference stream value. This is to be expected since Spring Creek reported high chloride and sulfate concentrations, which contribute to TDS. Several TDS measurements from Osage Creek, Mud Creek, and Sager Creek from 2018-2022 also exceed 240 mg/L but have median concentrations below the 240 mg/L reference stream value.

Table 21: Summary statistics for TDS measurements from 2018-2022 (stations listed in downstream order, first row is farthest upstream station).

Organization	Station ID#	Stream ID+	Number of measures*	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	KM Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L	Criteria, mg/L	Number of Values > Criteria	Percentage of Values > Criteria
DEQ	ARK0040[a]	IR	52	140	155	175	178	198	222	300	0	0%
USGS	07194800[a]	IR	20	64	169	185	182	205	223	300	0	0%
DEQ	LARK015A	LF	12	84	109	117	117	126	144	240	0	0%
USGS	071948095	MC	24	85	151	206	183	219	246	240	3	13%
DEQ	ARK0010C	CC	51	93	185	193	190	200	218	240	0	0%
USGS	07194880	OC	9	54	69	100	99	131	156	240	0	-*
USGS	07194906	SC	4	46	54	60	77	83	144	240	0	-*
USGS	07194933	SC	26	68	239	269	258	321	385	240	18	69%
DEQ	OSC0004	OC	51	137	229	254	257	291	330	240	31	61%
USGS	07195000	OC	20	165	218	249	241	260	298	240	11	55%
DEQ	ARK0204	BC	7	173	183	187	189	197	203	240	0	-*
DEQ	ARK0082	OC	54	163	189	202	206	223	266	240	6	11%
DEQ	ARK0006B	IR	8	156	171	187	186	201	216	300	0	-*
DEQ	ARK0141	CnC	48	158	178	188	186	193	212	240	0	0%
DEQ	ARK0006[b]	IR	43	154	169	182	185	198	236	300	0	0%
USGS	07195430[b]	IR	20	118	171	187	184	205	223	300	0	0%
DEQ	ARK0004A	FC	48	130	144	149	149	154	168	240	0	0%
DEQ	ARK0005	SG	47	158	201	228	232	255	326	240	17	36%
DEQ	ARK0007A	BF	54	138	165	182	179	190	216	240	0	0%
USGS	07196900	BF	20	141	168	179	179	188	208	240	0	0%

*DEQ requires at least 10 measurements over two years and uses a 25 percent exceedance rate for assessment.
Stations in this table with the same superscript letter are at the same location.
+ IR = Illinois River, LF = Lake Fayetteville, MC = Mud Creek, CC = Clear Creek, OC = Osage Creek, SCS = Spring at Cave Springs, SC = Spring Creek, BC = Brush Creek, LS = Logan Spring, CnC = Cincinnati Creek, FC = Flint Creek, SG = Sager Creek, BF = Baron Fork

Figure 19 shows the box and whisker graphs of TDS concentrations in the Upper Illinois River watershed from 2018-2022. Spring Creek station 07194933 has the highest maximum and median TDS concentration. The median TDS concentration at the Spring Creek station is statistically significantly higher than median concentrations at the rest of the graphed stations, except for two (2) Osage Creek stations. Median TDS concentrations at Osage Creek stations downstream of the confluence with Spring Creek are also higher than median values for the other graphed stations but decreases to 202 mg/L median TDS at ARK0082 near the confluence with the Illinois River mainstem. Sager Creek reports most of its measurements between 200-250 mg/L, and the median TDS concentration is statistically significantly higher than the Illinois River median TDS concentrations, though less than the TDS reference stream value.

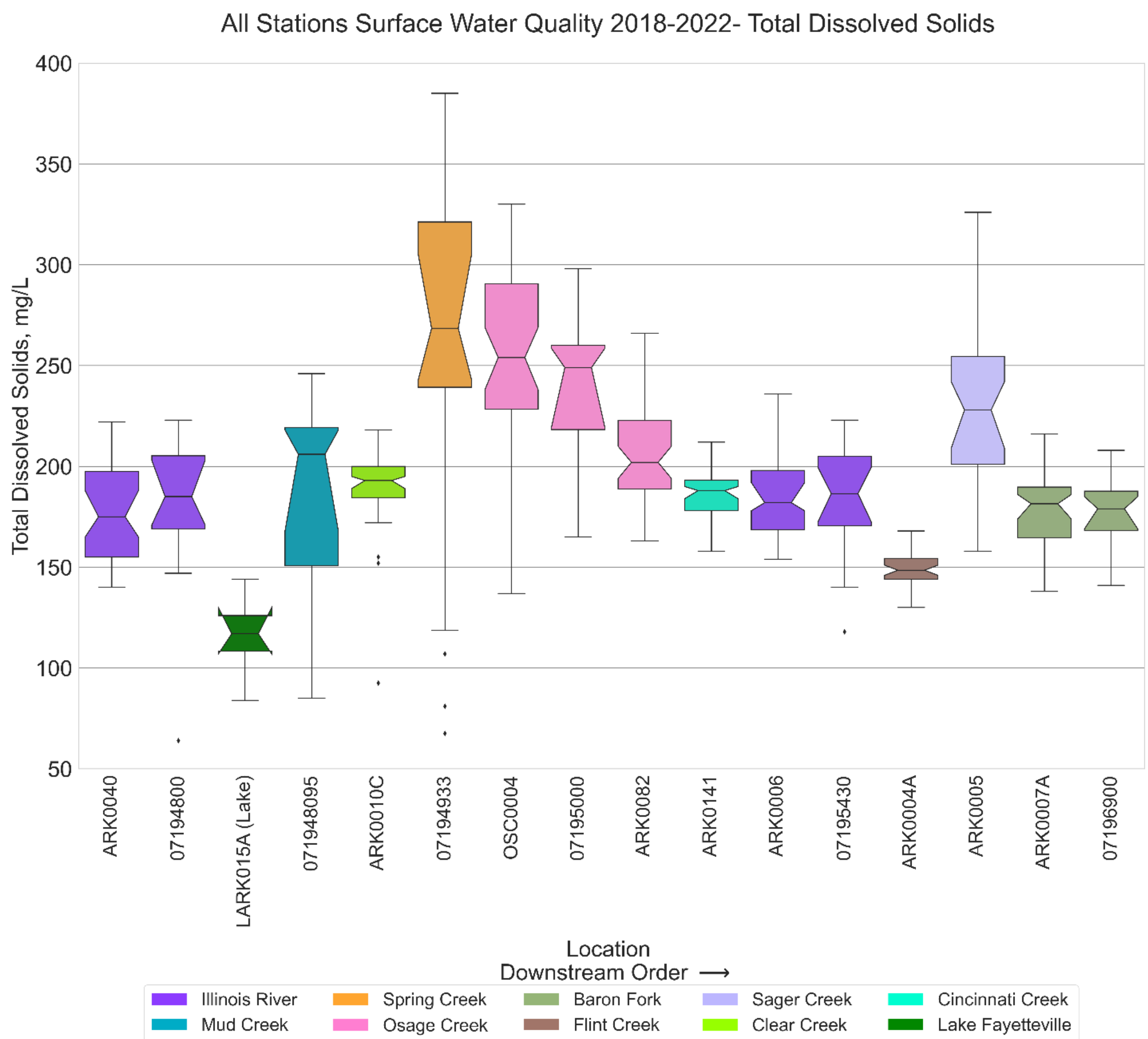

Figure 19: Box and whisker graph of TDS concentrations from stations with at least 10 measurements from 2018-2022. Illinois River stations ARK0040 and 07194800 are at the same location as well as ARK0006 and 07195430.

Data Gaps

Additional monitoring on listed impaired segments within the watershed is recommended to analyze trends in several constituents.

- Bacteria data is needed to assess current conditions and trends in the watershed. DEQ has six stream assessment units (AU) listed as impaired for *E. coli* on the approved 2018 303(d) list (DEQ, 2019); however, no *E. coli* measurements have been collected from these AUs. Only USGS reported *E. coli* from 2018-2022. The reported stations in this assessment are not on impaired stream segments.
- Brush Creek is listed as impaired for DO, but the Brush Creek station has not been sampled since 2018.
- There are four (4) AUs listed as impaired for sulfates in the watershed, but only the mainstem Illinois AUs had monitoring data for sulfate from 2018-2022. The other two (2) AUs (Moores Creek and Muddy Fork) do not appear to have been sampled since the 1990s.
- Additional monitoring on the mainstem of the Illinois River, especially upstream of the Savoy location and just downstream of the Osage Creek confluence would be beneficial for assessing conditions in the watershed.

Summary

Measurements of selected parameters of concern were collected during the period 2018-2022 by DEQ, AWRC, and USGS in the Upper Illinois River Watershed. There are 35 water quality monitoring stations in the watershed at 24 locations (Figure 1).

Bacteria, pH, and Alkalinity

Bacteria data (*E. coli)* was only collected at eight (8) stations by USGS during 2018-2022. None of the USGS stations were on AUs listed as impaired for bacteria. Upper Illinois River watershed has six (6) AUs listed as impaired on the 2018 303(d) List and five AUs listed on the draft 2020 303(d) List (DEQ, 2019; DEQ, 2022). Clear Creek has been proposed as delisted for bacteria on the 2020 303(d) list (DEQ, 2022).

Lake Fayetteville is listed as impaired for pH on the 2018 and draft 303(d) lists. DEQ took twelve samples for pH from 2020-2022, and none were outside of the acceptable range. However, Lake Fayetteville had the lowest alkalinity in the watershed, with a median alkalinity of 76.75 mg/L as CaCO3. In Arkansas, alkalinity in surface water is typically greater than 100 mg/L as CaCO3.

Sediment

DEQ sampled water quality monthly, USGS sampled quarterly, and AWRC sampled more often to better characterize water quality and loads under a variety of hydrologic conditions**.** Therefore, AWRC stations generally report higher turbidity compared to DEQ or USGS stations. For storm turbidity, Cincinnati Creek had the lowest median turbidity and stations on the Illinois River mainstem like Savoy and Watts frequently exceed criteria with significant percentages (31 percent and 34 percent, respectively). For base flow turbidity, levels are generally lower. However, several stations exceed the criterion, with significant exceedance at Watts (51 percent).

For TSS and SSC, higher flow events show much higher TSS levels, with significant variations across stations. SSC is highest at the station at Watts on the Illinois River, indicating high sediment loads.

Temperature

No streams are listed as impaired for temperature in the Upper Illinois River watershed. From 2018 to 2022, temperature measurements from only four stations occasionally exceeded their temperature criteria. Summary statistics reveal that Lake Fayetteville has the highest median temperature, which is consistent with expectations.

Dissolved Oxygen

During the Primary Season, most stations met the DO criteria, with very few measurements falling below the six (6) mg/L standard. The Brush Creek station had two (2) out of nine (9) measurements below six (6) mg/L and should continue to be monitored. Most stations met the DO criterion of five (5) mg/L for Critical Season DO. Baron Fork is classified as impaired due to low DO in the Draft 2020 and 2022 303(d) lists but no DO measurements from 2018-2022 were below the five (5) mg/L criterion.

For percent DO saturation, median values were around 100 percent in many locations, with some variability. Baron Fork had the widest range of values (59 percent-132 precent). BOD measures the amount of oxygen required to decompose organic matter in a water sample. At the Sager Creek station (only station with data), half the BOD measurements were below 0.2 mg/L, indicating low organic pollution. The highest BOD recorded was 2.32 mg/L.

Phosphorus

Although Arkansas does not have numeric water quality standards for total phosphorus (TP), Oklahoma applies a standard of 0.037 mg/L to several streams in the Upper Illinois River watershed that cross the state boundary. Many Upper Illinois River stations reported over 50 percent of TP values above 0.037 mg/L, indicating high phosphorus concentrations. Notable findings include:

- Stations consistently exceeding the 0.037 mg/L standard: Most stations, particularly in the Illinois River, Flint Creek, and Sager Creek, recorded phosphorus levels above the standard for a significant percentage of measurements.
- Stations with values below the standard: A few stations, those on Mud Creek and Clear Creek, had median and geometric means below the 0.037 mg/L though maximum values were greater than 0.037 mg/L.
- Median TP concentrations in Spring Creek and Sager Creek downstream of the Oklahoma border are statistically significantly higher than the median TP concentrations for the other graphed stations.
- Median TP concentrations in the Illinois River do not change significantly between Savoy and Watts.

Nitrogen

In Arkansas, water quality standards address ammonia nitrogen (based on temperature and pH) and nitrate nitrogen (10 mg/L limit for drinking water). No specific standards exist for total nitrogen (TN), but its levels are monitored due to concerns related to nutrient pollution.

Ammonia levels are generally low, though Sager Creek exhibited occasional higher concentrations. Nitrate and nitrite levels are mostly below the 10 mg/L threshold, with Cincinnati Creek recording the highest value at 13.2 mg/L. The highest median nitrate and nitrite concentration was in Sager Creek. Total nitrogen, encompassing all nitrogen forms, shows Sager Creek downstream of the Oklahoma border with the highest median levels and Mud Creek with the lowest. These median values are statistically significantly different from median values for the other stations graphed. Median TN levels in the Illinois River are similar at all the monitoring locations, medians do not change significantly from Savoy to Watts. Effective monitoring and management are essential to mitigate nutrient pollution and its effects on water quality in the watershed.

Minerals

Mineral levels in the Upper Illinois River watershed focuses on chloride, sulfate, and total dissolved solids (TDS), which are crucial for assessing water quality and its suitability for various uses.

- Chloride: Data from 2018-2022 indicate that while some stations, particularly Spring Creek, Osage Creek, and Sager Creek downstream of the Oklahoma border, show elevated chloride levels, most measurements in the Illinois River mainstem remain below the 20 mg/L criterion. Median chloride concentrations for all stations on the Illinois River are similar, with no significant difference between medians at Savoy and at Watts.

- Sulfate: The data from most stations exhibit sulfate levels above criterion and reference stream levels. Spring Creek has the highest median sulfate values, with median values at Osage Creek stations downstream of Spring Creek confluence, and at Mud Creek also being statistically significantly higher than median values at the other graphed stations. Several stations are on AUs classified as impaired due to high sulfate levels on the approved 2018 and draft 2020 and 2022 303(d) lists.
- TDS: Spring Creek exhibits the highest median TDS concentration and percentage of values above the reference stream value, although no stations are listed for TDS impairment on the approved or draft 303(d) lists. The Spring Creek median TDS value is statistically significantly higher than median values for the other graphed stations.

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APPENDIX F
EVALUATION OF WATER QUALITY CHANGE SINCE 2012 WATERSHED MANAGEMENT PLAN

In the 2012 Upper Illinois River Watershed-based Plan, water quality summary statistics for 1997-2011 were presented for seven (7) DEQ water quality monitoring locations. Statistics were presented for dissolved oxygen (DO), turbidity, total suspended solids (TSS), total dissolved solids (TDS), nitrate + nitrite, ammonia, total phosphorus, total nitrogen, chloride, sulfate, calcium, magnesium, and alkalinity. These same seven locations were also sampled for these parameters during 2017-2021 (Table 1). To get an idea of whether water quality has changed since 2012, we compared median values for current water quality measurements (2017-2021) to median values for the water quality information presented in the 2012 Upper Illinois River watershed management plan using box and whisker graphs (see Appendix E for an explanation of box and whisker graphs). A summary of the findings is provided in Table 2. Only two parameters exhibited an increase in concentration and at only one location each; sulfate increased at ARK0040 on the Illinois River at Savoy (stream reach listed as impaired due to sulfate), and total suspended solids (TSS) increased at ARK0005 on Sager Creek at Beaver Springs Road in Oklahoma (stream reach listed as impaired due to turbidity in Oklahoma). All parameters but DO exhibit a decrease in concentrations at a minimum of two locations. No change was apparent in DO concentrations between the two data periods.

Table 1. Comparison of water quality stations reported in 2012 Upper Illinois River watershed-based plan and stations sampled 2017-2021. X means the station ID did not change from 2012 plan.

Location reported in 2012 plan	Station ID	Sampled 2017-2021
IR at Savoy	ARK0040	X
Clear Creek	ARK0010C	X
Osage Creek at Elm Springs	ARK0041 (07195000)	Osage, 07195000
IR near Siloam Springs	ARK0006	X
Flint Creek	ARK0004A	X
Sager Creek	ARK0005	X
Baron Fork	ARK0007A	X

Table 2. Summary of comparison of concentrations of selected parameters 1997-2011 and 2017-2021.

Site	Chloride	DO	Nitrite + Nitrate as N	Sulfate	Total Phosphorus	Total Nitrogen	Total Suspended Solids
ARK0040	no change	no change	no change	increase	decrease	no change	no change
ARK0010C	decrease	no change	decrease	decrease	decrease	decrease	decrease
USGS07195000	no change	no change	no change	no change	decrease	no change	decrease
ARK0006	decrease	no change	no change	no change	no change	no change	no change
ARK0004A	decrease	no change	no change	decrease	no change	no change	decrease
ARK0005	decrease	no change	decrease	no change	decrease	decrease	increase
ARK0007A	decrease	no change	no change	no change	decrease	no change	no change

Below, we present box and whisker graphs comparing the median water quality statistics for selected parameters of interest from these two (2) time periods. For those locations where DEQ sampled during both time periods, only the DEQ data are compared. Since DEQ did not collect samples from the Osage Creek at Elm Springs station (ARK0041) during 2017-2021, only USGS data were used for comparisons at this location.

Figure 1 shows a box and whisker graph comparing measured turbidity from 1997-2011 and 2017-2021. There is no statistically significant difference in median turbidity levels at the Illinois River stations (IR at Savoy and IR near Siloam Springs). However, at the other monitoring locations, the median turbidity levels for 2017-2021 are statistically significantly lower compared to those from1997-2011.

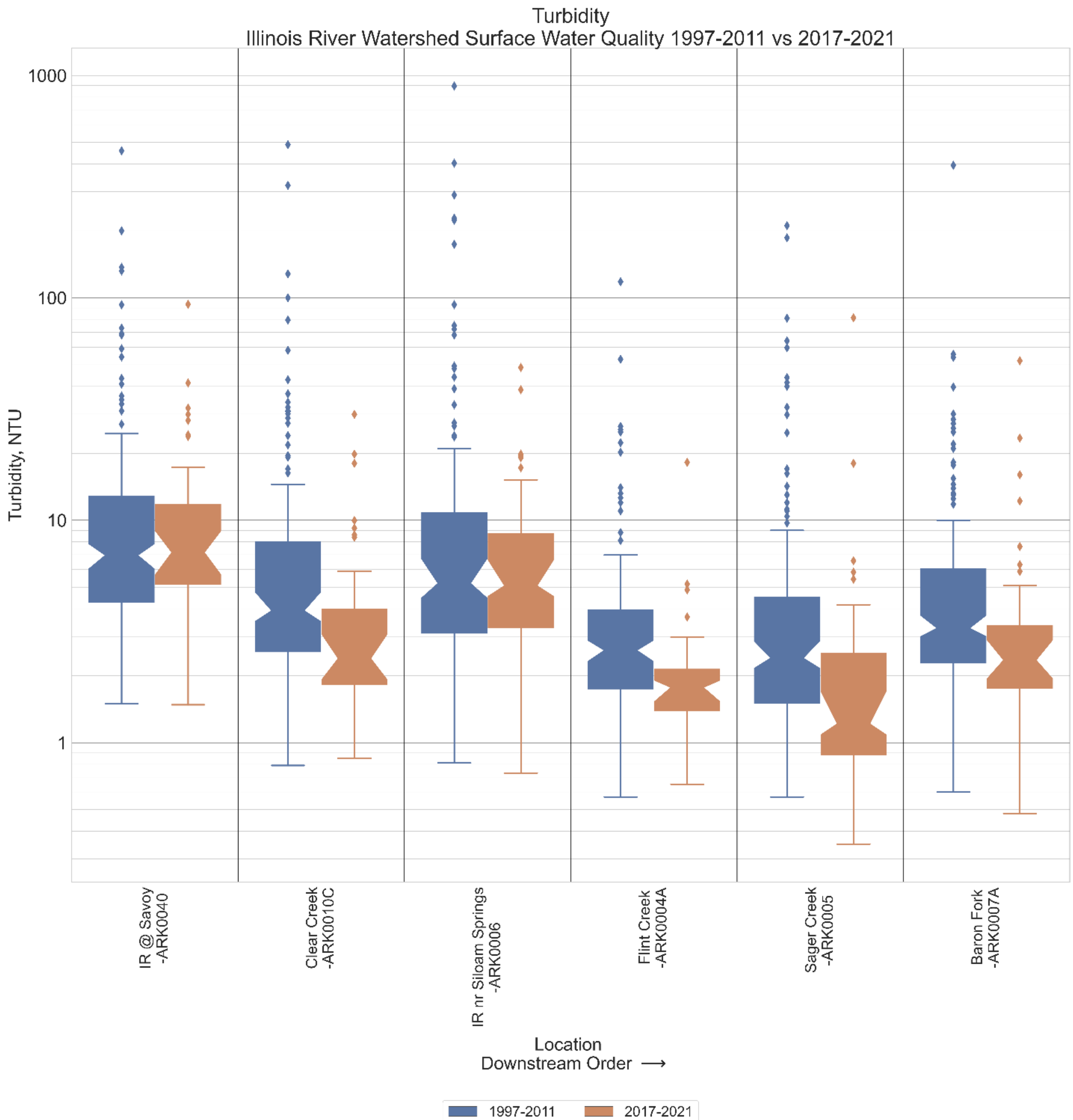

Figure 1: Comparison of turbidity levels 1997-2011 and 2017-2021.

Figure 2 shows a box and whisker plot comparing TSS concentrations from 1997-2011 to those from 2017-2021. There is no statistically significant difference in median TSS concentrations at the Illinois River stations (IR at Savoy and IR near Siloam Springs), the Sager Creek, or the Baron Fork stations. At the Clear Creek, Osage Creek, and Flint Creek monitoring locations, the median TSS concentrations for 2017-2021 are statistically significantly lower than the median for 1997-2011.

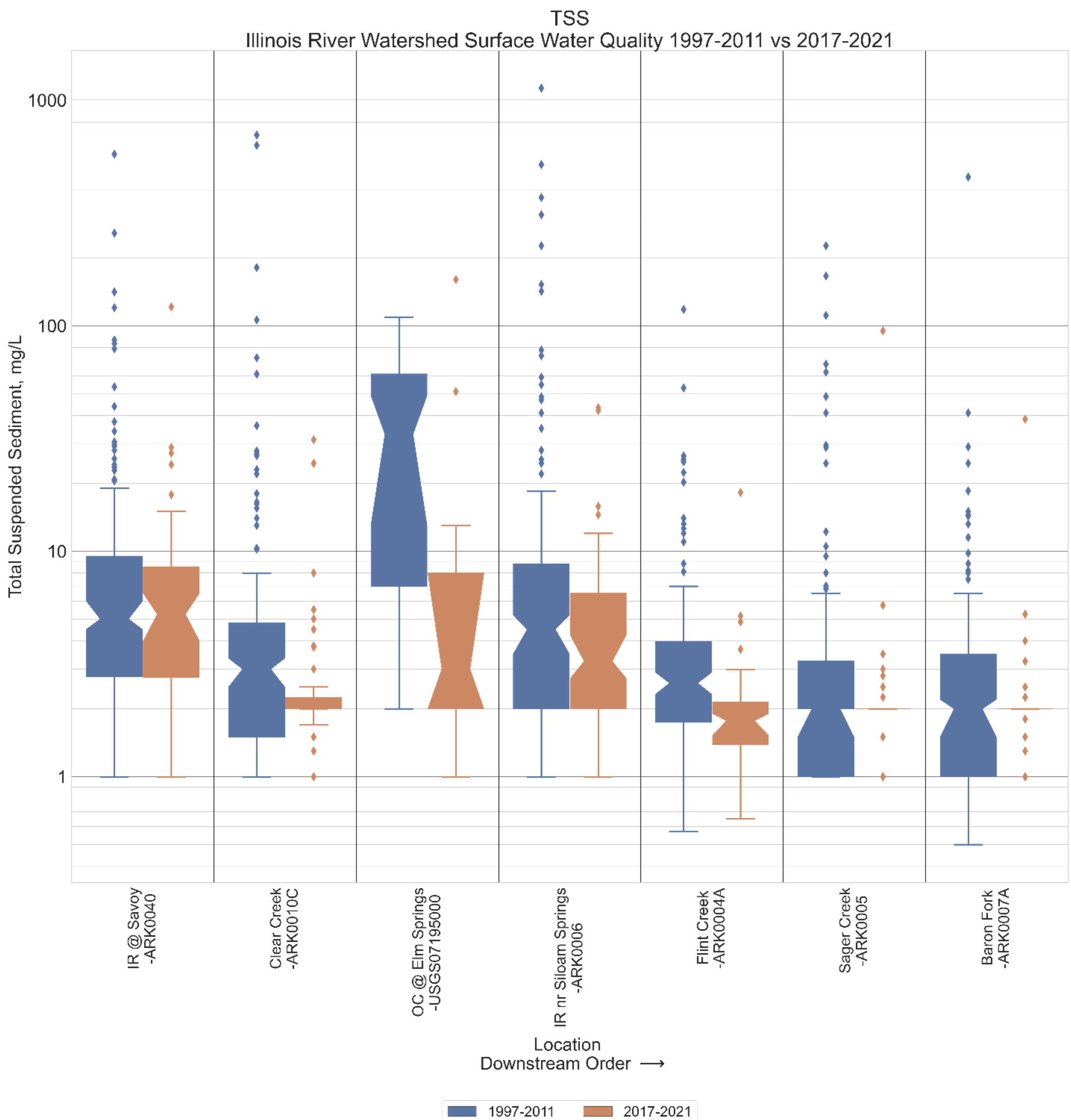

Figure 2:Comparison of TSS concentrations 1997-2011 and 2017-2021.

Figure 3 shows a box and whisker plot comparing total nitrogen concentrations from 1997-2011 to those from 2017-2021. At the Clear Creek and Sager Creek monitoring locations, the median total nitrogen concentration for 2017-2021 is statistically significantly lower than the median for

1997-2011.There is no statistically significant difference in median total nitrogen concentrations at the remaining monitoring locations.

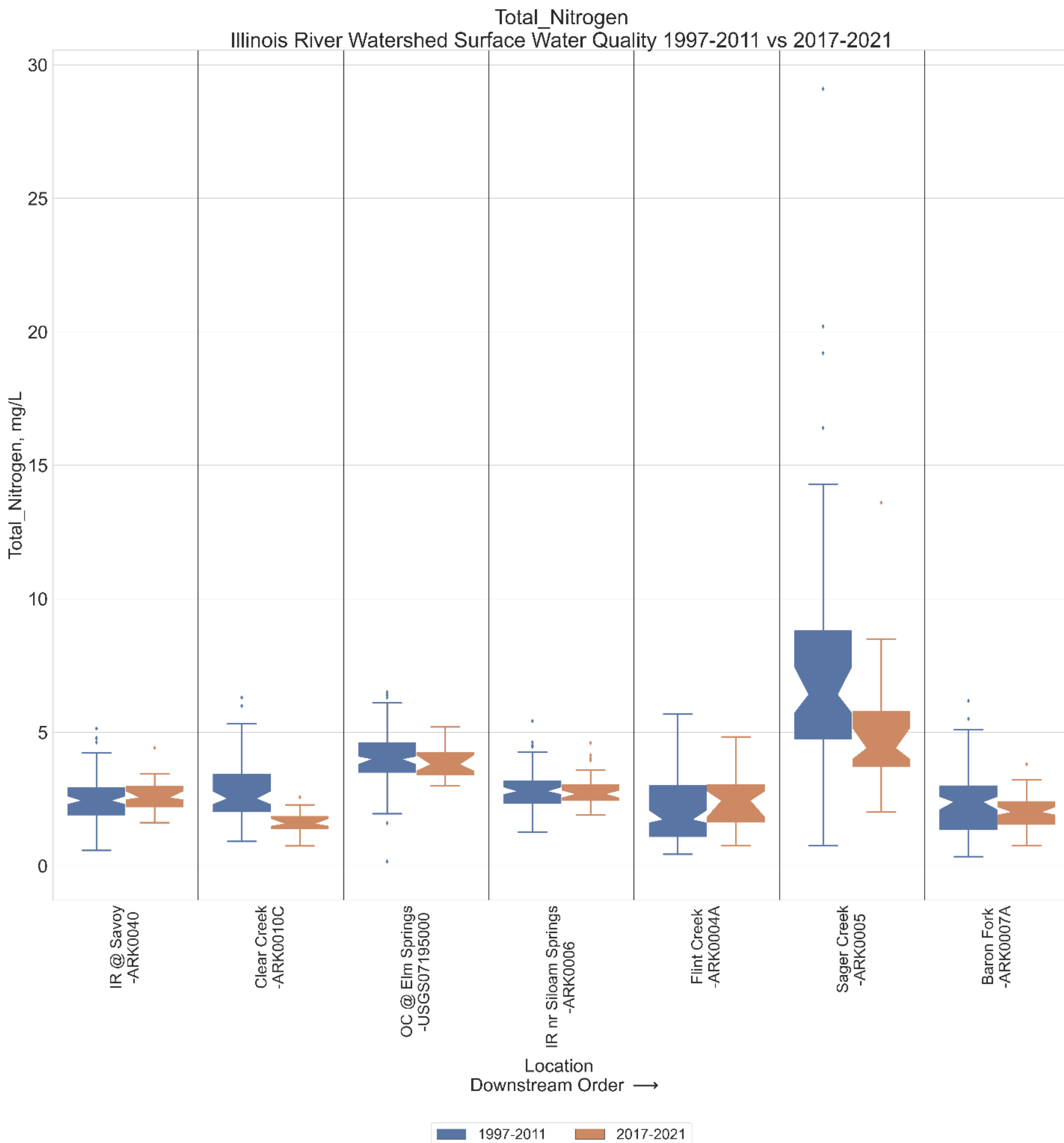

Figure 3: Comparison of total nitrogen concentrations 1997-2011 and 2017-2021.

Figure 4 shows a box and whisker plot comparing nitrate+nitrite nitrogen concentrations from 1997-2011 to those from 2017-2021. At the Clear Creek and Sager Creek monitoring locations, the median nitrate+nitrite nitrogen concentration for 2017-2021 is statistically significantly lower than the median for 1997-2011.There is no statistically significant difference in median nitrate+nitrite nitrogen concentrations at the remaining monitoring locations.

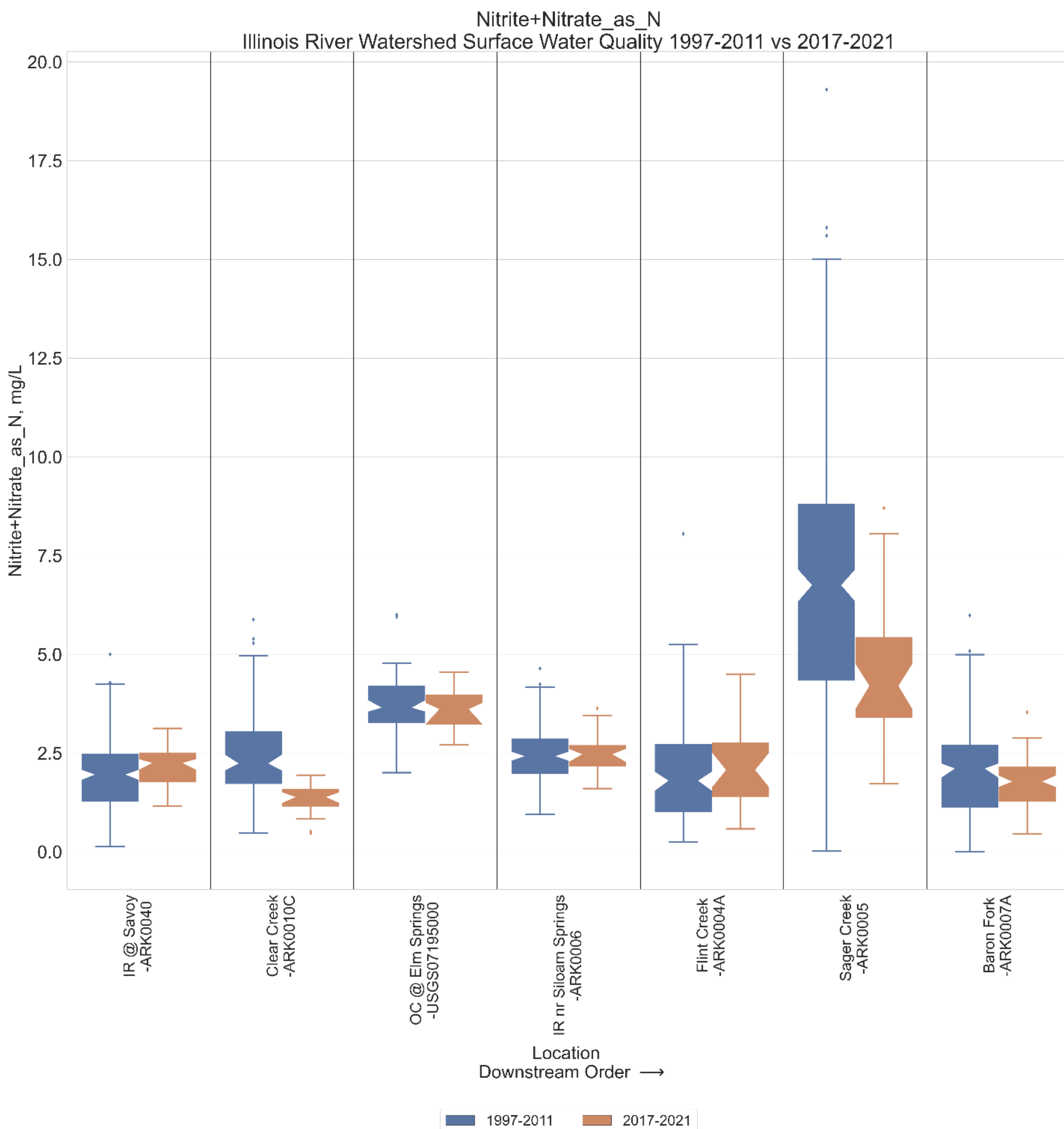

Figure 4: Comparison of nitrate+nitrite nitrogen concentrations 1997-2011 and 2017-2021.

Figure 5 shows a box and whisker plot comparing ammonia nitrogen concentrations from 1997-2011 to those from 2017-2021. At the Osage Creek monitoring location, the median ammonia nitrogen concentration for 2017-2021 is statistically significantly lower than the median for 1997-2011.There is no statistically significant difference in median ammonia nitrogen concentrations at the remaining monitoring locations.

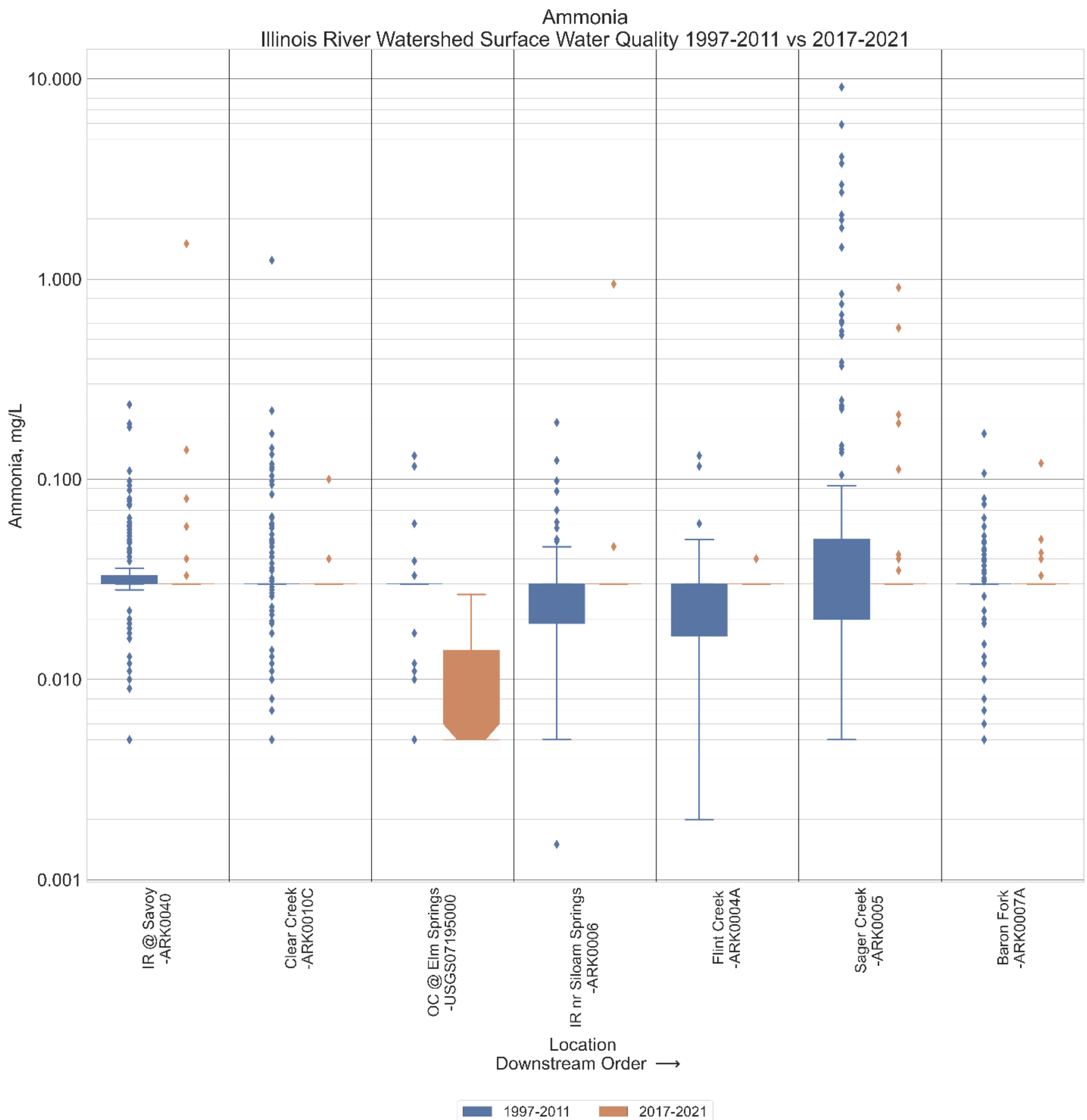

Figure 5: Comparison of ammonia nitrogen concentrations 1997-2011 and 2017-2021.

Figure 6 shows a box and whisker plot comparing total phosphorus concentrations from 1997-2011 to those from 2017-2021. The median total phosphorus concentrations for the two (2) time periods at the Illinois River near Siloam Springs and Flint Creek are not statistically significantly different. The median total phosphorus concentrations at the remaining monitoring locations are statistically significantly lower in 2017-2021 than in 1997-2011.

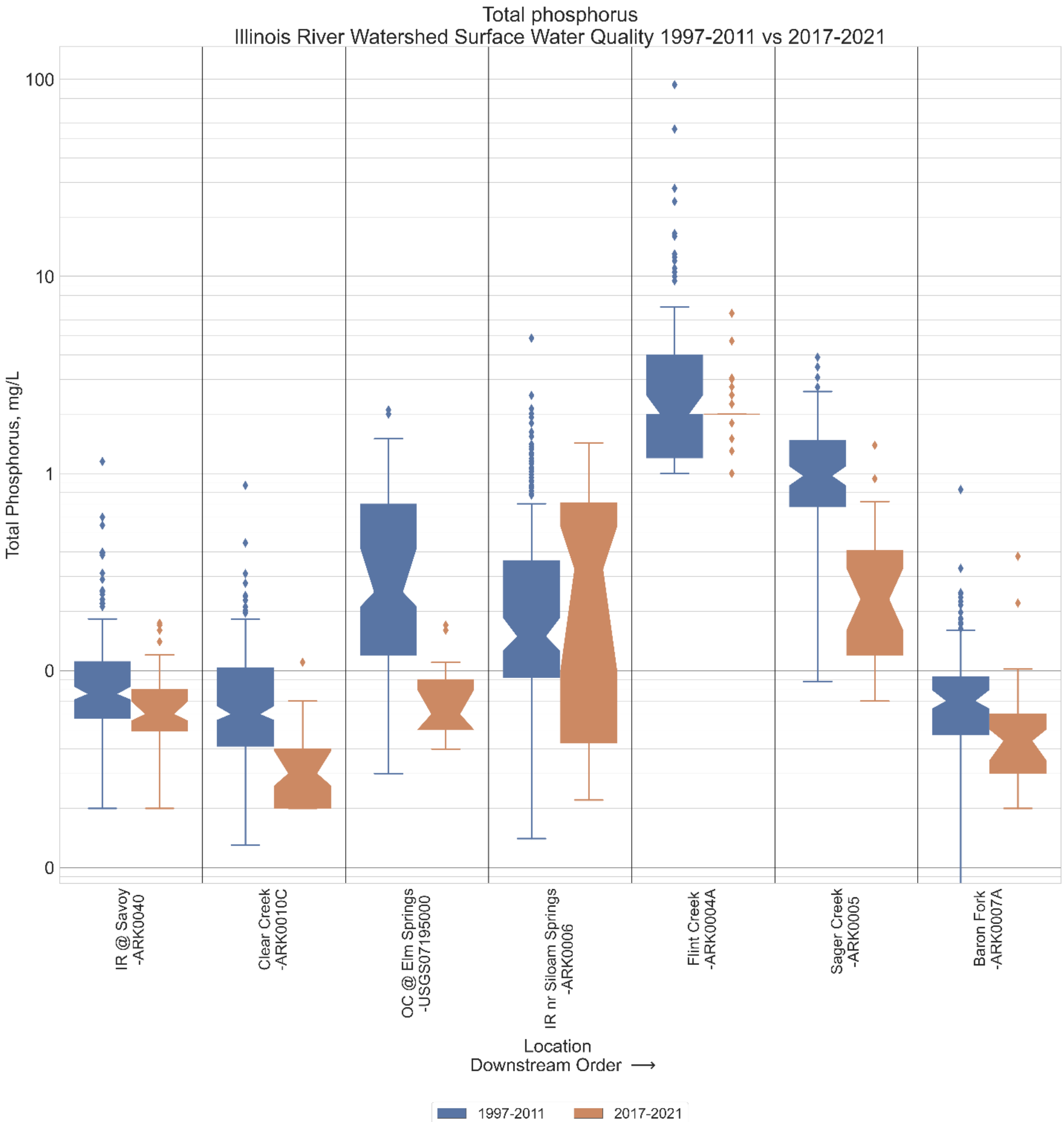

Figure 6: Comparison of total phosphorus concentrations 1997-2011 and 2017-2021.

Figure 7 shows a box and whisker plot comparing dissolved oxygen (DO) concentrations from 1997-2011 to those from 2017-2021. Overall, there has not been a statistically significant change in DO concentrations at the monitored locations in the watershed between the two (2) time periods.

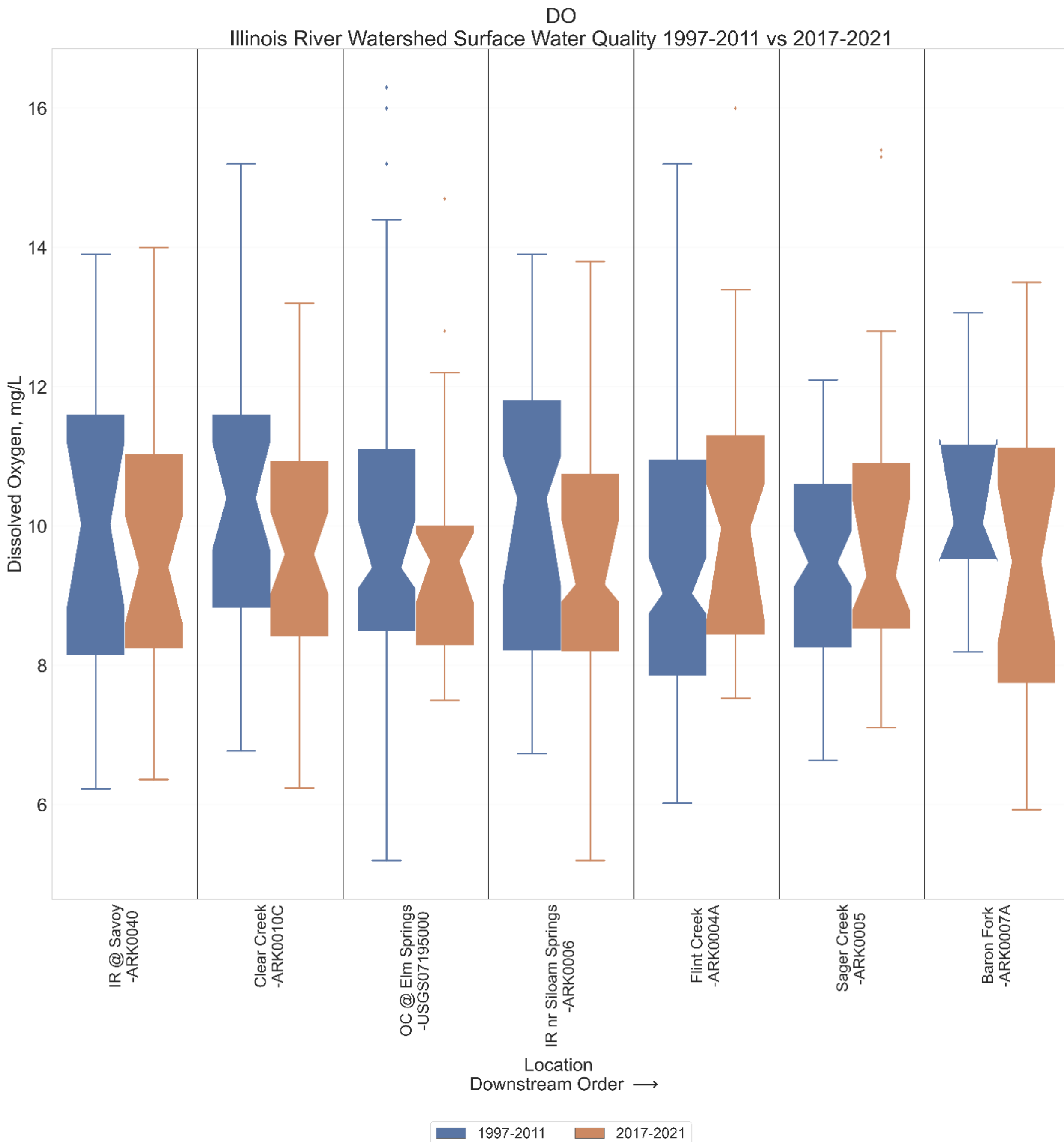

Figure 7: Comparison of dissolved oxygen concentrations 1997-2011 and 2017-2021.

Figure 8 shows a box and whisker plot comparing chloride concentrations from 1997-2011 to those from 2017-2021. The median chloride concentrations for the two (2) time periods are not statistically significantly different at the Illinois River station at Savoy and Osage Creek stations.

The other stations in the watershed exhibit statistically significant decreases in chloride concentrations between 1997-2011 and 2017-2021.

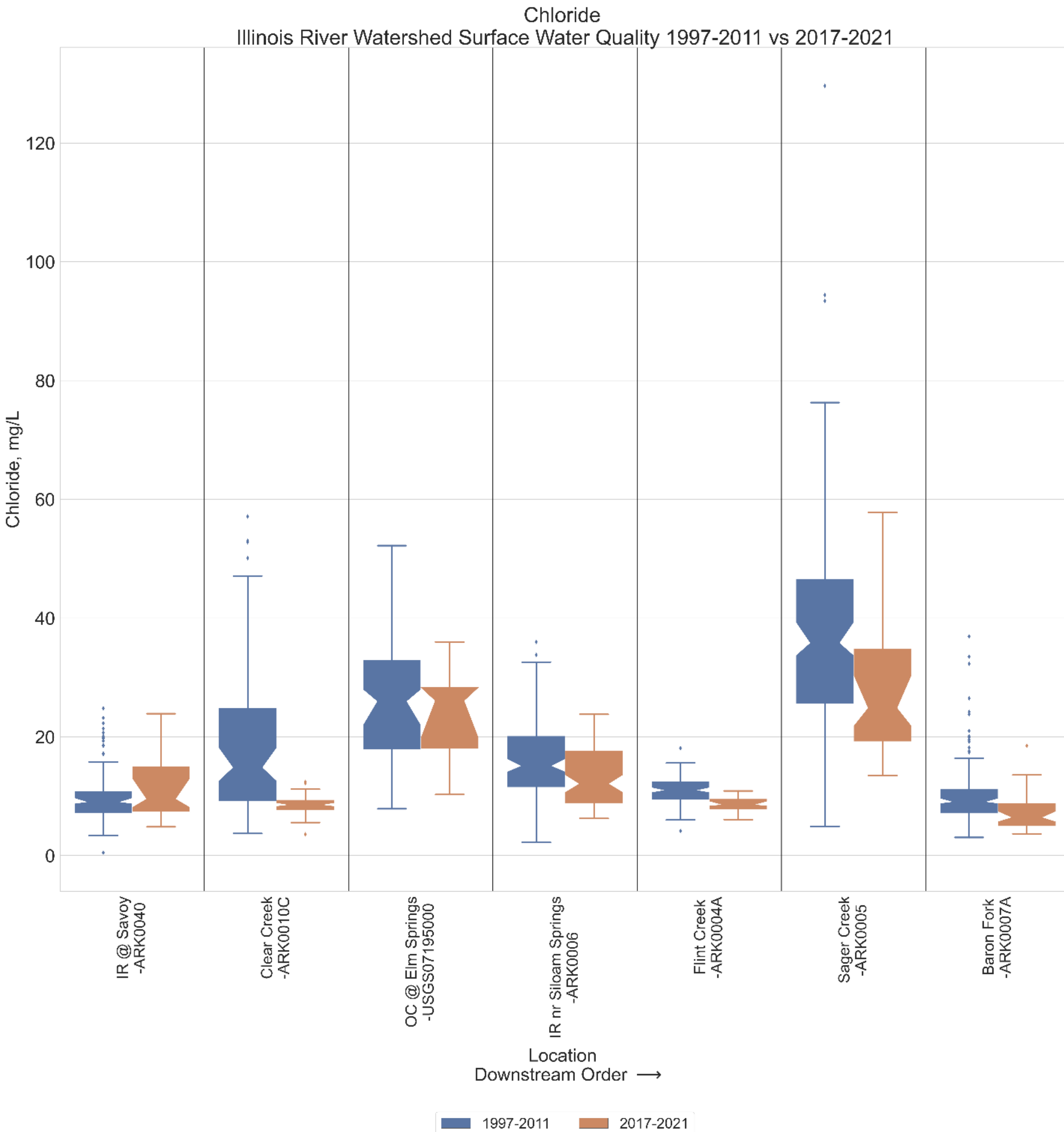

Figure 8: Comparison of chloride concentrations 1997-2011 and 2017-2021.

Figure 9 shows a box and whisker plot comparing sulfate concentrations from 1997-2011 to those from 2017-2021. The Illinois River station at Savoy shows statistically significant increase in median sulfate concentration between 1997-2011 and 2017-2021, and Osage Creek median sulfate concentration is also higher for 2017-2021, though not statistically significantly higher. Clear Creek and Flint Creek stations show statistically significant decreases in median sulfate concentrations between 1997-2011 and 2017-2021. The other four (4) stations in the watershed show no statistically significant change in median sulfate concentrations from 1997-2011 to 2017-2021.

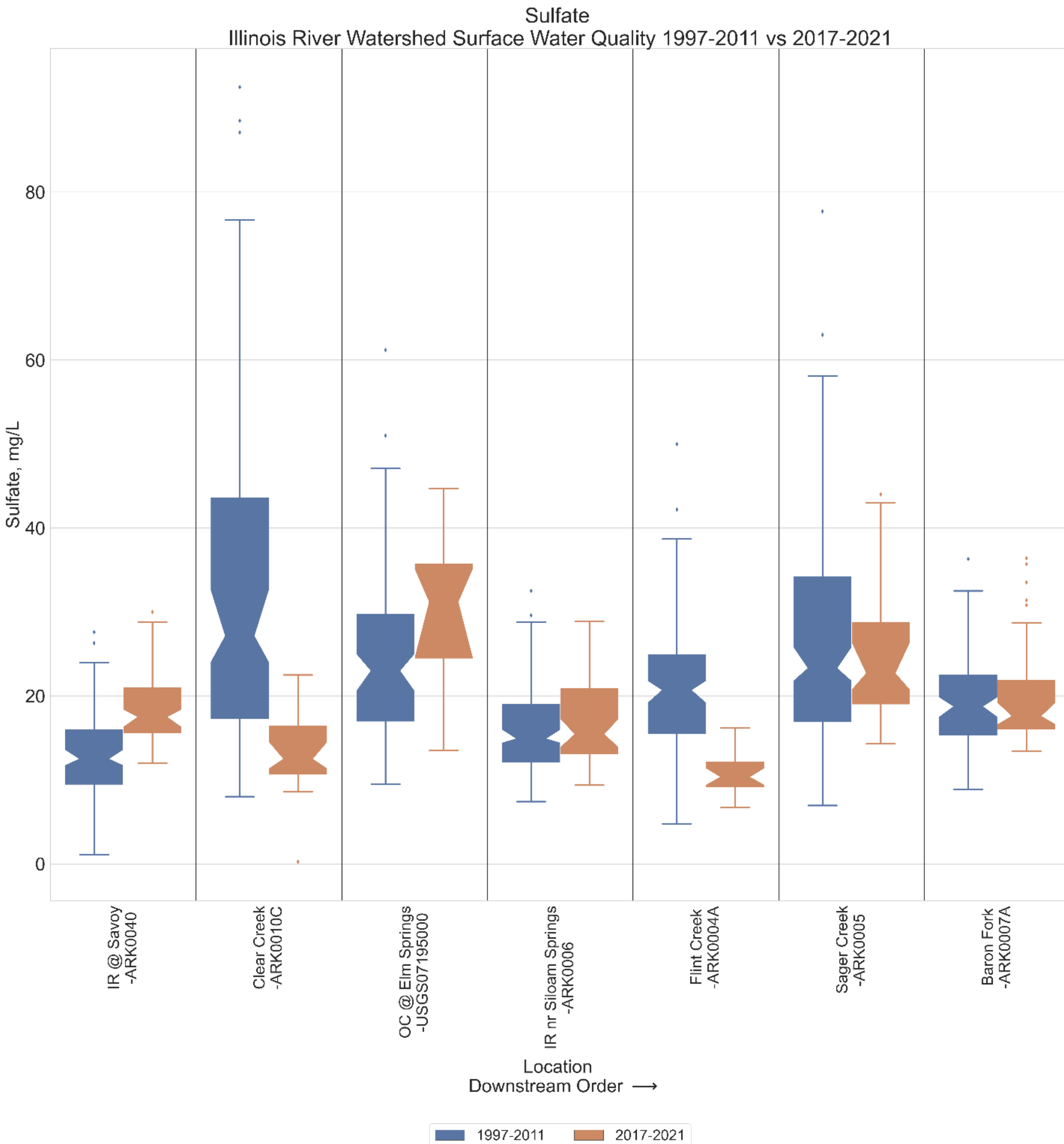

Figure 9: Comparison of sulfate concentrations 1997-2011 and 2017-2021.

Groundwater Quality Summary

Measurements of selected parameters of concern collected during 2018-2022 by DEQ and 2000-2023 by USGS are summarized below. The data used for this summary were downloaded in March 2023 and July 2024 from online databases managed by DEQ and USGS (DEQ 2023, USGS 2023). Analysis of nitrate + nitrite, phosphorus, sulfate, chloride, and toxics were performed with respect to human health and possible sources of nutrients and minerals to surface water. Monitored springs reflect water quality in the Springfield Plateau aquifer.

Movement of contaminants through karst systems in northwest Arkansas can have a significant impact on surface water and groundwater quality (DEQ 2008). Green and Haggard (2001) estimated annual phosphorus and nitrogen (n = 35) loads to the Illinois River south of Siloam Springs, Arkansas (gaging station 07195430) from 1997 to 1999. They found that on average, groundwater contributed 15 percent of the annual total phosphorus load and 46 percent of the annual total nitrogen load.

Nitrate + Nitrite in Groundwater

Nitrite + nitrate were measured once by USGS at wells and springs in the watershed, from 2000 to 2017 (Table 1). Nitrate + nitrite nitrogen was measured at two DEQ spring stations during 2018 (Table 2). Most of the nitrate + nitrite nitrogen measurements from groundwater collected by USGS from the Upper Illinois River watershed were greater than the 10 mg/L drinking water standard except for the well in the Everton Formation (Table 1). The DEQ-sampled springs, however, had concentrations that did not exceed the drinking water standard (Table 2).

Researchers have suggested that a conservative estimate of background nitrate concentrations for the Springfield Plateau and Ozark aquifers is 0.4 mg/L (T. Kresse, et al. 2011, T. Kresse, et al. 2014). Nitrate levels measured in wells and springs in the Upper Illinois River watershed are above the estimated background level. Several studies of groundwater quality in Northwest Arkansas have looked at nitrate levels and factors that appear to influence it. The results of these studies indicate that elevated nitrate levels in groundwater occur where more than 40 percent of the land cover is agricultural, near septic systems, and in areas where karst features are more prevalent (T. Kresse, et al. 2014).

Table 1. USGS groundwater nitrate and nitrite measurements in Upper Illinois River watershed 2000-2017 *(USGS 2023)*.

Aquifer	Monitoring Location Type (number)*	Nitrite, mg/L	Nitrate, mg/L	Nitrate + Nitrite, mg/L
Springfield Plateau	Spring (7)	0.004 to 0.412 (0.146)	17.6 to 31.1 (25.1)	17.6 to 31.0 (23.3)
Springfield Plateau	Well (3)	0.006 to 0.012 (0.009)	17.6 to 42.5 (27.4)	22.0 to 42.5 (32.3)
Everton Formation	Well (1)	0.004	8.23	8.23

Note: *Count in parentheses

Table 2. DEQ groundwater (spring) nitrate+nitrite measurements in Upper Illinois River watershed 2018-2022 (DEQ 2023).

Station ID	Spring Name	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
ARK0199	Cave Springs	4	5.35	5.463	5.525	5.588	5.65	5.95
ARK0202	Logan Spring	5	4.89	5.3	5.45	5.388	5.45	5.85

Green and Haggard (2001) estimated annual nitrogen loads to the Illinois River south of Siloam Springs, Arkansas (gaging station 07195430) from 1997 to 1999 (n=35). They found that, on average, groundwater contributed 46 percent of the annual total nitrogen load to the Illinois River at that location.

Dissolved and Total Phosphorus

Phosphorus and nitrogen are two nutrients that could threaten surface water and groundwater in the Ozarks due to a combination of agricultural practices (poultry, cattle, and swine production) and the underlying karst terrain. Phosphorus is typically strongly bound to clays and organic matter in soils, so very little phosphorus is transported in the dissolved state (Kresse et al., 2014). EPA currently has no drinking water standard for phosphorus. Most total phosphorus measurements from Cave Spring and Logan Spring are greater than 0.037 mg/L, though all are less than the target stream total phosphorus for the Ozark Highlands (0.07 mg/L). Thus, groundwater can contribute to surface water phosphorus level concerns in this watershed. Green and Haggard (2001) found that, between 1997 and 1999, groundwater contributed, on average, 15 percent of the annual total phosphorus load to the Illinois River south of Siloam Springs, Arkansas (gaging station 07195430).

Table 3. USGS groundwater dissolved phosphorus measurement in Upper Illinois River watershed in 2000 *(USGS 2023)*.

Station ID	Aquifer (depth)	Number of measures	Dissolved Phosphorus, mg/L
361745094234902	Boone Formation	1	0.006

Table 4. DEQ groundwater (spring) total phosphorus measurements in Upper Illinois River watershed 2018-2022 (DEQ 2023).

Station ID	Spring Name	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
ARK0199	Cave Springs	6	0.038	0.04	0.04	0.0415	0.0408	0.05
ARK0202	Logan Spring	7	0.035	0.039	0.04	0.0396	0.04	0.0441

Pathogens

The frequent presence of pathogens in the Springfield Plateaus aquifer limits its use as a drinking water supply. Sources of these pathogens are related to agricultural and urban land use. One study found that concentrations of pathogen-indicator bacteria (i.e., *E. Coli*) in spring water increased by several orders of magnitude during storm events. This study also found that these bacteria survived in groundwater at least four months, probably in sediments (T. Kresse, et al. 2014). There were no measurements of *E. Coli* in the monitored springs of the Upper Illinois River watershed.

Groundwater can transport pathogens from the area of contamination to the stream where groundwater discharges to surface flow (Davis, Hamilton and Brahana 2005). E. coli have been found in groundwater and cave streams in the Upper Illinois River watershed (Davis, Brahana and Johnston 2000, Davis, Hamilton and Brahana 2005). Brown et al. (1998) and Graening and Brown (1999, 2000) found a correlation between E. coli in cave streams and the infiltration of runoff during storm events. The karst geology in the watershed permits rapid infiltration into groundwater.

Minerals

Sulfate levels are generally low in the aquifers of the Ozark Highlands and Boston Mountains. As is shown in Tables 5 and 6, sulfate concentrations measured in surface water and groundwater of the Upper Illinois River watershed are less than the surface water quality criteria, and the Ozark Highlands ecoregion reference stream value of 17 mg/L. One measurement in a Boone Formation well had a slightly higher concentration than the criteria value.

Table 5. USGS groundwater sulfate measurements in Upper Illinois River watershed 2000-2023 (USGS 2023).

Aquifer	Monitoring Location Type*	Sulfate, mg/L
Springfield Plateau	Spring (7)	1.75 to 7.21 (3.62)
Springfield Plateau	Well (5)	0.48 to 17.3 (5.25)
Ordovician System/ Everton Formation	Well (2)	0.36 to 11.3 (5.83)

Note: *Count in parentheses

Table 6. Spring sulfate data from Upper Illinois River watershed 2018-2022 *(DEQ 2023)*.

Station ID	Spring Name	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
ARK0199	Cave Springs	6	3.53	3.903	4.145	4.047	4.29	4.3
ARK0202	Logan Spring	7	3.61	3.695	3.81	4.329	4.795	5.9

Chloride concentrations have been documented previously to be lower than 10 mg/L within the Ozarks (Kresse et al., 2014). Some samples obtained by the USGS exceeded 10 mg/L (Table 7), but springs sampled by DEQ were lower than the drinking water standard on average (Table 8).

Table 7. USGS groundwater chloride measurements in Upper Illinois River watershed 2000-2017 (USGS 2023).

Aquifer	Monitoring Location Type*	Chloride, mg/L
Springfield Plateau	Spring (7)	4.94 to 18.4 (8.35)
Springfield Plateau	Well (5)	5.58 to 20.5 (11.1)
Ordovician System/ Everton Formation	Well (2)	11.5 to 33.7 (22.6)

Note: *Count in parentheses

Table 8. Groundwater chloride data from Upper Illinois River watershed 2018-2022 (DEQ 2023).

Station ID	Spring Name	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
ARK0199	Cave Springs	6	6.83	7.668	7.76	7.685	7.928	8.14
ARK0202	Logan Spring	7	5.03	6.07	7.47	6.887	7.73	8.11

Toxics

DEQ sampled springs during 2017-2018 and USGS measured metals concentrations in springs and wells during the period 2000-2023. EPA has established drinking water Maximum Contaminant Levels (MCL) for many of the metals measured in the groundwater in Upper Illinois River watershed (EPA 2023). These MCLs are intended to protect human health. Table 9 lists the metals drinking water MCLs with levels reported in the groundwater samples from 2017-2018

(DEQ spring) and 2000-2023 (USGS wells and springs). Measured metals concentrations do not exceed the drinking water MCLs.

Table 9. Drinking water MCLs for metals compared to reported concentrations.

Metal	Drinking water MCL, mg/L	DEQ reported dissolved values 2017-2018, mg/L (Spring)	USGS measurement, dissolved values 2000-2023, mg/L (Spring)	USGS measurement, dissolved values 2000-2023, mg/L (Well)
Antimony	0.006	<0.025	0.000097 to 0.000217	0.000065 to 0.000141
Arsenic	0.01	<0.001	0.00012 to 0.00025	0.00006 to 0.00011
Barium	2	0.039-0.062	0.0392 to 0.114	0.00416 to 0.0341
Beryllium	0.004	<0.0005	0.00002	0.000012 to 0.000172
Cadmium	0.005	<0.0003	0.000072 to 0.000595	0.000078 to 0.00022
Chromium	0.1	<0.002	0.00039 to 0.0012	0.00013 to 0.0003
Copper	1.3	0.010	0.00026 to 0.0069	0.0003 to 0.0054
Fluoride	4.0	-	0.00006	0.00445
Lead	0.015	<0.0005	0.000035 to 0.00036	0.00007 to 0.000357
Selenium	0.05	<0.003	0.0001 to 0.00033	0.00006 to 0.00054
Thallium	0.002	<0.0005	0.000144	0.00004

DEQ did not measure organics in the springs during 2018-2022. USGS did measure organics in the springs originating from the Boone Formation (station 361540094130701), but not in the sampling well. Table 10 lists the 53 organics for which USGS tested. Measurements of these organics were all reported as less than detection. As a result, there is no indication that metals or pesticides in groundwater are a human or wildlife health concern.

Table 10. Analysis of organics from a spring originating from the Everton Formation sampled by USGS.

Organic Name	EPA Drinking Water MCL, mg/L	Sources of contamination	USGS measurement, dissolved values 2000-2017, mg/L (Spring)
2,4-D	0.07	Herbicide	<0.00016
Alachlor	0.002	Herbicide	<0.000008
Atrazine	0.003	Herbicide	0.000003 to 0.000009
Benzo[a]pyrene	0.0002	Leaching from water storage tanks and distribution lines	<0.00012
Carbofuran	0.04	Leaching of soil fumigant	<0.00006
Dinoseb	0.007	Herbicide	<0.00009
Oxamyl	0.2	Insecticide	<0.00016
p-Dichlorobenzene	0.075	Industrial discharge	0.000017
Simazine	0.004	Herbicide	0.00002 to 0.000174

Organic Name	EPA Drinking Water MCL, mg/L	Sources of contamination	USGS measurement, dissolved values 2000-2017, mg/L (Spring)
Tetrachloroethylene	0.005	Industrial discharge	<0.00018
1,1,1-Trichloroethane	0.2	Industrial discharge	Not measured
1,1,2-Trichloroethane	0.005	Industrial discharge	Not measured
1,1-Dichloroethylene	0.007	Industrial discharge	Not measured
1,2,4-Trichlorobenzene	0.07	Industrial discharge	Not measured
1,2-Dibromo-3-chloropropane (DBCP)	0.0002	Runoff/leaching of soil fumigant	Not measured
1,2-Dichloroethane	0.005	Industrial discharge	Not measured
1,2-Dichloropropane	0.005	Industrial discharge	Not measured
2,4,5-TP (Silvex)	0.05	Banned herbicide residue	Not measured
Acrylamide	TT*	Added to water during sewage/wastewater treatment	Not measured
Benzene	0.005	Industrial discharge; gas storage tank and landfill leaching	Not measured
Carbon tetrachloride	0.005	Industrial discharge	Not measured
Chlordane	0.002	Banned termiticide residue	Not measured
Chlorobenzene	0.1	Industrial discharge	Not measured
cis-1,2-Dichloroethylene	0.07	Industrial discharge	Not measured
Dalapon	0.2	Herbicide runoff	Not measured
Di(2-ethylhexyl) adipate	0.4	Industrial discharge	Not measured
Di(2-ethylhexyl) phthalate	0.006	Industrial discharge	Not measured
Dichloromethane	0.005	Industrial discharge	Not measured
Dioxin (2,3,7,8-TCDD)	0.00000003	Waste incineration and other combustion emissions; industrial discharge	Not measured
Diquat	0.02	Herbicide runoff	Not measured
Endothall	0.1	Herbicide runoff	Not measured
Endrin	0.002	Banned insecticide residue	Not measured
Epichlorohydrin	TT*	Industrial discharge; water treatment chemical impurity	Not measured
Ethylbenzene	0.7	Petroleum refinery discharge	Not measured
Ethylene dibromide	0.00005	Petroleum refinery discharge	Not measured
Glyphosate	0.7	Herbicide runoff	Not measured
Heptachlor	0.0004	Banned termiticide residue	Not measured
Heptachlor epoxide	0.0002	Heptachlor breakdown	Not measured
Hexachlorobenzene	0.001	Metal refinery and agricultural chemical factory discharge	Not measured
Hexachlorocyclopentadiene	0.05	Industrial discharge	Not measured
Lindane	0.0002	Runoff/leaching from insecticide	Not measured
Methoxychlor	0.04	Runoff/leaching from insecticide	Not measured

Organic Name	EPA Drinking Water MCL, mg/L	Sources of contamination	USGS measurement, dissolved values 2000-2017, mg/L (Spring)
o-Dichlorobenzene	0.6	Industrial discharge	Not measured
Pentachlorophenol	0.001	Industrial discharge	Not measured
Picloram	0.5	Herbicide runoff	Not measured
Polychlorinated biphenyls (PCBs)	0.0005	Landfill runoff; discharge of waste chemicals	Not measured
Styrene	0.1	Industrial discharge; landfill leaching	Not measured
Toluene	1.0	Industrial discharge	Not measured
Toxaphene	0.003	Insecticide runoff/leaching	Not measured
trans-1,2-Dichloroethylene	0.1	Industrial discharge	Not measured
Trichloroethylene	0.005	Industrial discharge	Not measured
Vinyl chloride	0.002	Leaching from PVC pipes; industrial discharge	Not measured
Xylenes (total)	10.0	Industrial discharge	Not measured

*Each water system must certify, in writing, to the state (using third-party or manufacturer's certification) that when acrylamide and epichlorohydrin are used to treat water, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows: Acrylamide = 0.05 percent dosed at 1 mg/L (or equivalent); Epichlorohydrin = 0.01 percent dosed at 20 mg/L (or equivalent) Source: https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations

Summary

Most of the nitrate + nitrite nitrogen measurements from groundwater collected by USGS from the Upper Illinois River watershed were greater than the 10 mg/L drinking water standard except for one well in a lower aquifer. DEQ-sampled springs, however, had concentrations that did not exceed the drinking water standard. Phosphorus, like nitrogen, is associated with the agricultural practices in the area. The USGS well that was sampled had a lower concentration (Table 3) than the DEQ-sampled springs (Table 4). These trends of nitrate+nitrite and phosphorus likely indicate that there are more surface-derived contributions within the watershed that infiltrate the karst features within the watershed.

Pathogens, including *E. Coli*, are known to be present in the aquifers of the region. *E. Coli* samples were not obtained for springs in the Upper Illinois River watershed. Samples should be collected in future projects to monitor for potential contamination in the drinking water supply.

Barium and copper are the only potential toxic that has been measured above detection levels in groundwater of the Upper Illinois River watershed measured by DEQ in 2017-2018. All toxics listed in Table 9 were listed above the detection limit in the USGS samples in 2000-2023. However, all the measured levels for DEQ and USGS are less than the drinking water maximum contaminant level. The only organic measured above detection limit within the spring measured by USGS was Atrazine. The concentrations, however, were still below the drinking water maximum contaminant level.

Sulfate concentrations measured by DEQ and USGS were mostly below the surface water criteria value except for one well sampled by USGS. This suggests that groundwater probably does not contribute to exceedances of minerals criteria in surface waters. Chloride concentrations have been noted to likely be derived from surface contamination and infiltrating through the karst features within the Ozarks, which could explain why a large majority of the wells measured by USGS had samples exceeding criteria number.

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APPENDIX H
POINT SOURCE FLOW EVALUATION

Increases in point source discharges associated with the marked increase in population and development in the Illinois River watershed, particularly municipal wastewater discharges, are likely contributing to increasing stream flows in this watershed. Annual average discharges from selected municipal wastewater treatment plants were compared to annual average stream discharge at downstream USGS gages for 2010, 2015, and 2020 (Table 1). Wastewater treatment plant flows were averages of monthly average flows reported on DMRs. This data was downloaded from EPA Enforcement and Compliance History Online application (EPA, 2021). Flow data for USGS gages were downloaded from the USGS National Water Information System (USGS Surface-Water Data for Arkansas).

Table 1. Comparison of selected wastewater facility discharges to receiving stream flow.

Wastwater treatment facility		Facility average flow, MGD			Facility average flow July-September			Downstream USGS gage		Average annual flow, MGD			Average flow July-September, MGD			Percent average annual flow			Percent average flow July-September		
NPDES permit number	name	2010	2015	2020	2010	2015	2020	ID number	name	2010	2015	2020	2010	2015	2020	2010	2015	2020	2010	2015	2020
AR0035246	City of Lincoln	0.483	0.722	0.630	0.328	0.543	0.278	07196900	Baron Fork at Dutch Mills	23.9952	65.7952	38.9451	7.696	51.682	3.811	2%	1%	2%	4%	1%	7%
AR0050024	Northwest Arkansas Conservation Authority (NACA) Regional Wastewater Treatment Facility	0.024	2.315	3.586	0.000	2.350	2.993	07195000	Osage Creek near Elm Springs, AR	94.477	170.672	181.000	75.406	119.826	93.530	0%	1%	2%	0%	2%	3%
AR0022063	Springdale Water and Sewer Commission Springdale Wastewater Treatment Facilities	12.908	14.250	14.308	13.667	13.867	12.967	07195000	Osage Creek near Elm Springs, AR	94.477	170.672	181.000	75.406	119.826	93.530	14%	8%	8%	18%	12%	14%
AR0043397	City of Rogers Pollution Control Facility	6.342	7.579	8.571	5.250	8.955	6.397	07195000	Osage Creek near Elm Springs, AR	94.477	170.672	181.000	75.406	119.826	93.530	7%	4%	5%	7%	7%	7%
Combined Osage Creek discharges									Osage Creek near Elm Springs, AR	94.477	170.672	181.000	75.406	119.826	93.530	20%	14%	15%	25%	21%	24%
AR0020184	City of Gentry	0.503	0.528	0.593	0.435	0.500	0.357	07195855	Flint Creek near West Siloam Springs	28.609	67.092	53.748	20.294	50.219	18.519	2%	1%	3%	2%	1%	2%
AR0050024																					

This comparison indicates that municipal wastewater discharges may account for from one (1) percent to 25 percent of stream flow. Some of these municipal wastewater discharges also exhibit increasing trends in flow over time (Figures 1-3). Increases in point source discharges are most likely to have increased minimum flows in receiving streams. They do not contribute significantly to flood events (Hart, Howe, & Blankenship, 2023).

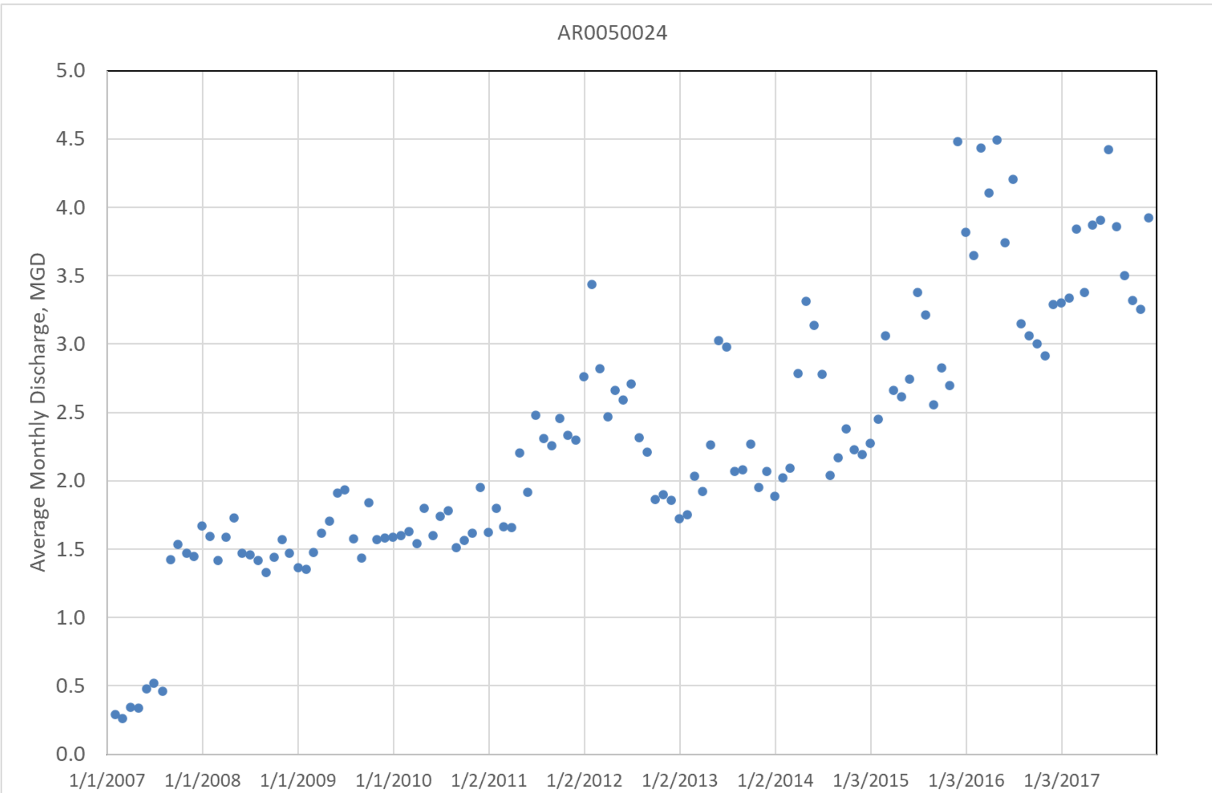

Figure 1. Average monthly discharge from Northwest Arkansas Conservation Authority (NACA) Regional Wastewater Authority treatment facility.

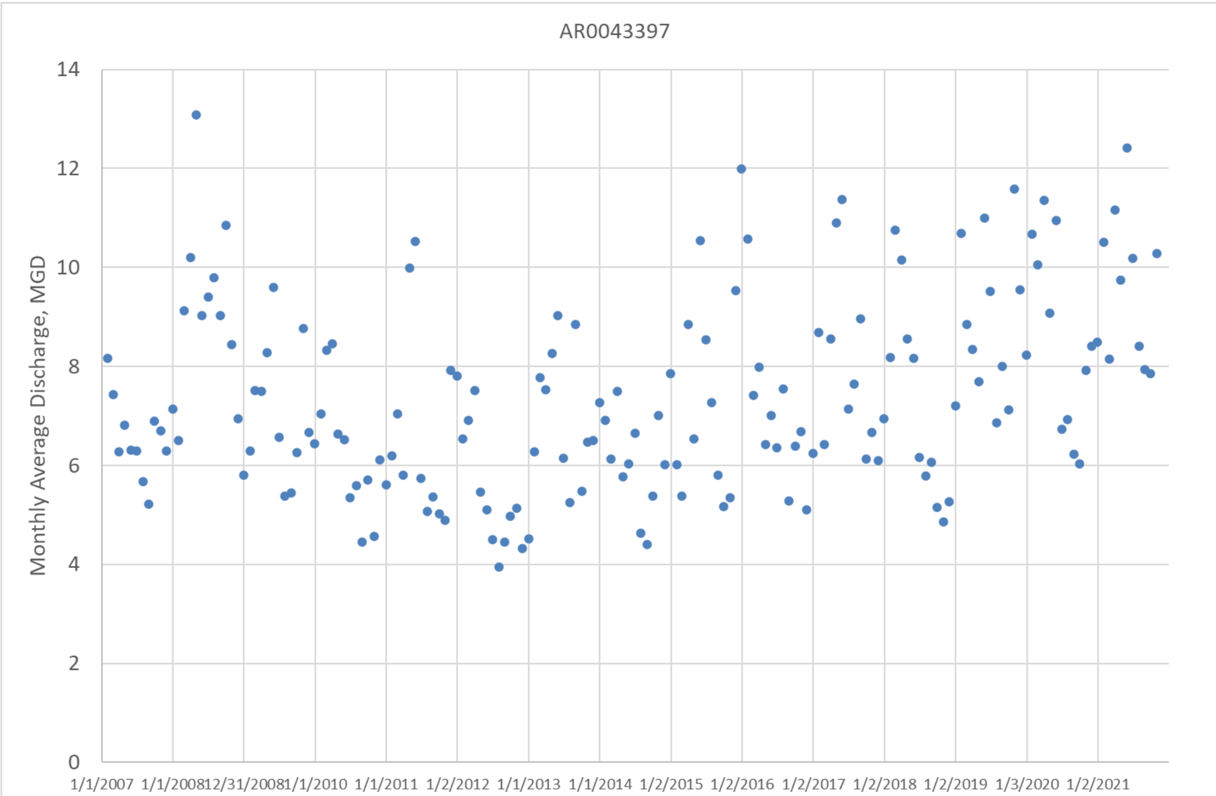

Figure 2. Monthly average discharge reported for City of Rogers Pollution Control Facility.

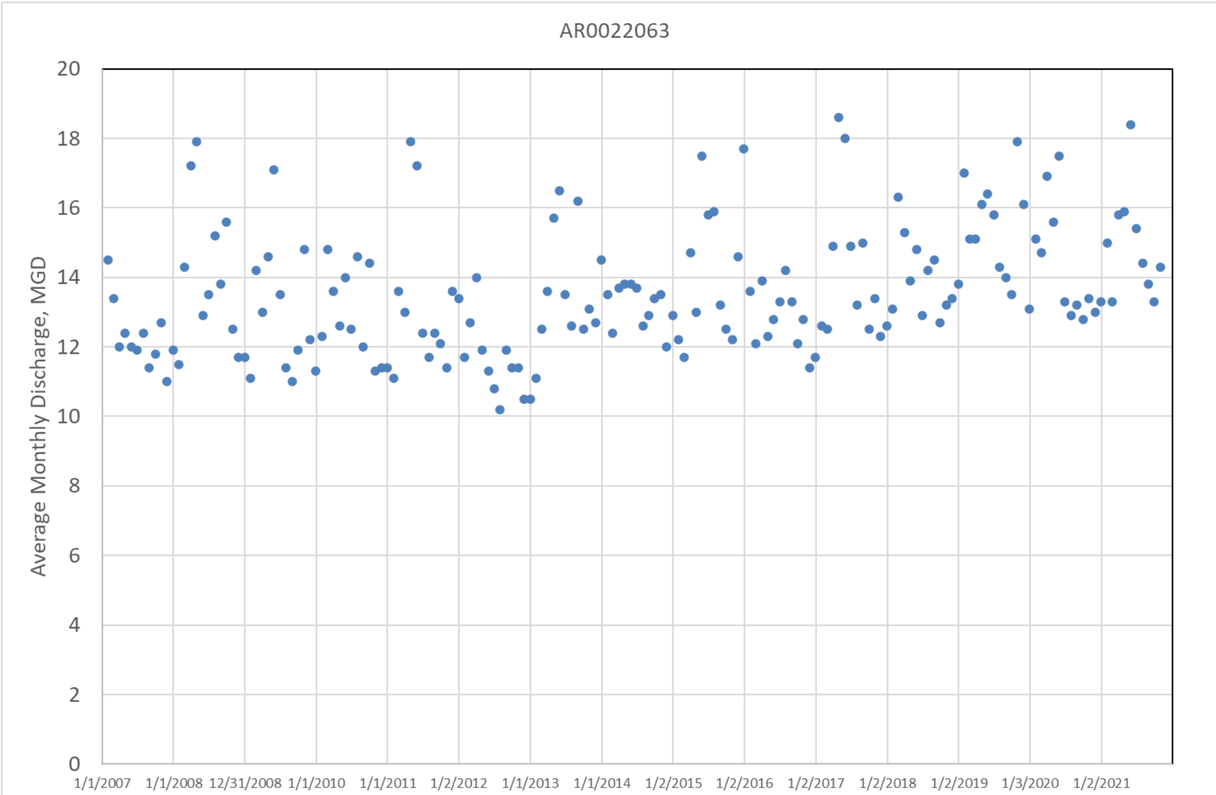

Figure 3. Average monthly discharge from Springdale Wastewater Treatment Facility.

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APPENDIX I
ESTIMATION OF SEPTIC SYSTEM NUMBERS IN THE UPPER ILLINOIS RIVER WATERSHED

The attached GIS layer files contain known locations of septic tanks in Washington and Benton Counties and derived and/or estimated locations of septic tanks in the remaining counties that overlap the Upper White River watershed.

Septic tank locations in the Upper Illinois River watershed were derived as follows.

- Locations of Arkansas Department of Health (ADH) permitted septic system locations in Benton County were downloaded from the county web server (Home - Geographic Information Systems (bentoncountyar.gov)).
- The City of Fayetteville provided a table of parcel IDs associated with septic tank permits.
- Fayetteville and Springdale: geospatial sewer infrastructure data were available from each city's web feature service. We selected 911 addresses within each city that represent buildings likely to be served by sewage infrastructure (e.g. residences and businesses). We selected real estate parcels that contain one of those addresses. Of those selected real estate parcels, we selected those that intersect sewer mains or sewer service lines, and those that are both a) within a subdivision newer than 2013 and b) less than 200' from a sewer main. Remaining pockets within each city were marked as having a septic tank and were checked against real estate information from Washington County provided by DataScout (DataScout, LLC (datascoutllc.com)).
- For smaller towns in Washington County (including Prairie Grove, Lincoln, and Tontitown) we used real estate information from Washington County provided by DataScout to mark locations of ADH septic tank permits.
- Areas outside the city limits of any town/city that offers sewage service in Washington County were treated the same as within city limits until the edge of the sewer service area was reached.
- Outside city limits in Washington County, we started with the 911 address points, then removed the address types least likely to include sewage facilities (barns, chicken houses, etc.) and classified those remaining as buildings with septic tanks. We spot-checked the information in Washinton County's real estate info (DataScout) to make sure we didn't overlook any pockets of centralized wastewater facilities in our analysis.

IDENTIFY RECOMMENDED SUB-WATERSHEDS

To identify HUC12 sub-watersheds to recommend for additional management of nonpoint source pollution under this plan, available information was used to rank the 26 HUC12 sub-watersheds of the Illinois River watershed with at least 50 percent of their area in Arkansas, in terms of water quality and habitat concerns. Four (4) sets of water quality-related information were used to rank the HUC12 sub-watersheds. The following information was used to rank the HUC12 sub-watersheds:

- Water quality impairment
- Modeled loads
- Water quality natural resource concerns from the 2015 NRCS State Resources Assessment
- Condition of macroinvertebrate communities

Scores were developed for each HUC12 sub-watershed based on this information. The methods used to develop these scores are described in the following subsections. The HUC12 sub-watersheds were then ranked based on a total score calculated by summing the scores from all the information categories (see subsection 1.5).

1.1 Water Quality Impairment

On the 2018 303(d) list, over 50 miles of streams and Lake Fayetteville (171 acres) in the watershed are classified as impaired. An additional 43 miles of streams are listed as impaired on the draft 2020 303(d) list. There are HUC12 sub-watersheds with more than one impaired assessment unit, and HUC12 sub-watersheds where assessment units are impaired due to more than one pollutant. HUC12 sub-watersheds containing impaired assessment units were assigned a value of one for each assessment unit-pollutant pair. Scores were first assigned based on the 2018 303(d) List. Then scores were added for assessment unit-pollutant pairs that are on the draft 2020 303(d) list but not the 2018 303(d) list. The maximum number of assessment unit-pollutant pairs in a sub-watershed was four. Normalized scores with a maximum value of one (1) were calculated by dividing the number of assessment unit-pollutant pairs by four (4). Figure 1 shows the water quality impairment scores for each of the ranked HUC12 sub-watersheds.

Figure 1. Summary of water quality impairment scores for Upper Illinois River sub-watersheds.

Modeled Nonpoint Source Pollutant Yields

A recent SWAT modeling project of the Upper Illinois River watershed estimated average annual nonpoint source flux of total nitrogen, total phosphorus, and suspended sediment from each of the HUC12 sub-watersheds with at least 50 percent of their area in (Olsson FTN 2024). Using flux to rank the HUC12s means that streambank erosion inputs are accounted for. Flux values can be negative. Negative flux values indicate that pollutant loads are being reduced in the HUC12 by nutrient uptake (nitrogen and phosphorus) or sedimentation (sediment).

Separate scores were assigned to the HUC12 sub-watersheds for total nitrogen, total phosphorus, and sediment yields, i.e., HUC12 flux/HUC12 area. Modeled sub-watershed yields ranged from 0.2 to 50.37 kg/hectare/year for total nitrogen, from 0.08 to 3.78 kg/hectare/year for total phosphorus, and from -0.74 to 5.35 tons/hectare/year for sediment. Negative yield occurs when the load leaving a sub-watershed is less than that entering the sub-watershed from upstream plus what is generated in the sub-watershed. Thus, a negative sediment yield suggests that deposition is greater than erosion within the sub-watershed.

We wanted the yields of each parameter to contribute equally to the pollutant yield score, while preserving the variations in sub-watershed yields. Therefore, a score for each parameter was calculated by dividing the sub-watershed yield by the maximum sub-watershed yield for that parameter. As an example, sub-watershed scores for yield of the parameter total nitrogen were calculated by dividing the total nitrogen yield for each sub-watershed by 50.37. For the one sub-watershed with a negative sediment yield, the absolute value of the yield was normalized. This was because sedimentation in the stream is a water quality concern, as well as erosion and turbidity resulting from sediment loads carried by the stream.

The normalized parameter scores were then summed for each sub-watershed. The highest sub-watershed sum of parameter scores was 1.91. The total sub-watershed scores were normalized to a maximum value of one by dividing all the parameter score sums by 1.91. Figure 2 shows the sub-watershed scores for modeled pollutant yields.

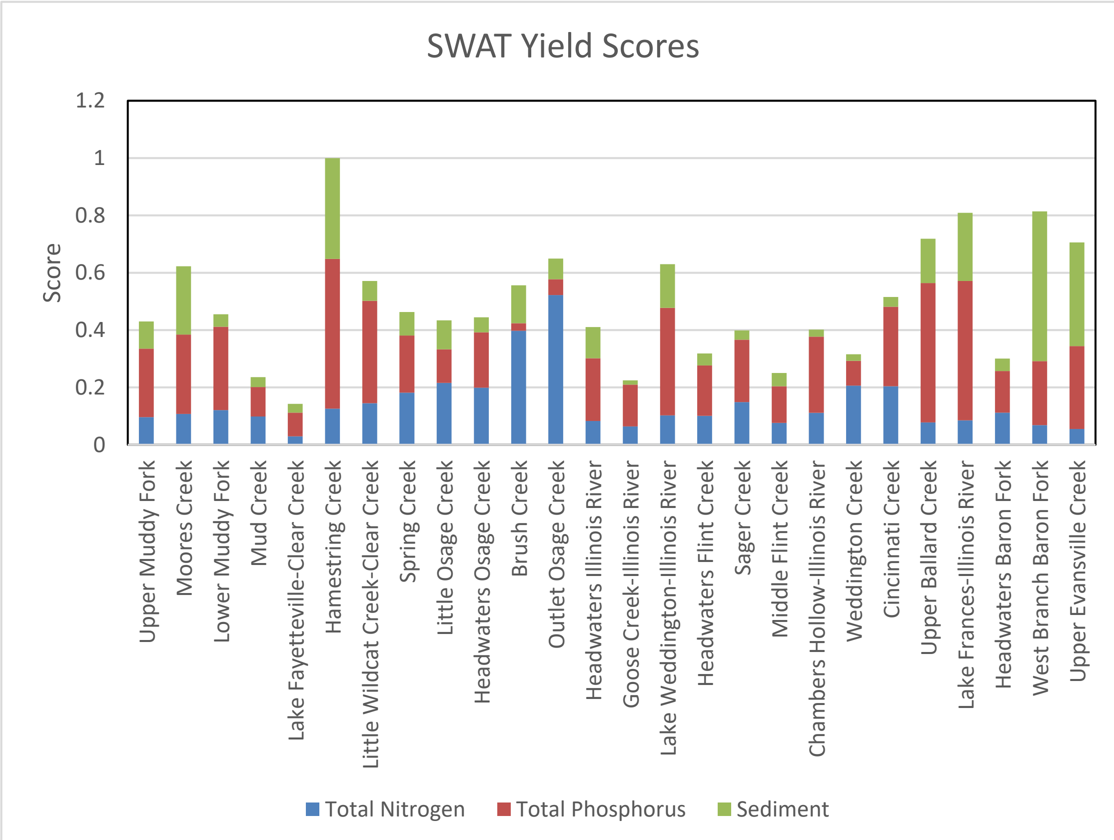

Figure 2. Summary of modeled pollutant yield scores for Upper Illinois River sub-watersheds.

Arkansas State Resource Assessment Water Quality Concerns

Scores were assigned to HUC12 sub-watersheds based on area-weighted risks assigned to HUC12 sub-watersheds for water quality degradation resource concerns in the US Natural Resources Conservation Service (NRCS) 2015 Arkansas State Resource Assessment (NRCS 2016). HUC12 sub-watersheds within the Illinois River watershed were assigned high risk for the five-water quality degradation resource concerns in the State Resource Assessment:

- Excess nutrients in surface water and groundwater
- Excess sediment in surface water
- Petroleum, heavy metals, and other pollutants transported to receiving water sources
- Pesticides and herbicides transported to surface water and groundwater
- Excess pathogens and chemicals from manure, biosolids, or compost applications

The area-weighted risks assigned to the five (5) water quality degradation concerns were used to rank the HUC12 sub-watersheds. Maximum risk values for the five (5) water quality degradation concerns ranged from one (1) to 32. To allow each concern to contribute equally to the rank, the risk values for each concern were normalized to a maximum value of one (1). The normalized risk values for the five (5) concerns were summed for each HUC12. The highest sum of HUC12 normalized risk values in the watershed was 4.4. To calculate a normalize score for each HUC12 the sum of the normalized risk values for each sub-watershed was divided by 4.4. Figure 3 shows the sub-watershed scores for Arkansas state resource assessment water quality degradation concerns.

Condition of Macroinvertebrate Communities

The condition of macroinvertebrate communities is used as a gage of overall water quality in streams. Illinois River Watershed Partnership has conducted repeated benthic macroinvertebrate surveys at several locations in the Upper Illinois River watershed. However, the IRWP surveys have been conducted in only six (6) of the 26 HUC12 sub-watersheds being ranked, and no effort is made to classify condition. Fox (2023) identified seven (7) HUC12 sub-watersheds where mussel surveys had been conducted (only one (1) of which was also where IRWP conducts macroinvertebrate surveys).

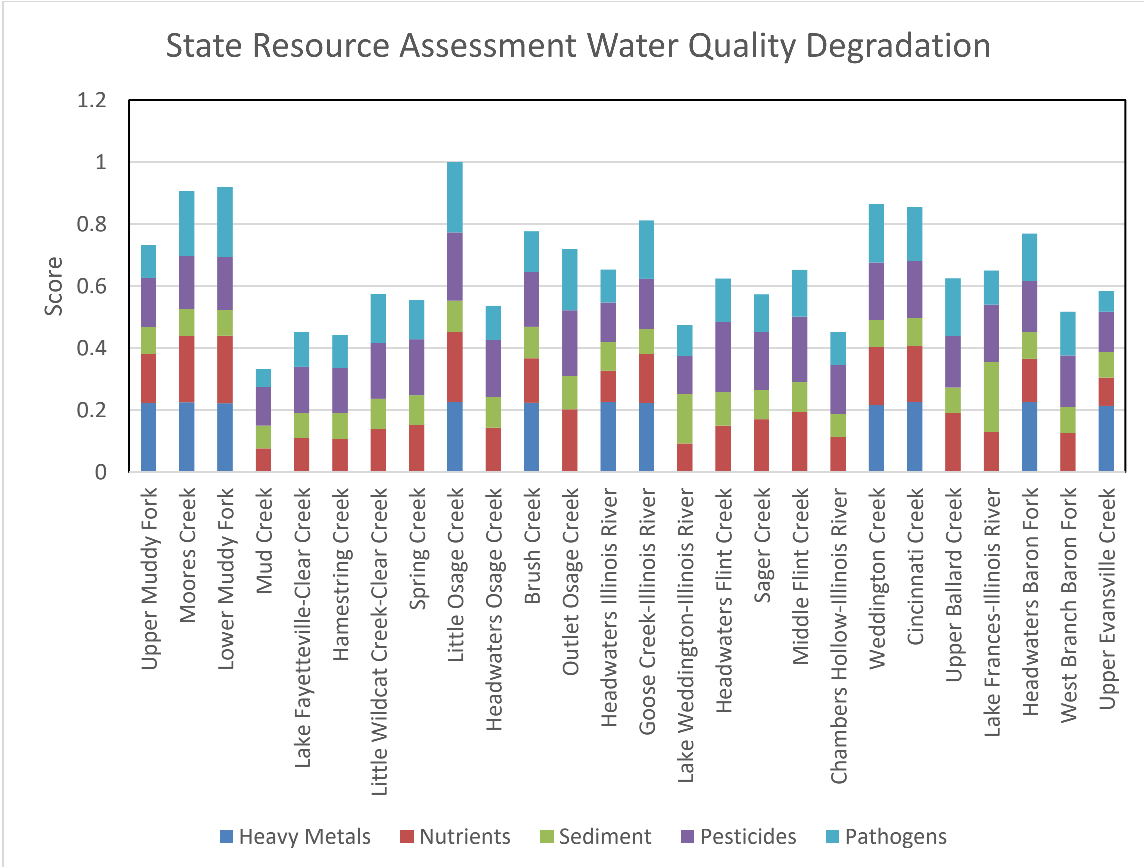

Figure 3. Summary of scores for water quality degradation concerns for Upper Illinois River sub-watersheds.

Researchers used the random forests approach and information from the 2008-2009 National Rivers and Streams Assessment to develop a predictive model of benthic condition based on local and upstream landscape features (Hill, et al. 2017). This model has been applied to the conterminous US and the results for stream segments of the National Hydrographic Dataset (NHD) are publicly available from the EPA StreamCat website (https://www.epa.gov/national-aquatic-resource-surveys/streamcat-dataset). Probability of good biological condition results were available for almost one-third of the NHD stream segments in the Upper Illinois River watershed (500 kilometers of 1,768 kilometers). A weighted average probability of good biological condition was calculated for each HUC12 by multiplying the probability of good biological condition for each stream segment, by the length of the stream segment, summing these products, and then dividing that sum by the sum of the lengths of stream segments with a probability value. Stream segments for which a probability of good biological condition was not estimated were not included in the weighted average calculation. Since our scoring approach assigns higher scores for poorer condition, we converted the probabilities of good biological condition to probabilities that condition is not good by subtracting them from one. The probabilities that biological condition is not good were used as the ranking scores for this element. These scores were not normalized to a maximum value of one because the maximum possible probability is one (1). Scores ranged from 0.55 to 0.70. In general, conditions in the Upper Illinois River watershed do not indicate that stream biological condition is likely to be good. This is in line with results from IRWP benthic surveys in this watershed (Natural State Streams LLC 2021).

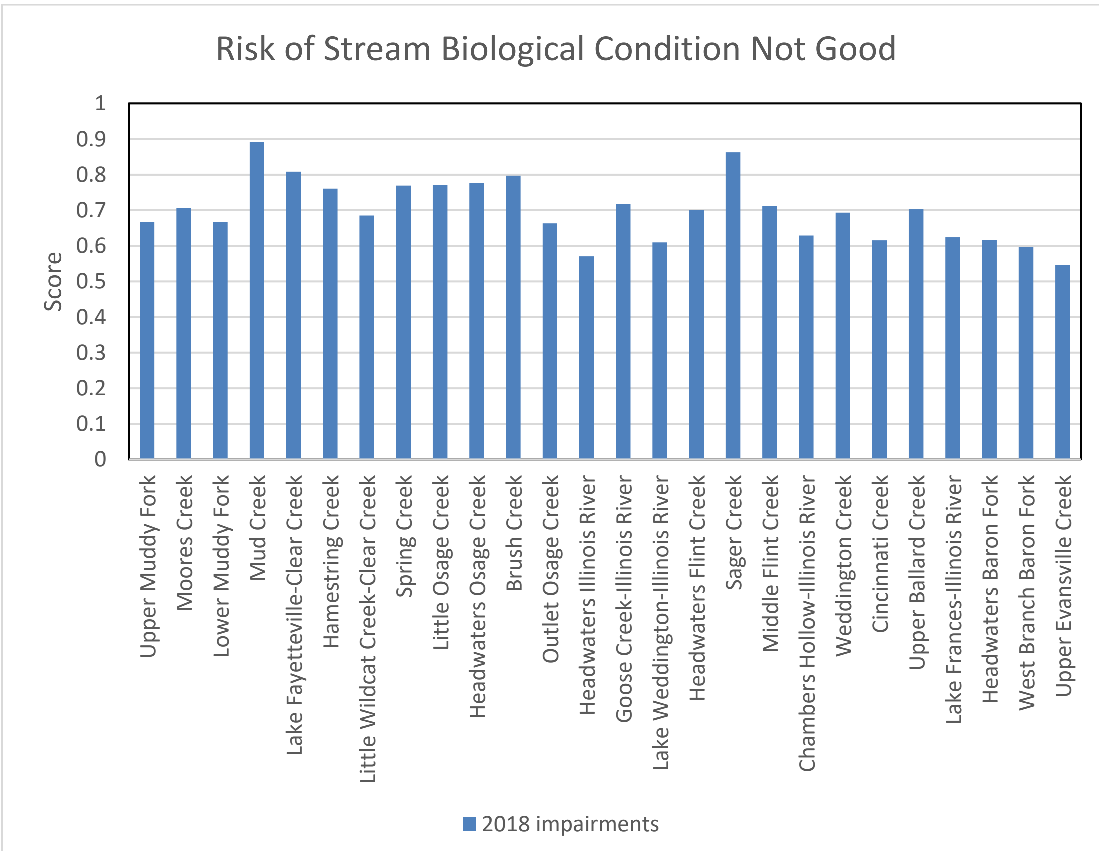

Figure 4. Summary of biological condition scores for Upper Illinois River sub-watersheds.

Ranking of HUC12 Sub-watersheds

Scores for all of the ranking characteristics were summed to identify HUC12 sub-watersheds with the greatest number of water quality-related concerns. Total scores for each of the HUC12 sub-watersheds are graphed in Figure 5. A scoring summary table for all of the HUC12 sub-watersheds is included as Attachment 1.

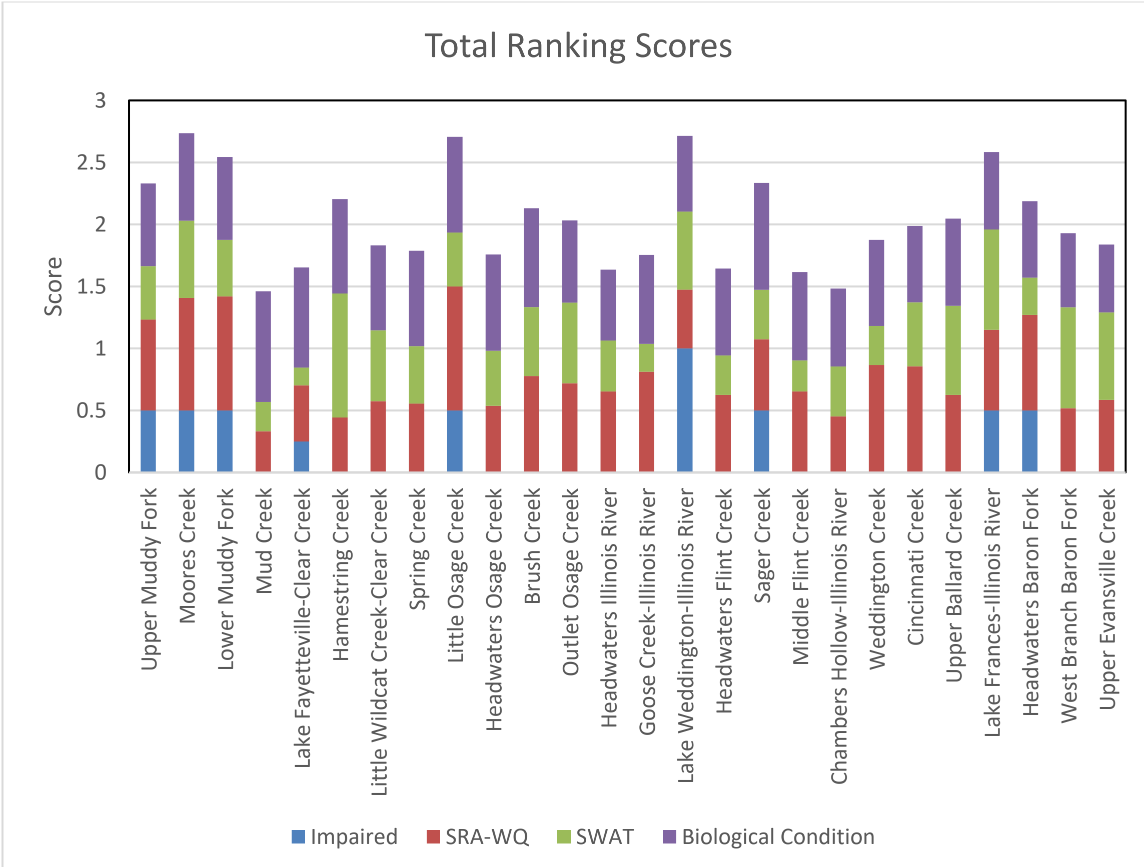

Figure 5. Total ranking scores for Upper Illinois River sub-watersheds.

The HUC12 sub-watersheds were assigned to one of three (3) categories based on the total rank scores. HUC12 sub-watersheds with total rank scores greater than 2.5 were assigned to Category 1. HUC12 sub-watersheds with total rank scores between 2.5 and 1.75 were assigned to Category 2, and HUC12 sub-watersheds with total rank scores of less than 1.75 were assigned to Category 3. Figure 6 shows the HUC12 categories. Higher total rank scores indicate that more of the data sources indicate poor water quality or a threat to water resources. Therefore, nonpoint source pollution management recommendations in this plan will focus on Category 1 sub-watersheds (Table 1).

Table 1. Recommended HUC12 sub-watersheds have total scores greater than 2.5.

HUC12 ID Number	HUC12 Name	Ranking Score
111101030102	Moores Creek	2.74
111101030103	Lower Muddy Fork	2.54
111101030302	Little Osage Creek	2.71
111101030403	Lake Wedington-Illinois River	2.71
111101030606	Lake Frances-Illinois River	2.58

This does not mean that there are no water quality issues in Category 2 and 3 sub-watersheds. For example, in the Category 3 Lake Fayetteville-Clear Creek sub-watershed, Lake Fayetteville has been classified as impaired due to high pH levels. Mud Creek sub-watershed, which is also in Category 3, had the highest probability of poor macroinvertebrate communities, and Grantz and Haggard (2023) identified increasing trends in sulfate and chloride concentrations in Mud Creek. This plan is not intended to restrict management activities in areas outside the Category 1 HUC12 sub-watersheds. Water quality management is essential, and is encouraged, throughout the Upper Illinois River watershed.

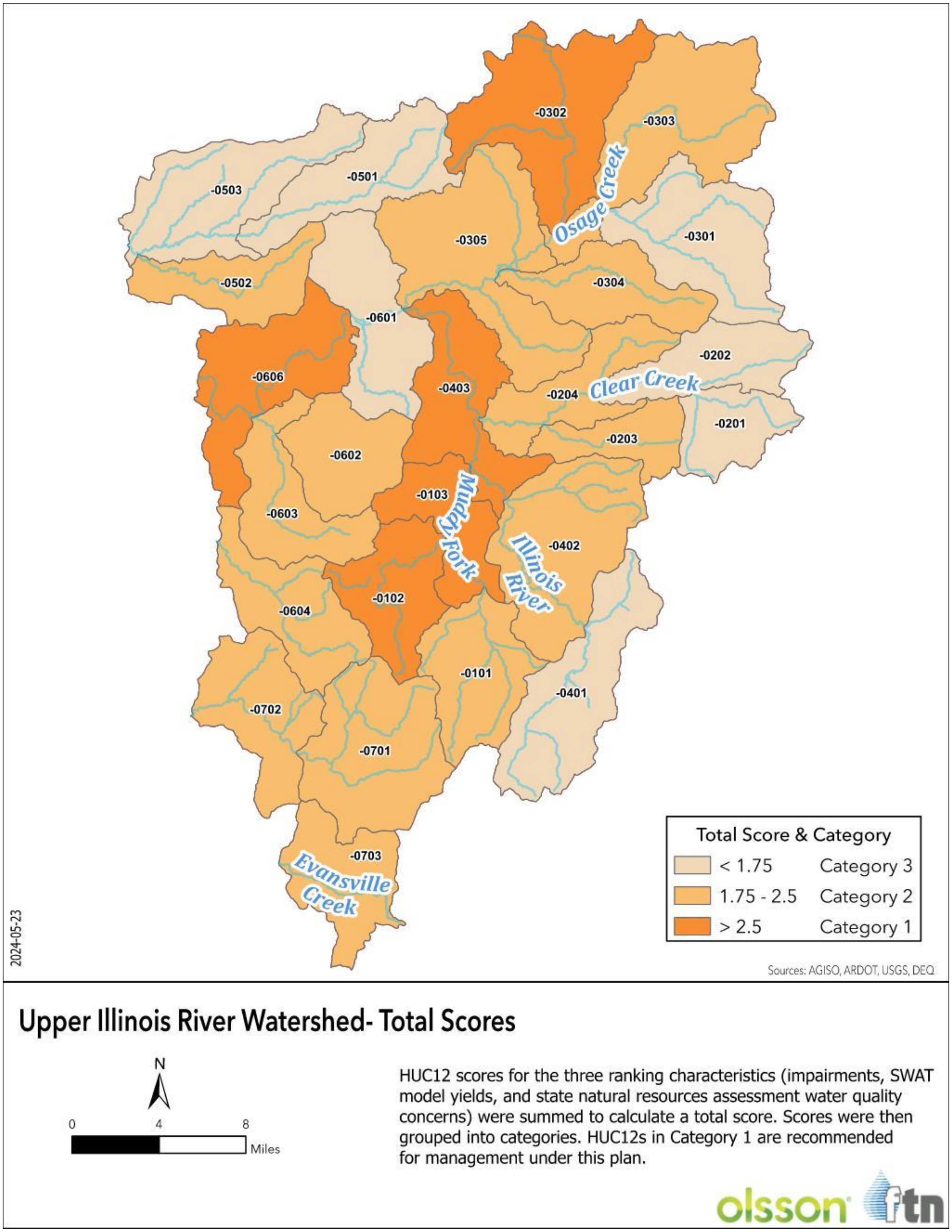

Figure 6. Ranking categories for Upper Illinois River watershed HUC12 sub-watersheds.

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Attachment 1

HUC12 Sub-watersheds Scores

HUC12 Number	HUC12 ID Name	Name of Main Stream	Scores					
			2018 303(d) Impaired	2020 303(d) Impaired	SWAT Yield	NRCS WQ Concerns	Probability stream biological condition is not good	Total
111101030101	Upper Muddy Fork	Muddy Fork	0.5	0	0.430	0.733	0.667	2.33
111101030102	Moores Creek	Moores Creek	0.5	0	0.623	0.907	0.707	2.74
111101030103	Lower Muddy Fork	Muddy Fork	0.5	0	0.455	0.920	0.668	2.54
111101030201	Mud Creek	Mud Creek	0	0	0.236	0.333	0.892	1.46
111101030202	Lake Fayetteville-Clear Creek	Clear Creek	0.25	0	0.143	0.452	0.808	1.65
111101030203	Hamestring Creek	Hamestring Creek	0	0	1.000	0.443	0.761	2.20
111101030204	Little Wildcat Creek-Clear Creek	Clear Creek	0	0	0.571	0.575	0.685	1.83
111101030301	Spring Creek	Spring Creek	0	0	0.463	0.555	0.769	1.79
111101030302	Little Osage Creek	Little Osage Creek	0.5	0	0.434	1.000	0.772	2.71
111101030303	Headwaters Osage Creek	Osage Creek	0	0	0.444	0.537	0.777	1.76
111101030304	Brush Creek	Brush Creek	0	0	0.556	0.777	0.797	2.13
111101030305	Outlet Osage Creek	Osage Creek	0	0	0.578	0.720	0.663	1.96
111101030401	Headwaters Illinois River	Illinois River	0	0	0.410	0.654	0.571	1.63

HUC12 Number	HUC12 ID Name	Name of Main Stream	Scores					
			2018 303(d) Impaired	2020 303(d) Impaired	SWAT Yield	NRCS WQ Concerns	Probability stream biological condition is not good	Total
111101030402	Goose Creek-Illinois River	Illinois River	0	0	0.225	0.812	0.717	1.75
111101030403	Lake Wedington-Illinois River	Illinois River	0.75	0.25	0.630	0.474	0.610	2.71
111101030501	Headwaters Flint Creek	Flint Creek	0	0	0.318	0.625	0.701	1.64
111101030502	Sager Creek	Sager Creek	0	0.5	0.399	0.573	0.863	2.33
111101030503	Middle Flint Creek	Flint Creek	0	0	0.250	0.653	0.712	1.62
111101030601	Chambers Hollow-Illinois River	Illinois River	0	0	0.402	0.452	0.629	1.48
111101030602	Wedington Creek	Wedington Creek	0	0	0.315	0.866	0.693	1.87
111101030603	Cincinnati Creek	Cincinnati Creek	0	0	0.516	0.856	0.615	1.99
111101030604	Upper Ballard Creek	Ballard Creek	0	0	0.719	0.625	0.703	2.05
111101030606	Lake Frances-Illinois River	Illinois River	0.5	0	0.809	0.650	0.624	2.58
111101030701	Headwaters Baron Fork	Baron Fork	0	0.5	0.300	0.770	0.617	2.19
111101030702	West Branch Baron Fork	Baron Fork	0	0	0.814	0.518	0.597	1.93
111101030703	Upper Evansville Creek	Evansville Creek	0	0	0.706	0.585	0.547	1.84

APPENDIX K
NUTRIENT AND SEDIMENT TARGET LOADS FROM SWAT OUTPUT

Target nitrogen and phosphorus yields were calculated by taking the median of yields predicted by SWAT for the Category 3 sub-watersheds. Targets were calculated for both upland yields and instream yields. Table 1 shows the data used to calculate nutrient target yields from SWAT output.

Table 1. Nutrient SWAT predicted yields for Category 3 HUC12 sub-watersheds.

HUC12 ID	HUC12 name	Instream yield, kg/ha/yr		Upland yield, kg/ha/yr	
		Nitrogen	Phosphorus	Nitrogen	Phosphorus
111101030201	Mud Creek	9.54	0.74	49.34	1.00
111101030202	Lake Fayetteville-Clear Creek	2.82	0.60	37.66	0.75
111101030301	Spring Creek	0.20	0.08	51.50	1.46
111101030401	Headwaters Illinois River	8.02	1.58	36.61	1.70
111101030501	Headwaters Flint Creek	9.74	1.27	26.77	1.27
111101030503	Middle Flint Creek	7.37	0.92	37.53	0.92
111101030601	Chambers Hollow-Illinois River	10.79	1.92	19.89	1.93
Median		8.02	0.92	37.53	1.27

SWAT model output loads were used to calculate sediment load targets for Category 1 sub-watersheds. There are 11 HUC12 sub-watersheds where turbidity was measured 2018-2022 and water quality standards were met (Table 2). The median of modeled instream and upland yields from these 11 HUC12s are used as sediment yield targets for this plan.

Table 2. Sediment SWAT predicted yields for HUC12 sub-watersheds where turbidity standards were met 2018-2022.

HUC12 ID	HUC12 name	Instream yield, ton/ha/yr	Upland yield, ton/ha/yr
111101030201	Lake Fayetteville-Clear Creek	0.35	3.24
111101030202	Mud Creek-Clear Creek	0.32	3.96
111101030301	Headwaters Osage Creek-Illinois River	0.07	3.24
111101030303	Little Osage Creek	0.54	3.69
111101030304	Brush Creek-Osage Creek	1.36	2.61
111101030305	Osage Creek-Illinois River	0.74	2.46
111101030502	Sager Creek	0.33	1.35
111101030503	Middle Flint Creek	0.48	0.90
111101030603	Cincinnati Creek	0.35	1.85
111101030606	Lake Frances-Illinois River	2.44	2.49
111101030701	Headwaters Baron Fork	0.44	1.71
Median		0.44	2.49

APPENDIX L
SWAT MODEL LOAD OUTPUT BY LAND USE

Table 1: Total Nitrogen (kg/yr) outputs from the 2023 UIRW SWAT Model by land use.

HUC12 number 11110103-	Deciduous Forest (kg/yr)	Evergreen Forest (kg/yr)	Hay/ Pasture (kg/yr)	Urban – Industrial (kg/yr)	Urban - High Density (kg/yr)	Urban - Low Density (kg/yr)	Urban - Medium Density (kg/yr)	Grand Total (kg/yr)
-0101	27,965		157,815			14,084		199,864
-0102	8,446		277,968		14,569	31,088	23,621	355,691
-0103	35,607		251,091			5,029		291,727
-0201	5,770		204,292	4,071	23,446	22,637	26,179	286,395
-0202	868		83,068	5,488	18,867	23,248	32,784	164,323
-0203	2,705		121,451		16,332	17,806	21,725	180,020
-0204	22,759		136,207			18,904		177,869
-0301	20,436		285,237	14,252	69,041	144,441	109,996	643,403
-0302	15,876		147,070	5,452	26,153	41,684	52,299	288,534
-0303	18,225		443,415		68,855	78,767	66,187	675,450
-0304	23,438		280,957		38,710	50,389	58,764	452,258
-0305	119,052		976,986			62,762		1,158,801
-0401	16,616		235,910			17,097		269,623
-0402	9,997		355,095			14,345		379,437
-0403	3,746		135,568			5,143		144,457
-0501	9,031		171,958			15,862	3,044	199,895
-0502	13,401		186,689	2,789	8,323	25,492	14,676	251,369
-0503	4,676		359,586			7,617		371,878
-0601	36,967		118,227					155,193
-0602	24,640		179,668					204,309
-0603	29,407		309,338					338,745
-0604	2,976		368,070			19,184		390,230
-0606	31,668	401	267,300			16,591		315,960
-0701	37,580		267,228			18,862		323,670
-0702	7,960	1,484	240,287			8,492		258,223
-0703	11,087		177,845					188,932

Table 2: Total Phosphorus (kg/yr) outputs from the 2023 UIRW SWAT Model by land use.

HUC12 number 11110103-	Deciduous Forest (kg/yr)	Evergreen Forest (kg/yr)	Hay/ Pasture (kg/yr)	Urban – Industrial (kg/yr)	Urban - High Density (kg/yr)	Urban - Low Density (kg/yr)	Urban - Medium Density (kg/yr)	Grand Total (kg/yr)
-0101	8,967		5,454			577		14,997
-0102	2,959		6,499		591	1,036	698	11,783
-0103	3,000		19,789			299		23,088
-0201	105		3,949	348	467	769	189	5,828
-0202	202		689	418	622	741	592	3,263
-0203	189		11,482		1,078	883	1,110	14,743
-0204	441		13,889			983		15,313
-0301	52		9,874	1,375	2,173	2,891	1,939	18,304
-0302	51		8,082	1,087	1,621	1,165	1,359	13,365
-0303	61		6,599		1,163	1,435	829	10,086
-0304	4		244		273	511	112	1,144
-0305	51		3,662			806		4,519
-0401	6,189		5,707			648		12,544
-0402	3,747		11,588			513		15,848
-0403	1,466		5,151			235		6,852
-0501	1,143		7,493			772	103	9,512
-0502	948		5,500	393	721	814	826	9,201
-0503	1,522		7,298			352		9,173
-0601	693		14,402					15,094
-0602	563		3,217					3,780
-0603	641		12,196					12,837
-0604	928		24,698			776		26,402
-0606	1,135	26	31,727			984		33,872
-0701	3,051		8,285			521		11,857
-0702	4,872	437	6,369			360		12,037
-0703	11,087		177,845					188,932

Table 3: Total Suspended Sediment (tons/yr) outputs from the 2023 UIRW SWAT Model by land use.

HUC12 number 11110103-	Deciduous Forest (tons/yr)	Evergreen Forest (tons/yr)	Hay/ Pasture (tons/yr)	Urban – Industrial (tons/yr)	Urban - High Density (tons/yr)	Urban - Low Density (tons/yr)	Urban - Medium Density (tons/yr)	Grand Total (tons/yr)
-0101	9,174		3,981			553		13,709
-0102	1,302		3,647		601	928	998	7,477
-0103	2,169		16,649			181		19,000
-0201	465		12,886	329	1,748	681	2,702	18,811
-0202	422		10,659	340	1,504	1,008	3,338	17,269
-0203	511		7,156		706	469	1,111	9,953
-0204	1,014		4,375			466		5,854
-0301	8,728		14,072	842	4,339	5,680	6,879	40,540
-0302	251		4,217	568	1,264	731	1,647	8,677
-0303	286		4,952		16,614	4,383	17,944	44,179
-0304	284		6,548		2,950	1,177	4,775	15,733
-0305	2,266		29,985			1,875		34,126
-0401	4,929		3,747			438		9,114
-0402	3,133		6,164			316		9,613
-0403	933		7,367			116		8,416
-0501	487		5,033			387	140	6,047
-0502	444		6,065	174	327	380	493	7,883
-0503	949		7,877			114		8,939
-0601	2,150		3,095					5,245
-0602	1,441		6,473					7,914
-0603	1,145		10,858					12,003
-0604	1,563		12,358			365		14,286
-0606	2,987	61	19,840			453		23,340
-0701	10,163		7,567			527		18,258
-0702	2,562	301	19,613			274		22,749
-0703	8,250		13,499					21,750

APPENDIX M
ESTIMATION OF POTENTIAL POLLUTANT LOAD REDUCTIONS THROUGH USE OF BMPS

PRACTICES AND THEIR REDUCTION EFFICIENCIES

Information has been published on the effectiveness of many of the BMPs identified in Section 4.7 for reducing selected pollutants in surface waters, including *E. Coli,* sediment, and nutrients. As part of a Gulf of Mexico Hypoxia Task Force project, Arkansas experts identified expected large-scale nutrient reduction efficiencies for selected individual and suites of agricultural BMPs often implemented in Arkansas (FTN Associates, Ltd., 2019). Load reduction efficiencies for nutrients and sediment were also identified for selected BMPs in the Beaver Lake Watershed Protection Strategy (RTI 2023). Literature reduction efficiencies for selected BMPs identified in Section 4.7 are listed in Tables 1 through 7 below by pollutant source (Literature values). Reduction efficiencies for fecal coliforms are also listed in these tables to provide guidance for E. coli reduction assumptions when E. coli reduction efficiencies are not reported in literature. Note that BMPs must be properly installed, operated, and maintained to achieve reported pollutant reduction efficiencies.

Values used to estimate load reductions from implementation of BMPs through this plan are also shown in Tables 1-7 (Calculation values). Calculation values are set only for practices that are used to estimate load reductions for Category 1 sub-watersheds. For those practices for which Arkansas nutrient reduction efficiencies have been set, the nutrient reduction calculation values were set to the values reported in FTN Associates, Ltd (2019). These values are highlighted in yellow in Tables 1 and 2. The majority of the remaining calculation values are based on the literature values. Exceptions are:

- Sediment and nutrient calculation values for prescribed grazing are also used for pasture/hay planting, based on the assumption that these two (2) practices have similar impacts on pasture condition, and pasture/hay planting would not reduce loads more than prescribed grazing.
- The E. coli calculation value for filter strips is also used for pasture/hay planting and riparian buffers.
- Sediment and E. coli calculation values for the Arkansas Pasture BMP Suite are set to the highest calculation values for the practices included in the suite.

We did not find information about the effectiveness of BMPs for reducing sulfate in runoff. Therefore, there are no calculations of the potential for reducing sulfate levels as a result of implementing BMPs. It is expected that practices that filter runoff or reduce the amount of stormwater runoff would also reduce the sulfate load from stormwater runoff.

Table 1. Literature pollutant reduction efficiency values reported for selected pasture management practices.

Practice	Efficiencies	Sediment reduction	Total Nitrogen reduction	Total Phosphorus reduction	E. coli reduction	Fecal coliform reduction
Prescribed grazing and grazing management	Literature values	60%[a], 8%[b], 30%[c], 33%[f], 25%[i]	34%[b], 9%-11%[c], 40.8[f], 10%[h], 25%[i]	24%[c], 22.7[f], 15%[h], 25%[i]	66% - 72%[b]	90-96%[b]
	Calculation values	30%	10%	15%	60%	--
Heavy use area protection	Literature values	75-98%[g], 33%[f]	86%[g], 10%[h], 18.3%[f]	50%[g], 19.3%[f], 15%[h]	No information found	92-99%[g]
Pasture/hay planting	Literature values	59%[a]	66%[a], 18.1%[f]	67%[a], 15%[f]	No information found	No information found
	Calculation values	30%	10%	15%	60%	--
Critical area planting	Literature values	42%[f]	17.5%[f]	20%[f]	No information found	No information found
Riparian forest buffer	Literature values	55%-95%[a], 40-60%[c], 60-90%[d], 53%-57%[f]	47-59%[a], 19-65%[c], 68-89%[d], 45%-48%[f], 35%[h]	53%-56%[a], 30-45%[c], 30-80%[d], 40%-46%[f], 35%[h]	No information found	No information found
	Calculation values	60%	35%	35%	60%	--
Riparian herbaceous buffer	Literature values	40-60%[c], 66-84%[d], 53%-65%[f]	13-46%[c], 50-76%[d], 34%-87%[f], 35%[h]	50-70%[c], 50-89%[d], 44%-77%[f], 35%[h], 36%[j]	No information found	21-100%[d], 70-95%[e]
	Calculation values	60%	35%	35%	60%	--

a (Merriman, Gitau, & Chauby, 2009)
b (Petersen, Redmon, & McFarland, 2011a)
c (Chesapeake Bay Program, 2022)
d (Klapproth & Johnson, 2009)
e (Koelsch, Lorimer, & Mankin, 2006)
f (TetraTech, 2018)
g (Peterson, Redmon, & McFarland, 2022)
h (FTN Associates, Ltd., 2019)
i (Pennsylvania Department of Environmental Protection, 2013)
1
j (Ashworth, et al., 2021)

Table 2. Literature pollutant reduction efficiency values reported for selected management practices used to control livestock access to streams and/or riparian areas.

Practice	Efficiencies	Sediment reduction	Total Nitrogen reduction	Total Phosphorus reduction	E. coli reduction	Fecal coliform reduction
Controlled stream access*	Literature values	82%-84%[a], 8%-82%[b], 60%[f], 40%[i]	34%[b], 10%[g]	75%[a], 76%[b], 15%[g], 60%[j]	37%-46%[h], 46%[d]	30%-94%[h], 44-52%[d]
	Calculation values	50%	10%	15%	40%	--
Watering facility	Literature values	38%-96%[a], 10%[c], 19%[f]	-27%-56%[a], 5%[c], 10%[g]	-10%-97%[a], 8%[c], 15%[g]	85%[e]	51-94%[e]
	Calculation values	30%	10%	15%	70%	

* Controlled stream access may be complete exclusion, or development of a stream crossing.
a (Merriman, Gitau, & Chauby, 2009)
b (Peterson, Redmon, & McFarland, ESP-409, 2011b)
c (Chesapeake Bay Program, 2022)
d (Peterson, Redmon, & McFarland, ESP-416, 2011d)
e (Peterson, Redmon, & McFarland, ESP-412, 2011e)
f (TetraTech, 2018)
g (FTN Associates, Ltd., 2019)
h (Peterson, Redmon, & McFarland, ESP-411, 2011c)
i (Owens, Edwards, & Keuren, 1996)
j (Anderson, et al., 2020)

Table 3. Literature pollutant reduction efficiency values reported for selected practices applicable to poultry operations.

Practice	Efficiencies	Sediment reduction	Total Nitrogen reduction	Total Phosphorus reduction	E. coli reduction	Fecal coliform reduction
Filter strip	Literature values	0-99%[a], 56%[b], 41-100%[c], 52%[d]	1-93%[a], 20%[b], 14%[d]	2-93%[a], 54%[b], 27-96%[c], increase[d]	58-99%[c]	30-100%[c]
	Calculation values	50%	15%	50%	60%	--
Grassed waterway	Literature values	17%[a], 52%[d]	28%-36%[e], 11%[d]	24%-32%[e], increase[d]	0[d]	
	Calculation values	30%	25%	25%	0	--
Vegetated treatment area	Literature values	70-90% of solids[f]	>85%, average 70%[f]	12-97%, average 70%[f]	No information found	64%-87%[f]
	Calculation values	80%	70%	70%	50%	
Manure stacking shed (poultry)	Literature values	None expected	52%[a], 14%[g], 35%[h]	58%[a], 14%[g], 54%[h]	97%-99%[h]	44%-99%[h]
	Calculation values	0	15%	15%	90%	--
Roof runoff structure	Literature values	40%[b], 40%[g]	20%[b], 10%-20%[g]	20%[b], 10%-20%[g]	No information found	No information found
	Calculation values	40%	15%	15%	0	--
Animal mortality facility	Literature values	None expected	14%[g]	14%[g]	No information found	No information found
Composting facility	Literature values	None expected	10%-33%[b]	No information found	No information found	No information found

a (Merriman, Gitau, & Chauby, 2009)
b (Chesapeake Bay Program, 2022)
f (Koelsch, Lorimer, & Mankin, 2006)
e (Virginia Department of Environmental Quality, 2013)
c (Peterson, Redmon, & McFarland, ESP-405, 2011f)
d (Clary, Jones, Leisenring, Hobson, & Strecker, 2020), calculated from reported median inflow and outflow concentrations
h (Peterson, Redmon, & McFarland, ESP-404, 2011g)
g (Pennsylvania Department of Environmental Protection, 2013)

Table 4. Literature pollutant reduction efficiency values reported for Environmentally Sensitive Road Maintenance practices.

Practice		Sediment reduction	Nitrogen reduction	Phosphorus reduction	E. coli reduction	Fecal coliform reduction
Environmentally sensitive road maintenance (ESRM)	Literature values	80-94%[a], 31-94%[b]	None expected	None expected	None expected	None expected

a (The Nature Concservancy, 2017)
b (Sheetz & Bloser, 2008)

Table 5. Literature pollutant reduction efficiency values reported for properly functioning septic systems.

Practice		Sediment reduction	Nitrogen reduction	Phosphorus reduction	E. coli reduction	Fecal coliform reduction
Fix failing septic systems	Literature values	None expected	10%-40%[a]	85%-95%[a]	73.915% – 99.99%[b]	99%-99.9%[a]
	Calculation values	0	25%	90%	90%	--

b (Wang, Zhu, & Mao, 2021)
a (Otis, et al., 2002)

Table 6. Literature pollutant reduction efficiency values reported for selected low impact development practices.

Practice		Sediment reduction	Nitrogen reduction	Phosphorus reduction	E. coli reduction	Fecal coliform reduction
Bioretention basin/rain garden	Literature values	55-90%[b], 90%[c], 77%[d], 87%[f]	64-90%[a], 25-80%[b], 75%[c], 24%[d], 96%[f]	55-90%[a], 45-85%[b], 75%[c], increase[d], 95%[f]	43%[d]	90%[c]
	Calculation values	75%	25%	0	40%	--
Permeable pavement	Literature values	55%-85%[b], 71%[d]	59%-81%[a], 10%-80%[b], increase[e]	59%-81%[a], 20%-80%[b], 41%[d]	No information found	No information found
	Calculation values	60%	60%	60%	0	--
Green streets	Literature values	No information found	No information found	53%-90%[g]	No information found	No information found
Hydrodynamic separation devices	Literature values	40%[d]	2%[d]	23%[d]	29%[d]	increase[d]
Media filters	Literature values	84%[d]	16%[d]	45%[d]	62%[d]	50%[d]

a (Virginia Department of Environmental Quality, 2013)
b (Simpson & Weammert, 2009)
c (Un, 2016)
d (Clary, Jones, Leisenring, Hobson, & Strecker, 2020)
e (The Water Research Foundation, American Society of Civil Engineers, US Environmental Protection Agency, US Department of Transportation, Geosyntec, Wright Water Engineers, Inc., 2024)
f (Roark, 2014)
g (Wood, 2018)

Table 7. Literature pollutant reduction efficiency values reported for practices to address streambank erosion.

Practice	Efficiencies	Sediment reduction	Nitrogen reduction	Phosphorus reduction	E. coli reduction	Fecal coliform reduction
Streambank stabilization	Literature values	58%-75%[a]	15%-75%[a]	22%-75%[a]	Not expected	Not expected
	Calculation values	60%	15%	20%	0	--
Stream restoration	Literature values	Near 100%[b], 58%-95%[c]	Near 100%[b], 15%-95%[c]	Near 100%[b], 22%-95%[c]	Not expected	Not expected
	Calculation values	75%	55%	60%	0	--

b (Van Eps, 2014)
a (TetraTech, 2018)
c (RTI, 2023)

Load reduction estimates

In the following subsections potential pollutant reductions from implementation of selected practices are estimated for Category 1 sub-watersheds. These estimates use the calculation reduction efficiency values from Tables 1-7. Percent load reductions are calculated by multiplying the calculation reduction efficiency by the assumed portion of the pollutant load from the treated source, and the portion of the source being treated. Table 8 lists the portion of upland loads from the Category 1 sub-watersheds modeled as coming from pastures. Table 9 lists the portion of upland loads from the Category 1 sub-watersheds modeled as coming from developed land.

Table 8. Portions of modeled upland load from pasture (from SWAT output).

Pollutant	Moores Creek (111101030102)	Lower Muddy Fork (111101030103)	Little Osage Creek (111101030302)	Lake Wedington-Illinois River (111101030403)	Lake Frances-Illinois River (111101030606)
Total nitrogen	78%	86%	51%	94%	85%
Total phosphorus	55%	86%	60%	75%	94%
Sediment	49%	88%	49%	88%	85%

Table 9. Portions of modeled upland load from developed land (from SWAT output).

Pollutant	Moores Creek (111101030102)	Lower Muddy Fork (111101030103)	Little Osage Creek (111101030302)	Lake Wedington-Illinois River (111101030403)	Lake Frances-Illinois River (111101030606)
Total nitrogen	19%	2%	44%	4%	5%
Total phosphorus	20%	1%	39%	3%	3%
Sediment	34%	1%	49%	1%	2%

A recent study of streambank erosion in the Upper Illinois River watershed estimated that streambank erosion contributes 102,822 tons of sediment and 154,233 pounds of phosphorus per year (Natural State Streams 2021). However, comparisons of estimates of sediment and nutrient loads from streambank erosion reported by the Watershed Conservation Resource Center (2020, 2022) suggest that phosphorus contributions from streambank erosion may be around 80,000 pounds per year, and nitrogen contributions may be around 200,000 per year. Grantz and Haggard (2023) estimate that annual Illinois River TSS loads at Interstate 59 average 243,442 tons per year, total phosphorus loads average 518,028 pounds per year, and total nitrogen loads average 3,3709,300 pounds per year. A comparison of the bank erosion sediment load to the TSS load suggests that streambank erosion may contribute around 40 percent of sediment load. A comparison of the above estimated nutrient loads from streambank erosion to Illinois River loads, suggests that streambank erosion may account for between 15 percent and 30 percent of phosphorus and five (5) percent of nitrogen load. In calculating load reductions from streambank stabilization or restoration, we assume the following portions of sub-watershed loads come from streambank erosion: 40 percent of sediment, 20 percent of phosphorus, and five (5) percent of nitrogen.

When a practice reduction efficiency is higher than the target load reduction, the portion of the source that needs to be treated to achieve the target load reduction is calculated by dividing the load reduction target value by the product of the portion of the pollutant load from the source and the practice reduction efficiency. When a practice reduction efficiency is less than the target load reduction, the estimate of the load reduction from implementing the practice is calculated assuming 100 percent of the source is treated. The results of the analysis of potential pollutant load reductions from implementation of selected practices indicate that it will not be possible to achieve the target load reductions using a single practice or approach.

Moores Creek

Due to the lack of recent water quality data, unknown impairment status, and conflicting results from the SWAT model and streambank erosion monitoring (see Section 4.6.1), the potential for meeting proposed sediment and phosphorus target load reductions was not evaluated. The potential for meeting the proposed 30 percent instream nitrogen load reduction was evaluated using agricultural conservation practices, i.e., pasture practices, reducing livestock time in streams, and poultry operation practices. Reduction calculations are shown in Table 10. Table 10 also shows potential reductions in phosphorus, sediment, and E. coli loads, and runoff volume, associated with practices that could be implemented to reduce nitrogen load. Assumptions used in these calculations are:

- A 30 percent reduction in upland nitrogen sources will result in a 30 percent reduction in instream nitrogen.

- Pasture, livestock, and poultry operation sources treated using conservation practices contribute 78 percent of the instream nitrogen (see Table 8).
- Septic systems remediated contribute 19 percent of the instream nitrogen (developed area contribution from Table 9).
- Reduction efficiencies of practices are the calculation values identified in Tables 1-7.

Table 10. Moores Creek sub-watershed potential load reductions from implementation of management practices.

Associated Reductions													
	Nitrogen reduction				Phosphorus			Sediment			E. coli		
Practices	Assumed portion of nitrogen load from treated source	Assumed nitrogen reduction efficiency	Portion of source to treat to meet target nitrogen reduction	Potential nitrogen load reduction	Assumed portion phosphorus load	Assumed phosphorus reduction efficiency	Potential phosphorus load reduction	Assumed portion sediment load	Assumed sediment reduction efficiency	Potential sediment load reduction	Assumed portion E.coli load	Assumed E.coli reduction	Potential E.coli reduction
Prescribed grazing	0.78	0.10	1.00	8%	0.55	0.15	8%	0.49	0.30	15%	1	0.60	60%
Watering facility	0.78	0.10	1.00	8%	0.55	0.15	8%	0.49	0.30	15%	1	0.70	70%
Access control	0.78	0.10	1.00	8%	0.55	0.15	8%	0.49	0.50	25%	1	0.40	40%
Restore riparian buffer	0.78	0.35	1.00	27%	0.55	0.35	19%	0.49	0.60	29%	1	0.55	55%
Pasture/hay planting	0.78	0.10	1.00	8%	0.55	0.15	8%	0.49	0.60	29%	1	0.30	30%
Waste storage	0.78	0.15	1.00	12%	0.55	0.15	8%	0.49	0.00	0%	1	0.90	90%
Grassed waterway	0.78	0.25	1.00	20%	0.55	0.25	14%	0.49	0.30	15%	1	0	0%
Roof runoff structure	0.78	0.15	1.00	12%	0.55	0.15	8%	0.49	0.40	20%	1	0	0%
Filter strip	0.78	0.15	1.00	12%	0.55	0.50	28%	0.49	0.50	25%	1	0	0%
Remediate failing septic systems	0.19	0.25	1.00	5%	0.20	0.90	18%	0.34	0.00	0%	1	0.90	90%

Lower Muddy Fork

The SWAT model results indicate that over 85% of upland nitrogen, phosphorus, and sediment yield comes from pasture in the Lower Muddy Fork sub-watershed. The one monitored streambank in this sub-watershed is classified as having a very high erosion rate, with a modeled erosion rate/land loss of over three (3) feet/year (Natural State Streams LLC 2021). The potential for meeting the proposed total phosphorus, total nitrogen, and sediment reduction targets for the Lower Muddy Fork sub-watershed was evaluated using agricultural practices and streambank erosion practices. Because the largest load reduction target is for phosphorus, the potential for meeting this target was evaluated first. Load reduction calculations are shown in Table 11. Table 11 also shows potential reductions in nitrogen, sediment, and E. coli loads associated with practices that could be implemented to reduce phosphorus load. Assumptions used in these calculations are:

- Reductions in upland yields will result in the same reduction in instream yield.
- Pasture, livestock, and poultry operation sources treated using conservation practices contribute 86 percent of nutrient yield and 88% of sediment yield (Table 8).
- Streambank erosion contributes 20 percent of instream phosphorus load, five (5) percent of nitrogen load, and 40 percent of sediment load.
- Septic systems remediated contribute one (1) percent of phosphorus and two (2) percent of nitrogen loads (developed area contribution from Table 9).
- Reduction efficiencies of practices are the calculation values from Tables 1-7.

Table 11. Lower Muddy Fork Creek sub-watershed potential load reductions from implementation of management practices.

	Associated Reductions												
	Phosphorus Reduction				Nitrogen Reduction			Sediment reduction			E. coli reduction		
Practices	Assumed portion phosphorus load from treated source	Assumed phosphorus reduction efficiency	Portion of source to treat to meet target nitrogen reduction	Potential phosphorus load reduction	Assumed portion nitrogen load	Assumed nitrogen reduction efficiency	Potential nitrogen load reduction	Assumed portion sediment load	Assumed sediment reduction efficiency	Potential sediment load reduction	Assumed portion E.coli load	Assumed E.coli reduction	Potential E.coli reduction
Prescribed grazing	0.86	0.15	1.00	13%	0.86	0.10	9%	0.88	0.30	26%	1	0.60	60%
Watering facility	0.86	0.15	1.00	13%	0.86	0.10	9%	0.88	0.30	26%	1	0.70	70%
Access control	0.86	0.15	1.00	13%	0.86	0.10	9%	0.88	0.50	44%	1	0.40	40%
Restore riparian buffer	0.86	0.35	1.00	30%	0.86	0.35	30%	0.88	0.60	53%	1	0.55	55%
Pasture/hay planting	0.86	0.15	1.00	13%	0.86	0.10	9%	0.88	0.60	53%	1	0.30	30%
Waste storage	0.86	0.15	1.00	13%	0.86	0.15	13%	0.88	0.00	0%	1	0.90	90%
Roof runoff structure	0.86	0.15	1.00	13%	0.86	0.15	13%	0.88	0.40	35%	1	0.00	0%
Grassed waterway	0.86	0.25	1.00	22%	0.86	0.25	22%	0.88	0.30	26%	1	0	0%
Filter strip	0.86	0.50	1.00	43%	0.86	0.15	13%	0.88	0.50	44%	1	0.6	60%
Remediate failing septic systems	0.01	0.90	1.00	1%	0.02	0.25	1%	0.01	0.00	0%	1	0.90	90%
Bank stabilization	0.20	0.15	1.00	3%	0.05	0.15	1%	0.40	0.60	24%	0	0	--
Stream restoration	0.20	0.60	1.00	12%	0.05	0.55	3%	0.40	0.75	30%	0	0	--

Little Osage Creek

Given the nonpoint sources present in Little Osage Creek sub-watershed, the potential for meeting the proposed load reduction targets was evaluated using agricultural practices, streambank erosion practices, and low impact development practices. Because the largest load reduction target is for nitrogen, the potential for meeting this target was evaluated first. Load reduction calculations are shown in Table 12. Table 12 also shows potential reductions in phosphorus, sediment, and E. coli loads associated with practices that could be implemented to reduce nitrogen load. Assumptions used in these calculations are:

- Reductions in upland yields will result in the same reduction in instream yield.
- Pasture, livestock, and poultry operation sources treated using conservation practices contribute 51 percent of nitrogen, 60 percent of phosphorus, and 49 percent of sediment loads (Table 8).
- Streambank erosion contributes 5 percent of nitrogen load, 20 percent of phosphorus load, and 40 percent of sediment load.
- Development sources treated using conservation practices contribute 44 percent of nitrogen, 39 percent of phosphorus, and 49 percent of sediment loads (Table 9).
- Reduction efficiencies of practices are the calculation values from Tables 1-7.

Table 12. Little Osage Creek sub-watershed potential load reductions from implementation of management practices.

Associated Reductions													
	Nitrogen reduction				Phosphorus			Sediment			E. coli		
Practices	Assumed portion of nitrogen load from treated source	Assumed nitrogen reduction efficiency	Portion of source to treat to meet target nitrogen reduction	Potential nitrogen load reduction	Assumed portion phosphorus load	Assumed phosphorus reduction efficiency	Potential phosphorus load reduction	Assumed portion sediment load	Assumed sediment reduction efficiency	Potential sediment load reduction	Assumed portion E.coli load	Assumed E.coli reduction	Potential E.coli reduction
Prescribed grazing	0.51	0.10	1.00	5%	0.60	0.15	9%	0.49	0.30	15%	1	0.60	60%
Watering facility	0.51	0.10	1.00	5%	0.60	0.15	9%	0.49	0.30	15%	1	0.70	70%
Access control	0.51	0.10	1.00	5%	0.60	0.15	9%	0.49	0.50	25%	1	0.40	40%
Restore riparian buffer	0.51	0.35	1.00	18%	0.60	0.35	21%	0.49	0.60	29%	1	0.55	55%
Bank stabilization	0.05	0.15	1.00	1%	0.20	0.15	3%	0.40	0.60	24%	0	0.00	--
Stream restoration	0.05	0.55	1.00	3%	0.20	0.60	12%	0.40	0.75	30%	0	0.00	--
Pasture/hay planting	0.51	0.10	1.00	5%	0.60	0.15	9%	0.49	0.60	29%	1	0.30	30%
Waste storage	0.51	0.15	1.00	8%	0.60	0.15	9%	0.49	0.00	0%	1	0.90	90%
Roof runoff structure	0.51	0.15	1.00	8%	0.60	0.15	9%	0.49	0.40	20%	1	0.00	0%
Grassed waterway	0.51	0.25	1.00	13%	0.60	0.25	15%	0.49	0.30	15%	1	0.00	0%
Filter strip	0.51	0.15	1.00	8%	0.60	0.50	30%	0.49	0.50	25%	1	0.60	60%
Remediate failing septic systems	0.44	0.25	1.00	11%	0.39	0.90	35%	0.49	0.00	0%	1	0.90	90%
Restore riparian buffer	0.44	0.35	1.00	15%	0.39	0.35	14%	0.49	0.60	29%	1	0.55	55%
Rain garden	0.44	0.25	1.00	11%	0.39	0.00	0%	0.49	0.75	37%	1	0.40	40%
Permeable pavement	0.44	0.60	1.00	26%	0.39	0.60	23%	0.49	0.60	29%	1	0.00	0%
Media filters	0.44	0.15	1.00	7%	0.39	0.45	18%	0.49	0.80	39%	1	0.60	60%
Hydrodynamic separation devices	0.44	0.02	1.00	1%	0.39	0.20	8%	0.49	0.40	20%	1	0.25	25%

Lake Wedington-Illinois River

Given the nonpoint sources present in Lake Wedington-Illinois River sub-watershed, the potential for meeting the proposed load reduction targets was evaluated using agricultural practices, and streambank erosion practices. Because the largest load reduction target is for sediment, the potential for meeting this target was evaluated first. Load reduction calculations are shown in Table 13. Table 13 also shows potential reductions in nitrogen, phosphorus, and E. coli loads associated with practices that could be implemented to reduce sediment load. Table 14 shows nutrient and E. coli load reduction potential for practices that do not reduce sediment loads, when applied to meet the phosphorus load reduction target for this sub-watershed. Assumptions used in these calculations are:

- Reductions in upland yields will result in the same reduction in instream yield.
- Pasture, livestock, and poultry operation sources treated using conservation practices contribute 94 percent of nitrogen, 75 percent of phosphorus, and 88 percent of sediment loads (Table 8).
- Streambank erosion contributes 40 percent of sediment load, five (5) percent of nitrogen load, and 20 percent of phosphorus load.
- Septic systems remediated contribute three (3) percent of phosphorus and sediment, and four (4) percent of nitrogen loads (developed area contribution from Table 9).
- Reduction efficiencies of practices are the calculation values from Tables 1-7.

Table 13. Lake Wedington-Illinois River sub-watershed potential load reductions from implementation of management practices to reduce sediment load.

Associated Reductions													
	Sediment Reduction				Phosphorus			Nitrogen Reduction			E. coli		
Practices	Assumed portion of sediment load from treated source	Assumed sediment reduction efficiency	Portion of source to treat to meet target sediment reduction	Potential sediment load reduction	Assumed portion phosphorus load	Assumed phosphorus reduction efficiency	Potential phosphorus load reduction	Assumed portion nitrogen load	Assumed nitrogen reduction efficiency	Potential nitrogen load reduction	Assumed portion E.coli load	Assumed E.coli reduction	Potential E.coli reduction
Prescribed grazing	0.88	0.30	1.00	26%	0.75	0.15	11%	0.94	0.10	9%	1	0.60	60%
Watering facility	0.88	0.30	1.00	26%	0.75	0.15	11%	0.94	0.10	9%	1	0.70	70%
Access control	0.88	0.50	1.00	44%	0.75	0.15	11%	0.94	0.10	9%	1	0.40	40%
Restore riparian buffer	0.88	0.60	1.00	53%	0.75	0.35	26%	0.94	0.35	33%	1	0.55	55%
Pasture/hay planting	0.88	0.60	1.00	53%	0.75	0.15	11%	0.94	0.10	9%	1	0.30	30%
Roof runoff structure	0.88	0.40	1.00	35%	0.75	0.15	11%	0.94	0.15	14%	1	0.00	0%
Grassed waterway	0.88	0.30	1.00	26%	0.75	0.25	19%	0.94	0.25	24%	1	0	0%
Filter strip	0.88	0.50	1.00	44%	0.75	0.50	38%	0.94	0.15	14%	1	0.6	60%
Bank stabilization	0.40	0.60	1.00	24%	0.20	0.15	3%	0.05	0.15	1%	1	0	0%
Stream restoration	0.40	0.75	1.00	30%	0.20	0.60	12%	0.05	0.55	3%	1	0	0%
Remediate failing septic systems	0.01	0.00	1.00	0%	0.20	0.90	18%	0.05	0.25	1%	1	0.9	90%

Table 14. Lake Wedington-Illinois River sub-watershed potential load reductions from implementation of management practices to reduce phosphorus load.

					Associated Reductions					
	Phosphorus Reduction				Nitrogen Reduction			E. coli reduction		
Practices	Assumed portion phosphorus load from treated source	Assumed phosphorus reduction efficiency	Portion of source to treat to meet target nitrogen reduction	Potential phosphorus load reduction	Assumed portion nitrogen load	Assumed nitrogen reduction efficiency	Potential nitrogen load reduction	Assumed portion E.coli load	Assumed E.coli reduction	Potential E.coli reduction
Waste storage	0.75	0.15	1.00	11%	0.94	0.15	14%	1	0.90	90%
Remediate failing septic systems	0.03	0.90	1.00	3%	0.04	0.25	1%	1	0.90	90%

Lake Frances-Illinois River

Given the nonpoint sources present in Lake Frances-Illinois River sub-watershed, the potential for meeting the proposed load reduction targets was evaluated using agricultural practices and streambank erosion practices. Because the largest load reduction target is for sediment, the potential for meeting this target was evaluated first. Load reduction calculations are shown in Table 15. Table 15 also shows potential reductions in nitrogen, phosphorus, and E. coli loads, and runoff volume, associated with practices that could be implemented to reduce sediment load. Table 16 shows nutrient and E. coli load reduction potential for practices that do not reduce sediment loads, when applied to meet the phosphorus load reduction target for this sub-watershed. Assumptions used in these calculations are:

- Reductions in upland yields will result in the same reduction in instream yield.
- Pasture, livestock, and poultry operation sources treated using conservation practices contribute 85 percent of sediment, 94 percent of phosphorus, and 85 percent of nitrogen loads (Table 8).
- Streambank erosion contributes 40 percent of sediment load, five (5) percent of nitrogen load, and 20 percent of phosphorus load.
- Septic systems remediated contribute three (3) percent of phosphorus and sediment, and five (5) percent of nitrogen loads (developed area contribution from Table 9).
- Reduction efficiencies of practices are the calculation values from Tables 1-7.

Table 15. Lake Frances-Illinois River sub-watershed potential load reductions from implementation of management practices to reduce sediment load.

Associated Reductions													
	Sediment Reduction				Phosphorus			Nitrogen Reduction			E. coli		
Practices	Assumed portion of sediment load from treated source	Assumed sediment reduction efficiency	Portion of source to treat to meet target sediment reduction	Potential sediment load reduction	Assumed portion phosphorus load	Assumed phosphorus reduction efficiency	Potential phosphorus load reduction	Assumed portion nitrogen load	Assumed nitrogen reduction efficiency	Potential nitrogen load reduction	Assumed portion E.coli load	Assumed E.coli reduction	Potential E.coli reduction
Prescribed grazing	0.85	0.30	1.00	26%	0.94	0.15	14%	0.85	0.10	9%	1	0.60	60%
Watering facility	0.85	0.30	1.00	26%	0.94	0.15	14%	0.85	0.10	9%	1	0.70	70%
Access control	0.85	0.50	1.00	43%	0.94	0.15	14%	0.85	0.10	9%	1	0.40	40%
Restore riparian buffer	0.85	0.60	1.00	51%	0.94	0.35	33%	0.85	0.35	30%	1	0.55	55%
Pasture/hay planting	0.85	0.60	1.00	51%	0.94	0.15	14%	0.85	0.10	9%	1	0.30	30%
Roof runoff structure	0.85	0.40	1.00	34%	0.94	0.15	14%	0.85	0.15	13%	1	0.00	0%
Grassed waterway	0.85	0.30	1.00	26%	0.94	0.25	24%	0.85	0.25	21%	1	0	0%
Filter strip	0.85	0.50	1.00	43%	0.94	0.50	47%	0.85	0.15	13%	1	0.6	60%
Bank stabilization	0.40	0.60	1.00	24%	0.20	0.15	3%	0.05	0.15	1%	1	0	0%
Stream restoration	0.40	0.75	1.00	30%	0.20	0.60	12%	0.05	0.55	3%	1	0	0%
Remediate failing septic systems	0.02	0.00	1.00	0%	0.20	0.90	18%	0.05	0.25	1%	1	0.9	90%

Table 16. Lake Frances-Illinois River sub-watershed potential load reductions from implementation of management practices to reduce phosphorus load.

					Associated Reductions					
	Phosphorus Reduction				Nitrogen Reduction			E. coli reduction		
Practices	Assumed portion phosphorus load from treated source	Assumed phosphorus reduction efficiency	Portion of source to treat to meet target nitrogen reduction	Potential phosphorus load reduction	Assumed portion nitrogen load	Assumed nitrogen reduction efficiency	Potential nitrogen load reduction	Assumed portion E.coli load	Assumed E.coli reduction	Potential E.coli reduction
Waste storage	0.94	0.15	1.00	14%	0.85	0.15	13%	1	0.90	90%
Remediate failing septic systems	0.03	0.90	1.00	3%	0.05	0.25	1%	1	0.90	90%

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APPENDIX N
ESTIMATION OF COSTS FOR IMPLEMENTING BMPS IN CATEGORY 1 SUB-WATERSHEDS

1. INTRODUCTION

This appendix describes how costs were estimated for implementing BMPs to achieve target nutrient and sediment loads. Cost estimates were calculated by multiplying an assumed unit cost for a practice by the number of units of the practice to be implemented. Unit costs used in these calculations are discussed in Section 2. The units of practices to be implemented in the Category 1 sub-watersheds are derived in Section 3. Section 4 presents the cost estimate calculations for the Category 1 sub-watersheds.

2. ASSUMED COST PER UNIT TREATED

The cost of implementing BMPs to reduce nonpoint source pollution can be variable, depending on materials markets and site conditions (e.g., slope, soil type). Table 1 lists available cost information for selected BMPs identified in Section 4.7. While NRCS EQIP reimbursement allocations do not reflect the actual cost of implementing the practice, they provide an idea of relative costs of the shown BMPs. In addition, the Illinois River Watershed Partnership reports that costs for septic tank remediation projects through their Septic Tank Remediation Program have ranged from \$2,500.00 to almost \$500,000.00 with an average around \$11,000.00 (44 projects 2021-2022) (L. Kindberg, IRWP, personal communication 2/10/2023).

Table 1. EQIP reimbursements and reported implementation costs for selected nonpoint source pollution BMPs applicable in the Upper Illinois River watershed.

Practice (NRCS ID Number)	Unit	2024 EQIP (non-HU[*]) 75% reimbursement per unit[a]	Unit Costs from Other Sources	Assumed Cost for Calculations
Fence (382)	Feet	\$1.47-\$3.49	\$2.15-\$2.60[b], \$0.23-\$2.54[j]	\$4.00
Watering facility <5,000 gallons (614)	Gallons	\$1.62-\$4.62	--	\$1,200
Watering facility, fountain (614)	Each	\$1,184.17	\$2,000-\$10,000[b]	
Watering facility (614)	Each	-	\$134.20-\$1,335.69[j]	
Livestock pipeline (516)	Feet	\$1.97-\$4.72	--	
Stream crossing (578)	Square feet	\$5.75-\$58.16	\$243-\$7,545 each[j]	\$3,000
Riparian forest buffer plants (391)	Each	\$0.91-\$2.01	--	\$800
Hardwood riparian forest buffer with forgone pasture income (391)	Acres	\$367.02-\$432.45	--	
Riparian forest buffer establishment & maintenance (391)	Acres	--	\$218- \$7,112[b-e]	

Practice (NRCS ID Number)	Unit	2024 EQIP (non-HU[*]) 75% reimbursement per unit[a]	Unit Costs from Other Sources	Assumed Cost for Calculations
Riparian herbaceous buffer (390)	Acres	$219.54-$280.62	$168- $400[b]	$280
Prescribed grazing, medium intensity (528)	Acres	$31.60	$30-$70[f], $14.27-$56.78[j]	$40
Grazing management, design & implementation, <501 ac (159)	Each	$1,254.51 - $1,568.14	--	
Filter strip (393)	Acres	$165.42-$209.74	$305.81[j], $4 per foot[m]	$250
Filter strip with forgone income (393)	Acres	$519.95-$564.27	--	
Grassed waterway (412)	Acres	$1,505.50	$17-$2,879[j]	$2,000
Bioretention basins (rain gardens)	Square foot	--	$3-$15[g], up to $14 (75% reimbursement)[l], $14[m], $1.39-$607.46[n], $197.28-$10,000 each per year[n]	$20
Streambank and shoreline protection (580)	Linear foot	$12.66-$254.48	$32.42-$209.79	$160
Streambank/channel restoration	Linear foot	--	$30,000 for 100 feet[i]	$3,000
Waste storage facility, dry stack (313)	Square foot	$2.77-$6.98	$231.84-$38,052.91 each[j]	$19,000 each
Pasture and hay planting (512)	Acres	$254.87-$408.86	$40.18-$343.64[j]	$400
Roof runoff structure (558)	feet	$10.85-$18.75	$2,306.40-$31,950 each[j]	$7,000 per house
Septic tank repair/replacement	Number	--	$2,500 to almost $500,000, average around $11,000[k]	$11,000
Permeable pavement	Square feet	--	$13[m], $2.07-$40.28 (capital cost)[n], $200-$21,300 each per year[n]	
Detention retrofit	Number	--	$10,000-$50,000[o]	$30,000
Media filter	Number	--	$0.02-$3,392.28 (capital cost)[n], $1,800-$60,000 each per year[n]	$3,000
Hydrodynamic separator	Number	--	$1,000-$4,250 each per year[n], $10,000-$40,000[p]	$20,000

HU = historically underserved producers
a (NRCS, 2022a),
b (Lynch & Tjaden 2000)
c (Butler & Long 2005)
d (Whitescarver 2013)
e (Washington State University 2006)

f (Undersander, Albert, Cosgrove, Johnson, & Peterson, 2002)
g http://raingardenalliance.org/what/faqs
h (Myers, Weber, & Tellatin, 2019)
i (E. Powers, AGFC, personal communication, 9/20/2022)
j (Christianson, 2020)
k L. Kindberg, IRWP, personal communication 2/10/2023 l (IRWP, 2014)
m (Center for Neighborhood Technology, 2020)
n (Municipal Water Infrastructure Council of EWRI; Water Research Foundation, 2022)
o (Pennsylvania Environmental Council, 2012)
p (US Environmental Protection Agency, 1999)
q (RTI, 2023)

3. UNITS OF PRACTICES TO IMPLEMENT

The units of a practice to be implemented are based on the extent of the targeted source, and the amount of that source to treat to meet the load reduction targets for a sub-watershed. Estimates of pollutant sources and the approaches used to derive them are described in the following subsections.

3.1 Prescribed Grazing

3.1.1 Extent of Source

Pasture accounts for between 30% and 68% of the land area of Category 1 sub-watersheds. Table 2 lists information about pasture area and cattle operations Benton and Washington Counties from the 2022 Census of Agriculture. As shown in Table 3, this information was used to calculate the average pasture area associated with each cattle operation in these counties (pasture divided by number of cattle farms), and the percentage of cattle operations in these counties using prescribed (rotational) grazing or grazing management (number of farms using rotational grazing divided by number of farms with cattle). In Table 3, these values are used to estimate the area of pasture in Category 1 sub-watersheds where prescribed grazing is not yet in use.

Table 2. Information about pasture and cattle operations in Benton and Washington Counties from the 2022 US Census of Agriculture. Census tables from which the information is taken are indicated in the "Information" column.

Information (Census Table number)	Benton County	Washington County
Acres pasture, all types (Table 8)	120,032	148,660
Number of farms with cattle (Table 11)	1,091	1,226
Average acres pasture with cattle farms	110	121
Number of farms using rotational grazing (Table 43)	269	367
Percent of cattle farms using rotational grazing	25%	30%

Table 3. Estimated pasture in Category 1 sub-watersheds without prescribed grazing.

Information	Moores Creek (111101030102)	Lower Muddy Fork (111101030103)	Little Osage Creek (111101030302)	Lake Wedington-Illinois River (111101030403)	Lake Frances-Illinois River (111101030606)
Total Pasture area, ha	3,705.4	3,701.7	7,460.8	2,424.2	3,609.9
Average acres/ cattle operation	121	121	110	121	110
Estimated No. cattle operations	31	30	68	20	33
Percent operations with prescribed grazing	30%	30%	25%	30%	25%
Estimated number operations without prescribed grazing	22	21	51	14	25
Estimated pasture area without prescribed grazing, ha	2,662	2,541	5,610	1,694	2,750

3.1.2 Units of Prescribed Grazing

Table 4 lists the units of prescribed grazing estimated for the Upper Illinois River watershed Category 1 HUC12s. These values are calculated by multiplying the estimated area of pasture without prescribed grazing from Table 3 by the portion to treat from Appendix M.

Table 4. Units of prescribed grazing estimated for Upper Illinois River Category 1 sub-watersheds.

	Moores Creek (111101030102)	Lower Muddy Fork (111101030103)	Little Osage Creek (111101030302)	Lake Wedington-Illinois River (111101030403)	Lake Frances-Illinois River (111101030606)
Portion to treat	100%	100%	100%	100%	100%
Units of practice	2,662 ha = 6,578 ac	2,541 ha = 6,279 ac	5,610 ha = 13,863 ac	1,694 ha =4,186 ac	2,750 ha =6,795 ac

3.2 Pasture and Hay Planting

Mittelstett et al. (2016) classified 2011 pasture in the Illinois River watershed as well managed or over grazed using aerial imagery. This information was saved as a GIS layer, which was provided to FTN by TAMU (K. Mendoza, TAMU, personal communication, 3/8/2024). This layer was used to estimate areas of poor-quality pasture in the Category 1 sub-watersheds where pasture and hay planting would be beneficial. These areas are listed in Table 5. Given the age of this data, we rounded the areas to thousands for estimating implementation costs.

Table 5. Acres of overgrazed pasture in Category 1 sub-watersheds from Mittelstett et al. 2016.

HUC12 Name	HUC12 ID Number	Acres Overgrazed (Mittelstett et al. 2016)	Acres Overgrazed Assumed for Calculation
Moores Creek	111101030102	1,136	1,000
Lower Muddy Fork	111101030103	2,251	2,000
Little Osage Creek	111101030302	6,213	6,000
Lake Wedington-Illinois River	111101030403	1,646	1,000
Lake Frances-Illinois River	111101030606	1,457	1,000

Table 6 lists the units of pasture and hay planting estimated for the Upper Illinois River watershed Category 1 HUC12s. These values are calculated by multiplying the acres overgrazed assumed for calculation from Table 5 by the portion to treat from Appendix M.

Table 6. Units of pasture runoff practices estimated for Upper Illinois River Category 1 sub-watersheds.

Information	Moores Creek (111101030102)	Lower Muddy Fork (111101030103)	Little Osage Creek (111101030302)	Lake Wedington-Illinois River (111101030403)	Lake Frances-Illinois River (111101030606)
Portion to treat	100%	100%	100%	100%	100%
Units of practice	1,000 ac	2,000 ac	6,000 ac	1,000 ac	1,000 ac

3.3 Other Pasture Runoff Management Practices

The extent of need for pasture management practices that address more localized issues, such as heavy use area protection, grassed waterways, and vegetated treatment areas. Therefore, implementation extent estimates are not calculated for the use of these practices to reduce pasture pollutant loss.

3.4 Livestock Access Control

StreamCat reports the percentage of the area within a 100-meter buffer around mapped streams that is in agriculture (Hill, Weber, Leibowitz, Olsen, & Thornbrugh, 2016). For the Category 1 sub-watersheds we assume agriculture means pasture. Miles of streambank associated with riparian pasture were estimated by dividing the area of riparian pasture reported in StreamCat by 100 meters (Table 7). These estimated lengths of streambanks are assumed to be suitable places for implementation of access control and/or riparian buffer restoration practices.

Table 7. Riparian pasture and associated streambank lengths in Upper Illinois River Category 1 sub-watersheds.

Information	Moores Creek (111101030102)	Lower Muddy Fork (111101030103)	Little Osage Creek (111101030302)	Lake Wedington-Illinois River (111101030403)	Lake Frances-Illinois River (111101030606)
Pasture within 100 m buffer, sq m	2,782,360.39	2,426,516.93	7,073,443.19	2,211,301.51	2,406,731.4
Associated streambank, m	27,823.6	24,265.2	70,734.4	22,113.0	24,067.3
Associated streambank, km	27.8	24.3	70.7	22.1	24.1

Table 8 shows the calculations of units of practices to reduce livestock access to streams. In estimating the extents of practices to implement it was assumed that one stream crossing and two (2) watering facilities will be installed for every km of streambank fenced (Mississippi State University Extension, 2022) (Reynolds, 2022).

Table 8. Units of livestock access control practices estimated for Upper Illinois River Category 1 sub-watersheds.

Practice	Information	Moores Creek (111101030102)	Lower Muddy Fork (111101030103)	Little Osage Creek (111101030302)	Lake Wedington-Illinois River (111101030403)	Lake Frances-Illinois River (111101030606)
Fence (access control)	Portion to treat	100%	100%	100%	100%	100%
	Units of practice	27.8 km = 91,206 feet	24.3 km = 79,723 feet	70.7 km = 231,952 feet	22.1 km = 72,505 feet	24.1 km = 79,067 feet
Stream crossing	Units of practice	27	24	70	22	24
Watering facilities	Units of practice	55	48	141	44	48

3.5 Poultry Operations

For estimating BMP costs, the number of poultry houses reported to the Natural Resources Division for 2019 were used to calculate the units of poultry operation practices needed (T. Wentz, Natural Resources Division, personal communication, 5/12/2022). The following assumptions were used in estimating cost of implementing practices to reduce pollutant loads from poultry operations:

- None of the evaluated practices are currently in use at the poultry houses in the Category 1 sub-watersheds.
- One of the following practices would be needed for every four poultry houses:
  - waste storage facility
  - filter strip (0.3 acres)
  - grassed waterway (1 acre)

One (1) roof runoff structure would be needed for each poultry house. Assumed filter strip and grassed waterway sizes are based on sizes of these practices funded through EQIP in Arkansas 2008-2020 (Christianson 2021). Table 9 shows the estimated practice units for poultry operations.

Table 9. Units of poultry operation practices estimated for Upper Illinois River Category 1 sub-watersheds.

Practice	Information	Moores Creek (111101030102)	Lower Muddy Fork (111101030103)	Little Osage Creek (111101030302)	Lake Wedington-Illinois River (111101030403)	Lake Frances-Illinois River (111101030606)
	Number of poultry houses reported	14	24	34	33	23
Waste storage facility	Portion to treat	100%	100%	100%	100%	100%
	Units of practice	4	6	9	8	6
Filter Strip	Portion to treat	100%	100%	100%	100%	100%
	Units of practice (number * 0.3 acres)	1.2 acres	1.8 acres	2.7 acres	2.4 acres	1.8 acres
Grassed waterway	Portion to treat	100%	100%	100%	100%	100%
	Units of practice (number * 1 acre)	4 acres	6 acres	9 acres	8 acres	6 acres

3.6 Restore Riparian Buffers

Riparian buffers in need of restoration are assumed to be represented by the length of streambank associated with riparian areas in agricultural or development land covers as reported in StreamCat (Hill, Weber, Leibowitz, Olsen, & Thornbrugh, 2016). The length of streambank associated with riparian areas in agricultural land cover is calculated in Table 7. Table 10 shows the calculation of streambank length associated with riparian areas in development land cover. To estimate the units of riparian buffer restoration, we assumed that restored riparian buffers would be 30 meters wide. The estimated units of riparian buffer restoration were calculated by multiplying the sum of the lengths of streambank associated with agricultural land cover and with development land cover by 30 meters (Table 11). The portion of riparian buffer needing to be restored in the Category 1 sub-watersheds is 100%.

Table 10. Riparian development and associated streambank lengths in Upper Illinois River Category 1 sub-watersheds.

Information	Moores Creek (111101030102)	Lower Muddy Fork (111101030103)	Little Osage Creek (111101030302)	Lake Wedington-Illinois River (111101030403)	Lake Frances-Illinois River (111101030606)
Development within 100 m buffer, sq m	255,595.76	165,916.37	2,073,196.09	303,223.29	416,256.43
Associated streambank, m	2,555.96	1,659.16	20,731.96	3,032.23	4,162.56

Table 11. Units of riparian buffer restoration estimated for Upper Illinois River Category 1 sub-watersheds.

Information	Moores Creek (111101030102)	Lower Muddy Fork (111101030103)	Little Osage Creek (111101030302)	Lake Wedington-Illinois River (111101030403)	Lake Frances-Illinois River (111101030606)
Streambank with agricultural land cover in riparian area, m	27,823.6	24,265.2	70,734.4	22,113.0	24,067.3
Streambank with development land cover in riparian area, m	2,555.96	1,659.16	20,731.96	3,032.23	4,162.56
Total riparian length for restoration, m	30,379.56	25,924.36	91,466.36	25,145.23	28,229.86
Units of riparian buffer restoration	911,386.8 square meters = 225 acres	777,730.8 square meters = 192 acres	2,743,990.8 square meters = 678 acres	754,356.9 square meters = 186 acres	846,895.8 square meters = 209 acres

3.7 Streambank or Stream Restoration

Streambank erosion monitoring has identified four sites that contribute over 10% of the estimated sediment load from streambank erosion. Two of these sites are located in the Lake Wedington-Illinois River Category 1 HUC12; Site 4 which is 516 feet long and Site 9 which is 428 feet long. Thus, a total of 944 feet of the Illinois River in the Lake Wedington-Illinois River sub-watershed is recommended for immediate stream restoration. As of August 2024, no restoration projects were known to be completed, in progress, or planned for these two streambank erosion sites (L. Kindberg, IRWP, personal communication, 8/1/2024).

As part of the Illinois River streambank erosion monitoring study, streambank erosion rates were predicted for much of the Illinois River and several of its tributaries, including Moores Creek and Muddy Fork. Table 12 lists total length of streambanks in Category 1 HUC12s where predicted streambank erosion rates are greater than two (2) foot/year, which is classified as a “very high” erosion rate (Natural State Streams LLC, 2021).

Table 12. Length of streambank in Category 1 HUC12s with predicted erosion rate greater than 2 ft/year.

HUC12 name	HUC12 ID Number	Streambank with predicted erosion rate > 2 ft/yr, miles	Streambank with predicted erosion rate > 2 ft/yr, km	Units streambank protection or restoration, feet
Moores Creek-Muddy Fork	111101030102	0.14	0.22	739
Lower Muddy Fork-Illinois River	111101030103	0.93	1.50	4,910
Lake Wedington-Illinois River	111101030403	1.97	3.16	10,402
Lake Frances-Illinois River	111101030606	0.78	1.26	4,118
Average		0.95	1.54	

Fox's (2023) evaluation of land lost to streambank erosion in the Upper Illinois River watershed indicates that streambank erosion is also likely to be an issue in the Little Osage Creek Category 1 sub-watershed. The estimated length of stream with development or pasture in the riparian area is about three times greater in the Little Osage Creek sub-watershed than in the other Category 1 sub-watersheds. Therefore, we assume that there will also be three (3) times more eroding streambanks in the Little Osage Creek sub-watershed, or approximately 2.9 miles or 4.6 km or 15,312 feet.

The units of streambank or stream restoration assumed for estimating cost is 100% of the stream miles predicted to have streambank erosion rates greater than two (2) feet/year.

3.8 Remediate Failing Septic Systems

The number of septic systems in use in the Category 1 sub-watersheds has been estimated and is listed in Table 13. We assume 3% of septic systems are failing and will need to be remediated. IRWP provided information that was used to determine how many failing septic systems in the Category 1 sub-watersheds have already been remediated through their Septic Tank Remediation Program. The units of septic tank remediations still needed was estimated by multiplying the number of septic systems by 0.03 and subtracting the number that have already been remediated (see Table 13).

Table 13. Estimated number of septic systems needing remediation in the Upper Illinois River Category 1 sub-watersheds.

Information	Moores Creek (111101030102)	Lower Muddy Fork (111101030103)	Little Osage Creek (111101030302)	Lake Weddington-Illinois River (111101030403)	Lake Frances-Illinois River (111101030606)
Number of septic systems 2024	210	173	434	179	332
Estimated number of failing systems (3%)	6	5	13	5	10
Number of systems remediated	6	0	1	1	8
Estimated number of systems needing remediation	0	5	12	4	2

4. COST ESTIMATES

Cost estimates are calculated by multiplying the units of a practice to be implemented by the assumed unit cost. Tables 14 through 18 show cost estimate calculations for implementing example BMPs in the Upper Illinois River Category 1 sub-watersheds.

4.1 low impact development

The CNT Green Values Stormwater Management Calculator (Green Values Stormwater Management Calculator (cnt.org)) was used to estimate example costs for implementing green infrastructure in the Little Osage Creek Category 1 sub-watershed. Table 14 lists assumptions and calculator output. The calculator site/lot area was set to the 2019 NLCD developed area in the sub-watershed, 7,500 acres. Impervious area was set to the 2019 value from Fox (2023), 340.4 acres (five (5) percent). Ninety-two percent of the developed area was classified as lawn/turf and four (4) percent was classified as shrub and bushes. The location for rainfall data was set to Bentonville, Arkansas. The default volume capacity goal of 0.5 inches of rainfall (617,826 cubic feet) was used to determine units of practices. Units of practices were selected that achieved 100% of the volume capacity goal.

Table 14. Example estimated cost for implementing green infrastructure practices in developed areas of Little Osage Creek sub-watershed.

Practice	Units of practice	Initial cost	Annual Maintenance cost	Life cost
Permeable pavement (parking)	2,964,000 square feet	$280,212,470	$48,513,769	$1,255,166,162
Bioswales	1,090,000 feet	$281,924,350	$51,363,609	$1,318,490,743
Rain garden	731,000 square feet	$267,450,620	$51,422,999	$1,294,914,357

4.2 Other Practices

Tables 15-19 show cost estimate calculations for each of the Category 1 sub-watersheds for BMP practice implementation. For the most part, these costs do not include maintenance costs. The costs presented represent a potential maximum cost, based on assuming that all of the target pollutants come from the treated source, and all of the available source is treated using a single BMP. In reality, a variety of BMPs is likely to be implemented. The information presented here is most useful for comparing the costliness of using these practices to improve water qualit

Table 15. Estimated costs for implementing practices in the Moores Creek sub-watershed.

Practice	Units to implement	Cost per unit	Maximum cost	Potential reduction			
				Total Nitrogen	Total Phosphorus	Sediment	E. coli
Prescribed grazing	6,578 acres	$40/acre	$263,120.00	8%	8%	15%	60%
Access control fence	91,206 feet	$4.00/foot	$364,824.00	8%	8%	25%	40%
Access control stream crossing	27 crossings	$3,000/crossing	$81,000.00	8%	8%	25%	40%
Watering facility	55 facilities	$1,200/facility	$66,000.00	8%	8%	15%	70%
Pasture and hay planting	1,000 acres	$400/acre	$400,000.00	8%	8%	29%	30%
Roof runoff structure	14 structures	$7,000/house	$98,000.00	12%	8%	20%	0%
Waste storage	4 facilities	$19,000/facility	$76,000.00	12%	8%	0%	90%
Filter strip	1.2 acres	$250/acre	$300.00	12%	28%	25%	0%
Grassed waterway	4 acres	$2,000/acre	$8,000.00	20%	14%	15%	0%
Restore riparian buffer (forest)	225 acres	$800/acre	$180,000.00	27%	19%	29%	55%
Restore riparian buffer (herbaceous)	225 acres	$200/acre	$63,000.00	27%	19%	29%	55%
Remediate failing septic systems	0 systems	$11,000/system	0	5%	18%	0%	90%

Table 16. Estimated costs for implementing practices in the Lower Muddy Fork sub-watershed.

Practice	Units to implement	Cost per unit	Maximum cost	Potential reduction			
				Total Nitrogen	Total Phosphorus	Sediment	E. coli
Prescribed grazing	6,279 acres	$40/acre	$251,160.00	9%	13%	26%	60%
Access control fence	79,723 feet	$4.00/foot	$318,892.00	9%	13%	44%	40%
Access control stream crossing	24 crossings	$3,000/crossing	$72,000.00	9%	13%	44%	40%
Watering facility	48 facilities	$1,200/facility	$57,600.00	9%	13%	26%	70%
Pasture and hay planting	2,000 acres	$400/acre	$800,000.00	9%	13%	53%	30%
Roof runoff structure	24 houses	$7,000/house	$168,000.00	13%	13%	35%	0%
Waste storage	6 facilities	$19,000/facility	$114,000.00	13%	13%	0%	90%
Filter strip	1.8 acres	$250/acre	$450.00	13%	43%	44%	60%
Grassed waterway	6 acres	$2,000/acre	$12,000.00	22%	22%	26%	0%
Restore riparian buffer (forest)	192 acres	$800/acre	$153,600.00	30%	30%	53%	55%
Restore riparian buffer (herbaceous)	192 acres	$200/acre	$53,760.00	30%	30%	53%	55%
Streambank protection	4,910 feet	$160/foot	$785,600.00	1%	3%	24%	--
Streambank or stream restoration	4,910 feet	$3,000/foot	$14,730,000.00	3%	12%	30%	--
Remediate failing septic systems	5 systems	$11,000/system	$55,000.00	1%	1%	0%	90%

Table 17. Estimated costs for implementing practices in the Little Osage Creek sub-watershed.

Practice	Units to implement	Cost per unit	Maximum cost	Potential reduction			
				Total Nitrogen	Total Phosphorus	Sediment	E. coli
Prescribed grazing	13,863 acres	$40/acre	$554,520.00	5%	9%	15%	60%
Access control fence	231,952 feet	$4.00/foot	$927,808.00	5%	9%	25%	40%
Access control stream crossing	70 crossings	$3,000/crossing	$210,000.00	5%	9%	25%	40%
Watering facility	141 facilities	$1,200/facility	$169,200.00	5%	9%	15%	70%
Pasture and hay planting	6,000 acres	$400/acre	$2,400,000.00	5%	9%	29%	30%
Roof runoff structure	34 houses	$7,000/house	$238,000.00	8%	9%	20%	0%
Waste storage	9 facilities	$19,000/facility	$171,000.00	8%	9%	0%	90%
Filter strip	2.7 acres	$250/acre	$675.00	8%	30%	25%	60%
Grassed waterway	9 acres	$2,000/acre	$18,000.00	13%	15%	15%	0%
Restore riparian buffer (forest)	678 acres	$800/acre	$542,400.00	18%	21%	29%	55%
Restore riparian buffer (herbaceous)	678 acres	$200/acre	$189,840.00	18%	21%	29%	55%
Streambank protection	15,312 feet	$160/foot	$2,449,920.00	1%	3%	24%	--
Streambank or stream restoration	15,312 feet	$3,000/foot	$45,936,000.00	3%	12%	30%	--
Remediate failing septic systems	12 systems	$11,000/system	$132,000.00	11%	35%	0%	90%
Permeable pavement	2,964,000 square feet	$94.50/square foot	$280,212,470	26%	23%	29%	0
Rain garden	731,000 square feet	$365.87/square foot	$267,450,620	11%	0	29%	40%

Table 18. Estimated costs for implementing practices in the Lake Wedington-Illinois River sub-watershed.

Practice	Units to implement	Cost per unit	Maximum cost	Potential reduction			
				Total Nitrogen	Total Phosphorus	Sediment	E. coli
Prescribed grazing	4,186 acres	$40/acre	$167,440.00	26%	11%	9%	60%
Access control fence	72,505 feet	$4.00/foot	$290,020.00	44%	11%	9%	40%
Access control stream crossing	22 crossings	$3,000/crossing	$66,000.00	44%	11%	9%	40%
Watering facility	44 facilities	$1,200/facility	$52,800.00	26%	11%	9%	70%
Pasture and hay planting	1,000 acres	$400/acre	$400,000.00	26%	19%	24%	0%
Roof runoff structure	33 houses	$7,000/house	$231,000.00	24%	3%	1%	0%
Waste storage	8 facilities	$19,000/facility	$152,000.00	44%	38%	14%	60%
Filter strip	2.4 acres	$250/acre	$600.00	0%	0%	0%	0%
Grassed waterway	8 acres	$2,000/acre	$16,000.00	30%	12%	3%	0%
Restore riparian buffer (forest)	186 acres	$800/acre	$148,800.00	53%	26%	33%	55%
Restore riparian buffer (herbaceous)	186 acres	$200/acre	$52,080.00	53%	26%	33%	55%
Streambank protection	10,402feet	$160/foot	$1,664,320.00	53%	11%	9%	30%
Streambank or stream restoration	10,402feet	$3,000/foot	$31,206,000.00	35%	11%	14%	0%
Remediate failing septic systems	4 systems	$11,000/system	$44,000.00	0%	18%	1%	90%

Table 19. Estimated costs for implementing practices in the Lake Frances-Illinois River sub-watershed.

Practice	Units to implement	Cost per unit	Maximum cost	Potential reduction			
				Total Nitrogen	Total Phosphorus	Sediment	E. coli
Prescribed grazing	6,795 acres	$40/acre	$271,800.00	26%	14%	9%	60%
Access control fence	79,067 feet	$4.00/foot	$316,268.00	43%	14%	9%	40%
Access control stream crossing	24 crossings	$3,000/crossing	$72,000.00	43%	14%	9%	40%
Watering facility	48 facilities	$1,200/facility	$57,600.00	26%	14%	9%	70%
Pasture and hay planting	1,000 acres	$400/acre	$400,000.00	26%	24%	21%	0%
Roof runoff structure	23 houses	$7,000/house	$161,000.00	24%	3%	1%	0%
Waste storage	8 facilities	$19,000/facility	$114,000.00	43%	47%	13%	60%
Filter strip	1.8 acres	$250/acre	$450.00	0%	0%	0%	0%
Grassed waterway	6 acres	$2,000/acre	$12,000.00	30%	12%	3%	0%
Restore riparian buffer (forest)	209 acres	$800/acre	$167,200.00	51%	33%	30%	55%
Restore riparian buffer (herbaceous)	209 acres	$200/acre	$58,520.00	51%	33%	30%	55%
Streambank protection	4,118 feet	$160/foot	$658,880.00	51%	14%	9%	30%
Streambank or stream restoration	4,118 feet	$3,000/foot	$12,354,000.00	34%	14%	13%	0%
Remediate failing septic systems	2 systems	$11,000/system	$22,000.00	0%	18%	1%	90%

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