Upper Saline River Watershed 9-Element Plan

The Nature Conservancy

Plan Update - October 8, 2025

ACRONYMS & ABBREVIATIONS

ASHP – Arkansas Stream Heritage Partnership

AWRC - Arkansas Water Resource Center

BEHI - Bank Erosion Hazard Index

BMP - Best Management Practices

ADEQ - Arkansas Department of Energy and Environment Division of Environmental Quality

DO – Dissolved Oxygen

EPA - Environmental Protection Agency

EQIP - Environmental Quality Incentives Program

ERQ - Extraordinary Resource Waters

ESM - Environmentally Sensitive Maintenance

FY - Fiscal Year

HUC - Hydrologic Unit Code

MK - Mann-Kendall

NBS – Nature-based Solution

NHDPlus HR - National Hydrography Dataset Plus High Resolution

NLCD - National Land Cover Database

NOAA - National Oceanic and Atmospheric Administration

NRCS - Natural Resources Conservation Service

PBA - Private Burn Association

SARP - Southeast Aquatic Resources Partnership

SRWA – Saline River Watershed Alliance

SRP - Soluble Reactive Phosphorus

SSURGO - Soil Survey Geographic Database

TDS - Total Dissolved Solids

TN - Total Nitrogen

TNC – The Nature Conservancy

TP - Total Phosphorus

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

USRW - Upper Saline River Watershed

EXECUTIVE SUMMARY

The Upper Saline River watershed in central Arkansas covers approximately 1,715 mi² spanning diverse topography across nine counties in central Arkansas and two ecoregions –the Ouachita Mountains and South Central Plains. The Saline River and its upper tributaries are designated as Ecologically Sensitive Waters and Extraordinary Resource Waters by the state, recognizing their clean water, scenic beauty, and critical habitat for rare species. The watershed hosts rich biodiversity including 45 Species of Greatest Conservation Need and several federally listed mussels. It is predominantly forested with silviculture as a key economic activity, and urban growth is concentrated in areas like Benton and Hot Springs Village.

The Arkansas Department of Agriculture's Natural Resources Division identified the Upper Saline River watershed as a priority due to concerns about sedimentation, chloride, sulfate, pH, mercury, and dissolved oxygen levels. To evaluate the connections between land use and water quality, and prioritize areas within the Upper Saline River watershed for implementation of conservation and management recommendations, the University of Arkansas Water Resources Center (AWRC) conducted a comprehensive monitoring effort to assess water quality trends in 12-digit hydrologic unit code (HUC12) sub-watersheds delineated by the United States Geological Survey (USGS). These priority areas present strategic opportunities for conservation. By focusing restoration and best management practices in these sub-watersheds, stakeholders can maximize water quality improvements.

The Upper Saline River 9-element Watershed Management Plan builds on previous management efforts, including those outlined in the original 2006 Upper Saline River watershed plan and the adaptive management approach formalized by the Natural Resources Division in 2012. The plan focuses on raising public awareness of water quality issues in the watershed and protecting and improving surface and groundwater quality by managing nonpoint source pollution through voluntary stewardship and non-regulatory conservation practices.

The development of this comprehensive plan incorporates extensive stakeholder input and collaboration, detailed watershed characterization, and adaptive management to address water quality impairments and promote sustainable land use and conservation practices. It further emphasizes the importance of continuous evaluation, stakeholder engagement, and adaptation to changing conditions within the watershed. Stakeholders identified major issues including urban development and construction leading to increased impervious surfaces and sedimentation, loss of riparian buffers causing erosion and elevated stream temperatures, stormwater runoff causing hydrologic alterations and flooding, road litter and illegal dumping, sedimentation from streambank erosion, erosion from unpaved roads, loss of wetlands and floodplain habitats, and impaired stream crossings disrupting aquatic connectivity.

To meet water quality targets and achieve anticipated load reductions, the plan recommends implementing best management practices (BMPs) such as green infrastructure for urban stormwater, riparian forest buffer restoration, erosion control on unpaved roads, wetland conservation and restoration, repair or replacement of inadequate stream crossings, and establishing conservation easements. Emphasis is placed on nature-based solutions, stakeholder education, and coordinated implementation. Through coordinated education, outreach, and the collaborative implementation of conservation and restoration practices, the plan aims to support the long-term integrity and ecological health of the Upper Saline River and its tributaries

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1. INTRODUCTION

This management plan addresses the Upper Saline River watershed (Hydrologic Unit Code; HUC8 08040203). The Saline River, including its major tributaries – the North, Alum, Middle, and South Forks – are designated as Arkansas Extraordinary Resource Waters (ERW). The Saline River and main tributaries, along with Ten Mile Creek are also designated as Ecologically Sensitive Waterbodies (ESW). The primary focus of this plan is protection and improvement of surface water quality in the Upper Saline River and its tributaries through management of unregulated nonpoint sources of pollution.

1.1 Plan Need and Mission

The Upper Saline 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 2022 state impaired waters list (303(d) list) due in part to pollution from nonpoint sources.

It has been over 19 years since a watershed management plan was developed for the Upper Saline River watershed (TNC, 2006). 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 Upper Saline River and its tributaries, and groundwater quality, through management of unregulated nonpoint sources of pollution. The mission of this plan is to increase awareness of the watershed and its water quality, and to encourage and support voluntary improvement of the integrity of the Upper Saline River through public education, outreach, and collaborative implementation of conservation and restoration practices throughout the watershed.

1.2 Watershed Vision

The watershed vision is articulated by the Saline River Watershed Alliance (SWRA): To conserve, protect, enhance, and maintain the Saline River Watershed as a unique aquatic and wildlife habitat and as a source of recreational natural scenic beauty. This vision reflects the values and priorities voiced by community members, landowners, producers, and partner organizations throughout the watershed management plan update process. Conservation partners are working together across private lands and public initiatives to promote practices that balance human use with ecological sustainability to protect and restore the Upper Saline River watershed's ecological health and water quality through sustainable land management and collaborative stewardship, to safeguard the Upper Saline River watershed's natural resources for generations to come.

1.3 Watershed Plan Process

Development of the Upper Saline 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 watershed management plan. 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), Green Bay Packaging Inc., 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 and landowner workshop 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. Sections 3 and 4 summarize conditions in the watershed, including water quality, hydrology, and ecology. Section 5 provides information on pollutant sources in the Upper Saline River watershed. Section 6 identifies watershed goals and objectives, subwatersheds recommended for initial management of nonpoint pollutant sources, pollutant load reduction targets, and management strategies for controlling nonpoint source pollution in the recommended subwatersheds. Section 7 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 8 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 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.

2. WATERSHED DESCRIPTION

2.1 Watershed Location and Physical Setting

The Upper Saline River watershed (HUC8 08040203) is located in central Arkansas and has a total drainage area of 1,715 mi^2 (Figure 2.1). The Upper Saline River watershed includes a majority of the land area within Grant and Saline Counties and portions of Garland, Cleveland, Hot Spring, Jefferson, Dallas, Pulaski and Perry Counties (Table 2.1). The Saline River is 202 miles in length and its headwaters originate in the Ouachita Mountain ecoregion in western Saline County and eastern Garland County and consists of four main tributaries: the North Fork, Alum Fork, Middle Fork, and South Fork Saline Rivers, which converge with the main stem of the Saline River just above the Gulf Coastal Plain ecoregion near Benton, Arkansas. After the four forks merge, the river flows generally south through Saline, Grant, Dallas, Cleveland, Bradley, Drew, and Ashley counties. Its other main tributaries, including Dry Lost Creek, Francois Creek, Hurricane Creek, and Derrieusseaux Creek, also flow generally south through the South Central Plains before reaching the confluence with the Ouachita River in the Felsenthal National Wildlife Refuge just north of the Louisiana border.

Table 2.1 County areas (mi^2) within the Upper Saline River Watershed.

County	County Area (mi^2)	County Area within Watershed	% County within Watershed	% Watershed within County
Grant	633	615	97.2	35.9
Saline	730.5	604	82.7	35.2
Garland	734.6	143	19.5	8.3
Cleveland	598.9	123	20.5	7.2
Hot Spring	622.2	110	17.7	6.4
Jefferson	916	67	7.3	3.9
Dallas	668	49	7.3	2.9
Pulaski	807.4	2	0.2	0.1
Perry	560.8	1	0.2	0.1

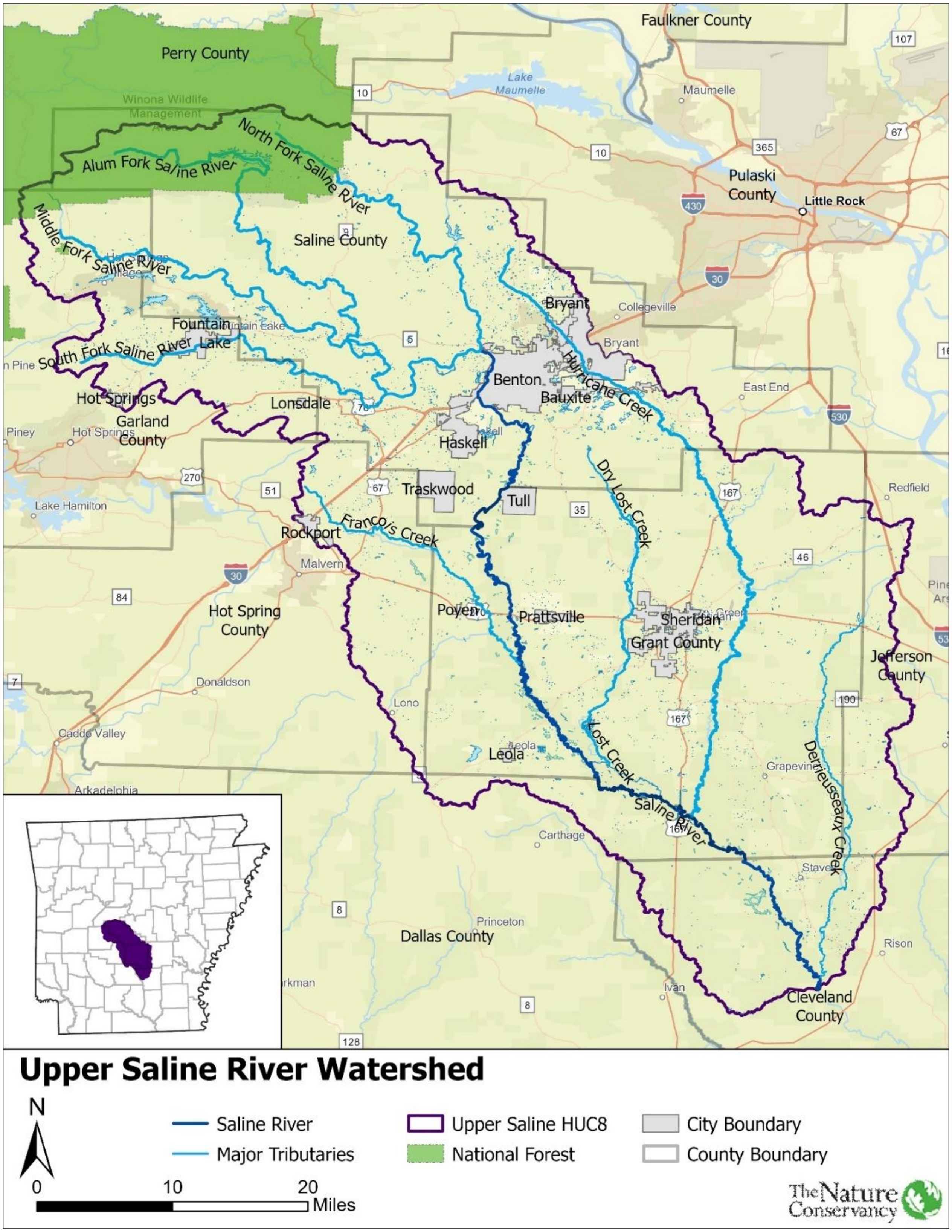

Figure 2.1 Map of the Upper Saline River watershed (HUC8 08040203) showing county and municipal boundaries, major roads and tributaries of the Saline River.

2.2 Demographic and Socioeconomic Conditions

The general socioeconomic conditions in the watershed can be summarized as follows:
(1) strongly silviculture oriented
(2) variable per capita income throughout the watershed
(3) increasing populations in several key areas: Benton, Bryant, Hot Springs Village, Sheridan

Saline (724 mi^2) and Garland Counties (678 mi^2) have the largest residential populations within the Upper Saline River Watershed. The population of Saline County in 2022 was 131,323 with an average annual population growth rate of 1.4% and a total increase of 22.6% between 2010 and 2024 (US Census Bureau 2024). The population of Garland County in 2024 was 99,902 and it had an average annual population growth rate of 0.3% and a total increase of 4.0%. In comparison, the population of Arkansas grew by 5.9% during the same time period. Benton (pop. 35,318) and Bryant (pop. 20,750) located within Saline County, and Hot Springs Village (pop. 16,843) in Garland County are the most populous towns within the Upper Saline Watershed, followed by the city of Sheridan (pop. 5,002) located in Grant County. Outside of the rapidly growing populations within the northern portion of the watershed, the southern portion of the Upper Saline watershed is primarily devoted to timber production interspersed with small rural communities.

Educational services, health care and social assistance account for the largest sectors of employment in Saline (23.5%) and Garland (25.2%) Counties. While silviculture is the predominant land use in the watershed, a relatively small work force is associated with this industry. Agriculture, forestry, fishing and hunting, and mining occupations combined represent 1.8% of the workforce in Saline County and 0.8% in Garland County (U.S. Census Bureau 2024). The percent of the population living at or below poverty level in Saline County is equal 9.5%, with Grant County poverty level at 13.5%, compared to a statewide average of 15.7% (US Census Bureau 2024).

Table 2.2 Population information for selected counties in the Upper Saline watershed and Arkansas as a whole (U.S. Census Bureau 2024).

County/State	Land Area (mi^2)	2010 Population	2010 Population Density (pop./mi^2)	2024 Total Population	2024 Population Density (pop./mi^2)	% Population Change 2010 –2024	% Population Change 2020–2024
Arkansas	51,993	2,915,918	56	3,088,354	59	5.9	2.6
Saline	724	107,118	148	131,323	181	22.6	6.3
Garland	678	96,024	142	99,902	147	4.0	-0.3
Grant	632	17,853	28	18,546	29	3.9	3.3
Hot Spring	615	32,923	54	33,313	54	1.2	0.8
Cleveland	598	8,689	15	7,367	12	-15.2	-2.4

2.3 Ecoregions

The Upper Saline River watershed boundaries fall within two distinct Level III ecoregions within the state of Arkansas (Figure 2.8). Sixty-five percent (1118 mi^2) of the Upper Saline River watershed falls within the South Central Plains (SCP) ecoregion and thirty-five percent (597 mi^2) falls within the Ouachita Mountains ecoregion.

2.3.1 Ouachita Mountain Ecoregion

The Ouachita Mountains ecoregion includes parts of Arkansas and Oklahoma and comprises a landscape of approximately 11.48 million acres of rugged mountain ridges, broad valleys, and the headwaters of several large river systems. The complex geological formations and soils of this forested landscape have created a tremendous diversity of habitat reflected in a biodiversity of ancient lineage; the Ouachita Mountains have been available for continuous occupation by terrestrial and aquatic life for 225 million years, and are a center for endemism in North America, particularly in the realm of aquatic species (TNC, 2003).

Smaller streams in the headwaters of the Saline River originate in the Ouachitas through surface and sheetflow-fed seeps, groundflow, and surface flow drainage. The main headwater tributaries of the Upper Saline River are the North, Middle, Alum, and South Forks and these feed into the Saline River near the boundary between the Ouachita Mountains and SCP. At this boundary between the headwaters and the larger Saline River, is a transition from gravel and cobble channel substrates to more fine substrates, such as sand and silt.

2.3.2 South Central Plains

The South Central Plains (SCP) ecoregion is an area of approximately 26,250,000 acres or 40,970 square miles, covering parts of Arkansas, Louisiana, Oklahoma, and Texas. Terrestrial systems in the SCP include bottomlands dominated by hardwood communities, primarily oak species, and more deeply flooded areas frequently have cypress and cypress-tupelo swamp vegetation. Upland areas consist of shortleaf and loblolly pines, mixed pine-hardwood communities, glades, and woodlands. Barrens and woodlands occur within this ecoregion on saline soil flats. Ancient volcanic intrusions formed bauxite deposits that are home to globally rare and endemic nepheline syenite communities.

Aquatic systems are characterized by low sloped, medium- to high-order streams, and riverine systems. Streams are sheet-, surface- and groundwater fed. Slower, larger rivers that originate in other ecoregions flow through the SCP and are home to diverse mussel and fish communities. Rivers are the predominant aquatic system in the SCP, and consist of substrates ranging from gravel, sand-gravel, to mud and silt. Seasonal and ephemeral flooding is a common natural aquatic process for river systems in the SCP.

2.4 Climate

The Upper Saline River watershed is located in the humid subtropical zone. Hot, sultry summers and moderately cool winters with some snow accumulations are normal. The climate is controlled by two different air masses. Warm, moist air from the Gulf of Mexico generally dominates especially in the spring and summer. Cooler, dryer air from the Central Plains enters the area in the winter (National Climatic Data Center 1979).

Table 2.4. Mean rainfall and temperature in the USRW

Month	Mean Precip. (in)	Mean Temp. (°F)
January	4.4	42
February	4	45.2
March	5.2	53.5
April	5.3	62.4
May	5.2	69.9
June	3.9	77.7
July	4	81.3
August	3.2	80.7
September	3.6	74.5
October	3.8	63.4
November	4.6	52.3
December	4.9	43.9
Annual	52	62.2

Precipitation is unequally distributed throughout the year with higher rainfall November-May (Table 2.4). Spring rainfall is important particularly because of drought conditions that routinely occur in the summer. Average precipitation in the watersheds is 52 inches decreasing from northeast to southwest within the watershed. Droughts occur most likely during late summer and fall with August-September typically having the lowest rainfall (National Climatic Data Center, 1979). Moderate droughts occur at 15-20 year intervals with several, multi-year droughts even less frequent. Tornadoes and floods may occur in any month but are most likely during the spring. Strong winter winds with sleet and freezing rains occur in late December, January, and February. Temperatures average from 42 degrees Fahrenheit in January to 81.3 degrees Fahrenheit in July. The peak high temperatures usually occur in July and August (PRISM 2014). The National Oceanic and Atmospheric Administration (NOAA) currently operates nine weather monitoring stations within the Upper Saline River watershed (Table 2.4.1).

Table 2.4.1. NOAA weather stations in the Upper Saline River watershed.

StationID	Station Name	Lat	Lon
USC00030130	ALUM FK	34.7961	-92.8417
US1ARSL0006	BENTON 11.4 NW	34.7021	-92.6972
US1ARSL0044	HOT SPRINGS VILLAGE 8.6 ESE	34.6379	-92.8519
US1ARPY0007	BIGELOW 6.2 SSW	34.9181	-92.6783
USC00035498	OWENSVILLE 3E	34.6133	-92.7742
US1ARSL0039	FOUNTAIN LAKE 2.6 NNE	34.6588	-92.9134
US1ARSL0043	HOT SPRINGS VILLAGE 5.0 E	34.6576	-92.9134
US1ARSL0001	SALEM 7.7 N	34.7405	-92.5503
US1ARSL0009	LITTLE ROCK 15.1 W	34.7177	-92.5521

2.5 Historical Information

Humans have been a powerful force in the ecological dynamics of the Ouachita Mountains and the South Central Plains for thousands of years. Shortleaf pine spread throughout the Ouachita Mountains 1600 to 1000 years ago. This spread was accompanied by the extensive use of fire by indigenous peoples. For more than 4000 years Native Americans used fire to increase forage for game animals. They also cleared fertile areas in the major river valleys to raise crops and in doing so introduced new species of plants and animals to the Ouachitas. These activities together with a complex geological and evolutionary history created the anthropogenic phenomenon that was the tessellated landscape present when the first European settlers arrived in the area (TNC, 2003).

The majority of forests within the Upper Saline watershed were cut over by the late 1920s and the second set of forest cut again in the 1940s and 50s. Only fragments remain in a "pre-settlement" condition within this reordered landscape. In addition, 70 years of fire suppression has led to changes in structure and composition of the remaining forested landscape. The riparian ecosystems have historically been disrupted in many areas by the building of railroads to extract timber. Many riparian areas were then homesteaded and have not regenerated.

2.6 Topography

The majority (65%) of the Saline River watershed lies within the South Central Plains ecoregion. The topography of the two ecoregions is very different with rugged terrain characterizing the Ouachita Highlands and rolling to flat topography representative of the Upper West Gulf Plain. The highest point within the watershed is 1,560 feet located near the Saline and Garland County boundary along Alum Fork, a tributary to the Saline River (Figure 2.6). Average relief within the Ouachita Highland region of the Saline watershed is approximately 200 feet. Slopes average less than 15% but range from 6% to 120%. The highest points in the South Central Plains are along terraces with average relief of less than 100 feet. Slopes in this region range from 0% to 20% and average less than 5%.

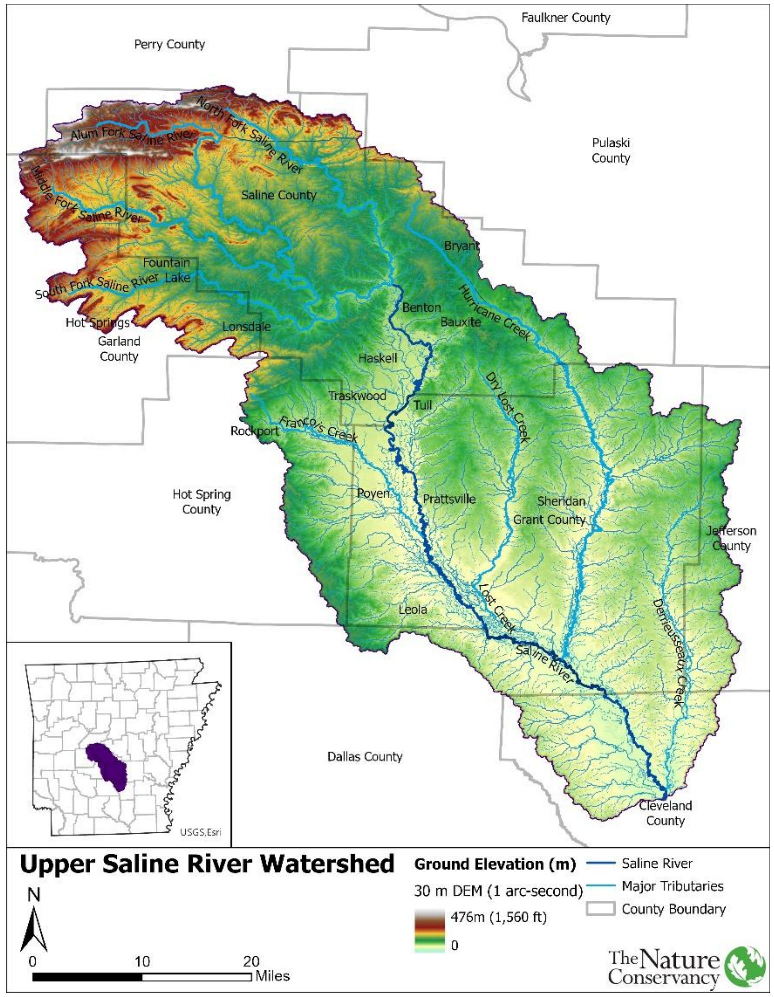

Figure 2.6. Mean elevation of the USRW derived from USGS 30m digital elevation model.

2.7 Geology

2.7.1 Ouachita Mountains

The Ouachita Mountain Ecoregion extends in a broad belt eastward from Atoka County, Oklahoma to the vicinity of Little Rock, Arkansas. The Ouachita Mountain region was created 345 million years ago by the same geophysical action that formed the Appalachian Mountains and Central Plateau of Texas. To the east, structural and stratigraphic features are buried by Cretaceous and Tertiary rocks and deposits of the Mississippi Embayment and to the west the structural trend curves south and is buried by Cretaceous strata of the Central Plains (Miser, 1929). This process has left the Ouachitas isolated from other mountain systems.

The landform of the Ouachita Mountains is an accretionary prism composed of intensely folded and deformed sandstone, shale and chert units that form one of the major fold-belt mountain ranges of the North American continent. Initial sedimentation occurred in deeply submerged ocean troughs. Silty oceanic ooze was lithified into thin layers of shale and chert during Paleozoic times. Occasional units of sandstone occur, probably emplaced by ocean currents and as fans at the heads of submarine canyons. Strata of Ordovician, Silurian, Devonian and Mississippian ages are exposed in the Ouachitas and represent this early phase of sedimentation. During late Mississippian and early Pennsylvanian periods huge deposits of sand entered the ocean from rivers which had their deltas in the area. These rivers deposited great volumes of sand and mud in the basin with accumulations reaching thicknesses of 45,000 feet. These strata are represented by the Stanley, Jackfork, Johns Valley and Atoka formations (Miser, 1929). The collision of two continental tectonic plates, Laurasia with the North American plate resulted in a mountain building process referred to as the Ouachita Orogeny. Oceanic oolitic and deltaic deposits were intensely deformed by compressive forces which were directed north toward the stable interior of the North American continent and metamorphism occurred. Twisted, warped and overturned folds and thrust faults reflect this violent collision (Viele, 1973). Deformed Paleozoic rocks were later intruded during the Cretaceous period by hydrothermal quartz and rock.

Erosion has been the dominant geological force over the last 300 million years. Soft shales have eroded away or deposited in valleys while resistant sandstones, cherts and novaculites have been formed into the dominant ridges we see today. This ridge and valley formation is characterized by long, hogback ridges with relief as great as 1600 feet above the valley floors and total elevations between 600 and 2,750 feet above sea level. These ridges run east-west and generally have long north and south facing slopes. Because of the way the rock strata fractured, north facing slopes tend to be steeper than south facing slopes. Surface rocks consist of sandstones, shales and cherts.

The Ouachita Mountains can be divided into four geologically distinct subsections (Honess, 1923) three of the four are found within the Saline River Watershed:

• **Northern Hogback Frontal Belt** (Fourche Mountains): These ridges are composed of massive formations of sandstone underlain in places by various shales.

• **Broken Bow-Benton Novaculite Uplift** (Central Ouachita Mountains): The most rugged terrain in Arkansas with sharp narrow ridges, shallow soils and narrow stony valleys. The ridges are capped with fractured novaculite, a hard, resistant siliceous igneous rock which has influenced the formation of glade communities. Found in the upper reaches of the watershed and the area is noted for its numerous springs and seeps.

• **Athens Plateau** (Piedmont): The novaculite formation grades southward to a gentler topography. Rivers flow south and drop over the fall line to the Gulf Coastal Plain. This is an area of low ridges 150-220 feet high. Uplifted toward the end of the Ouachita orogeny, this plateau was dissected by downcutting rivers.

2.7.2 South Central Plains

The South Central Plains geologic features primarily consist of two types of materials: those deposited in shallow seas of the Mississippi Embayment during the Late Cretaceous and Early Tertiary periods, and those subsequently deposited as alluvium during the Quaternary period. The highest elevation is found along the Deweyville terrace sequence approximately 850 feet above sea level. Recent geologic formations include Quaternary age Pleistocene deposits and Holocene alluvial deposits. Very prominent terrace deposits are found along the Saline River; most are the remnants of floodplains that were deposited in the late Early Pleistocene, more than 800,000 years ago. These terraces are identified as the Montgomery Terrace and originated during interglacial periods of high sea levels. A nearly continuous terrace system that belongs to the Deweyville sequence also is found along the Saline River. These were created during a period of maximum glaciation that occurred over a span of more than 15,000 years, beginning approximately 30,000 years before present (Saucier and Smith, 1986).

The nepheline syenite outcrops in the bauxite producing region of Arkansas' South Central Plains are among the rarest of the igneous outcrop-based ecosystems in the southern United States. These outcrops of intrusive igneous rock provide a variety of important and specialized habitats for uncommon plant communities and rare plant species in the Coastal Plain. The Bauxite Mining Reclamation Area (BMRA) is one of three such outcroppings known from North America and is generally composed of gray nepheline syenite with gentle topography. The outcrops proper are small but numerous, interspersed with dry woodland and forest vegetation over shallow to deeper soils.

Historic bauxite mining in Pulaski and Saline counties began in the late 19th century and reached its peak in 1943, after which local mining activity steadily contracted. By the 1980s, nearly all mining had ceased due to competition from overseas ore sources and the low realized economic return on the remaining ore.

2.8 Soils

In-situ soil development within the Upper Saline River watershed is strongly influenced by the parent material and topography where formed. Within the two ecoregions found in the USRW, major soil groups are markedly different.

2.8.1 Ouachita Ecoregion Soils

The soils formed are very diverse because of the complex interplay of several factors, but most important are aspect, slope, and bedrock. The ridges are composed of sandstone and chert and extremely steep slopes with numerous rock exposures. Soils that form are thin, have low permeabilities and moderate to rapid runoff (Figure 2.8). The ridge tops are characterized by very shallow soils and rock glaciers have formed on the steepest slopes. The valleys between the ridges are underlain by shale and have gentle relief. The valley soils are a mixture of loam and clayey loam. Drainage ranges from moderate to slow and runoff potential is moderate.

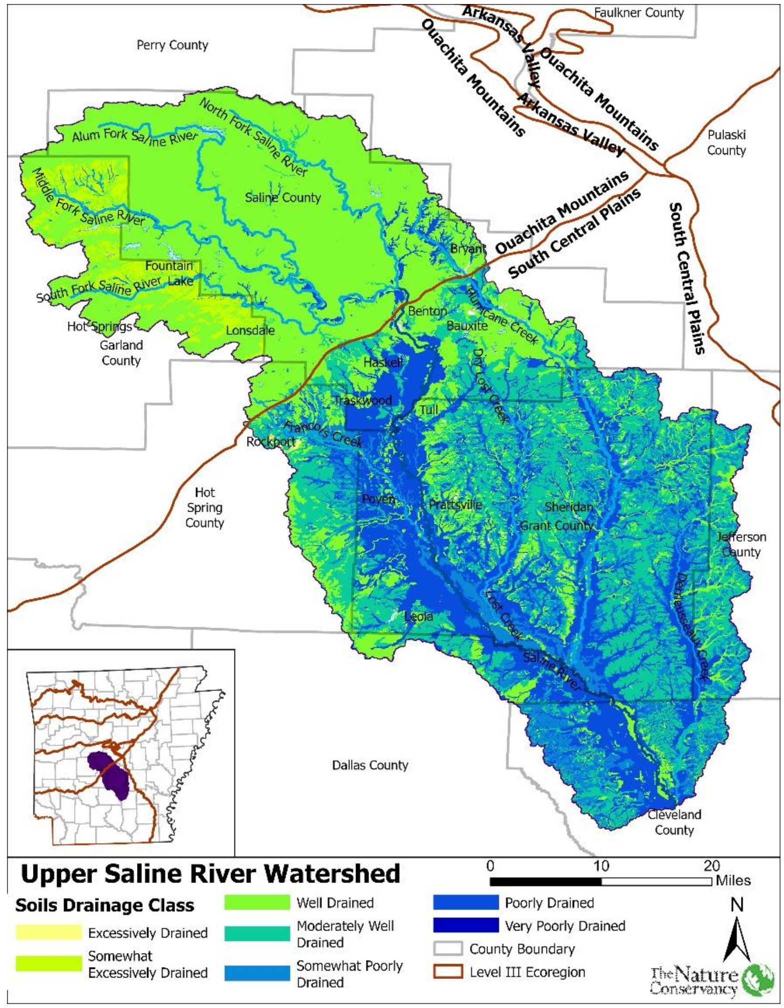

Figure 2.8. Map showing the rate at which water moves through soils. US Department of Agriculture, Natural Resources Conservation Service SSURGO 2017.

2.8.2 South Central Coastal Plains Soils

Soil formation in the SCP is very different from those of the Ouachita Mountain Ecoregion primarily because of the differences in parent material, aspect, and slope. Parent material consists predominately of sandstones, siltstones, and shale units. Soils formed on the broad upland flats and long, narrow ridges of stream terraces have subsoils of silt loam to silty clay loam. These soils are characterized as having moderate to poor drainage with moderate runoff potential (Figure 2.8). The upland soils are poorly to moderately drained and characteristically have a runoff potential that is moderate. Bottomland soils formed on nearly level topography surrounding the Saline River are frequently flooded and are poorly drained.

2.9 Hydrology

2.9.1 Subwatersheds and Stream Network

Within the HUC8 Upper Saline River watershed are nested nine HUC10 watersheds and 40 smaller HUC 12 subwatersheds (Table 2.9, Figure 2.9), ranging in size from Ray Creek-Hurricane Creek (64.9 mi^2) to the smallest, Beech Creek-Cow Head Creek (12.8 mi^2).

Table 2.9. HUC12 subwatersheds of the Upper Saline River ordered from largest to smallest total area.

HUC12 Subwatershed	Hydrologic Unit Code	Area Acres	Area mi^2	Area km^2
Ray Creek-Hurricane Creek	80402030405	41544.2	64.9	168.1
Little Hurricane Creek-Hurricane Creek	80402030401	37991.7	59.4	153.8
Pine Bridge Creek-Saline River	80402030903	37197.0	58.1	150.5
Cedar Creek-South Fork Saline River	80402030201	36625.1	57.2	148.2
Chapel Creek-Saline River	80402030808	35240.5	55.1	142.6
Outlet Middle Fork Saline River	80402030304	34940.2	54.6	141.4
Trace Creek-Saline River	80402030703	34544.1	54.0	139.8
Headwaters Alum Fork Saline River	80402030302	34053.5	53.2	137.8
Headwaters Middle Fork Saline River	80402030301	33676.3	52.6	136.3
Thunder Branch-Big Creek	80402030603	33434.9	52.2	135.3
Steep Creek-Saline River	80402030902	32730.6	51.1	132.5
Jordan Creek-Saline River	80402030704	32622.0	51.0	132.0
White Oak Creek-Hurricane Creek	80402030406	32540.5	50.8	131.7
Tenmile Creek-Francois Creek	80402030602	32360.2	50.6	131.0
Little Lost Creek-Lost Creek	80402030802	32047.0	50.1	129.7
Simpson Creek	80402030403	31208.2	48.8	126.3
Mud Creek-Hurricane Creek	80402030404	31173.7	48.7	126.2
Middle North Fork Saline River	80402030102	30999.4	48.4	125.5
Lower North Fork Saline River	80402030103	30745.8	48.0	124.4
Graves Creek-Lost Creek	80402030801	29601.1	46.3	119.8
Big Creek-Alum Fork Saline River	80402030305	28689.8	44.8	116.1
Depot Creek-Saline River	80402030702	27768.2	43.4	112.4
Mud Creek-Saline River	80402030806	27304.9	42.7	110.5
Johnson Creek-Derrieusseaux Creek	80402030502	25942.3	40.5	105.0
Mill Creek-South Fork Saline River	80402030202	25840.2	40.4	104.6
Logan Creek-Hurricane Creek	80402030402	25456.8	39.8	103.0
Little Alum Fork-Alum Fork Saline River	80402030303	24702.1	38.6	100.0
Upper North Fork Saline River	80402030101	24558.2	38.4	99.4
Allgood Creek-Derrieusseaux Creek	80402030503	24030.4	37.5	97.3
Little Derrieusseaux Creek-Derrieusseaux Creek	80402030501	23317.2	36.4	94.4
Panther Creek-Derrieusseaux Creek	80402030504	21527.1	33.6	87.1
Moccasin Creek-Saline River	80402030701	20493.9	32.0	82.9
Tenmile Creek-South Fork Saline River	80402030203	19878.9	31.1	80.5
Little Creek-Saline River	80402030901	19083.4	29.8	77.2
Flat Creek-Lost Creek	80402030803	18627.1	29.1	75.4
Cox Creek	80402030805	16972.6	26.5	68.7
Big Creek-Francois Creek	80402030604	16748.6	26.2	67.8
Brush Creek	80402030804	14481.3	22.6	58.6
Brushy Creek	80402030601	8967.6	14.0	36.3
Beech Creek-Cow Head Creek	80402030807	8206.3	12.8	33.2

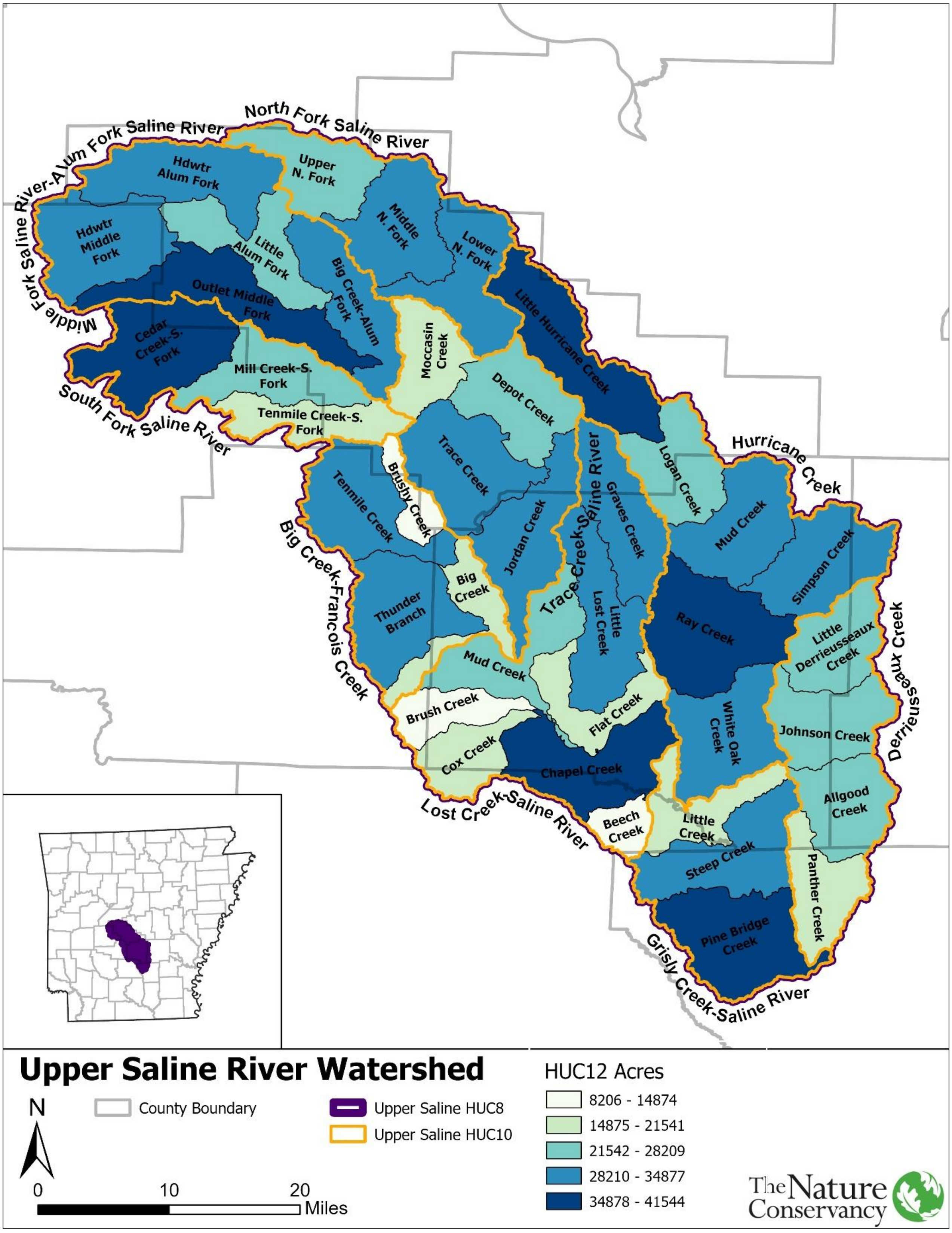

Figure 2.9. Map of HUC10 (orange boundaries) and HUC12 (black boundaries) subwatersheds within the Upper Saline River watershed (HUC8: 08040203).

Table 2.9.1. Upper Saline River Watershed stream network summarizing stream order (Modified Strahler Method) and length in miles, along with mean channel slope based on the High Resolution National Hydrography Database (NHDPlus HR; USGS 2022).

Stream Order	Total Length (mi)	Mean Channel Slope (%)
1st	2,770.57	1.20%
2nd	963.03	0.48%
3rd	554.01	0.28%
4th	285.45	0.12%
5th	194.80	0.09%
6th	179.84	0.04%
7th	0.00	No Data
8th	0.00	No Data
9th	0.00	No Data
10th	0.00	No Data
Other	20.42	No Data
Combined	4,968.12	1.30%

Length in agricultural areas = 173.11 mi
Length in non-agricultural areas = 4,795.01 mi

The USGS National Hydrography Dataset Plus High Resolution (NHDPlus HR; Buto and Anderson 2020; USGS 2022) includes 4,968 miles of streams and rivers in the Upper Saline River Watershed. The majority of the watershed's hydrologic network is composed of small seasonally ephemeral and intermittent first order streams (Modified Strahler Method; Table 2.9.1). Approximately 3% of the watershed's stream network (173 mi.) is located in areas classified as agricultural land use. These many small low-order (1^{st} and 2^{nd} order) headwater streams of the Upper Saline are considered typical of upland, cool Ouachita Interior Highland streams, and provide habitat for diverse fish communities (Robison and Buchanan, 2020). Streambed substrates are predominantly composed of cobble and exposed bedrock. Headwater streams are historically clear and cool with medium to high gradients, and these flow into higher-order big rivers which have lower gradients and more sand and gravel dominated substrates. Major tributaries of the Upper Saline River include: Alum Fork, Middle Fork, North Fork, South Fork, Derrieusseaux Creek, Francois Creek, Lost Creek and Hurricane Creek (Figure 2.1). These larger rivers and streams provide critical habitat for freshwater mussel communities and beds, many of which are species of greatest conservation need (SGCN, Table 2.9.4). Within the Ouachita ecoregion, only two rivers have remained unimpounded including the Saline River mainstem; however, the four forks of the Saline River have multiple impounded tributaries.

2.9.2 Municipal Water Usage

The watershed contains Lake Winona an important drinking water source for Central Arkansas. Lake Winona is surrounded by the Ouachita National Forest and has a watershed of 43 square miles. It is managed by Central Arkansas Water (CAW), a metropolitan water utility serving a population of nearly 500,000, including the community of Paron (pop. 2,071), located in the Upper North Fork (HUC12 8040203010).

2.9.3 Groundwater

Most of the ground water supplies in the Saline River Watershed are obtained from six water-bearing formations called aquifers or aquifer systems. These aquifers in order of increasing depth are the Quaternary Alluvial, Cockfield Formation, Cane River Formation, Sparta- Memphis Sand, Wilcox Group, and rocks of Paleozoic age. The majority of the reported ground water use in the Upper Saline watershed comes from the Quaternary Alluvial and Sparta-Memphis Sand aquifers which are mostly utilized for public water supply use and industrial purposes. The highest demand for water consumption within the Saline River Watershed is from surface water as opposed to ground water. Adequate ground water supplies are available for consumptive use; however, current demand is not excessive and readily available. Overall, Arkansas is withdrawing groundwater from the Alluvial and Sparta/Memphis aquifers in eastern and southern Arkansas at a rate far above that which is estimated to be sustainable (Arkansas Department of Agriculture, 2022). Hydrologic data for groundwater depth from locations in Grant County collected in 2020 and 2021 showed modest gains in groundwater depth (+2.63 ft below ground surface 2020-‘21) but a decline in Jefferson County (-1.35 ft bgs).

Table 2.9.3 Groundwater well monitoring data for salinity, temperature and pH from three sites in Grant County within the Upper Saline and four additional sites located outside the watershed boundary but within counties that are part of the watershed.

Site ID	County	Coordinates	Aquifer	Temp C	Specific Conductance	Hydrogen ion (mg/L)	pH
341024092354501 06S15W26ACA1	Grant	34°10'21.99", 92°35'37.59"	Sparta/Memphis	20.6	56	0.00782	5.1
341341092141401 06S11W05ACD1	Grant	34°13'40.82", 92°14'13.01"	Sparta/Memphis	28.1	135	0.00027	6.6
341841092332001 05S14W06DCC1	Grant	34°18'42.50", 92°33'26.69"	Sparta/Memphis	21.1	90	0.00096	6
341918091504901 04S08W35BBD1	Jefferson	34°19'09.06", 91°50'56.13"	Sparta/Memphis	24.7	146	0.00014	6.9
334758091595701 10S09W35ACD1	Cleveland	33°47'57.93", 91°59'57.13"	Sparta/Memphis	25	230	0.00002	7.8
334543092142201 11S11W16AAB1	Cleveland	33°45'43.01", 92°14'23.47"	Sparta/Memphis	25.6	366	0.00001	7.9
335916092413701 08S15W36BDA1	Dallas	33°59'16.40", 92°41'36.86"	Sparta/Memphis	29.9	336	0.00024	6.6

The United State Geological Survey (USGS) monitor for groundwater salinity data (Table 2.9.3) from a network of 100 wells, 50 in the Mississippi River Valley Alluvial aquifer and 50 wells in the Sparta/Memphis aquifer, on a rotation of 25 wells per year and alternating years between the alluvial and Sparta aquifers (Arkansas Department of Agriculture, 2023). In addition to the state Groundwater Salinity Program, other water quality parameters are monitored through the Arkansas Masterwell Network program, a long-term groundwater quality network comprised of 47 active wells and springs in 14 different aquifers across the state. Each year five sites are sampled for a variety of water-quality constituents including common ions, metals, nutrients, and radiochemistry.

Quaternary Alluvial Aquifer

Sometimes called the Alluvial Aquifer is the upper aquifer of the Mississippi embayment aquifer system. In the Saline River watershed, deposition of sediment from Pleistocene and Holocene time produced a series of sands, silts and clays that constitute this alluvial aquifer and semi-confining units. The aquifer dependent upon the thickness of the confining unit can behave as a “leaky aquifer” and contribute water to the Saline River along some portions of its course.

Sparta/Memphis Sand Aquifer

This Eocene-age aquifer ranks second in total ground water withdrawals in the Saline River basin. The aquifer is composed mainly of sand with considerable amounts of silt, clay, shale, and lignite, which are found in lenses throughout the unit. Lithologically it has considerable variance both vertically and laterally. In general, water in the Sparta Aquifer is of good quality and used chiefly for irrigation and for domestic water supply.

Cockfield Aquifer

This Eocene-age aquifer ranks third in total ground water withdrawals in the watershed. The Cockfield Aquifer generally consists of fine to medium sand in the basal part and silt, clay and lignite in the upper part. The yields of water are moderate to small and are mostly used for domestic consumption.

2.9.4 Aquatic biodiversity

With its distinct upland and lowland habitats, the Upper Saline River in Arkansas hosts one of the most biodiverse freshwater faunas in Arkansas. The region contains many endemic species and exhibits distinct biogeographic patterns, with connections to the Ozark Plateaus and other highland areas (Mayden, 1985). Fish assemblages in the Upper Saline are adapted to its dynamic hydrologic environment and are influenced by strong seasonal changes in stream flows, particularly drought conditions, which affect both water availability and water quality (Love et al., 2008). Among the 45 Species of Greatest Conservation Need (SGCN) in the watershed are 17 fish, 5 crayfish, and 8 and mussel species. These include several narrow range endemics like the Redspotted Stream Crayfish (*Orconectes acares*), Ouachita Madtom (*Noturus lachneri*), Caddo Sallfly (*Alloperla caddo*), and the Arkansas Fatmucket Mussel (*Lampsilis powellii*), as well as three federally listed mussel species: the Arkansas Fatmucket, Pink Mucket (*Lampsilis abrupta*), and Rabbitsfoot (*Thelyderma cylindrica*). Three additional species, the Pyramid Pigtoe (*Pleurobema rubrum*), Ouachita Fanshell (*Cyprogenia sp. cf aberti*), and Alligator Snapping Turtle (*Macrochelys temminckii*), are proposed for listing as threatened (Table 2.9.4)

Table 2.9.4. Freshwater Species of Greatest Conservation Need (SGCN) in the Upper Saline River watershed.

Scientific Name	Common Name	G Rank	S Rank	Federal Status	Taxa
Dryophytes avivoca	Western Bird Voiced Treefrog	G5	S3		Amphibian
Eurycea paludicola	Western Dwarf Salamander	G5	S3		Amphibian
Hemidactylium scutatum	Four-toed Salamander	G5	S2		Amphibian
Orconectes acares	Redspotted Stream Crayfish	G4	S3		Crayfish
Orconectes leptogonopodus	Little River Creek Crayfish	G4	S3		Crayfish
Faxonius palmeri	Gray-speckled Crayfish	G5	S?		Crayfish
Procambarus parasimulans	Bismarck Burrowing Crayfish	G4	S3		Crayfish
Procambarus simulans	Southern Plains Crayfish	G5	S1		Crayfish
Ameiurus nebulosus	Brown Bullhead	G5	S2		Fish
Anguilla rostrata	American Eel	G4	S3		Fish
Ammocrypta vivax	Scaly Sand Darter	G5	S3S4		Fish
Erimystax x-punctatus	Gravel Chub	G4	S3?		Fish
Etheostoma nigrum	Johnny Darter	G5	S2S3		Fish
Etheostoma parvipinne	Goldstripe Darter	G4G5	S3		Fish
Etheostoma stigmaeum	Speckled Darter	G5	S2S3		Fish

Lepomis marginatus	Dollar Sunfish	G5	S3?		Fish
Lepomis symmetricus	Bantam Sunfish	G5	S3S4		Fish
Lythrurus fumeus	Ribbon Shiner	G5	S3S4		Fish
Notropis ortenburgeri	Kiamichi Shiner	G3	S3		Fish
Notropis perpallidus	Peppered Shiner	G3	S3		Fish
Notropis texanus	Weed Shiner	G5	S3		Fish
Noturus eleutherus	Mountain Madtom	G4	S3S4		Fish
Noturus lachneri	Ouachita Madtom	G2	S2		Fish
Opsopoeodus emiliae	Pugnose Minnow	G5	S3S4		Fish
Percina vigil	Saddleback Darter	G5	S3		Fish
Alloperla caddo	Caddo Sallfly	G1G2	S1		Insect
Ophiogomphus westfalli	Ozark Snaketail Dragonfly	G3	S1S2		Insect
Lirceus bicuspidatus	Isopod	G3Q	S3		Invertebrate
Alasmidonta marginata	Elktoe	G4	S3		Mussel
Cyprogenia sp. cf aberti	Ouachita Fanshell	G2	S3	Proposed Threatened	Mussel
Lampsilis abrupta	Pink Mucket	G2	S3	Endangered	Mussel
Lampsilis ornata	Southern Pocketbook	G5	S2		Mussel
Lampsilis powellii	Arkansas Fatmucket	G2	S2	Threatened	Mussel
Pleurobema cordatum	Ohio Pigtoe	G3	S3		Mussel
Pleurobema rubrum	Pyramid Pigtoe	G2G3	S2	Proposed Threatened	Mussel
Pleurobema sintoxia	Round Pigtoe	G4G5	S3		Mussel
Ptychobranchus occidentalis	Ouachita Kidneyshell	G3G4	S3		Mussel
Thelyderma cylindrica	Rabbitsfoot	G3	S3	Threatened	Mussel
Toxolasma lividum	Purple Lilliput	G2	S3		Mussel
Toxolasma parvum	Lilliput	G5	S3		Mussel
Toxolasma texasense	Texas Lilliput	G4	S3		Mussel
Truncilla donaciformis	Fawnsfoot	G5	S3		Mussel
Uniomerus tetralasmus	Pondhorn	G4	S2		Mussel
Liodytes rigida	Gulf Swampsnake	G5	S3		Reptile
Macrochelys temminckii	Alligator Snapping Turtle	G3	S3	Proposed Threatened	Reptile

2.10 Land use/Landcover

Landcover in the Upper Saline River watershed is predominantly forested (72.4%), with evergreen and pine dominated forest (38%), deciduous forest (13.2%) and mixed forest (5.7%) covering 56.9% of the land area (Figure 2.10, USGS National Landcover Database, NLCD 2021). Woody wetlands (15.5%) cover larger portions of the watershed below the “fall line” along the ecoregion boundary between the Ouachita Mountains and South Centrals Plains. These high biodiversity areas of bottomland forest and shrubland are periodically saturated or inundated with water and cover large proportions of many HUC12 subwatersheds below the fall line, including Little Creek-Saline River (52% woody wetlands), Big Creek-Francois Creek (49%), Chapel Creek-Saline River (47%), and Steep Creek-Saline River (41%; Figure 2.10, Appendix D Table D2). Land area classified as shrub/scrub (5.5%) is variable over annual time scales as pine forests are harvested for timber and these areas begin to regrow. There is a growing developed/urban component comprising 8.6% of the watershed’s land use and a smaller, but significant portion, 6%, of pasture land (Figure 2.10). Detailed descriptions of the NLCD landcover categories for the HUC12 are included in Appendix C.

Prior to development, the watershed basin was predominantly covered with thick growths of a mixture of hardwoods and pines. Associated with the onset of settlers in the 1800’s and the outbreak of World War II, lumbering became high priority and a chief source of income in this area. Much of the forested land is still managed today for the production of pulpwood, poles, and saw logs and is a strong economic force in the watershed.

While ninety-five percent of the land within the watershed boundary is under private ownership the majority of private lands remain forested. Large tracts are owned by paper and timber companies with farm ownership ranging from small to large tracts of land. Most of the agricultural lands in the watershed are devoted to hay and cattle production but overall agricultural land use is low in the Upper Saline compared to other watersheds across the state.

The 1.8 million-acre Ouachita National Forest is the South’s oldest and largest National Forest, extending into parts of eleven counties in Arkansas and two counties in Oklahoma. Portions of the Ouachita National Forest located in the Upper Saline watershed are found in Garland, Saline, and Hot Springs Counties.

The Arkansas Game and Fish Commission (AGFC) manages the Winona Wildlife Management Area (WMA, established in 1968) consisting of 145,276 acres of moderate to rugged mountain terrain and narrow valleys and a 14,724 acre section of Cedar Mountain WMA in Perry and Saline Counties located along the southeast border of the Winona WMA. These WMAs are popular hunting areas managed under a cooperative agreement between the AGFC and U.S. Forest Service, with primary ownership by the USDA and Green Bay Packaging, Inc. The AGFC annually leases large portions of land from Green Bay Packaging, Inc. to enhance public access and hunting.

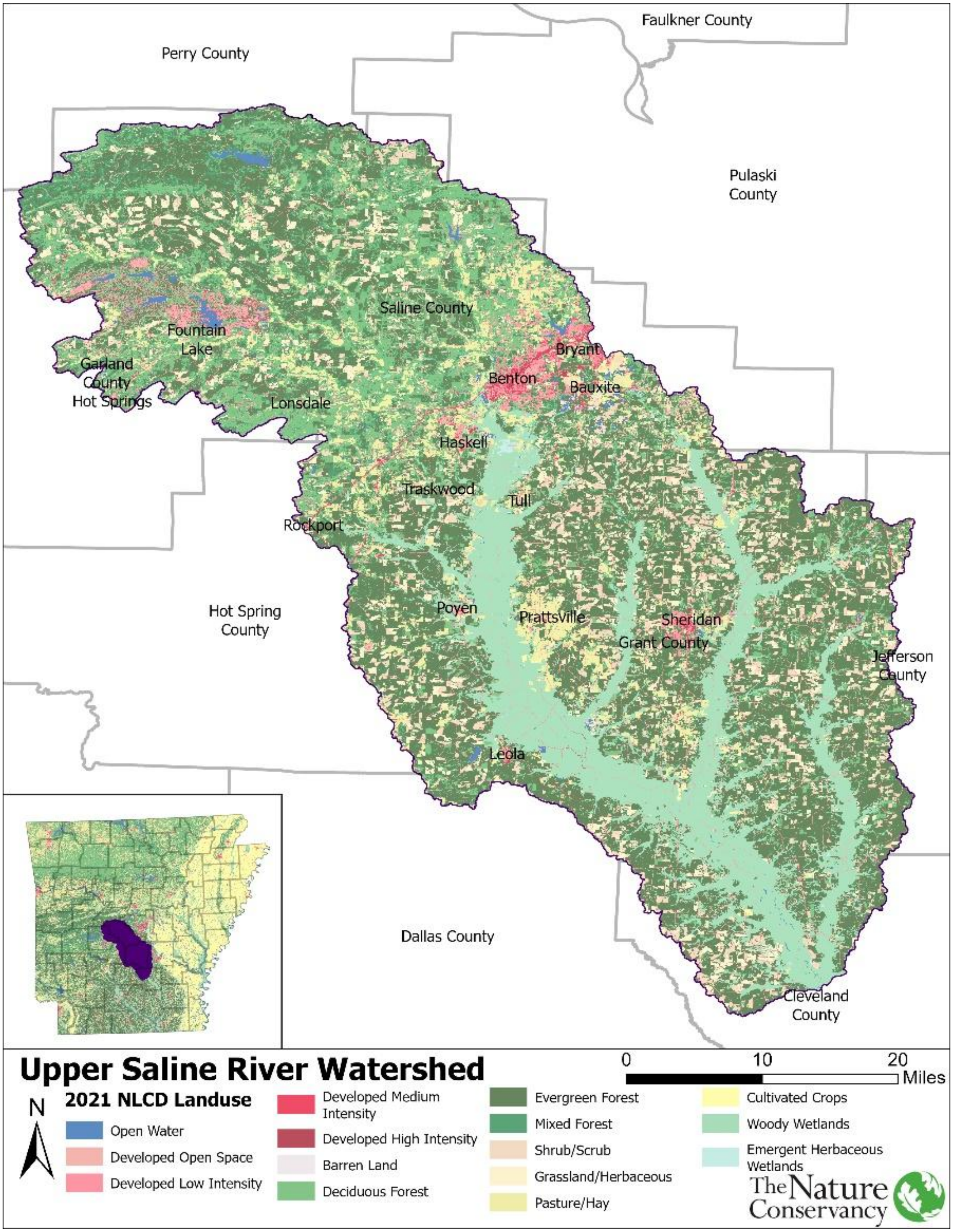

Figure 2.10. Map of 2021 NLCD land use and landcover in the USRW

Acreage managed and owned federally by the US Forest Service within the Upper Saline watershed includes approximately 45,294 acres. State land holdings are limited but include Jenkins Ferry State Park, approximately 32 acres south of the city of Sheridan, managed by The Arkansas State Parks. Jenkins Ferry offers restrooms, a pavilion, swimming and a launch ramp on the Saline River. The Arkansas Forestry Commission and the Arkansas Department of Agriculture own and manage approximately 565 acres of conservation land within the watershed located in the vicinity of Fountain Lake.

The Arkansas Department of Transportation (ARDOT) currently manages two mitigation areas: the Lockett Creek Mitigation Area (240 ac.) bordering the South Fork Saline River near Hot Springs Village in Garland County and the Upper Saline River Mitigation Area (327 ac.) between the Alum Fork and Middle Fork near Crows in Saline County.

The Nature Conservancy owns several small preserves including the Cooper Preserve (123 ac.) located along a large bend of the Middle Fork Saline just north of Hot Springs Village There are several natural areas established within the Bauxite Mining Reclamation Area near Bauxite, AR totaling approximately 194 acres including IP Pipewort Glade Unique Area, and Dry Lost Creek Preserve.

In 2007, the Arkansas Natural Heritage Commission (ANHC) acquired roughly 135 acres within the Middle Fork Saline sub-watershed named The Middle Fork Barrens Natural Area; a site where several globally rare, endemic plant species occur. Alum Fork Natural Area became part of ANHC's System of Natural Areas in 2018 and now totals 493 acres, of which 234 acres are co-owned and managed in partnership with The Nature Conservancy. It has been expanded since to protecting approximately 2.4 miles of river frontage along the Alum Fork and many smaller tributaries. In 2022, ANHC added Goat's Beard Bluff Natural Area (540 acres) located along the lower portion of the Alum Fork of the Saline River, 3 miles upstream from its confluence with the North Fork. Some hunting is also allowed on the Alum Fork and Goats Beard Bluff natural areas through a cooperative agreement between ANHC and the AGFC, which incorporated certain natural areas into AGFC's Wildlife Management Area (WMA) system. Private ownership accounts for the remaining 1,032,434 acres of land within the Upper Saline River Watershed.

2.10.1 Land use/cover change

The mapping and classification of landcover and land use data is important in determining what threats are contributing to water quality and quantity changes within the Upper Saline Watershed. The Nature Conservancy (TNC) utilized geographical information system and remote sensing (GIS/RS) technologies to analyze land use practices and patterns within the watershed. TNC's Arkansas Field Office GIS\RS lab conducted a spatial and temporal analysis for the Upper Saline Watershed. National Land Cover Database classifications from 2006 and 2021 were used to examine and quantify changes in the watershed between these time periods.

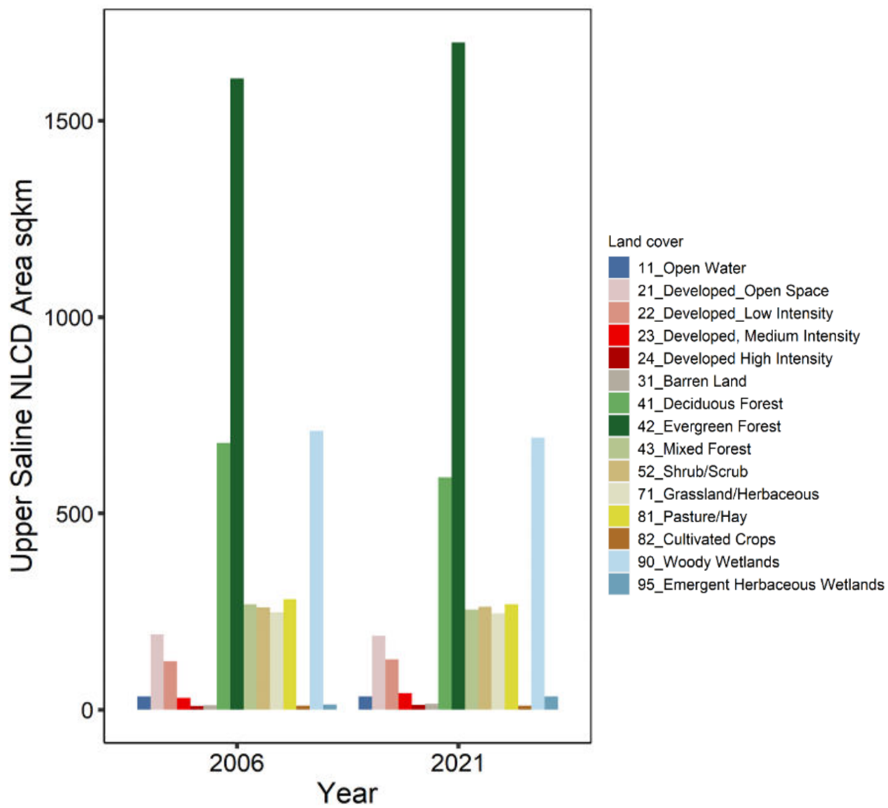

Figure 2.10.1. Land use and landcover in the Upper Saline River Watershed in 2006 and 2021 (NLCD 2021).

The results provide a landscape level view of major changes within the watershed. Quantifying these significant changes in the Upper Saline watershed assists in determining anthropogenic impacts such as deforestation, sedimentation, declining water quality and other hydrologic alterations in the watershed. Land managers, city and county officials can use this information to focus on employing appropriate management activities to reduce the most detrimental impacts to surface and groundwater.

Analysis of broad landcover changes occurring in the HUC8 watershed showed that, between 2006 and 2021, evergreen forest associated primarily with pine plantations increased by 6% (35.3 mi^2, 22,616 acres). During the same period, deciduous forest decreased by 13% (33.7 mi^2, 21,611 acres) and mixed forest matrix decreased by 5% (5 mi^2, 3,199 acres) (See Appendix D Table D1). The dominant processes contributing to the loss of deciduous and mixed forest was conversion to grassland/herbaceous and shrub/scrub landcover, along with conversion to developed open space and low intensity urban area (Appendix D Table D4).

Another significant change in the landcover classification was the growing urban component of the watershed. Urban developed areas (combined low, medium, and high intensity) increased by 12% (7.6 mi^2, 4850 acres) throughout the Upper Saline (Figure 2.10.1, Appendix D). The majority of developed area expansion occurred in Saline County around the city of Benton in the Little Hurricane Creek-Hurricane Creek (HUC12 80402030401) and Depot Creek-Saline River (80402030702) subwatersheds and in Garland County around the eastern shore of Lake Balboa in the Cedar Creek-South Fork Saline River (80402030201). The greatest driver of changes from other landcover categories to developed/urban land use was conversion of deciduous forest to developed open space (253 ac.) and low intensity urban development (160 ac.), and pasture/hay landcover conversion to developed open space (211 ac.) and low intensity urban development (205 ac.) (Appendix D Table D4).

Land cover	Area Sq. km 2006	Area Sq. km 2021	Change in Area Sq. km	Change in Area Acres	Percent Change	2006 % of Watershed	2021 % of Watershed
11_Open Water	34	33	-1	-149	-2	0.8	0.7
21_Developed_Open Space	192	188	-3	-850	-2	4.3	4.2
22_Developed_Low Intensity	123	128	5	1221	4	2.8	2.9
23_Developed, Medium Intensity	30	42	12	2964	41	0.7	0.9
24_Developed High Intensity	9	12	3	665	29	0.2	0.3
31_Barren Land	11	14	4	949	36	0.2	0.3
41_Deciduous Forest	679	592	-87	-21611	-13	15.2	13.2
42_Evergreen Forest	1607	1699	92	22616	6	35.9	38.0
43_Mixed Forest	268	255	-13	-3199	-5	6.0	5.7
52_Shrub/Scrub	261	261	1	195	0	5.8	5.8
71_Grassland/Herbaceous	247	245	-2	-565	-1	5.5	5.5
81_Pasture/Hay	281	268	-13	-3217	-5	6.3	6.0
82_Cultivated Crops	10	10	0	23	1	0.2	0.2
90_Woody Wetlands	709	693	-16	-3957	-2	15.9	15.5
95_Emergent Herbaceous Wetlands	13	33	20	4904	151	0.3	0.7

Figure 2.10.2. Land use/landcover changes in the Upper Saline River watershed (HUC8) from 2006 to 2021 based on the National Landcover Database (NLCD 2021). Blue fields indicate a decrease in total land use/land cover between 2006 and 202, and orange fields indicate an increase.

3. 9-ELEMENT WATERSHED BASED STRATEGY & GOALS

The updated Upper Saline River 9-Element Plan Watershed Management Plan is a joint venture between the Arkansas Department of Agriculture's Natural Resources Division and the Nature Conservancy's (TNC) Arkansas Field Office in an attempt to prioritize specific non-point source (NPS) pollution management measures and provide a plan to the Environmental Protection Agency (EPA) for this priority watershed. In order to identify the priority NPS management measures, the following things needed to be accomplished (1) documentation of past, current, and future efforts for the evaluation of baseline ecological, hydrological, and geomorphological conditions within the Upper Saline watershed and (2) identification of critical data gap that inhibit prioritization of non-point pollution reduction efforts within the watershed.

The Nature Conservancy of Arkansas and the Saline River Watershed Alliance (SRWA) hosted four "Watershed Stakeholders" meetings and one landowner streamside management workshop throughout 2023-2025 to discuss restoration planning for the Upper Saline River watershed. Involving local stakeholders in the planning process helped to ensure the plan takes into consideration input from those who live, work, or enjoy recreational activities in the watershed. Stakeholder participation in watershed planning also increases direct local involvement in best management practice (BMP) implementation. The objective of the stakeholder meetings was two-fold: 1) to disseminate information on past, current, and ongoing research and restoration efforts within the watershed, and 2) to discuss stakeholder issues of concern, identify short and long term goals for the watershed, and the steps necessary to achieve those goals. Meeting participants included a variety of stakeholders within the watershed including: watershed groups, timber producers, construction/development representatives, private landowners, city/municipal representatives, county representatives, and local, state, and federal agency personnel involved with research and restoration within the Upper Saline Watershed. A complete list of representative groups is included in Appendix A.

In addition to the in-person stakeholder meetings, TNC created and distributed a watershed questionnaire comprised of a series of questions focused on gauging public perceptions of water quality in the Upper Saline River watershed, including concerns and perceived threats. The questionnaire included 16 questions and a total of 58 stakeholders responded with input, although not all respondents replied to every question. A copy of the questionnaire and selected responses are included in Appendix I. Respondents ranked perceived water quality issues into one of five categories which were assigned point scores ranging from severe (3 points), moderate (2), slight (1), to not an issue, or "don't know" (0). The respondent scores were summed for each issue to produce an overall ranking that were assessed alongside input from attendees of in-person stakeholder meetings to determine the top water quality concerns within the watershed, which are discussed in detail below.

The following is a summary of the top issues of concern in Upper Saline River watershed and potential causes identified through the stakeholder meetings and community watershed questionnaire. Conservation and management strategies are described for each of the concerns/issues.

3.1 Land development/construction

Nested Issues: Increased impervious surface area and storm water runoff, erosion, land conversion, increased sedimentation, inputs of roadside trash in stream channels, illegal dumping in the watershed

Saline County ranks as the fifth fastest growing county in the state with a population increase of more than 6.3% since 2020 (Table 2.2). The city of Benton now has the tenth largest population in the state, while Bryant and Sheridan are also experiencing significant population growth. To accommodate future population growth and traffic projections, the Arkansas Department of Transportation (ARDOT) completed a project widened approximately 18 miles of Highway 70 to five lanes, extending generally from Hot Springs in Garland County to Interstate 30 in Saline County. ARDOT also recently completed a widening and safety improvement project along the I-30 corridor in Saline County in January 2025, which included replacement of the westbound and eastbound I-30 bridges over the Saline River and several other tributary streams (ARDOT 2016).

In many urban areas in the Upper Saline, soil erosion is accelerated where land has been disturbed, and vegetation or other natural protective cover of the soil has been removed. Increased development and the resulting increase in sedimentation was identified as a top issue of concern in the Upper Saline Watershed, particularly in areas around Benton and Hot Springs Village. The greatest increases in total land area classified as urban developed (combined low, medium and high intensity) from 2006-2021 were seen in the HUC12 subwatersheds of Little Hurricane Creek-Hurricane Creek (1412 acres, 32% increase), Depot Creek-Saline River (719 acres, 12% increase), and Cedar Creek-South Fork Saline River (432 acres, 15% increase).

Looking closer at the percent of impervious surface area (ISA) within 100m of stream channels across the HUC12 subwatersheds (Figure, 3.1.1; Table 3.1), Depot Creek-Saline River had the highest ISA (5.12%) within its riparian buffer, followed by Little Hurricane Creek-Hurricane Creek (4.6%) and Cedar Creek-South Fork Saline River (4.16 %). ISA is closely related to the levels of urban development (urban open space, low, medium and high intensity) within riparian areas. These four development categories were summed to represent the cumulative extent of development with these riparian zones (Total % Riparian Developed; Figure 3.1.2; Table 3.1). ISA was not included in this total, as it was assumed to be already accounted for in the other development categories. Across the HUC12 subwatersheds in the Upper Saline, the total percent riparian developed ranged from a high of 22.63% in Cedar Creek-South Fork Saline River to a low of 1.92% in Cox Creek.

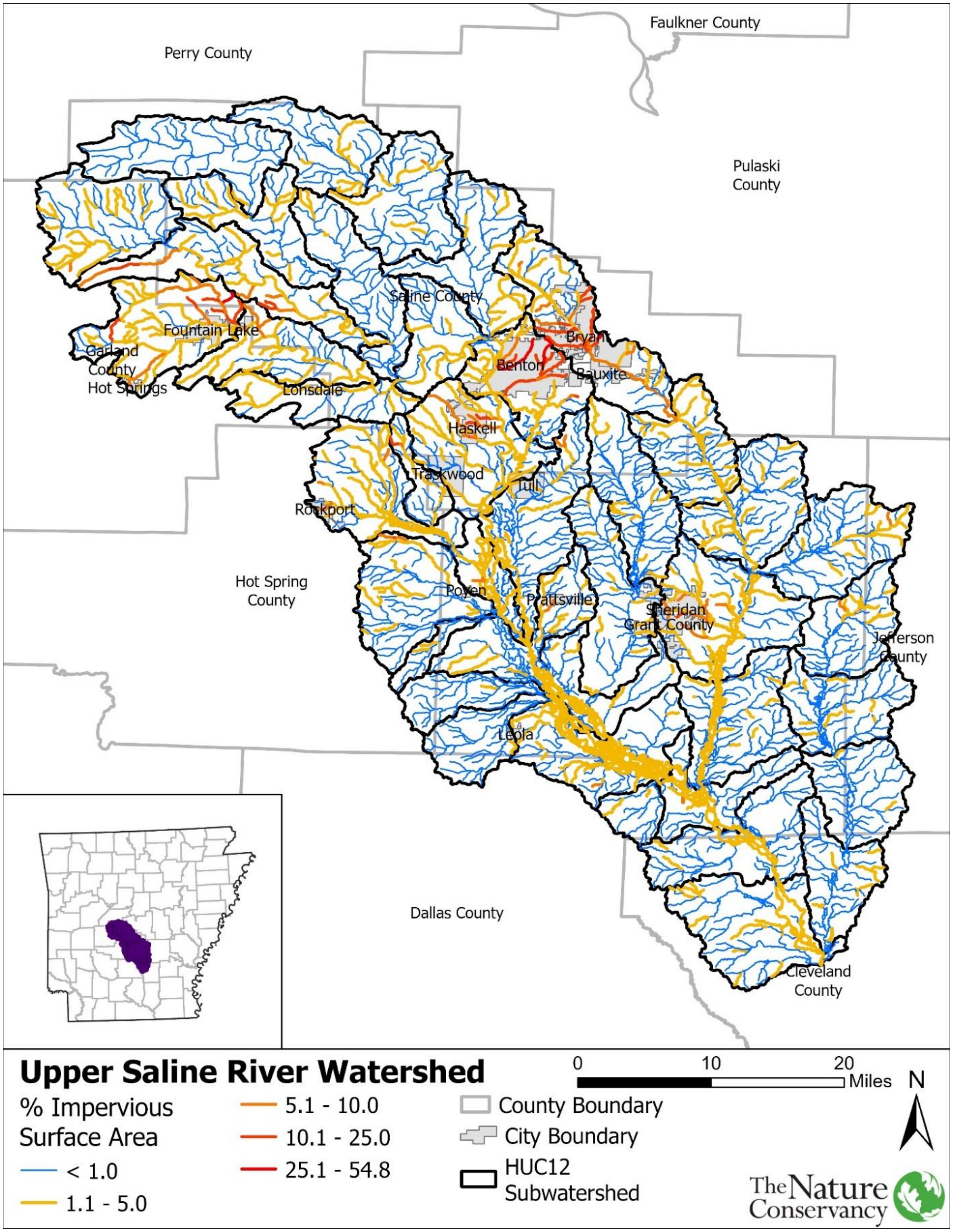

Figure 3.1.1. Impervious surface area (ISA) within a 100m linear distance of stream channels. The values were calculated from the 2019 National Land Cover Database (NLCD) and are available in the EPA map database (Hill et al., 2016).

Table 3.1. The extent of development within a 100m linear distance of stream channels in each HUC12 subwatershed. The values were calculated from the 2019 National Land Cover Database (NLCD) and are available in the EPA StreamCat database.

HUC12 Name	HUC12 Area (mi^2)	Mean % Impervious 100m	Mean % Urban Open100m	Mean % Urban Low Intensity100m	Mean % Urban Med Intensity100m	Mean % Urban High Intensity100m	Total % Riparian Developed
Cedar Creek-South Fork Saline River	57.2	4.16	14.33	5.64	2.19	0.47	22.63
Depot Creek-Saline River	43.4	5.12	8.05	6.21	3.33	0.86	18.46
Outlet Middle Fork Saline River	54.6	2.68	12.78	3.62	1.31	0.22	17.93
Little Hurricane Creek-Hurricane Creek	59.4	4.60	6.61	4.72	4.06	1.40	16.80
Mill Creek-South Fork Saline River	40.4	2.36	6.24	3.26	1.18	0.27	10.94
Trace Creek-Saline River	54.0	2.11	4.63	2.99	1.19	0.32	9.12
Tenmile Creek-South Fork Saline River	31.1	1.37	6.44	1.88	0.54	0.08	8.94
Ray Creek-Hurricane Creek	64.9	1.87	3.73	3.62	0.99	0.13	8.47
Logan Creek-Hurricane Creek	39.8	1.83	3.89	2.77	1.31	0.29	8.26
Headwaters Middle Fork Saline River	52.6	1.09	6.01	1.68	0.37	0.10	8.15
Little Alum Fork-Alum Fork Saline River	38.6	0.97	5.13	1.72	0.22	0.01	7.08
Moccasin Creek-Saline River	32.0	0.97	4.62	1.41	0.47	0.07	6.57
Brushy Creek	14.0	1.81	2.38	2.01	1.69	0.21	6.28
Tenmile Creek-Francois Creek	50.6	1.29	3.75	1.61	0.78	0.09	6.22
Chapel Creek-Saline River	55.1	1.24	3.41	1.91	0.60	0.13	6.06
Big Creek-Francois Creek	26.2	1.18	3.38	1.63	0.56	0.16	5.72
Lower North Fork Saline River	48.0	0.72	3.71	1.22	0.44	0.05	5.42
Little Creek-Saline River	29.8	1.09	2.69	1.89	0.51	0.13	5.23
Flat Creek-Lost Creek	29.1	1.04	2.92	1.68	0.46	0.11	5.17
Thunder Branch-Big Creek	52.2	1.09	2.78	1.72	0.25	0.20	4.96
Mud Creek-Saline River	42.7	1.01	2.72	1.74	0.37	0.11	4.93
Jordan Creek-Saline River	51.0	0.88	2.79	1.41	0.43	0.10	4.73
Middle North Fork Saline River	48.4	0.54	3.55	0.85	0.17	0.01	4.58
Pine Bridge Creek-Saline River	58.1	0.95	2.03	2.09	0.38	0.07	4.56
Simpson Creek	48.8	0.79	2.33	1.87	0.25	0.03	4.48
Upper North Fork Saline River	38.4	0.53	3.41	0.88	0.12	0.00	4.41
Mud Creek-Hurricane Creek	48.7	0.85	2.11	1.75	0.41	0.09	4.36
White Oak Creek-Hurricane Creek	50.8	0.81	2.10	1.57	0.36	0.07	4.11
Little Derrieusseaux Creek-Derrieusseaux Creek	36.4	0.75	1.87	1.81	0.18	0.00	3.86
Steep Creek-Saline River	51.1	0.71	1.93	1.38	0.31	0.07	3.69
Headwaters Alum Fork Saline River	53.2	0.22	3.37	0.17	0.03	0.00	3.57
Big Creek-Alum Fork Saline River	44.8	0.51	2.18	0.95	0.16	0.01	3.29
Graves Creek-Lost Creek	46.3	0.53	1.82	1.33	0.08	0.01	3.24
Little Lost Creek-Lost Creek	50.1	0.53	1.72	1.34	0.04	0.00	3.09
Beech Creek-Cow Head Creek	12.8	0.65	1.15	1.84	0.08	0.01	3.08
Brush Creek	22.6	0.53	1.63	1.25	0.08	0.01	2.98
Johnson Creek-Derrieusseaux Creek	40.5	0.52	1.64	1.21	0.10	0.00	2.95
Panther Creek-Derrieusseaux Creek	33.6	0.52	1.34	1.42	0.06	0.00	2.82
Allgood Creek-Derrieusseaux Creek	37.5	0.43	1.59	1.06	0.08	0.00	2.73
Cox Creek	26.5	0.37	1.09	0.75	0.09	0.00	1.92

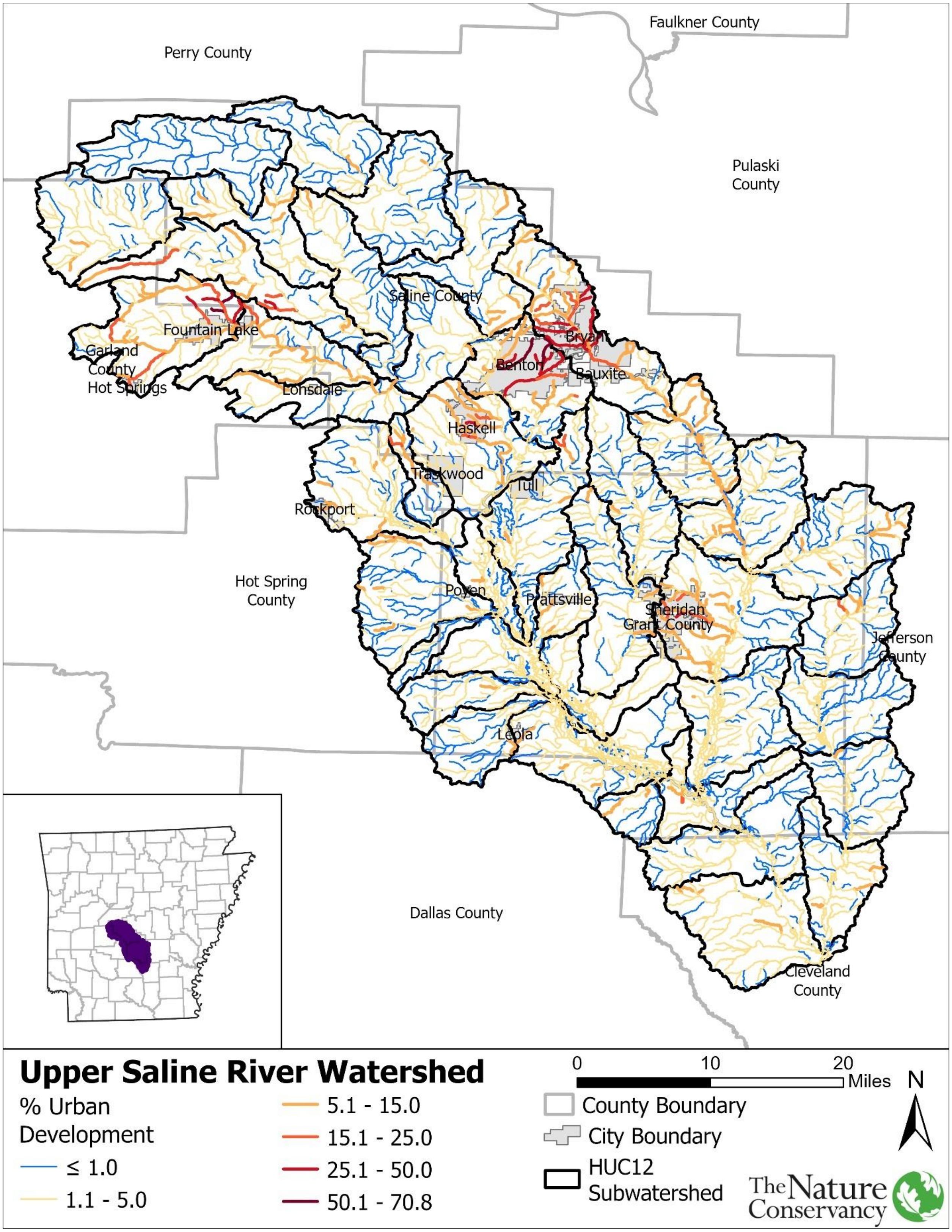

Figure 3.1.1. Urban development (combined urban open space, low, medium and high intensity) within a 100m linear distance of stream channels.

Conservation and Management Strategies:

Urban development can significantly impact water quality, but various best management practices (BMPs) and low impact development (LID) techniques can help mitigate these effects. BMPs and LID approaches for reducing and treating urban stormwater runoff include vegetated storm water retention ponds, green roofs, rain barrel/cisterns, bioretention systems, porous pavement, permeable patio, grass strip and swales, wetland channel, retention pond, infiltration systems, sand filters, riparian tree planting and vegetative practices (Dunn et al., 1995). Installing these approaches have been shown to the potential to reduce urban runoff volume by up to 26.47% and pollutant loads by 27-61% (Liu et al., 2015). Simply integrating grass strips into impervious areas like sidewalks and parking lots can prove to be among the most cost-efficient and effective practices for achieving reductions in storm runoff and pollutants (Liu et al., 2015). Focusing on higher-density urban development and reducing the size of the urban footprint can also help to reduce per capita pollutant loadings and runoff (Jacob & Lopez, 2009).

Installation and diligent maintenance of appropriate erosion control measures is needed in all construction project areas in order to minimize the impact to both intermittent and perennial streams. Change or update municipal and county building codes to allow and/or incentivize green infrastructure and low impact design and development – this may include use of bioretention basins, bioswales, green roofs and rain gardens, use of permeable pavement and restoration and expansion of riparian buffers. Work with city planning boards to implement a sensible zoning plan and storm water system improvements – developing a vulnerability map – reduce impervious surface – it is hard to depave but much easier to implement more pervious designs in new construction. Develop a detailed streamside and floodplain vulnerability maps – reduce impervious surface and implement more pervious designs. Explore local investment in floodplain work – Shelter Insurance may have some interest through home insurance programs. AR-DOT – Clint Hutchinson – buy some floodplain and maintain as mitigation offset. Green Bay working together with local partners to improve floodplain connectivity in strategic areas of their operating area.

Stream mitigation banking (SMB) emerged in the 1990s as a market-based approach to environmental conservation under the Clean Water Act Section 404 program. The 2008 Compensatory Mitigation Rule developed jointly by the U.S. EPA and Army Corps of Engineers requires that permitted unavoidable impacts to surface water are off-set by purchasing mitigation credits produced at a mitigation bank; a segment of a stream that is restored, enhanced, or conserved to provide ecological benefit according to crediting criteria (Lave et al. 2008). In 2013, ARDOT completed their Upper Saline River Mitigation Bank prospectus pursuant to Section 404 of the Clean Water Act (33 U.S. Code 1344). The Upper Saline River Mitigation Bank is intended to restore, establish, enhance and preserve streams, wetlands, and their associated uplands to mitigate for any unavoidable impacts to aquatic resources resulting from future permitted activities (https://ardot.gov/divisions/environmental/natural-resources/mitigation/). ARDOT currently manages two mitigation areas: the Lockett Creek Mitigation Area (240 ac.) bordering the South Fork Saline River near Hot Springs Village in Garland County and the Upper Saline River Mitigation Area (327 ac.) between the Alum Fork and Middle Fork near Crows in Saline County.

3.2 Loss of riparian tree buffers along streams/loss of deciduous forest across the watershed

Nested Issues: Increased sedimentation, runoff from forest roads, turbidity, nutrient runoff, stream temperature.

Riparian buffers provide numerous ecological and environmental benefits to aquatic ecosystems and water quality by intercepting sediment, increasing dissolved oxygen levels, and reducing the concentrations of nutrients and other pollutants (Mayer et al., 2010; Chase et al., 2016; Feld et al., 2018). Riparian forest buffers further enhance fish and aquatic insect biodiversity and overall ecosystem health by stabilizing streambanks, providing shade, regulating water temperature, reducing hydrologic variability, and contributing organic matter and large wood to streams (Feld et al., 2018). In urban environments, riparian buffers can help mitigate the effects of development by supporting benthic diatom communities and reducing pollution-tolerant species (Mutinova et al., 2020). Riparian buffers may be more effective at countering urbanization impacts on water quality than previously thought, even in highly urbanized watersheds (Denning and Schulte, 2024), further underscoring the importance of riparian buffer conservation and restoration for maintaining stream ecosystem health and services. Forested and grass or herbaceous buffer strips offer different benefits and services and zoned buffers with distinct woody and grassy zones can optimize their multifunctional benefits (Cole et al., 2020).

Loss of streamside forest typically results in accelerated bank erosion, channel shallowing, increases in stream temperature, loss of aquatic habitat and other detrimental effects (Sweeny et al., 2004). Improperly maintained streamside protection zones may adversely affect species diversity and biological productivity by degrading water quality (i.e. nutrient loading, sediment loading), energy sources and altering flow regimes and physical habitat (Davidson, Clem 2002). For watershed management purposes, it is important to assess land use categories in the context of land coverage within critical riparian areas of the watershed (Wenger, 1999). While optimal buffer dimensions vary depending on specific stream characteristics and management goals (Frimpong et al., 2005; Broadmeadow & Nisbet, 2004), riparian forest buffers of 30 meters or wider are generally recommended to maintain physical, chemical, and biological stream integrity (Sweeney & Newbold, 2014; Broadmeadow & Nisbet, 2004), although). Riparian buffer length can be as much or more influential than width in improving water quality, with lengths of 500-1000 meters showing greater positive effects (Brumberg et al., 2021). Large-scale research studies have found that 60% forest cover within a 10m buffer, or 45% within a 30m buffer, correspond to good ecological status (Van Looy et al., 2013). In New Zealand, catchments with 80-90% native forest were associated with clean water quality, while 40-60% cover retained 80% of stream biodiversity (Death & Collier, 2010). Maintaining and reestablishing wider and more connected forested buffers with mixed native tree species and varied age classes is optimal to preserving water quality and ecological integrity (Broadmeadow & Nisbet, 2004).

The percent coverage of deciduous, coniferous, mixed forest and total riparian forest in 2019 within 100m linear distance of streams in the Upper Saline were mapped (Figure 3.2.1) and summarized for the HUC12 subwatersheds (Table 3.2) using ESRI ArcPro. Landcover data were obtained from the EPA The Stream-Catchment (StreamCat) Dataset (https://www.epa.gov/national-aquatic-resource-surveys/streamcat-dataset; Hill et al., 2016). StreamCat is an extensive publically available database of landscape metrics for ~2.65 million stream segments, and their associated catchments, within the conterminous United States (U.S.) for both catchments (i.e., the nearby landscape flowing directly into streams) and full upstream watersheds of specific stream reaches.

Across the Upper Saline River watershed total riparian forest cover averaged 56.8%. Riparian forest area was greatest in the Headwaters Alum Fork Saline River (87.1%), Upper North Fork Saline River 79.1%) and Headwaters Middle Fork Saline River (70.3%) and lowest in White Oak Creek-Hurricane Creek (43.7%), Mud Creek-Saline River (41.8%) and Little Creek-Saline River (39.7%). Within the Upper Saline the average percent coniferous forest cover (34.4%) in riparian buffers exceeded deciduous (15.5%) and mixed forest (6.9%) in most subwatersheds and was highest in Graves Creek-Lost Creek (58.3%), Mud Creek-Hurricane Creek (58%), and Thunder Branch-Big Creek (56%). Deciduous riparian forest was highest in Tenmile Creek-South Fork Saline River (46.6%), Lower North Fork Saline River (42.1%), and the Upper North Fork Saline River (29.3%), while mixed riparian forest was greatest in Headwaters Alum Fork Saline River (29.4%), Upper North Fork Saline River (19.5%), and Headwaters Middle Fork Saline River (18.8%).

Conservation and Management Strategies:

To address loss of riparian buffers and the decline of deciduous forests, conservation efforts should prioritize restoring native vegetation along streambanks through targeted reforestation and invasive species removal. Planting native trees and shrubs from container stock or direct seeding, where feasible (i.e. in areas where seeds will have time to germinate and establish), can be used to establish riparian woody vegetation Direct seeding also could more effectively mimic natural processes of seed dispersal and seedling recruitment ultimately resulting in a more ecologically sound restoration project (Young and Evans, 2005; Young and Evans, 2001). An important step in this process is conducting mapping and assessment of current forest cover and riparian conditions using GIS tools and field surveys to enable the identification of degraded areas, high-priority habitats, and connectivity gaps. Prioritization should be guided by ecological value, erosion risk, water quality impacts, and stakeholder readiness, ensuring that restoration efforts are strategically focused. Implementing flexible conservation easements in priority areas can also be used to support ecological restoration activities. Forest management plans should incorporate selective prescribed fire and long-term monitoring to enhance forest structure and resilience. Stand thinning may also be used to assist the development of riparian areas toward a mosaic of riparian forest interspersed with native forbs and grasses. Large dimeter trees are an essential component for effective watershed restoration, as their strong root systems provide critical structure for fish habitat and help prevent stream bank erosion. Watershed-scale planning—supported by subwatershed prioritization, stakeholder engagement, and biological monitoring—ensures that actions are adaptive, measurable, and aligned with long-term conservation goals. These integrated strategies, backed by partnerships and sustainable funding, help stabilize streambanks, improve water quality, and restore critical wildlife habitat.

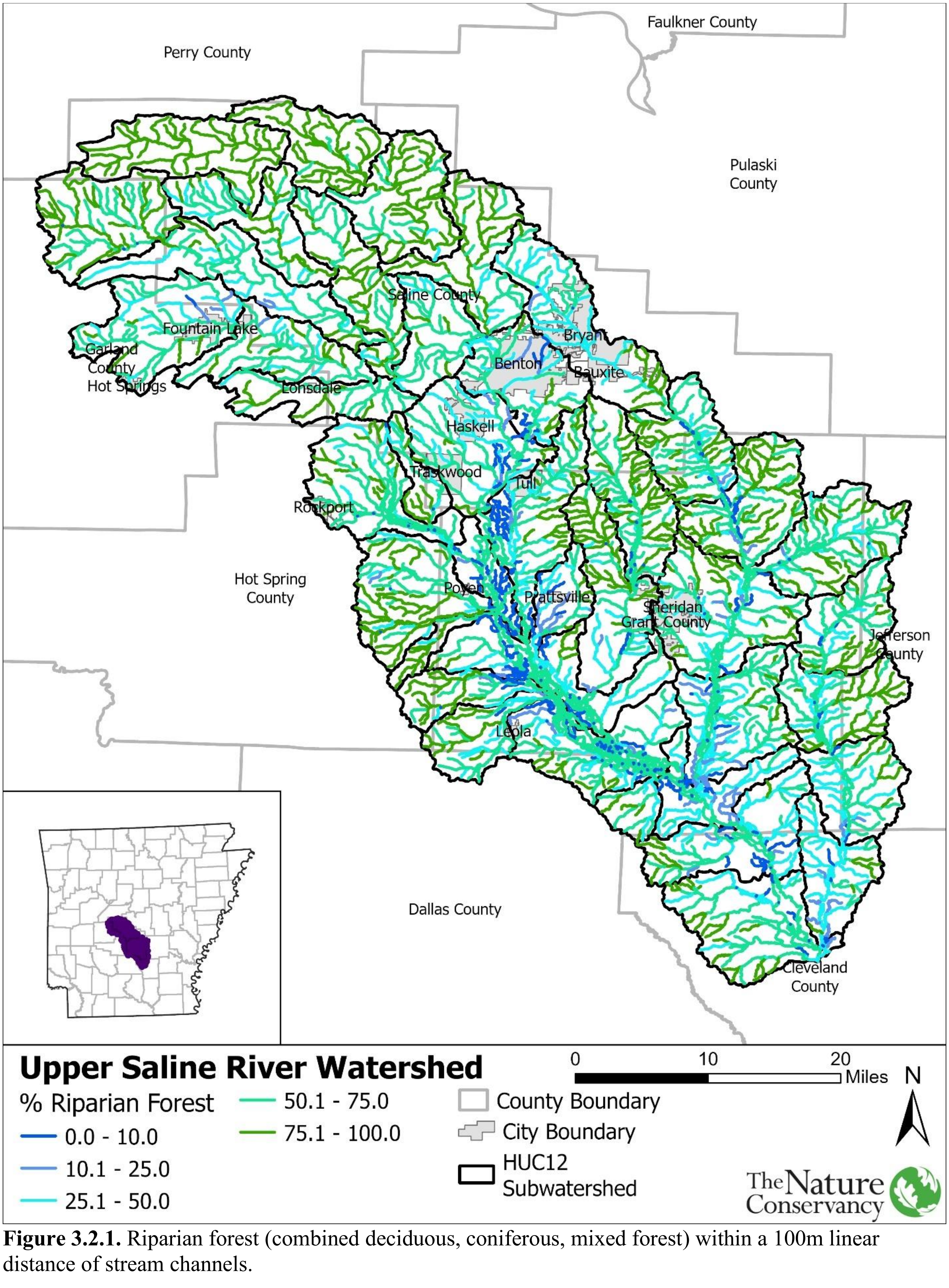

Figure 3.2.1. Riparian forest (combined deciduous, coniferous, mixed forest) within a 100m linear distance of stream channels.

Privately owned lands make up the majority of the Upper Saline River Watershed. Education and outreach efforts with landowners focusing on the importance of establishing and maintaining riparian buffers and riparian conservation efforts on private land will be an important component of maintaining and improving water quality. There is strong potential for expanding the use of conservation easements and other landowner agreements to preserve and restore riparian forest corridors. This may include developing landowner conservation plans for stream restoration and establishment and maintenance of SMZs (stream-side management zones), riparian tree planting, vegetation buffer strips, and grass drainage ways. Cost share and land management consulting services can help landowners with appropriate riparian buffer management activities. While impacts of livestock on water quality and streambank erosion are generally limited in the Upper Saline compared to other watersheds in Arkansas, alternative watering sources can be developed and fencing can be installed in pasture areas to exclude livestock and protect riparian buffer plantings and restored streambanks.

Coordination of conservation and restoration planning among stakeholders within the watershed is recommended to take full advantage of cost-share programs for riparian habitat improvement such as the Environmental Quality Incentives Program (EQIP), Agricultural Conservation Easement Program (ACEP), Wetland Reserve Program (WRP), Wetland Reserve Enhancement Partnership (WREP), Conservation Reserve Program (CRP), and the Wetland and Riparian Zone Tax Credit Program through Natural Resources Division. Leveraging and building upon existing watershed-based groups, plans, and processes will be essential to the success of both restoration and monitoring efforts. Monitoring efforts including fish and macroinvertebrate sampling, habitat assessments, and water chemistry testing should be conducted before and after riparian restoration projects.

Restoration of riparian forest is recommended for the major headwater tributaries of the Upper Saline Watershed, along with planting native hardwood tree species in former bottomland agricultural fields. To aid development of a subwatershed-based implementation strategy that identifies and prioritizes areas for riparian restoration and protection projects within the watershed, TNC mapped stream reaches in HUC12 subwatersheds with less than 45% riparian forest cover (e.g. combined area classified as deciduous, mixed and coniferous forest cover in the 2019 NLCD) within 100m of the stream channel (Figure 4.5.3). Estimated financial costs associated with reforestation of these riparian areas in high priority subwatersheds are addressed in Section 4.5 – Element 4.

Table 3.2. Percent coverage of deciduous, coniferous, mixed forest, and total riparian forest within 100m linear distance of streams in the Upper Saline and summarized for each HUC12 subwatershed.

HUC12 Name	HUC12 Area (mi^2)	Mean % Decidous100	Mean % Coniferous100	Mean % MixedForest100	Total % Riparian
Headwaters Alum Fork Saline River	53.2	24.0	33.7	29.4	87.1
Upper North Fork Saline River	38.4	29.3	30.3	19.5	79.1
Headwaters Middle Fork Saline River	52.6	22.4	29.1	18.8	70.3
Middle North Fork Saline River	48.4	26.2	31.6	11.0	68.8
Graves Creek-Lost Creek	46.3	7.6	58.3	2.6	68.5
Tenmile Creek-South Fork Saline River	31.1	46.6	10.5	11.1	68.2
Thunder Branch-Big Creek	52.2	7.6	56.0	4.4	68.0
Lower North Fork Saline River	48.0	42.1	14.4	10.1	66.6
Mud Creek-Hurricane Creek	48.7	6.4	58.0	2.1	66.5
Little Lost Creek-Lost Creek	50.1	6.1	55.3	2.1	63.5
Little Alum Fork-Alum Fork Saline River	38.6	17.5	34.4	11.1	63.0
Little Derrieusseaux Creek-Derrieusseaux Creek	36.4	5.5	55.1	2.2	62.9
Brush Creek	22.6	5.0	55.6	1.4	61.9
Johnson Creek-Derrieusseaux Creek	40.5	5.0	52.2	1.7	58.9
Big Creek-Alum Fork Saline River	44.8	22.8	26.3	8.7	57.9
Tenmile Creek-Francois Creek	50.6	24.8	25.2	7.8	57.8
Simpson Creek	48.8	7.4	46.8	3.3	57.5
Beech Creek-Cow Head Creek	12.8	2.3	53.0	1.8	57.2
Logan Creek-Hurricane Creek	39.8	13.2	39.3	4.2	56.6
Cox Creek	26.5	9.6	43.7	2.9	56.2
Brushy Creek	14.0	18.1	31.2	6.1	55.4
Ray Creek-Hurricane Creek	64.9	6.9	45.8	2.4	55.1
Pine Bridge Creek-Saline River	58.1	5.9	46.6	2.5	55.0
Mill Creek-South Fork Saline River	40.4	25.7	18.8	9.6	54.0
Outlet Middle Fork Saline River	54.6	17.8	24.5	11.7	54.0
Moccasin Creek-Saline River	32.0	28.6	15.5	8.2	52.2
Chapel Creek-Saline River	55.1	16.1	26.8	6.9	49.7
Cedar Creek-South Fork Saline River	57.2	25.1	12.0	12.2	49.2
Little Hurricane Creek-Hurricane Creek	59.4	25.8	14.4	8.7	49.0
Allgood Creek-Derrieusseaux Creek	37.5	3.4	43.7	1.7	48.8
Depot Creek-Saline River	43.4	20.9	17.7	10.1	48.7
Jordan Creek-Saline River	51.0	11.3	31.8	5.4	48.4
Trace Creek-Saline River	54.0	19.5	20.4	7.3	47.2
Panther Creek-Derrieusseaux Creek	33.6	2.9	42.1	1.5	46.6
Big Creek-Francois Creek	26.2	14.5	25.4	6.7	46.5
Steep Creek-Saline River	51.1	6.9	34.4	3.2	44.4
Flat Creek-Lost Creek	29.1	12.4	26.7	5.2	44.3
White Oak Creek-Hurricane Creek	50.8	4.9	37.0	1.8	43.7
Mud Creek-Saline River	42.7	9.5	29.0	3.4	41.8
Little Creek-Saline River	29.8	10.6	24.7	4.4	39.7

3.3 Stormwater runoff/ hydrologic alteration/ flooding

Nested Issues: Increased sedimentation, streambank erosion, turbidity, mobilization of pollution, nutrient runoff, infrastructure damage.

Urbanization significantly degrades freshwater streams, leading to flashier hydrographs, reduced water quality and biodiversity, increased flooding, and erosion. (Walsh et al., 2005). The primary driver of these impacts is stormwater runoff from impervious surfaces directly connected to streams via drainage systems (Walsh, 2004; Walsh et al., 2005). Approaches to mitigate these effects include reducing direct urban storm drainage connections to streams, slowing stormwater runoff times and water velocities, and limiting catchment imperviousness (Walsh, 2004). Riparian tree planting can also significantly improve water quality indicators like temperature, dissolved oxygen, eutrophication and algal blooms in urban rivers (Hutchins et al., 2023). However, the complexity of urban impacts on streams necessitates localized solutions based on unique urban templates and socioeconomic factors in the larger cities in the Upper Saline River watershed (Heaney, 2002, Parr et al., 2016).

Changes in rainfall patterns and streamflow have been observed across many watersheds in Arkansas. A study of 14 United States Geological Survey (USGS) stream gages in northwest Arkansas found statistically significant increases in flow statistics over the long-term monitoring period of record, and these increases were correlated with urban land use and change in urban land use over time (McMullen et al. 2024). Projections over the next several decades of extreme high precipitation events (the top 10% monthly precipitation amounts) for the Arkansas-Red River Basin show a high likelihood of increase during winter and spring seasons, and a general decrease during summer and autumn (Qiao et al. 2017). In the Upper Saline, precipitation summary statistics during winter and spring for the Alum Fork weather station show an increase in total rainfall received in the headwaters and the number of days that rainfall amounts exceeded 0.1 inch and 1 inch (Table 3.6.1).

Nature-based solutions (NBS), including urban forests, rain gardens parks, green roofs, bioswales and constructed wetlands, are effective and sustainable approaches for managing stormwater in urban areas, significantly reducing runoff volume, attenuate peak flows, and decrease pollutant concentrations (Orta-Ortiz & Geneletti, 2021; Palermo et al., 2023). NBS operate through various ecosystem functions, such as infiltration, evapotranspiration, and filtration, helping to restore the urban hydrological cycle (Palermo et al., 2023; Davis et al., 2010), while offering multiple benefits over traditional grey infrastructure (Sun et al., 2024). These solutions can significantly reduce runoff volume, attenuate peak flows, and improve water quality (Orta-Ortiz & Geneletti, 2021). NBS have demonstrated comparable or improved flood risk reduction to concrete channelization while maintaining natural ecosystem functions and having long lasting socioeconomic benefits (Ourloglou et al., 2020).

Another promising approach to reducing the volume and velocity of stormwater runoff is “Stage-0 (zero)” restoration. Stage 0 restoration aims to reconnect streams with their floodplains and offers significant benefits for flood management, ecosystem services, and improved drinking water quality. The defining characteristic of Stage 0 conditions is improved connectivity (longitudinal, lateral, and vertical) at base flows, which can be achieved through various methods like large wood placement in steep headwaters, valley floor reset, and use of low-cost beaver analogs to slow water and capture sediment (Clarke, 2025). Stage-0 approaches can reduce peak flow by up to 37% and increase floodplain exchange by up to 46% during small, frequent storms (Federman et al., 2022).

Table 3.3.1. Precipitation summary statistics during the period October-April for the NOAA Alum Fork weather monitoring station.

StationID	Station Name	Lat	Lon
USC00030130	Alum Fork	34.7961	-92.8417
Time Period	Avg. Total Rainfall (in.)	Avg. Days Rainfall ≥0.1"	Avg. Days Rainfall ≥1"
1949-2023	33.5	44	11
2007-2023	36.7	50	12
Percent Change	+9.6%	+13.6%	+9.1%

The longest continuously running USGS streamflow monitoring gage in the Upper Saline River watershed is located on the Saline River in Benton, AR (07363000, Table 4.10.1). Flow duration curves calculated from daily flow measurements from late 1950-present characterize river hydrology by plotting the percentage of time a given discharge (cfs/s, m3/s) is equaled or exceeded during a given time period. The resulting flow duration curve accounts for the full range of possible flow magnitudes measured by USGS stream gages and allows for comparing and visualizing changes in an entire streamflow regime over time. Examining flow duration statistics describing threshold flows exceeded 80% (Qlow.thr) and 20% (Qhigh.thr) of the gages period of record indicate that high flow thresholds have increased by 11.7% since 2010, compared to the period 1951-2025, while low flow thresholds have declined by 6.9% (Table 3.3.1, Figure 3.3.1). These data show the Saline River is experiencing a combination of higher flow magnitude and durations during wet period and lower flows during dry periods, reflecting increasing rainfall variability across the region, and highlighting the need for adaptive water resource management and land use planning.

Maintaining natural flow regimes is crucial for preserving river ecosystem services, water quality, and biodiversity (Sofi et al., 2020). Flow regime characteristics, including the magnitude, frequency, duration, timing, and rate of change of flow significantly impact aquatic organisms and in-stream ecological processes. Understanding flow-ecology relationships across different flow regime classes and ecoregions is essential for effective instream flow management and assessing the effects of flow alterations on riverine assemblages (Fox & Magoulick, 2022; Bower et al., 2021). Leasure et al. (2016) classified seven distinct natural flow regimes for streams in the Ozark-Ouachita Interior Highlands region exhibits, each characterized by specific hydrological patterns, and these relationships can help guide water management decisions.

The Ecological Limits of Hydrologic Alteration (ELOHA) framework also provides a flexible approach for developing environmental flow standards across multiple streams and rivers (Poff et al., 2007). Key steps include building a hydrologic foundation, classifying river types, computing flow alterations, and defining flow alteration-ecological response relationships (Kendy et al., 2010). River classification based on flow patterns provides a foundation for developing hydro-ecological relationships and informing environmental flow management. It is important that any management practices developed for the Upper Saline River watershed should be based on scientific principles that consider the dynamic character of natural flow regimes.

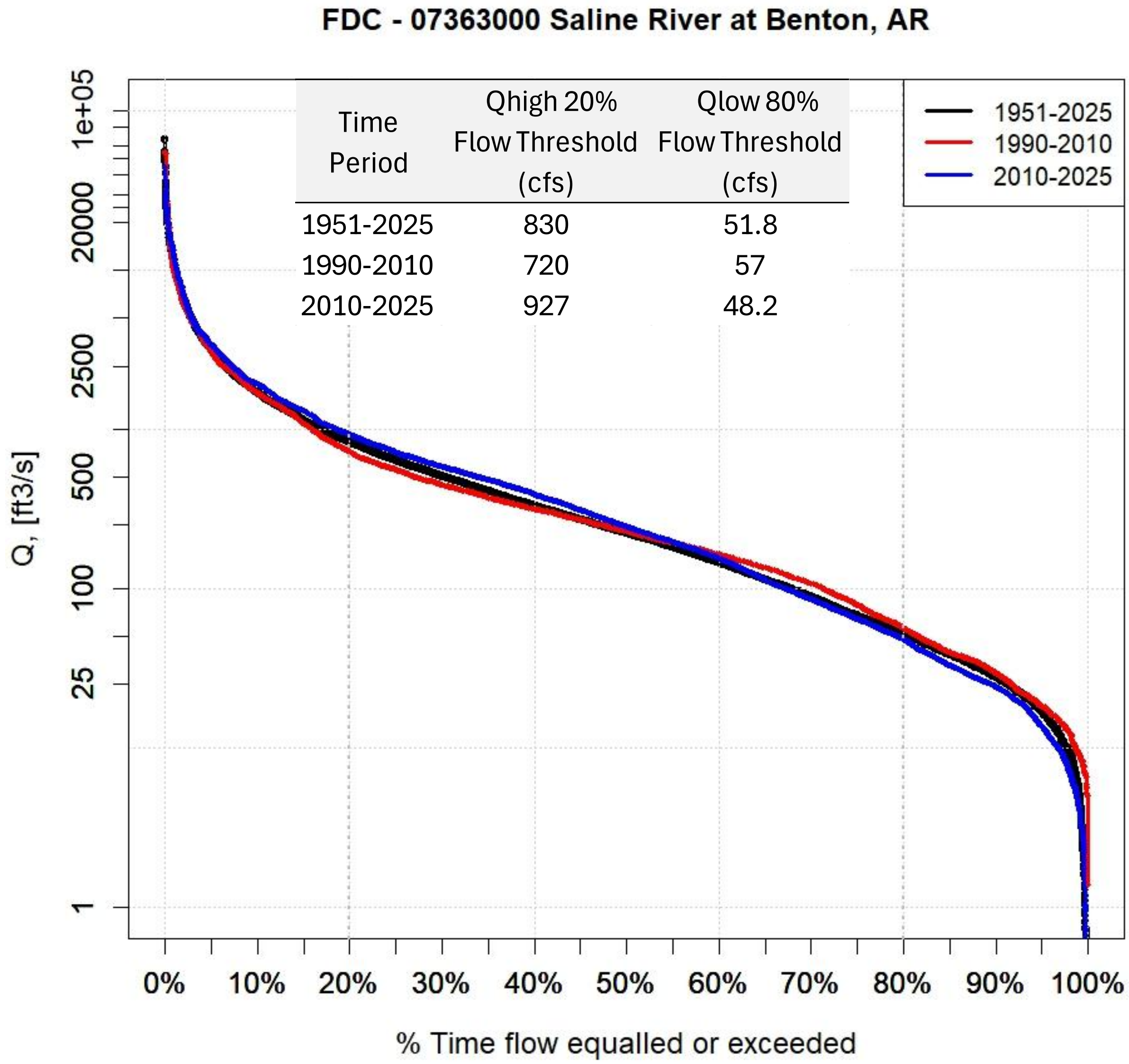

Figure 3.3.2. Flow duration curves and summary statistics for the USGS stream gage on the Saline River at Benton.

Conservation and Management Strategies:

Given the increasing trend in winter and spring precipitation across the Interior Highlands region of Arkansas, it is important to consider the potential impacts of stream bank erosion and flooding in all future land use planning, permitting, and zoning. This includes prioritizing natural flood control mechanisms while taking actions to reduce flood damage in vulnerable areas. To increase flood resilience within a watershed, key strategies include: preserving natural features like wetlands and floodplains, minimizing impervious surfaces like concrete, implementing green infrastructure for stormwater management, restoring riparian buffers along streams, removing or replacing undersized culverts in low water crossings with structures that allow greater flow, managing land use to limit development in flood-prone areas, and developing community flood preparedness plans. The Conway Urban Watershed Framework Plan (https://uacdc.uark.edu/work/conway-urban-watershed-framework-plan) provides a comprehensive guide detailing approaches and low impact designs for nature based solutions that can help other municipalities to address storm water runoff, urban flooding, and streambank erosion.

3.4 Inputs of litter in streams/ illegal dumping in the watershed

> ***Nested Issues: abused public access points, lack of corporate responsibility for litter, lack of public litter awareness and education.***

Roadside litter, including microplastics, significantly impacts stream ecosystems through various pathways, with stormwater runoff functioning as a major source of litter inputs (Wang et al., 2022). Rivers also serve as primary transport routes for human-generated trash and microplastics from terrestrial areas to oceans (Li et al., 2023). The input of roadside litter and human-generated trash into streams was identified by stakeholders as a major issue in the Upper Saline River watershed, especially along the rapidly-urbanizing I-30 corridor and in waterways near the cities of Benton, Bryant, and Sheridan. According to the Arkansas Department of Transportation, the state has the 12th longest State Highway System in the nation, with over 100,000 acres of public roadside along its 16,367 miles of highways, including 9,700 miles of streams and 600,000 acres of lakes. The Keep Arkansas Beautiful's Great Arkansas Cleanup (GAC), is an annual cleanup effort hosted in all 75 counties. In 2023 more than 22,500 volunteers contributed 147,230 hours to remove 636 tons of litter from Arkansas' roadways, waterways and public spaces. According to Keep Arkansas Beautiful, the value of volunteer cleanup efforts across the state exceeds $4 million annually.

Illegal dumping of trash in public use areas and the deposition of animal carcasses during the hunting season has been noted at many access points throughout the watershed. There is also evidence of dumping along privately owned riparian areas in the watershed. A shortage of disposal options, lack of information exchange and public awareness, and limited enforcement capacity were all cited as factors contributing this problem within the watershed.

Voluntary clean-up efforts have been implemented through counties, local watershed and recreation groups, businesses, and conservation districts. In addition to leading regular stream and riparian clean up events, the Friends of the Saline and Saline River Canoe maintain a trash trap on McNeil Creek. Their observations have identified roadside trash, retail businesses and their parking lots, and unsheltered activity along creeks as the primary sources of litter inputs. The most common forms of litter found in litter traps include cigarette butts, plastic foam, food wrappers and plastic containers, and increasingly microplastics (M. Sacomani, *personal communication*).

Conservation and Management Strategies:

Stakeholders recommended examining the feasibility of establishing watershed protection areas targeted at reducing litter within sensitive areas to provide the foundation to engage businesses and corporate responsibility. Specific recommendations include increasing parking lot cleanings, enhancing regulations for dumpster enclosures, such as locating dumpsters away from streams and storm drains, and requiring the use of lids on and enclosures around dumpsters, combined with increased code enforcement. In addition, stakeholders recommended exploring the establishment of "trash management areas" along portions of the I-30 corridor and other main travel corridors and parking lots where inputs of aquatic litter have been identified as being an issue. Stakeholders also identified a need for additional trash traps upstream on McNeil Creek, as well as on other tributaries in urban areas throughout the watershed.

Improving stream-side access sites in combination with increasing the availability of regularly maintained trash containers can help adjust the perception of an area from dumping ground to valued open space. Continued efforts to mitigate illegal dumping are suggested, including supporting initiatives by the City of Benton Stormwater Department in partnership with non-profit groups to schedule coordinate municipal trash pickups and work with local business to sponsor cleanups. An initiative currently in development with the Benton High School Environmental and Spatial Technology (EAST) program to engage students in cleanup efforts. The 2024 legislation, Arkansas Learns Act, includes a requirement that all students in public schools complete 70 hrs. of community service prior to graduation. This may provide additional opportunities to involve students in litter clean ups, however students will need guidance and supervision for such activities. The AGFC Stream Habitat program is another resource to help landowners and stream users plan and carry out litter control activities, as well as community education and outreach. The EPA's Trash Free Waters (TFW) program offers numerous resources for addressing aquatic trash (https://www.epa.gov/trash-free-waters/learn-about-aquatic-trash). Offering free or subsidized waste services to residents, in addition to alternative disposal options like recycling and compost centers can also encourage legal disposal. Informing residents and businesses of legal waste disposal options through mailed flyers, newspaper and radio announcements, and signage at and around areas that are known illegal dumping sites can also help deter illegal dumping. In rural areas, gating access to areas frequently used as illegal dump sites may also be an option.

3.5 Sedimentation in streams/streambank erosion.

Nested Issues: loss of riparian land & forest connectivity, sedimentation, turbidity, nutrient runoff.

Streambank erosion is a significant contributor to sediment and phosphorus pollution in waterways, impacting water quality and aquatic habitats (Peacher et al., 2018), while higher water temperatures, water pH, and runoff of road salt can interact to affect erosion in complex ways (Hoomehr et al., 2018). Soil bulk density, freeze-thaw cycling, soil moisture, root density, and soil texture are also important factors (Wynn & Mostaghimi, 2006). Riparian vegetation plays a crucial role in reducing erosion through root reinforcement, soil moisture regulation, and microclimate alteration (Wynn & Mostaghimi, 2006; Tufekcioglu et al., 2024). Forested riparian zones maintain ambient water temperatures, stabilize stream banks, filter sediment, leachates, nutrients, and other harmful pollutants, provide woody debris for macroinvertebrate and fish habitat, contribute channel forming units, and provide much of the energy input, especially in flowing water systems. Planting native willows along stream bends can stabilize banks by recreating riparian habitats that dissipate water energy (Johnson, 2006). Negative effects for landowners with eroding riparian areas are rapid loss of land, decreased fishery, and subsequent impacts to water quality.

Suspended sediment has been identified by the Arkansas Department of Environmental Quality (ADEQ) and the Arkansas Natural Resource Division as a priority non-point source pollutant of concern within the Saline River watershed, thus identification and prioritization of sediment sources is needed. Several parameters heavily influence sediment contributions to the Upper Saline watershed including geologic formations, slope, and soil types. Identification of sediment sources and prioritizing stream segments with the highest need of sediment abatement strategies is considered a high priority.

The Nature Conservancy completed a reconnaissance level survey (TNC, 2008) of the stream bank erosion conditions based on Bank Erosion Hazard Index (BEHI) and Near Bank Shear Stress (NBSS) estimation to predict total bank erosion for each site, based on stream bank erodibility curves developed by Rosgen (2001). These curves were developed based the entire length of the Middle Fork Saline River, approximately 39.89 miles in 2008. The results of survey indicated that the majority of the stream banks fell under the “Low” and “Moderate” categories, representing 61% of the total banks surveyed, with 30% of the banks in the “High” to “Extreme” category.

Additional channel stability assessments of the Alum Fork and North Fork Saline River were completed in 2021 by TNC as part of a State Wildlife Grant funded project to provide baseline geomorphic data for tracking changes in habitat condition and to prioritize reaches for restoration needs (Final Report for State Wildlife Grant Agreement T-72, 2021). North Fork and Alum Fork Saline watersheds have high development potential considering their proximity to Benton and Little Rock, Arkansas. Channel stability based on the parameters of Bank Erosion Hazard Index (BEHI), Near-Bank Stress (NBS) and overall channel stability were assessed for 36 miles of the North Fork Saline River and 53 miles of the Alum Fork Saline River.

The headwaters of Alum Fork and North Fork are located in the Ouachita National Forest north-northeast of Jessieville, Arkansas, and drain steep, rocky, and forested valleys of the Ouachita Mountains. In these headwaters, the streams are mostly stable, with large cobbles, boulders, bedrock, and intact riparian areas protecting stream banks. The few areas of instability were found to be mostly due to high width-depth ratio causing aggradation and braiding, however, aerial imagery over the past 20 years did not show significant lateral migration in these areas indicating that they have stabilized over time. As the Alum Fork and North Fork drain to the southeast, they exit the Ouachita National Forest and enter private pasture and timber lands where the effects of more intensive forestry practices and riparian clearing are evident. Here, the valley slopes begin to flatten, channel sinuosity increases, and streambanks contain more erosive gravel, sands, and silt. Moderately unstable reaches were more common within this middle section, but the banks were predominately stable. Unstable reaches were similar to that of the headwater reaches, with high width-depth ratio and aggradation creating high shear stress conditions against streambanks. When these conditions intersect with streambanks that do not have adequate riparian areas, potential for channel erosion, incision and rapid lateral channel migration increases.

Table 3.5.1. Location, BEHI and sediment loss for priority streambanks along the lower Alum Fork and North Fork.

Priority Reaches - Top Five Highest Contributors of Sediment from Bank Erosion				
Priority #	Location	BEHI Ranking	Reach Length (Ft.)	Predicted Sediment Loss (Tons/Yr.)
1	34.575045°, -92.690671°	Very High	1,005	1,059
2	34.577356°, -92.652279°	Very High	1,330	782
3	34.582233°, -92.665647°	High	1,044	181
4	34.577519°, -92.661910°	Very High	1,088	157
5	34.588647°, -92.665928°	Moderate	2,659	220

In the lower reaches of the North Fork and Alum Fork, valley slopes flatten further, and the floodplains widen. Pasture for cattle and hay production was once the dominant land-use type directly adjacent to the main stems, however much of the pasture has recently experienced conversion to residential development. Private timber production is still present outside of the floodplain and along tributaries. Bedrock-controlled reaches are uncommon and erosive gravel, sands, and silt are the dominant bank materials. Unstable reaches typically exhibited a combination of high shear stress conditions against erodible banks, and loss of riparian vegetation due to subdivision and home building, a pattern which continues to the confluence of the North Fork and Alum Fork. All five priority reaches identified by the survey are found on the Alum Fork within this section (Figure 3.5.1, Table 3.5.1)

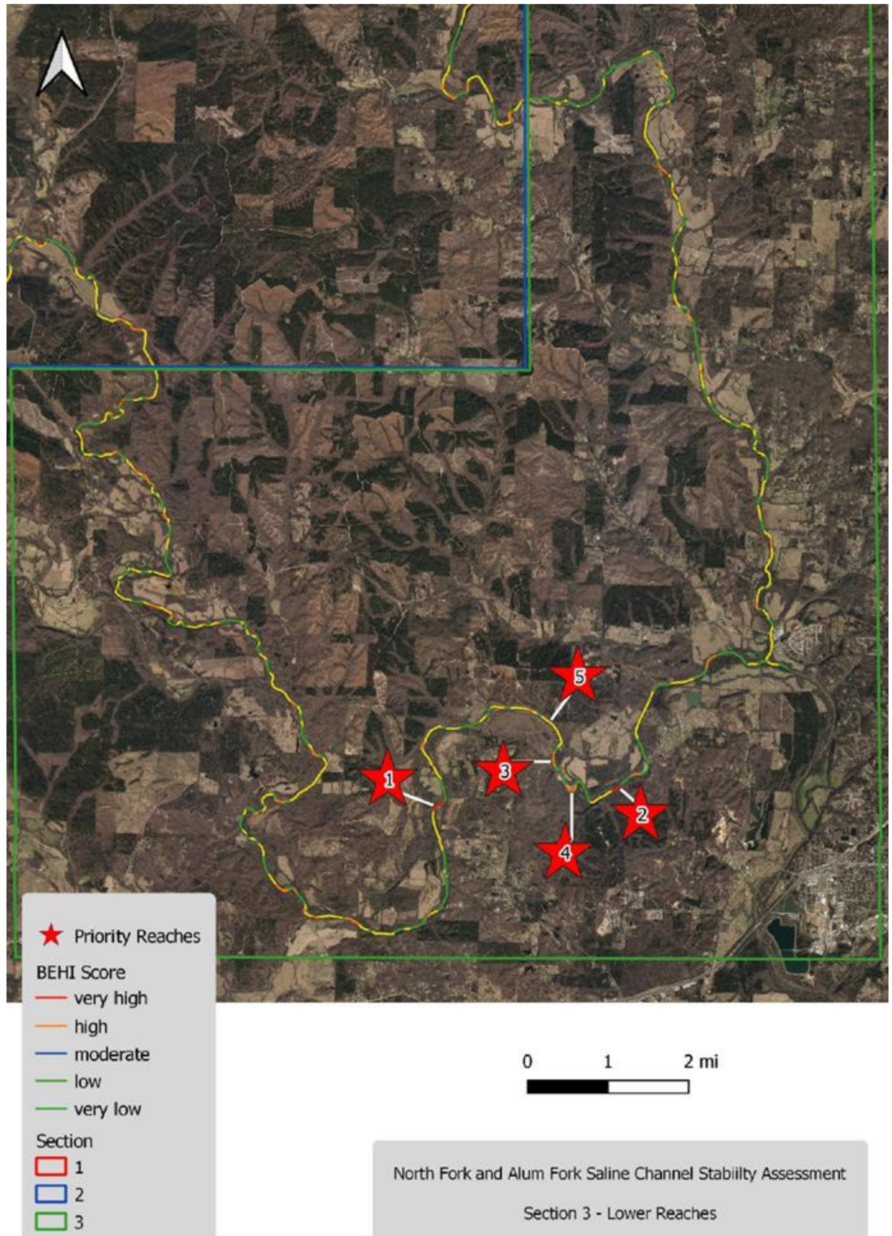

Figure 3.5.1. Overview of Section 3 - Lower Reaches of the assessment area on the Alum Fork and North Fork Saline rivers, including BEHI rankings and the top five priority reaches related to sediment contribution from bank erosion (TNC, 2021).

Conservation and Management Strategies:

In the upper reaches where riparian vegetation is intact, and streambanks consist of boulder and bedrock, erosion potential is still low, but in the middle and lower reaches where the valley slope flattens and the floodplain widens, lateral migration of the stream channel can be extreme in areas where riparian buffers are degraded or non-existent. Expanded adoption of best management practices (BMPs) on private lands is the single most important need for long-term, watershed-scale conservation and restoration. Timber management is the dominant land-use within the Alum Fork, North Fork, and Middle Fork watersheds, with conversion of floodplain/riparian and pasture areas to residential developments becoming more common as you move closer to urban areas in the lower reaches. Working with private landowners along the river, especially timber companies, farmers, contractors and developers to develop and implement practices that keep more sediment out of rivers and creeks is a high priority. While livestock impacts on water quality and stream erosion are limited in the Upper Saline River, fencing of livestock from riparian areas can aid successful re-establishment and growth of herbaceous plant and tree species. In addition to native vegetation restoration, techniques to be employed in erosion control may include willow fascines, live stakes, reseeding, and erosion control blankets. Importantly, any future streambank stabilization efforts need to incentivize Nature Based Solutions (NBS) and approaches.

BEHI data show that areas with intact riparian buffers have lower potential for erosion. Floodplains that are forested also slow flood waters, retaining sediment, and keeping stream power high within the channel to move bedload. Reforestation of Upper Saline River riparian areas, especially in the headwaters and floodplains, is a priority for long-term restoration and creates resilience to changes in the watershed. Regeneration of riparian buffers is also key to ensuring long-term success of any future bank stabilization projects. While stream bank stabilization projects may still be effective at reducing sediment and improving water quality and aquatic habitat in the short term, restoration projects will be most effective when addressing riparian restoration at the watershed scale. Strategies for reducing storm runoff velocity and erosive energy include reducing impervious surface area and increasing pervious cover, implementing low impact development (LID) practices and best management practices (BMPs) to decrease runoff volume, peak flows, and pollutant loads. Policies like financial incentives and encouraging voluntary participation can be used to improve urban watersheds. Water quality and watershed health can be improved through location-specific application of urban forestry practices. Establishment of tree buffers and grass strips in riparian and urban paved areas can improve water quality, reduce stormwater runoff, and increase groundwater recharge in urbanizing watersheds. Stormwater control measures (SCMs) that promote detention, infiltration and rainwater harvesting have also shown effectiveness in managing peak flows and volumes (Jefferson et al., 2017).

3.6 Erosion of unpaved roads

Nested Issues: increased sedimentation, turbidity, loss of aquatic habitat

Over 85% of county roads in Arkansas are unpaved, providing the rural transportation backbone for many the state's citizens and economic sectors, including agriculture, forestry, energy, and outdoor recreation. Sediment is the largest pollutant by volume to the waters of Arkansas and unpaved roads are the second leading cause of non-point source pollution impacting Arkansas' rivers, lakes, and municipal water sources (Arkansas Unpaved Roads Manual). Erosion of unpaved road surfaces is influenced by many factors including precipitation, land use, lack of surface cover, clay content and mean particle size, road maintenance procedures such as grading, wildfire frequency, and land slope, with steeper road segments generally experiencing greater sediment erosion (Sosa-Pérez & Macdonald, 2017). Unpaved roads slopes above 7% (4 deg.) are typically considered to be at a higher risk for erosion with soil type (higher erosion rates are generally observed in sandy silt soils compared to loam silt soils) and rainfall intensity also impacting erosion rates. Unpaved roads may be a significant source of sediment even in forested catchments, with erosion rates from county roads, open and closed Forest Service roads, and open and closed ATV trails ranging from 75-210 tons/ha/year in the Ouachita Mountains of Arkansas (Marion et al., 2019).

Runoff and sedimentation from a dense network of unpaved roads was identified as a major threat to water quality in the Upper Saline River watershed. During heavy rain events unpaved roads and their ditches generate sediment-laden runoff and transport pollutants from adjacent land. Unpaved roads can deliver sediment and nutrients directly into streams at crossings, or indirectly by overland flow or gullies (Macdonald, 2008). Roads and road ditches may intercept flow and drain it into streams, thereby acting as expanded channel networks causing an increase in sediment delivery and peak flows. In addition to having a negative effect on surface water quality, storm flows can quickly exceed the hydraulic capacity of unpaved road culverts and crossings, resulting in clogging of undersized culverts with sediment and debris along with flood damage to road infrastructure and adjacent property.

Table 3.6.1. Summary of unpaved roads density (miles roads/HUC12 area) within HUC12 subwatersheds sorted from highest to lowest density values.

HUC12 Subwatershed Name	HUC12	Area (mi^2)	Unpaved Road Length (mi)	Unpaved Road Density (mi/mi^2)	% of HUC12	HUC12 Slope (avg. deg)
Headwaters Middle Fork Saline River	80402030301	52.6	119.0	2.26	7.4	7.12
Mill Creek-South Fork Saline River	80402030202	40.4	79.1	1.96	4.9	4.93
Pine Bridge Creek-Saline River	80402030903	58.1	102.5	1.76	6.3	1.29
Little Alum Fork-Alum Fork Saline River	80402030303	38.6	63.7	1.65	3.9	6.25
Brushy Creek	80402030601	14.0	22.5	1.61	1.4	1.71
Cedar Creek-South Fork Saline River	80402030201	57.2	91.1	1.59	5.6	6.18
Tenmile Creek-South Fork Saline River	80402030203	31.1	48.1	1.55	3.0	7.08
Middle North Fork Saline River	80402030102	48.4	70.6	1.46	4.4	7.15
Headwaters Alum Fork Saline River	80402030302	53.2	76.4	1.44	4.7	8.22
Tenmile Creek-Francois Creek	80402030602	50.6	68.7	1.36	4.2	3.10
Moccasin Creek-Saline River	80402030701	32.0	42.3	1.32	2.6	4.75
Upper North Fork Saline River	80402030101	38.4	48.5	1.27	3.0	7.86
Lower North Fork Saline River	80402030103	48.0	54.0	1.12	3.3	5.54
Steep Creek-Saline River	80402030902	51.1	53.5	1.05	3.3	1.71
Graves Creek-Lost Creek	80402030801	46.3	47.9	1.04	3.0	2.22
Panther Creek-Derrieusseaux Creek	80402030504	33.6	33.3	0.99	2.1	1.49
Little Hurricane Creek-Hurricane Creek	80402030401	59.4	58.7	0.99	3.6	2.35
Logan Creek-Hurricane Creek	80402030402	39.8	38.7	0.97	2.4	2.16
Big Creek-Alum Fork Saline River	80402030305	44.8	40.2	0.90	2.5	5.37
Thunder Branch-Big Creek	80402030603	52.2	46.8	0.90	2.9	2.24
Outlet Middle Fork Saline River	80402030304	54.6	47.2	0.86	2.9	6.95
Depot Creek-Saline River	80402030702	43.4	36.4	0.84	2.2	3.42
Trace Creek-Saline River	80402030703	54.0	43.6	0.81	2.7	1.74
Beech Creek-Cow Head Creek	80402030807	12.8	9.8	0.77	0.6	1.42
Brush Creek	80402030804	22.6	16.8	0.74	1.0	2.30
Allgood Creek-Derrieusseaux Creek	80402030503	37.5	23.8	0.63	1.5	1.40
Cox Creek	80402030805	26.5	15.3	0.58	0.9	3.60
Johnson Creek-Derrieusseaux Creek	80402030502	40.5	23.0	0.57	1.4	1.62
Simpson Creek	80402030403	48.8	27.1	0.55	1.7	1.71
Jordan Creek-Saline River	80402030704	51.0	28.0	0.55	1.7	2.24
Flat Creek-Lost Creek	80402030803	29.1	15.3	0.52	0.9	0.86
Little Creek-Saline River	80402030901	29.8	13.9	0.47	0.9	1.02
Big Creek-Francois Creek	80402030604	26.2	11.6	0.45	0.7	0.99
Chapel Creek-Saline River	80402030808	55.1	21.1	0.38	1.3	1.32
Mud Creek-Saline River	80402030806	42.7	15.2	0.36	0.9	1.05
Little Derrieusseaux Creek-Derrieusseaux Creek	80402030501	36.4	12.5	0.34	0.8	1.67
Ray Creek-Hurricane Creek	80402030405	64.9	18.4	0.28	1.1	1.66
Little Lost Creek-Lost Creek	80402030802	50.1	13.3	0.27	0.8	1.65
White Oak Creek-Hurricane Creek	80402030406	50.8	13.4	0.26	0.8	1.37
Mud Creek-Hurricane Creek	80402030404	48.7	7.6	0.16	0.5	1.63

Analysis of roads data from the Arkansas Department of Transportation and The Nature Conservancy, the density of unpaved roads in Upper Saline watershed is highest in portions of the Headwaters Middle Fork Saline River (HUC80402030301, 2.26 mi/mi^2), Mill Creek-South Fork Saline River (HUC80402030202, 1.96 mi/mi^2), Pine Bridge Creek-Saline River (HUC80402030903, 1.76 mi/mi^2), and Little Alum Fork-Alum Fork Saline River (HUC80402030303, 1.65 mi/mi^2) sub-watersheds (Table 3.6.1). The Headwaters Middle Fork Saline River and Little Alum Fork-Alum Fork Saline River subwatersheds also have among the steepest terrain and unpaved road grade (Table 3.6.2, Figure 3.6.1). These and other steep headwater HUC12 subwatersheds with high unpaved road densities are a priority for implementing unpaved roads BMPs to reduce sedimentation in streams.

To refine and aid prioritization of unpaved roads for BMP implementation, public road segments in the Upper Saline River watershed with an average grade greater than 5 degrees (8.75%) that intersect a surface water feature were mapped. The resulting unpaved roads priority map (Figure 3.6.2) and summary table (Table 3.6.2) show Garland County has the most high priority unpaved roads (29.1 mi.), followed by Saline County (24.5 mi.), and Hot Spring County (1.9 mi.). Within the HUC12 subwatersheds, the Middle North Fork Saline River (13.4 mi.) and Cedar Creek-South Fork Saline River (11.3 mi.), and Mill Creek-South Fork Saline River (8.9 mi.) had the greatest total length of highest priority unpaved road segments (Table 3.6.2).

Table 3.6.2. Table of the highest priority unpaved road segments for BMP implementation in HUC12 subwatersheds based on average road segment slope (degrees) and proximity to surface water.

County and HUC12	Avg_Slope (deg)	Road Segments	Feet	Miles
Garland County	**6.3**	**30**	**153504**	**29.1**
Cedar Creek-South Fork Saline River	6.2	12	59721	11.3
Headwaters Middle Fork Saline River	7.1	5	19777	3.7
Mill Creek-South Fork Saline River	5.8	8	47085	8.9
Outlet Middle Fork Saline River	6.7	1	2193	0.4
Tenmile Creek-South Fork Saline River	6.0	4	24729	4.7
Hot Spring County	**6.0**	**4**	**10020**	**1.9**
Tenmile Creek-Francois Creek	6.0	3	9605	1.8
Thunder Branch-Big Creek	5.9	1	415	0.1
Saline County	**6.1**	**34**	**129212**	**24.5**
Big Creek-Alum Fork Saline River	5.1	1	1960	0.4
Depot Creek-Saline River	5.6	1	4514	0.9
Headwaters Alum Fork Saline River	5.3	1	2683	0.5
Little Alum Fork-Alum Fork Saline River	6.0	3	8873	1.7
Logan Creek-Hurricane Creek	5.6	1	398	0.1
Lower North Fork Saline River	5.9	4	20520	3.9
Middle North Fork Saline River	6.1	13	70700	13.4
Mill Creek-South Fork Saline River	5.5	2	3402	0.6
Moccasin Creek-Saline River	5.9	4	10798	2.0
Outlet Middle Fork Saline River	7.7	4	5364	1.0
Total	**6.2**	**68**	**292736**	**55.4**

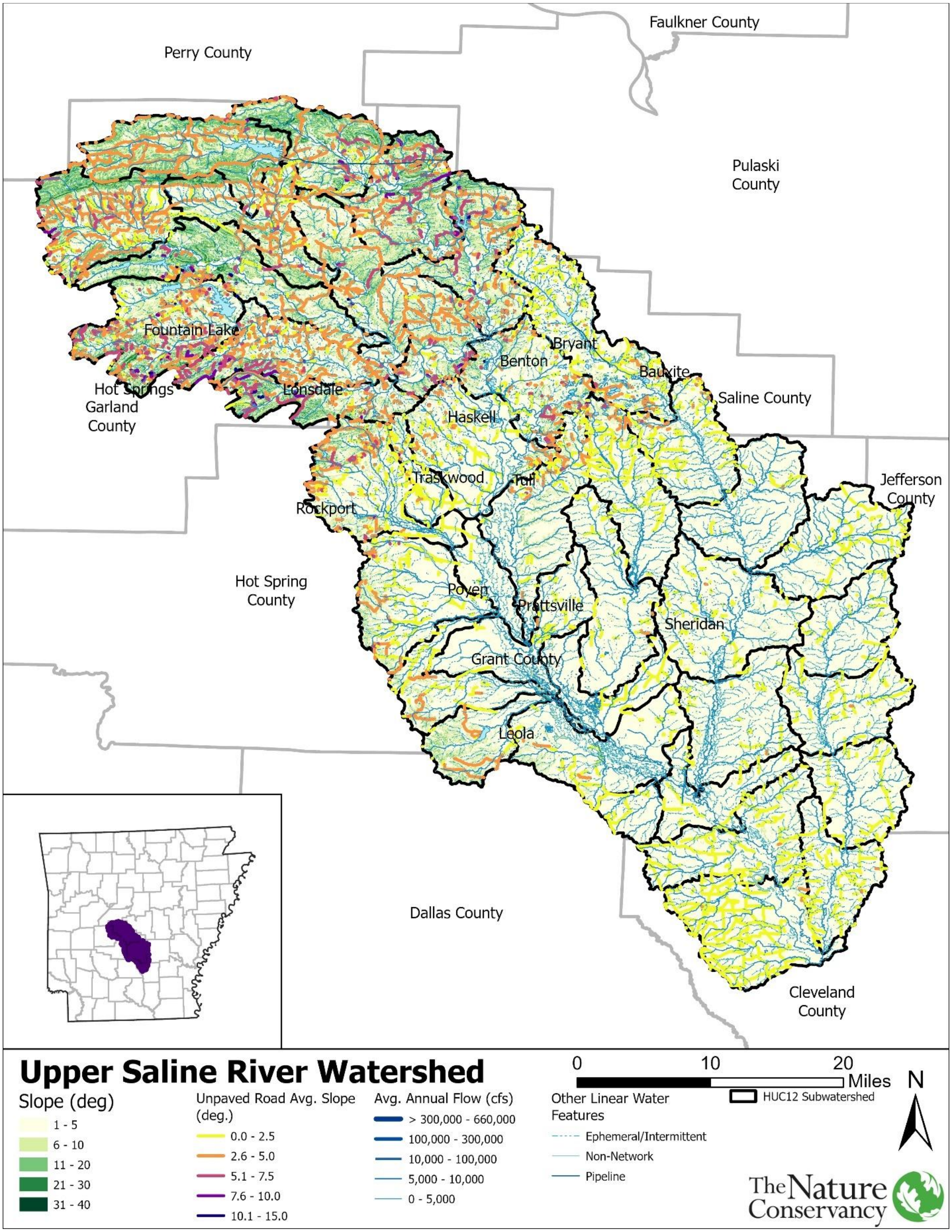

Figure 3.6.1. Map of unpaved roads in the Upper Saline River watershed showing the slope (degrees) of terrain and unpaved road segments.

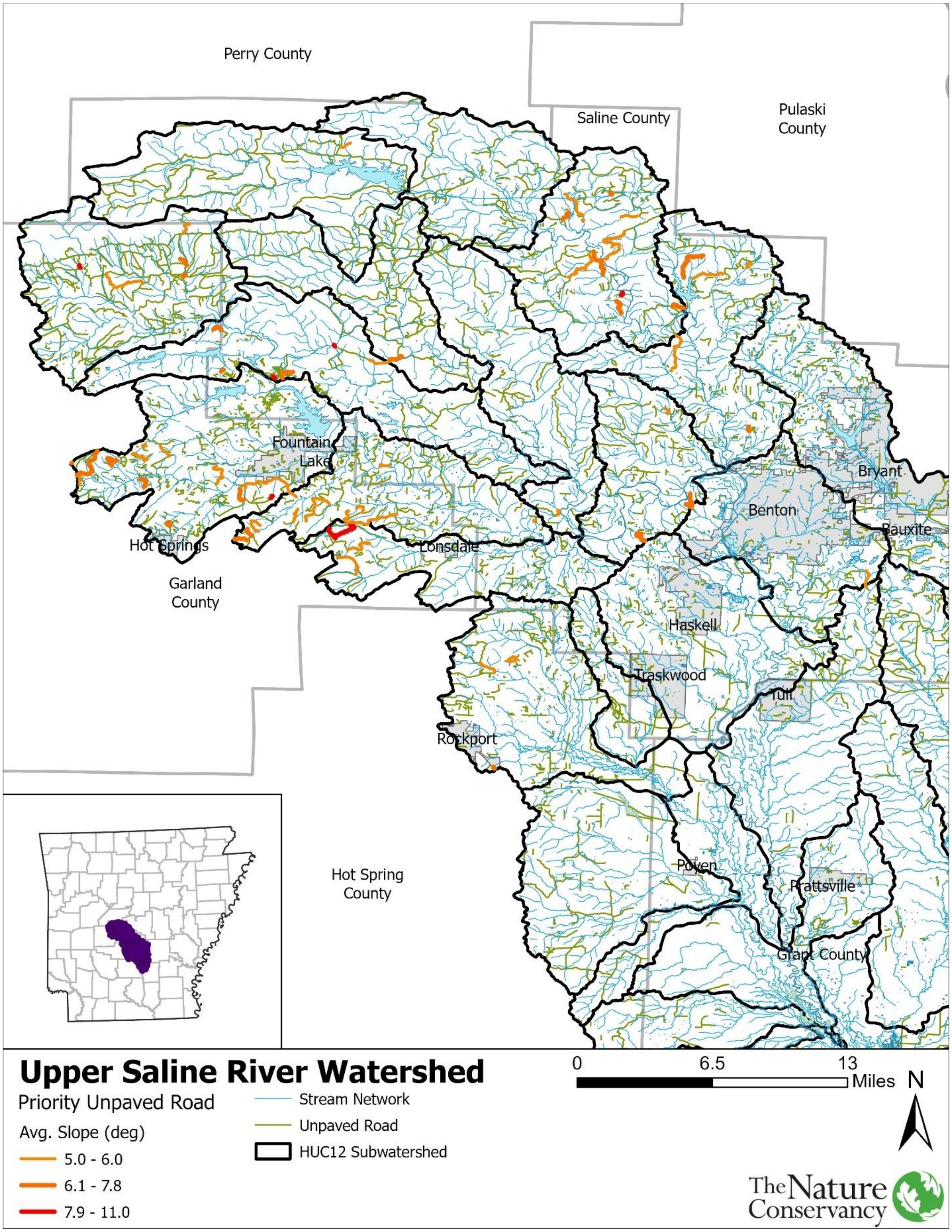

Figure 3.6.2. Map of the highest priority unpaved roads for implementation of BMPs based on average road segment slope (degrees) and proximity to surface water sources.

Conservation and Management Strategies:

There is an immediate need for measures to reduce sedimentation runoff from unpaved roads. County, state and private road managers can use training and implement techniques for more robust stream crossing infrastructure and improved road design. It is highly recommended that road managers adopt the use of Best Management Practices (BMPs) to reduce erosion and sedimentation by establishing better drainage to unpaved road systems, stabilizing erodible ditches and drainage outlets, and creating a more durable driving surface (Arkansas Unpaved Roads Program). Specific BMPs for unpaved roads include: proper road design with crown elevation, adequate drainage systems like ditches and culverts, water bars, broad-based dips, wing ditches, rock check dams, vegetation establishment on slopes, regular grading and maintenance, proper material selection for the road base, and sediment traps at drainage outlets to minimize erosion and sediment runoff from the road surface.

3.7 Loss of wetlands/floodplain habitat

Nested Issues: Increased sedimentation, flooding, turbidity, mobilization of pollution.

Wetlands are crucial ecosystems that support biodiversity and provide various benefits to society including nutrient recycling, flood attenuation, groundwater recharge, water purification as well as providing food, water supply, fuel, fodder, wildlife habitat, recreation, and many other vital needs. Wetland loss and degradation are global issues driven by human activities and natural processes. Urban development and population growth are leading causes of wetland degradation due to urban, industrial, and agricultural activities (Patel et al. 2021). Arkansas has lost an estimated 72% of its wetlands, which amounts to more lost wetland acres than any other inland state in the nation.

Wetlands support a wide diversity of wading and migratory birds, and other wildlife. A majority of freshwater fish species caught by recreational anglers rely on wetlands for shelter, food, spawning, and nursery areas. Wetlands and streams act as sponges during rainy periods, storing water, nutrients, and sediment that would otherwise runoff into streams and rivers causing flooding, siltation, water quality declines and bank erosion. Riparian wetlands also provide base flow reserves for tributaries during drought through slow release of water through subsurface transport. In addition to flooding and aquatic species impacts, failure to protect wetlands associated with intermittent streams and perennial rivers may increase drinking water treatment costs and risks to public health.

Woody wetlands cover a large proportion of the Upper Saline River watershed below Interstate 30 and the “fall line” separating the Ouachita Mountains and South Coastal Plains ecoregions (Figure 3.7.1). These woody wetlands and bottomland hardwood riparian forests are critical ecosystems that provide valuable services such as wildlife habitat, flood control, nutrient and carbon storage (Boix et al., 2019; Faulkner et al., 2011; Kingsford et al., 2016). Effective conservation practices should prioritize restoring riparian forest and wetland hydrology, as both are crucial for wetland ecosystem processes. Wetland restoration activities should be followed up with monitoring by state agencies and local watershed and citizen groups. Additionally, wetland conservation strategies should consider socio-economic factors and address broader issues of population growth and economic development goals for areas surrounding these vital ecosystems.

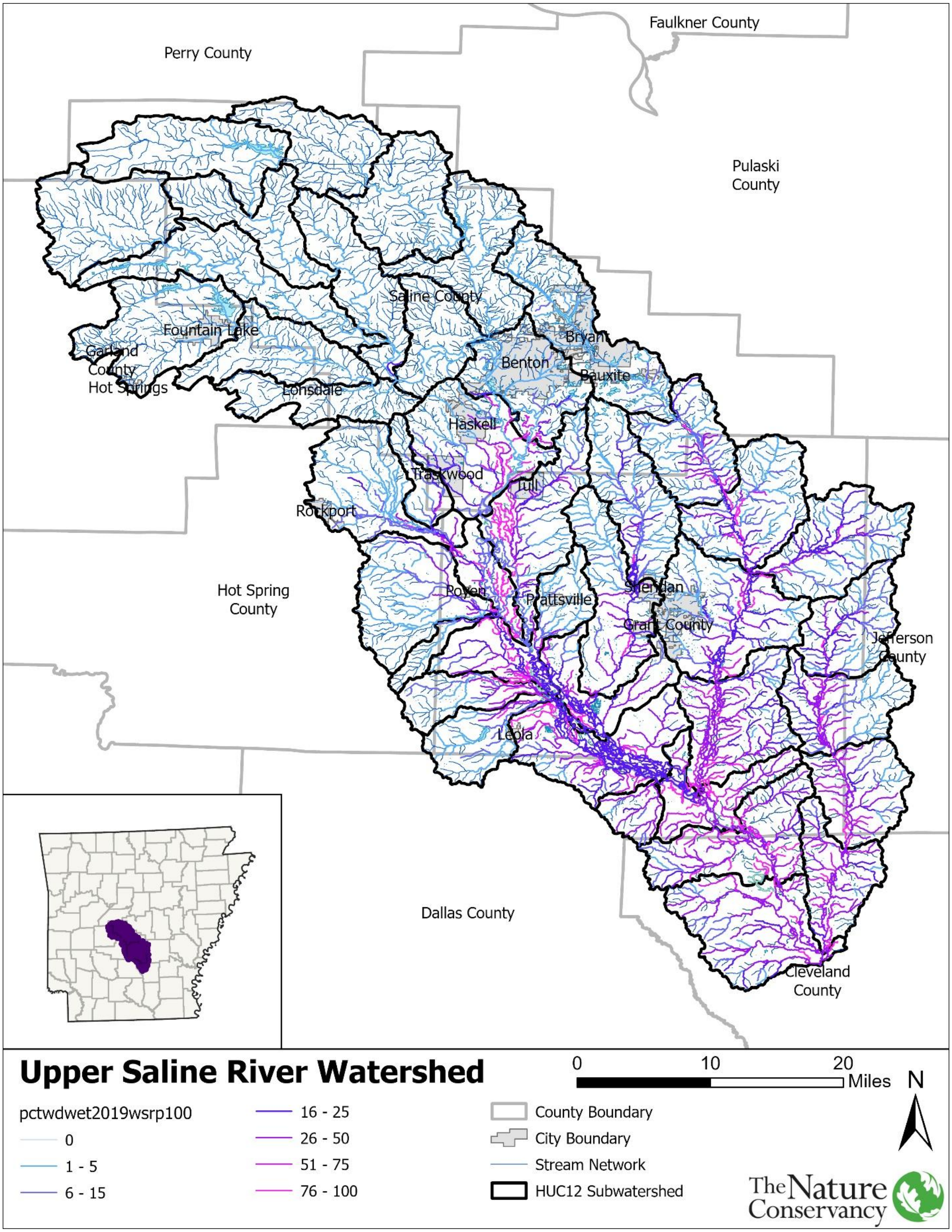

Figure 3.7.1 Percent woody wetlands land cover within a 100m of stream channels.

In urban areas, vegetated detention basins, bioswales, and other nature-based solutions (NBS) offer numerous benefits. Similar to engineered wetlands, these green infrastructure systems increase water storage and reduce runoff time and volumes, peak flows, and pollutant loads, including suspended solids, nutrients, and metals (Gonzalez-Meler et al., 2013). Restoring and engineering wetlands within the urban matrix can be very beneficial for water quality and flood control and do not significantly increase mosquito numbers compared to pre-construction levels (Anderson et al., 2007). Several strategies can effectively control mosquito populations in these environments. Maintaining healthy populations of wetland fishes and macroinvertebrates are a key factor in the control of mosquito larvae, ensuring that predation rates limit the development of pupae and the emergence of adults.

In agricultural areas, two-stage ditches offer several benefits for water quality and stream ecosystems over traditional, channelized ditches. By creating a floodplain bench, two-stage ditches provide additional storage for floodwaters, reducing turbidity and suspended sediment export, decreasing downstream flooding risk and promoting more stable, self-cleaning channels (Mahl et al., 2015; Davis et al., 2015). They also enhance nitrogen removal through increased denitrification on floodplains, particularly during inundation events and can decrease soluble reactive phosphorus concentrations at base flow (Mahl et al., 2015)

Conservation and Management Strategies:

Strategic wetland restoration using an adaptive management approach can help regain some of lost ecosystem services by targeting marginal agricultural lands and prioritizing optimal wetland characteristics. Key strategies for protecting and restoring riparian-adjacent and woody wetlands and floodplains include: protection and restoration of riparian forest, not filling in wetlands when developing a property, offering tax credits and other incentives to landowners to conserve and restore wetlands, using "living shoreline" techniques instead of concrete structures on waterfront property, keeping construction staging and stockpiling of materials out of wetlands, avoiding using heavy equipment in wetland areas to reduce soil compaction and rutting. Conservation efforts for woody wetlands should focus on multiple approaches: legal protection, sustainable management, restoration, and collaborative conservation. The USDA Natural Resources Conservation Service (NRCS) has developed conservation practice standards for open channels and wetlands to help mitigate nutrient and sediment loading to surface water bodies. While agricultural activities including row crop cultivation are limited within the Upper Saline, application of practices such as the two-stage ditch can also be used to improve water quality. In urban areas, using wetlands, vegetated detention basins, bioswales, and other nature based solutions (NBS) as water treatment systems can provide a range of long-term water-quality, wildlife habitat, and economic benefits.

3.8 Aging low water stream crossings/reduced stream habitat connectivity

Nested Issues: Increased sedimentation, streambank erosion, flooding, reduced fish passage, higher municipal maintenance costs, transportation infrastructure and property damage.

A major challenge to aquatic conservation in the Upper Saline River watershed, and across the Ozark-Ouachita Interior Highlands region, are the thousands of antiquated low water road crossings, which are often slabs of hastily poured concrete with undersized in-stream culverts. These low water crossings can significantly disrupt aquatic ecosystem connectivity by acting as dams or barriers, preventing fish and other aquatic organisms from migrating and accessing habitat critical to their life cycles. Water flows through inadequate and undersized culverts often exceed velocities permitting upstream passage by fishes and other aquatic organisms, and they frequently become clogged with sediment, rocks and other debris, blocking water flow and biotic movement. If a crossing design isn't adequate for handling a range of stream flows, sediment can accumulate upstream and downstream of the crossing, altering the streambed profile and further impacting streamflow dynamics and causing erosion issues. During high-flow events fast-moving water can scour the streambed around the crossing, causing undermining of the structure and damage to the roadbed, potentially resulting in failure of the crossing. While construction costs for low water crossings are generally low compared to other crossing structures, long-term maintenance costs may be higher due to the need for regular inspections to monitor for erosion, debris buildup, changes in the stream channel, and structural damage, with repairs including frequent sediment and debris removal, road bed and bank stabilization, and addressing crossing structural issues, in addition to public transportation disruption and safety concerns during high water events.

Stream/road crossings, including paved and unpaved roads, were evaluated for the Upper Saline watershed using crossing data provided by Southeast Aquatic Resources Partnership (SARP) barrier inventory (https://aquaticbarriers.org/; accessed July 2024). The highest densities of stream/road crossings (count/sqkm) were observed in the Depot Creek-Saline River (HUC80402030702, 2.05/sqkm), Cedar Creek-South Fork Saline River (HUC 80402030201, 1.97/sqkm), Little Hurricane Creek-Hurricane Creek (HUC 80402030401, 1.89/sqkm), and Headwaters Middle Fork Saline River (HUC 80402030301, 1.37/sqkm) subwatersheds. Since 2010, nine road-related barriers that have been or are actively being removed or mitigated in the Upper Saline, gaining 21 miles of reconnected rivers and streams (Figure 3.8.1).

Figure 3.8.1. Stream barrier removal and mitigation progress in the Upper Saline River watershed.

Survey efforts are ongoing to inventory stream crossings in the Upper Saline for their severity in preventing aquatic organism passage (AOP). Survey data are a valuable resource to counties, other conservation stakeholders for prioritizing stream crossings for remediation or removal. The SARP barrier prioritization tool (https://aquaticbarriers.org/priority/) provides a way to track and monitor the progress of barrier surveys and allows users to explore and download barrier inventory information at different scales. This goal of the SARP inventory and tools are to build a community of practice among resource managers and enable them to identify high priority aquatic connectivity restoration projects, and better reflect the degree of aquatic habitat fragmentation from aquatic barriers across geographic and administrative boundaries.

Conservation and Management Strategies:

Develop and coordinate communication and knowledge exchange among local, state, and federal agencies around establishing a common set of approaches for preserving and restoring ecological connectivity of rivers and streams. Coordinated efforts should focus on ensuring stream crossing projects and resources employed by state agencies and counties preserve connectivity through avoiding or minimizing any negative impacts to aquatic organism passage. Taking a similar approach to wetlands conservation outlined under Section 404 of the Clean Water Act, new construction of low water crossings and other state and county roads projects should strive to result in no net loss of connectivity to stream ecosystems.

4.1 Element 1 – Causes and Sources of NPS Pollution

4.1.1 Low Dissolved Oxygen

Low dissolved oxygen (DO) in streams within the watershed can stem from high nutrient levels or water temperature. The increase in nutrients in a waterbody can create a significant increase in algal blooms during the day, particularly in the warmer months. During evening hours, the algal blooms begin to die off creating low dissolved oxygen conditions. Stream reaches in the North Fork Saline River (011), Alum Fork (014,018), Middle Fork (019), Cedar Creek (021), and Big Creek (904) are listed due to low dissolved oxygen concentrations (Table 4.1, Figure 4.1). Lockett Creek (seg 922) is listed for impairment of aquatic life due to low dissolved oxygen violations. The source of the impairment is documented as unknown at this time by the Arkansas Department of Environmental Quality (ADEQ). While agricultural land uses like hay and cattle production can be a source of nutrients contributing to DO declines, their influence on DO levels in the impaired reaches is assumed to be limited due to the relatively small spatial footprint of agriculture in the watershed. Big Creek below the City of Sheridan is listed as impaired due to organic enrichment, siltation & turbidity. The local municipal wastewater discharge is identified as the impairment source for organic enrichment and lead. There have also been observed and documented dissolved oxygen violations for the Middle Fork of the Saline below Mill Creek, the location for Hot Springs Village municipal discharge. Elevated turbidity and total phosphorus have been documented for the four forks of the Saline during storm events indicating both nonpoint source pollution as well as municipal point source contribution. Likely sources for nutrient impacts in the Upper Saline watershed include municipal point sources, increased sedimentation, runoff and tailwater from golf course irrigation, agriculture/grazing practices, and septic systems.

Table 4.1. Impaired stream reaches within the Upper Saline River watershed on the 2022 303(d) list as defined by the Arkansas Department of Energy and Environment (ADEQ, 2023).

Watershed	Stream	Reach	Miles	Non-Attained Standards[1]	Source[2]
8040203	Saline River	001	1.50	Hg	UN
8040203	Lost Creek Ditch	008	21.3	pH	AG
8040203	Saline River	010	27.64	TDS	UN
8040203	North Fork Saline River	011	37.5	DO	UN
8040203	Alum Fork Saline River	014	19.3	DO, pH	UN
8040203	Alum Fork Saline River	018	7.7	pH, DO	UN
8040203	Middle Fork Saline River	019	37.1	DO	UN
8040203	Cedar Creek	021	1.2	DO	UN
8040203	South Fork Saline River	022	13.6	Biological Integrity-Fish & Macroinvertebrates	UN
8040203	Skull Creek	824	0.5	pH	IP, RE
8040203	Big Creek	904	15.60	DO, Turbidity	AG, SE
8040203	Saline River	913	10.20	TDS	UN
8040203	Lockett Creek	922	8.8	DO, pH, Biological Integrity-Fish	UN
8040203	Reyburn Creek	924	8.1	pH	IP, RE

[1]Hg=Mercury, TDS=Total Dissolved Solids, DO=Dissolved Oxygen, [2]AG=Agricultural Activities, IP=Industrial Source Point, RE=Resource Extraction, UN=Unknown, SE=Surface Erosion.

4.1.2 Water pH

Stream pH is the most common impairment of 303(d)-listed reaches in the Upper Saline River Watershed, after low dissolved oxygen. Streams and reaches listed as impaired include: Lost Creek Ditch (008), Alum Fork Saline River (014, 018), Skull Creek (824), Lockett Creek (922), and Reyburn Creek (924). pH is a measure of how acidic/basic water is and stream pH can affect organisms living in the water. Changes in stream pH can be an indicator of increasing pollution or some other environmental factor and also influences how much and what form of phosphorus is most abundant in the water. In the case of heavy metals (lead, mercury, copper, cadmium, etc.) lower pH levels can increase their toxicity because they are more soluble and hence more bioavailable to aquatic organisms (Michaud, 1991). The sources of pH impairments for most of the listed reaches are currently unknown but are likely atmospheric, while agricultural sources are cited for impairments in Lost Creek Ditch and industrial point sources and resource extraction for sections of Skull Creek and Reyburn Creek. Historical open-pit bauxite mining located in the Upper Saline watershed has impacted local waterways with runoff from this area associated with changes in pH values and an increase in total dissolved solids, minerals, and sulfates delivered to the streams. Since the early 2000s, conservation actions have focused on establishing natural areas and buffers, and re-establishing high-quality bottomland hardwood forests—especially riparian forests—to filter stormwater and reduce sediment delivery. Additional intensive reclamation efforts have focused on remediating legacy mining wastes, including capping impoundments with clay, revegetation, treatment (pH neutralization/settling), and regulation of discharge under NPDES permitting. Arkansas DEQ permitting and long-term management of the BMRA also includes pond closure planning with substantial revegetation and wetland restoration components to mitigate runoff.

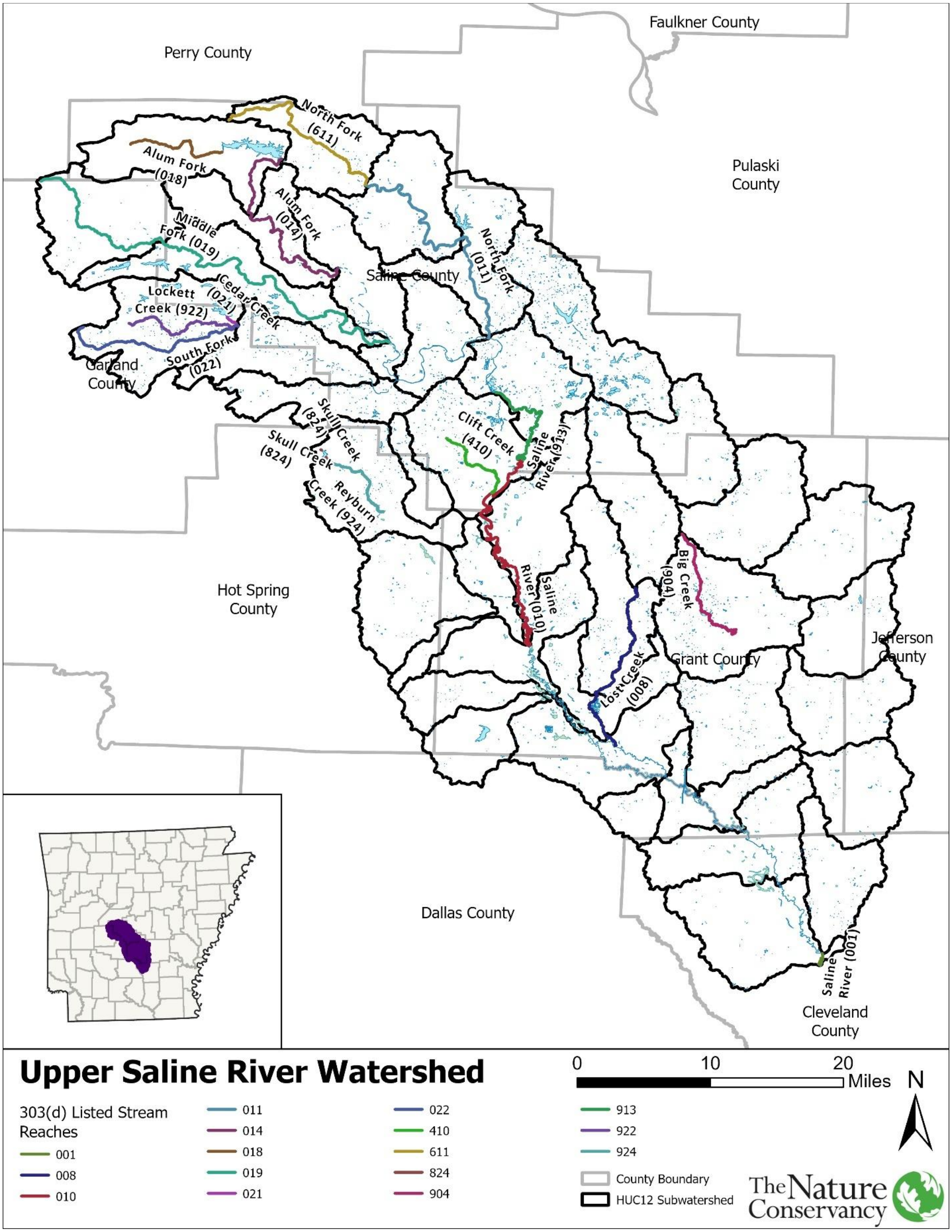

Figure 4.1. 303(d) listed stream reaches in the Upper Saline River watershed (ADEQ, 2023).

4.1.3 Siltation/Turbidity

Big Creek (904) is listed as impaired due to turbidity and Saline River (010 and 913) is listed as impaired due to total dissolved solids from unknown sources. The four forks of the Saline are experiencing an increase in turbidity, particularly during storm events. The potential sources for impairments due to siltation and turbidity include riparian forest removal, stream bank erosion, construction and silviculture practices within the watershed, and stormwater runoff from gravel roads. It is likely sedimentation in these streams is nonpoint source related and it is highly probable the source of sediment is coming from intermittent and ephemeral streams throughout the watershed.

4.1.4 Mercury Contamination

The mercury water quality standard for Arkansas waters for all ecoregions is 0.012ug/L (ppb), expressed as total recoverable mercury. Although this water quality standard is to protect aquatic life, it was developed to protect humans from consuming aquatic life contaminated by mercury. There is a segment of the Saline River, located in the Upper Saline Watershed, listed as impaired due to mercury contamination (reach 001), although it is not included in the segments listed for fish consumption advisories at this time. Lake Winona and Lake Sylvia are also listed as impaired due to mercury contamination, both with fish consumption advisories.

The completed TMDL for the Ouachita River Basin, of which the Saline River watershed is part, indicates after evaluating all NPDES facilities within the watershed that less than 1% of the mercury load comes from point source wasteloads (FTN Assoc., 2002). The geology of the Ouachita Mountains contains rock with relatively high, naturally occurring mercury concentrations. The soils in the basin reflect this geology and also receive mercury from atmospheric deposition. It was determined that the predominant sources of mercury loading to the entire Ouachita River basin are from atmospheric deposition, watershed nonpoint sources, and background loads (FTN Assoc., 2002).

4.1.5 Hydrologic and Geomorphologic Changes

Hydrologic data are crucial for managing water resources and for understanding how streamflow characteristics change over time due to factors like urbanization, agriculture, and climate variability, as well as for interpreting changes in water quality and geomorphology. Geomorphologic changes within the Upper Saline watershed are worth noting as these changes tend to be indicators for trends in declining water quality and associated aquatic habitat impacts. In particular, the southern portion of the watershed found in the South Central Plains is showing stress conditions such as (1) loss of form and function of the channel due to bank destabilization, riparian forest removal, down cutting and head cutting and (2) declines in water quality due to non-point source runoff, erosion, sedimentation, channel degradation, and the legacy effects of open-pit bauxite mining. Some of these changes, in part, might also be contributing to landscape-scale changes in gradient and baseline conditions of the Ouachita River basin. The Saline River basin and the Ouachita River basin meet near the Louisiana border. Landscape changes occurring in both watersheds meet at this point where degradation from one basin can affect the other, moving upstream or "head cutting". Other potential factors involved in degradation of the Saline River mainstem include the removal of riparian vegetation and conversion of the landscape scale forest matrix. The headwater region of the Upper Saline River watershed is experiencing a slightly different set of changes and impacts including (1) hydrologic regime alterations due to dam construction, water withdrawals for irrigation, and water diversion in the creation of ponds and recreational lakes, (2) streambank erosion to a lesser extent than in the mainstem due to removal of riparian buffers, and (3) declining trends in water quality due to both point source discharges and non-point source runoff, erosion, and sedimentation.

4.1.6 Nutrient Criteria and Biotic Communities

The 2006 9-element plan highlighted the need for development of nutrient criteria for surface water and establishing more explicit criteria for evaluating nutrients within the Upper Saline Watershed. In 2010, ADEQ reported their results of a three-year pilot study (https://www.adeq.state.ar.us/water/planning/pdfs/publications/WQ10-10-01.pdf) to test and refine methodologies outlined in State of Arkansas Nutrient Criteria Development Plan within the upper Saline River watershed. Nutrient concentrations were found to be comparable to or less than those of previous studies conducted in the Upper Saline River watershed. Nutrient enriched sites (75th percentile) exhibited only slightly higher nutrient concentrations than least-disturbed sites (25th percentile), and mostly lacked significant differences among the aquatic biota. Macroinvertebrate communities in the Upper Saline River watershed showed little spatial or temporal differences and were mostly similar between nutrient enriched and least-disturbed sites. Taxa richness and EPT richness for the least disturbed sites were only slightly higher than those for the nutrient enriched sites. However, it was noted that the small sample size of the study prevented identification of concentration thresholds for nutrients using aquatic life.

4.2 HUC-12 Prioritization within the Upper Saline River Watershed

The Arkansas Department of Agriculture – Natural Resources Division (Natural Resources Division) identified the Upper Saline River watershed as a 319 NPS priority watershed with primary concerns about in stream sedimentation, chloride, sulfate, pH, mercury, and dissolved oxygen levels (ANRC, 2018). To address water quality issues and aid the revision of the 2006 9-element plan, the University of Arkansas Water Resources Center (AWRC) at the Department of Biological and Agricultural Engineering was contracted to conduct monthly water quality monitoring at 29 sites and identify priority areas at the HUC-12 subwatershed-scale for the Upper Saline River Watershed.

The main objectives accomplished in this study were: 1) assessment of trends in stream water quality using historical monitoring data, 2) evaluation of correlations between stream water quality and catchment land use across sites representing different catchment areas, and 3) evaluation of the influence of watershed metrics on stream water quality using Classification and Regression Tree (CART) analysis.

4.2.1 Water Quality Sampling and Analysis

Water samples were collected from public access bridges at 29 sites within the Upper Saline River watershed and water samples were collected monthly from January 2023 to November 2023 (Appendix H, Fig. 1; Table 2). Sites were selected to represent a broad range and mix of urban, agricultural, and forested areas to evaluate how LULC affects water quality within the watershed. All samples were analyzed for anions (chloride (Cl), fluoride (F), and sulfate (SO_4)), dissolved nutrients (soluble reactive phosphorus (SRP), ammonia (NH_3-N), nitrate plus nitrite (NO_3-N + NO_2-N)), total nutrients (TN and TP), total suspended solids (TSS), turbidity, and conductivity (See Appendix H for detailed description of the sampling and analytical methods and instruments used).

4.2.2 Historical Water Quality Data Analysis

The prioritization process took into account historical data available for the watershed, and changes in nutrient concentrations over time at the watershed (HUC-8) and site level were assessed using water quality monitoring data from sites within the Upper Saline River Watershed. Water quality data were gathered from January 1, 1990, to December 31, 2023, using the Arkansas Department of Energy and Environment ambient water quality monitoring database accessed via the water quality monitoring data portal. To analyze watershed level trends, the yearly median of total nitrogen (TN) and total phosphorus (TP) at each selected site was calculated. The 75th percentile of median TN and TP concentrations for each year was then calculated across monitoring sites within the basin each year and statistical tests were used to detect significant changes and trends in water quality over time (see Appendix H for detailed description of statistical methods used)

4.2.3 Changes in Total Phosphorus (TP)

Between 1990 and 2023, the annual 75th percentile median TP concentrations within the Upper Saline River watershed ranged from 0.020 to 0.175 mg/L. The TP concentrations within the watershed showed a general decreasing trend between 1990 and 2023 (Figure 4.2.3), with a decrease of 1.5%/yr on average across the USRW. However, while there was a decrease in the annual 75th percentile median TP concentrations until 2014, since 2014, there has been a general increasing trend in median TP concentrations. Phosphorus load reduction targets should focus on achieving a decreasing trend in average TP comparable to that observed between 1990 and 2023 (1.5%/yr) with the target of maintaining TP concentrations at or below established Arkansas standards or reference values for designated uses of 0.04 mg/L (Table 4.3.1).

Figure 4.2.3. Mean of the sites 75th percentile TP concentrations within the Upper Saline River Watershed through time. The red dashed line represents the LOESS relationship. Dot sizes change based on how many monitoring sites were considered for each year (MK p=0.04) (MK slope = -1.5 %/yr).

4.2.4 Changes in Total Nitrogen (TN)

Annual 75th median percentile TN concentrations within the watershed ranged from 0.35 to 1.44 mg/L between 1990 and 2023. Like TP, the TN concentrations within the watershed showed a general decreasing trend (Fig. 4). Specifically, the MK results showed an average annual TN concentration decrease of 2.6%/yr across the watershed ($p<0.01$). However, the TN concentration trends were more significant than TP's. Also like TP, TN's LOESS line showed variation within the data with a general annual 75th percentile median TN concentration decrease until 2014, where after 2014, TN began to increase again (Fig. 4.2.4).

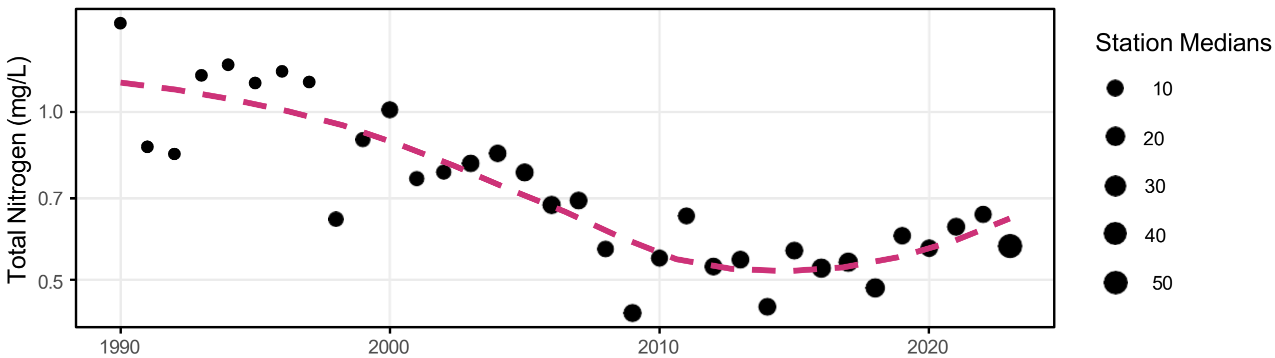

Figure 4.2.4 Mean of the sites 75th percentile TN concentrations within the Upper Saline River Watershed through time. The red dashed line represents the LOESS relationship. Dot sizes change based on how many monitoring sites were considered for each year (MK $p<0.01$) (MK slope = -2.6 %/yr).

4.2.5 Upper Saline River HUC-12 Subwatershed Prioritization

HUC-12 areas within the Upper Saline River watershed were gathered from the Arkansas GIS office's "12 Digit Watershed Boundary Dataset 2017" layer (USGS, 2023) (Fig. 2). All watershed metrics were found for each HUC-12 area using the same methods as previously described (Table 3).

4.2.6 Classification and Regression Tree (CART) Analysis

Classification and regression tree (CART) analyses using the geometric means of the water quality constituents were used to build HUC-12 watershed prioritization maps because CART explained the greatest variation in the data when compared to simple linear regression. The given CART watershed metric thresholds for each water quality constituent were applied to each of the HUC-12 watersheds. For a detailed description of all statistical and modeling methods and results of the CART analyses see Appendix H.

4.2.7 Water Quality Constituent Mapping and Prioritization

To address the chemical constituents carrying most of the prioritization weight, chemical constituents maps were combined into four main groups: nitrogen, phosphorus, sediments, and human influence. To do this, the high, medium, and low-priority HUC-12s were ranked as 5, 3, and 1 for each priority map. Then, each HUC-12 ranking for each map was added together. HUC-12s were then re-ranked based on the HUC-12 sums. HUC-12s falling with a rank of 10 were high priority, HUC-12s ranked between 6-9 were medium priority, and HUC-12s with a rank of 5 or below were low priority.

If a HUC-12 area included a 303(d) listed stream within its boundaries, it was ranked as a high priority, while if no listed stream was present, it was ranked as a low priority. The forest landcover change from 2001 to 2021 was calculated for each HUC-12s' 90 m riparian buffer and HUC-12 area. If a 90 m riparian buffer area or HUC-12 area lost more than 1% of its forest cover, then it was ranked as a high priority, while if less than 1% was lost, it was ranked as a low priority. The two forest cover change maps HUC-12 areas were then ranked using the same methods as the chemical constituents, where a high priority area had a rank of 5, a medium priority had a rank of 3, and a low priority area had a rank of 1.

4.2.8 Human Influence Prioritization

The two human influences water quality constituents, chloride and conductivity, HUC-12s were ranked based on the priority category each HUC-12 area fell into. The two maps were added together to create one human influence priority map. The overall human influence priority map has 3 HUC-12 areas within the high priority category, 24 within the medium, and 13 within the low category (Figure 4.2.8).

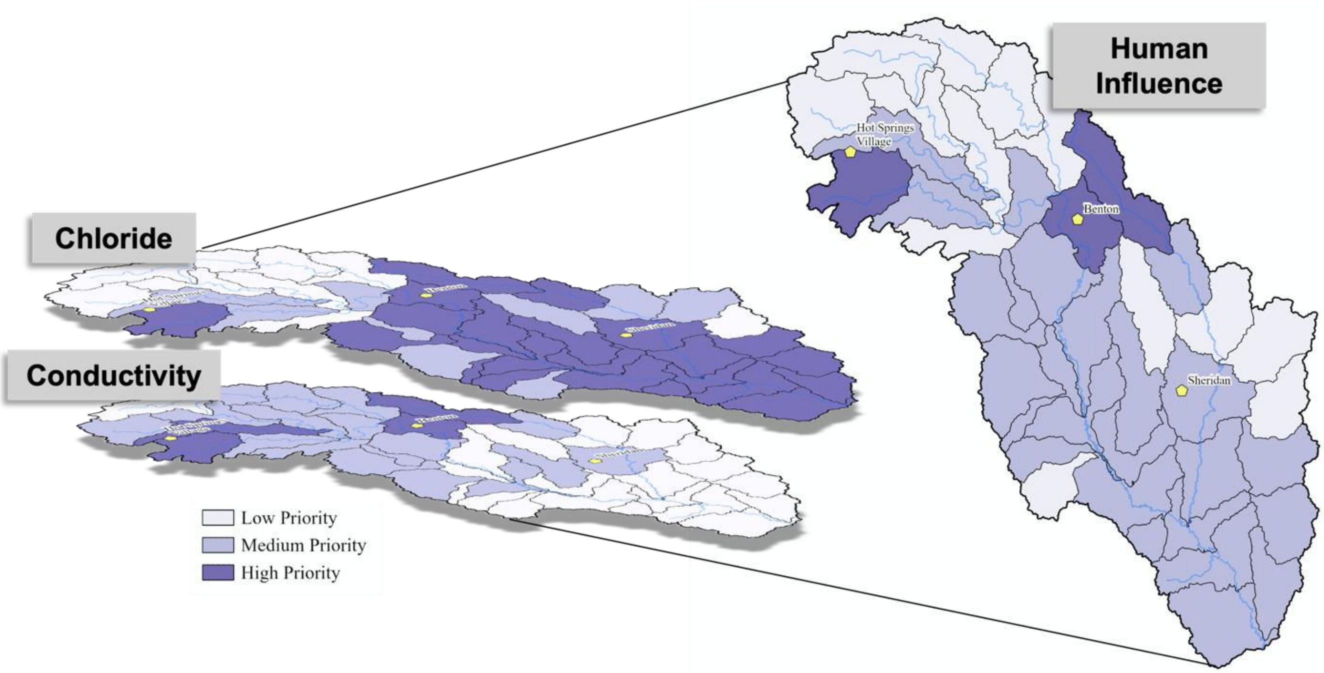

Figure 4.2.8. Prioritization of HUC-12 watersheds within the Upper Saline River Watershed based on chloride and conductivity water quality constituents. Priority varies from lightest (low priority) to darkest (high priority).

4.2.9 Phosphorus Prioritization

The two phosphorus water quality constituents, SRP and TP, HUC-12s were ranked based on the priority category each HUC-12 area fell into. The two maps were added together to create one phosphorus priority map. The overall phosphorus priority map has 22 HUC-12 areas within the high priority category, 3 within the medium, and 15 within the low (Figure 4.2.9).

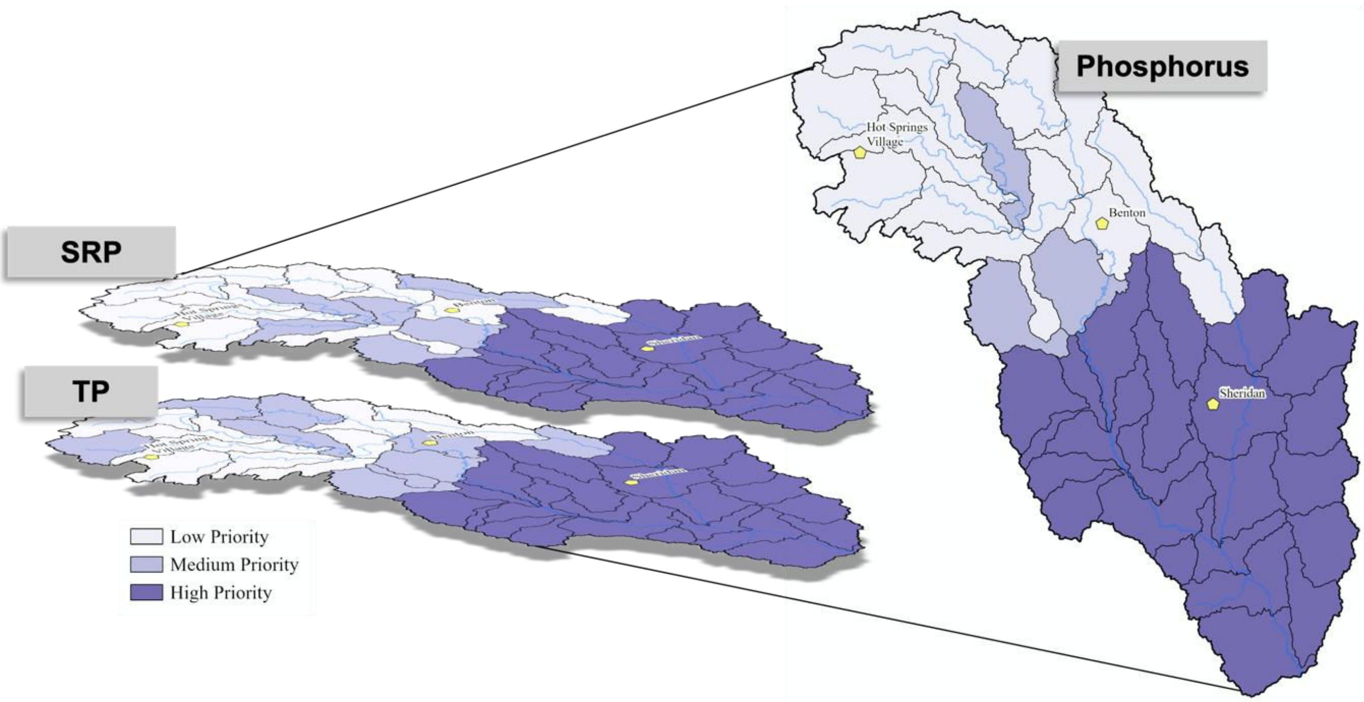

Figure 4.2.9. Prioritization of HUC-12 watersheds within the Upper Saline River Watershed based on phosphorus water quality constituents. Priority varies from lightest (low priority) to darkest (high priority).

4.2.10 Nitrogen Prioritization

Three nitrogen water quality constituents, ammonia, nitrate, and TN were used for the overall nitrogen priority ranking. Their HUC-12s were ranked based on the priority category each HUC-12 area fell into. The three maps were added together to create one nitrogen map. The overall nitrogen priority map has 21 HUC-12 areas within the high priority category, 9 within the medium, and 10 within the low (Figure 4.2.10).

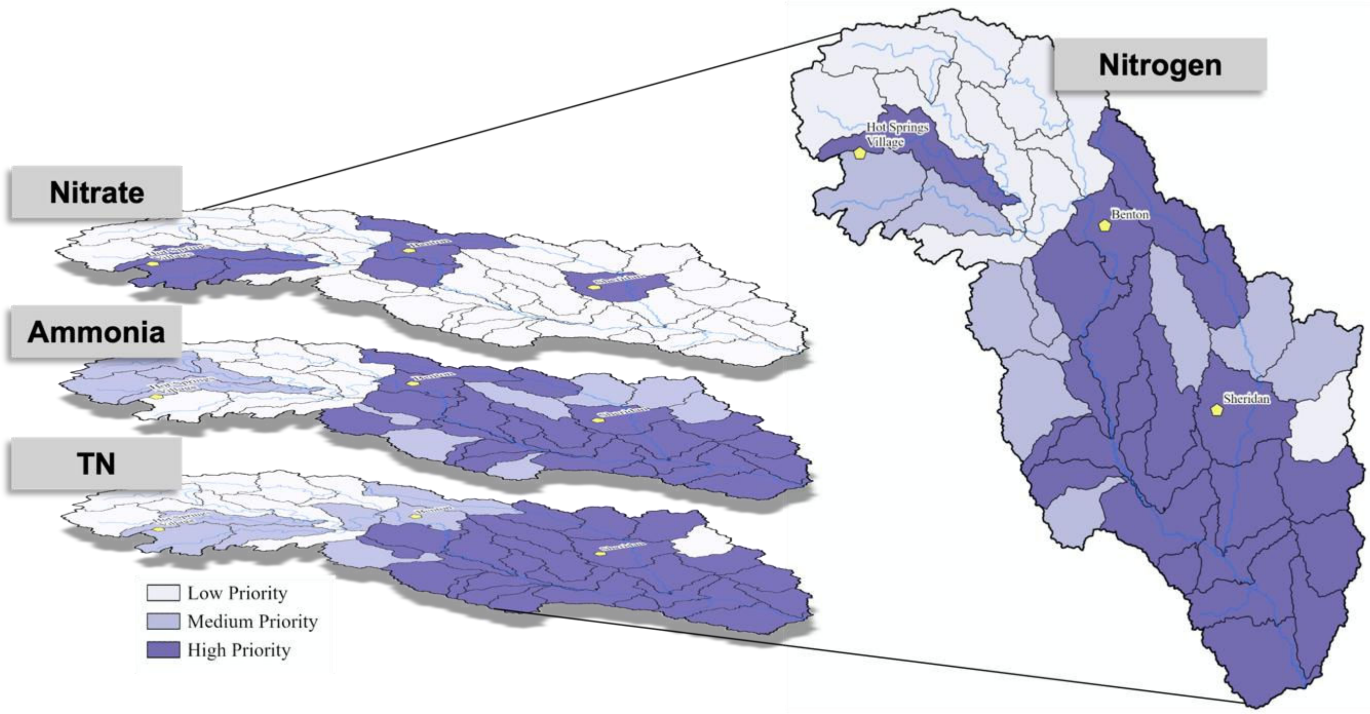

Figure 4.2.10. Prioritization of HUC-12 watersheds within the Upper Saline River Watershed based on nitrogen water quality constituents. Priority varies from lightest (low priority) to darkest (high priority).

4.2.11 Sediment Prioritization

The two sediment water quality constituents, TSS and turbidity, were used for the overall sediment priority ranking. Their HUC-12s were ranked based on the priority category each HUC-12 area fell into. The three maps were added together to create one sediment map. The overall sediment priority map has 17 HUC-12 areas within the high priority category, 10 within the medium, and 13 within the low (Figure 4.2.11).

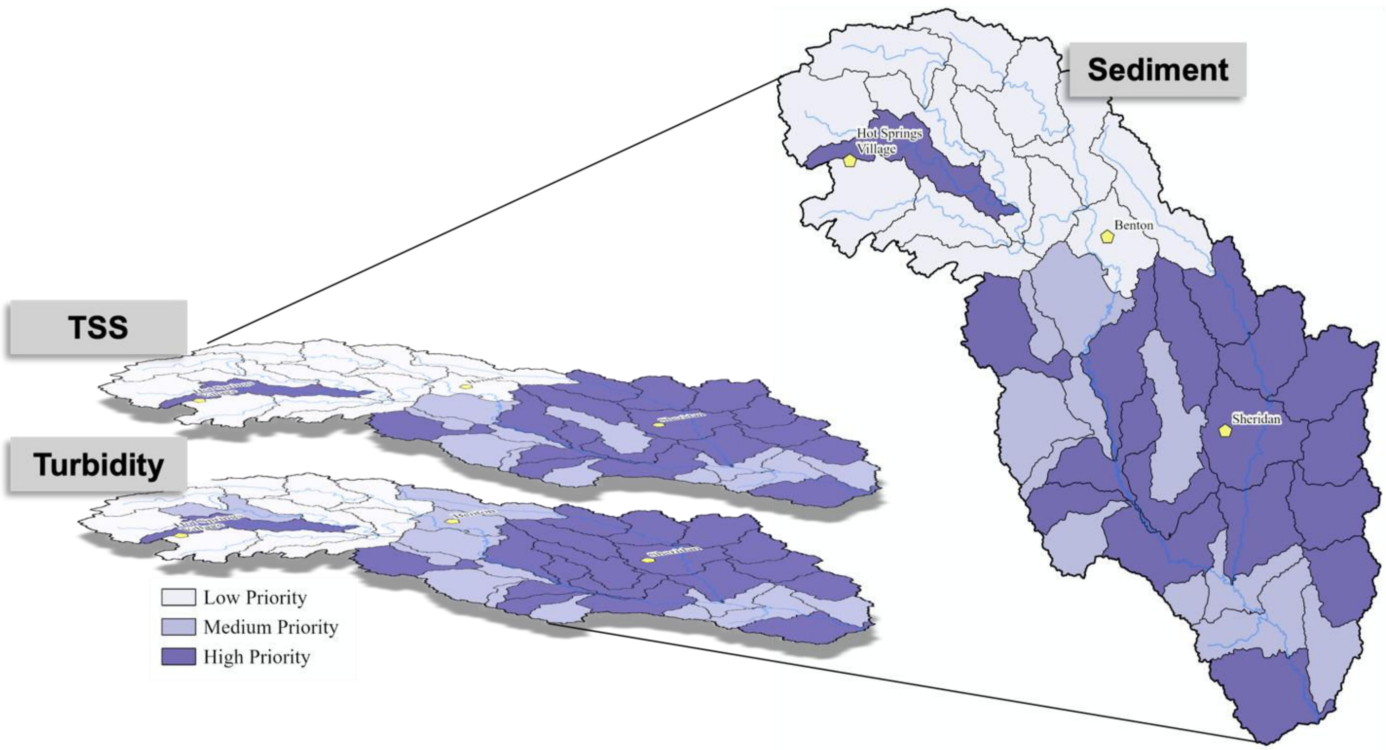

Figure 4.2.11. Prioritization of HUC-12 watersheds within the Upper Saline River Watershed based on sediment water quality constituents. Priority varies from lightest (low priority) to darkest (high priority).

4.2.12 303(d) Impaired Streams

Several stream reaches within the Upper Saline River watershed have been identified as impaired on recent 303(d) lists (ADEQ, 2023). To ensure that these 303(d) listed streams were addressed in the HUC-12 watershed prioritization, any HUC-12 with an impaired stream within its boundaries was categorized as a high priority, while HUC-12s with no impaired streams were categorized as low priority for conservation and protection. The resulting 303(d) listed streams priority map had 17 HUC-12 areas within the high priority category and 23 within the low category (Figure 4.2.12)

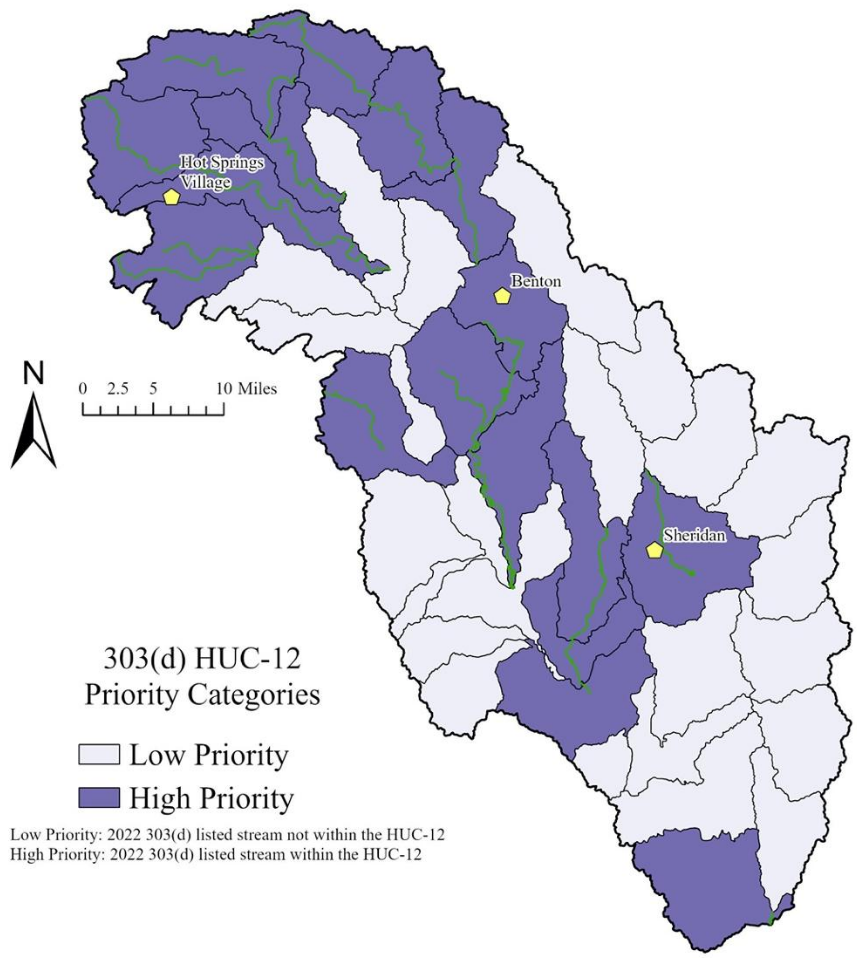

Figure 4.2.12. Prioritization of HUC-12 watersheds within the Upper Saline River Watershed based on 2022 303(d) listed streams. Priority varies from lightest (low priority) to darkest (high priority). Green stream lines represent the 2022 303(d) listed stream segments.

4.2.13 90m Forest Landcover Change

Landcover change within the riparian areas was a concern within the Upper Saline River Watershed. To ensure that riparian landcover change was addressed in the HUC-12 watershed prioritization the change in forest landcover within the 90 m riparian buffer was calculated from 2001 to 2021. Any HUC-12 area that lost more than 1% of its forest cover within the 90 m riparian buffer area was listed as a high priority area, while HUC-12 areas that lost less than 1% were categorized as low priority areas. The resulting 90 m forest cover change priority map has 21 HUC-12 areas within the high priority category and 19 within the low category (Figure 4.2.13)

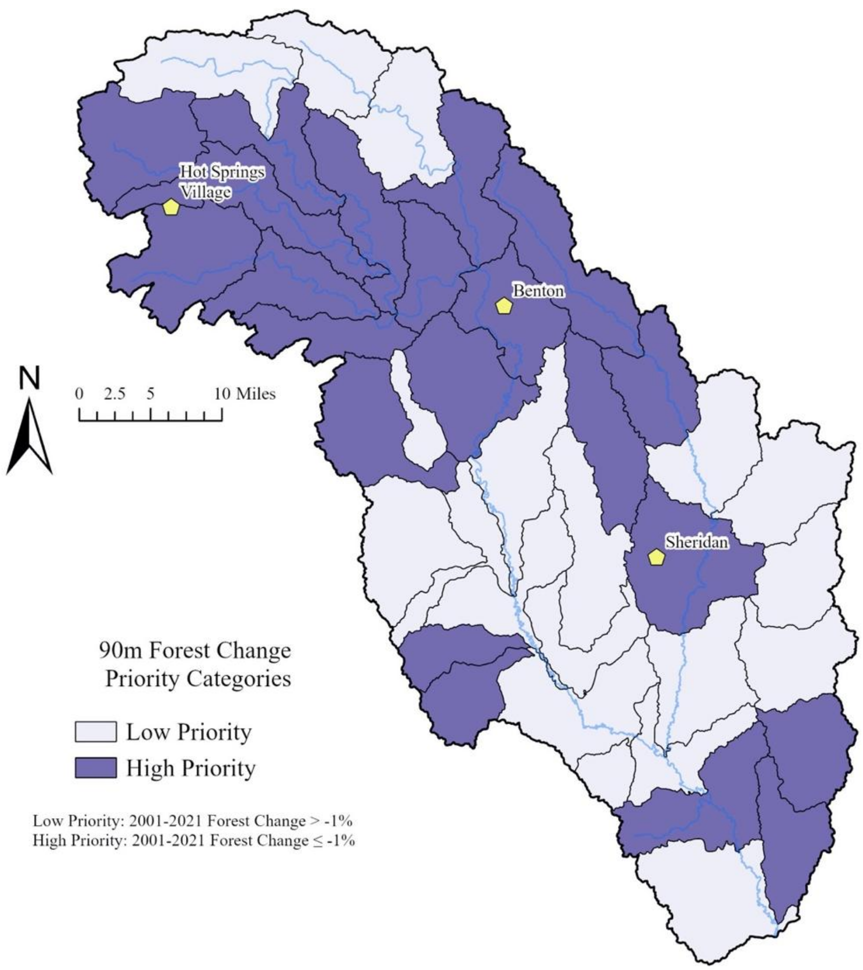

Figure 4.2.13. Prioritization of HUC-12 watersheds within the Upper Saline River Watershed based on the 90 m forest riparian buffer cover change from 2001 to 2021. Priority varies from lightest (low priority) to darkest (high priority).

4.2.14 HUC-12 Landcover Change

Landcover change within the whole HUC-12 area was also a concern within the Upper Saline River Watershed. To ensure that landcover change was addressed in the HUC-12 watershed prioritization, the change in forest landcover within the HUC-12 area was calculated from 2001 to 2021. Any HUC-12 area that lost more than 1% of its forest cover was listed as a high priority area, while HUC-12 areas that lost less than 1% were categorized as low priority areas. The resulting HUC-12 area forest cover change priority map had 11 HUC-12 areas within the high priority category and 29 within the low category (Figure 4.2.14)

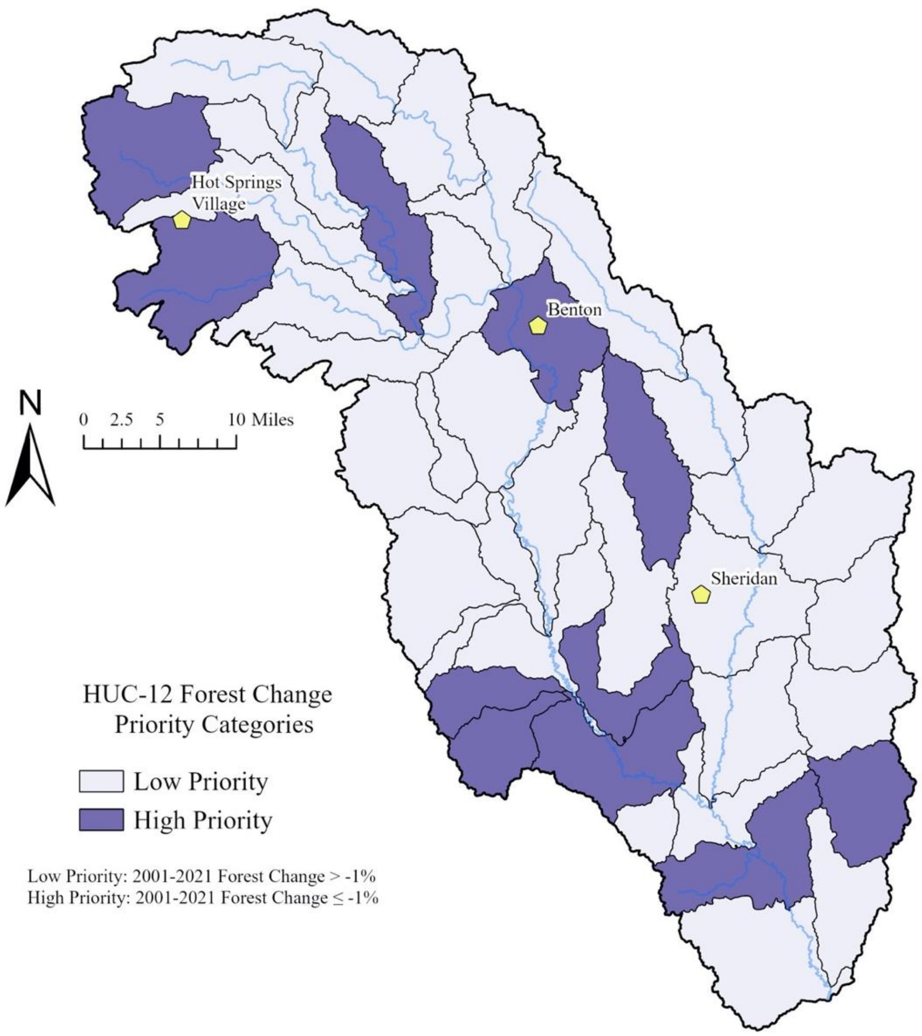

Figure 4.2.14. Prioritization of HUC-12 watersheds within the Upper Saline River Watershed based on the HUC-12 buffer forest cover change from 2001 to 2021. Priority varies from lightest (low priority) to darkest (high priority).

4.2.15 Combined Water Quality Mapping and Overall Prioritization

To calculate a final HUC-12 prioritization map for the Upper Saline River Watershed, the sum of each HUC-12's ranks from the final seven priority maps (human influence, phosphorus, nitrogen, sediments, 303(d) listed streams, 90 m forest change, and HUC-12 forest change) was added together. The 1/3rd percentile (value of 17) and 2/3rd percentile (value of 24) were used to split the HUC-12s into three groups. If a HUC-12 had a sum between 7 and 16, it was ranked as a low priority, a sum between 17 and 23 was ranked as medium priority, and a sum between 24 and 35 was ranked as high priority. The resulting final prioritization map for the watershed has 14 HUC-12 areas within the high priority category, 16 within the medium priority, and 10 within the low category (Figure 4.2.15; Table 4.2)

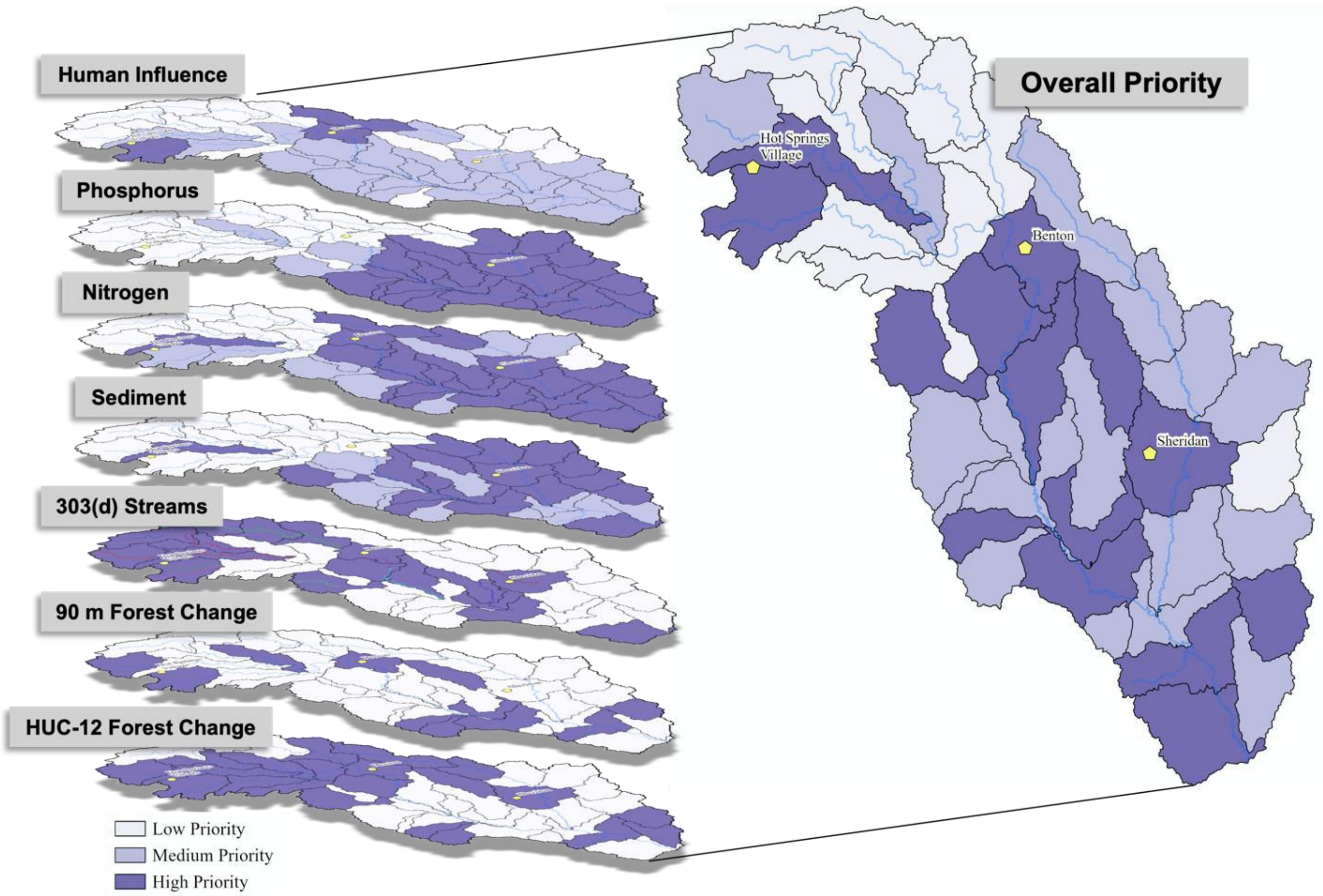

Figure 4.2.15 . Combined final prioritization of HUC-12 watersheds within the Upper Saline River Watershed based on the seven HUC-12 prioritization maps. Priority varies from lightest (low priority) to darkest (high priority)

Table 4.2 Upper Saline River watershed HUC-12 subwatersheds and their final prioritization.

HUC-12 Name	Final Score	Priority Category
Allgood Creek-Derrieusseaux Creek	29	High
Brush Creek-Saline River	29	High
Chapel Creek-Saline River	29	High
Flat Creek-Dry Creek	29	High
Ray Creek-Hurricane Creek	29	High
Depot Creek-Saline River	27	High
Grisley Creek-Saline River	27	High
Cedar Creek-South Fork Saline River	25	High
Graves Creek-Dry Lost Creek	25	High
Jordan Creek-Saline River	25	High
Pine Bridge Creek-Saline River	25	High
Tailwaters Middle Fork Saline River	25	High
Tenmile Creek-Francois Creek	25	High
Trace Creek-Saline River	25	High
Cox Creek	23	Medium
Little Lost Creek-Dry Lost Creek	23	Medium
Panther Creek-Derrieusseaux Creek	23	Medium
Johnson Creek-Derrieusseaux Creek	21	Medium
Logan Creek-Hurricane Creek	21	Medium
Mud Creek-Saline River	21	Medium
White Oak Creek-Hurricane Creek	21	Medium
Beech Creek-Cow Head Creek	19	Medium
Big Creek-Francois Creek	19	Medium
Headwaters Middle Fork Saline River	19	Medium
Little Creek-Saline River	19	Medium
Little Hurricane Creek-Hurricane Creek	19	Medium
Big Creek-Saline River	17	Medium
Mud Creek-Hurricane Creek	17	Medium
Simpson Creek	17	Medium
Thunder Branch-Big Creek	17	Medium
Little Derrieusseaux Creek-Derrieusseaux Creek	15	Low
Lower North Fork Saline River	15	Low
Mill Creek-South Fork Saline River	15	Low
Tailwaters Alum Fork Saline River	15	Low
Brushy Creek-Francois Creek	13	Low
Moccasin Creek-Saline River	13	Low
Headwaters Alum Fork Saline River	11	Low
Middle North Fork Saline River	11	Low
Tenmile Creek-South Fork Saline River	11	Low
Upper North Fork Saline River	11	Low

4.3 Element 2 – Estimated Load Reductions

The year-long water quality analyses completed by the AWRC showed the average concentrations of measured water quality constituents for the Upper Saline River Watershed were all at levels below established Arkansas standards or reference values for designated uses, except for Total Phosphorus (TP; Table 4.3.1). These results indicate surface water quality in Upper Saline River watershed is generally very good compared to many other watersheds in Arkansas. Therefore, recommendations for meeting designated uses presented in the management plan focus primarily on the goal of maintaining the generally high level of water quality of streams in the watershed. Load reduction estimates and recommendations focused on addressing pH, DO and turbidity impairments, and lowering TP water concentrations are discussed in further detail below.

Table 4.3.1. Average concentrations in the Upper Saline Watershed for water quality constituents measured by AWRC along with established state standards and/or reference values. Sources for the reference values are included in Appendix G.

Water Quality Parameter	Average	AR Standard	Reference Value
Ammonia-N (mg/L)	0.04	N/A	0.3
Chloride (mg/L)	4.3	13-14	-
Conductivity (µS/cm)	120.37	N/A	105-134
Nitrate-N (mg/L)	0.17	N/A	1
SRP (mg/L)	0.04	N/A	0.05
Total Nitrogen (mg/L)	0.59	N/A	0.69
Total Phosphorus (mg/L)	0.09	N/A	0.04
Total Suspended Solids (mg/L)	8.36	N/A	10
Turbidity (NTU's)	12.75	10-21	-

4.3.1 pH and Dissolved Oxygen (DO)

The majority of stream reaches in the Upper Saline River watershed included in the 2022 303(d) list cite impairments due to non-attainment of water pH and critical season dissolved oxygen (DO; Table 4.1). Lake Winona, a primary drinking water source, is also listed as having pH impairments. Land use changes can also influence surface water pH and DO, however both pH and DO levels can be influenced by numerous extraneous factors and spatial heterogeneity in the watershed The source of these pH and critical season DO impairments is currently unknown. Drivers of freshwater acidification in the watershed can stem from various sources, including natural factors like geological, hydrologic, and climatic conditions, but since the 1960s, atmospheric deposition had been a primary concern (Galuszka & Migaszewski, 2020). It is recommended that a continuous monitoring study of water pH and DO be prioritized to identify and address the sources of these impairments. Recommended conservation practices in rural and urbanizing areas of the watershed, along with their associated estimated load reductions targeting pH, DO, and Phosphorus impairments, and estimates of other key load reductions are included in Table 4.3.2 and Table 4.3.3 and are discussed in detail below.

Table 4.3.2. Recommended rural watershed conservation practices targeting pH and DO impairments and other key load reductions, including Phosphorus and other nutrients, sediment, and water temperature. Estimates of load reductions are based on best practices and typical pollutant load modeling approaches used in similar headwater stream systems.

Practice	DO Increase (mg/L)	pH Change	Key Load Reductions	Reference Sources
Riparian Buffer Restoration	0.5–1.5	Stabilize (6.5–8.5)	Nutrients ↓ 30–50%, Sediment ↓ 40–60%, Temperature ↓ 1–3°F	EPA Watershed Academy: https://www.epa.gov/watershedacademy; USDA NRCS Riparian Forest Buffer Standard (Code 391): https://www.nrcs.usda.gov/resources/guides-and-instructions/riparian-forest-buffer-ac-391-conservation-practice-standard; 1
Livestock Exclusion and Streambank Restoration	0.3–0.8	+0.2–0.5	Organic ↓ 50–70%, Fecal ↓ 70–90%	Arkansas NRCS Conservation Practice Catalog: https://www.nrcs.usda.gov/state-offices/arkansas/arkansas-conservation-practice-catalog; 2
Nutrient Management	0.5–1.0	Stabilize	Nitrogen ↓ 30–60%, Phosphorus ↓ 40–70%	EPA Nutrient Control Design Manual: https://www.epa.gov/sustainable-water-infrastructure/nutrient-control-design-manual; USDA Conservation Effects Assessment Project (CEAP): https://www.nrcs.usda.gov/ceap;
Stream Habitat Enhancement	0.5–1.2	Indirect stabilization	Organic ↓ 20–40%, Temperature ↓ 1–3°F	EPA Healthy Watersheds Program: https://www.epa.gov/climate-change-water-sector/healthy-watersheds-program; 4
Septic System Upgrades	0.4–0.9	+0.2–0.4	Nutrients ↓ 50–75%, Pathogens ↓ 80–95%	EPA SepticSmart Program: https://www.epa.gov/septic/septicsmart; Arkansas DEQ Water Quality and No-Discharge Permits: https://www.adeq.state.ar.us/water; 5

[1] Mayer et al (2007), [2] Line et al. (2000), [3] Sharpley et al. (2009), [4] Palmer et al. (2010), [5] Wither et al. (2012)

Table 4.3.3. Recommended urban watershed conservation practices targeting pH and DO impairments and other key load reductions, including Phosphorus and other nutrients, sediment, and water temperature. Estimates of load reductions, implementation costs, and BMP maintenance are based on best practices and typical pollutant reduction approaches used in other similar urban areas.

Practice	DO Increase (mg/L)	pH Change	Key Load Reductions	Details	Reference Sources
Bioswales	0.2–0.5	Stabilize	Phosphorus ↓ 20–40%, Nutrients ↓ 30–80%, Sediment ↓ 70–90%	Bioswales intercept and filter stormwater, reducing phosphorus before it enters streams. Maintenance includes mowing, debris removal, and inspection for clogging.	EPA Green Infrastructure: https://www.epa.gov/green-infrastructure; 7-9
Rain Gardens/Bioretention	0.2–0.6	Stabilize	Phosphorus ↓ 30–60%, Nutrients ↓ 40–90%, Sediment ↓ 60–90%	Rain gardens filter runoff through engineered soils and vegetation. Iron-enhanced media can boost dissolved phosphorus removal to >90%. Maintenance includes weeding, mulch replacement, and sediment removal.	USDA NRCS Conservation Practice Standards: https://www.nrcs.usda.gov/resources/guides-and-instructions; 4-6
Green Roofs	0.1–0.3	Stabilize	Nutrients ↓ 40–60%, Sediment ↓ 50–70%	Green roofs can reduce nutrients by retaining rainfall and filtering through substrate.	EPA Green Infrastructure: https://www.epa.gov/green-infrastructure; Green Roofs for Healthy Cities: https://greenroofs.org
Filter Strips/Vegetated Buffers	0.2–0.5	Stabilize	Phosphorus ↓ 40–80%, Nutrients ↓ 40–80%, Sediment ↓ 60–90%	Filter strips trap sediment and nutrients from runoff before it reaches water bodies. Maintenance includes mowing, sediment removal, and vegetation management.	USDA NRCS Conservation Practice Standards: https://www.nrcs.usda.gov/resources/guides-and-instructions; 10-12
Stormwater Wetlands/Constructed Wetlands	0.3–0.7	Stabilize	Phosphorus ↓ 70–93%, Nutrients ↓ 50–90%, Sediment ↓ 70–95%	Wetlands remove nutrients via sedimentation, plant uptake, and microbial processes. Performance is highest in large, well-vegetated systems; maintenance includes vegetation management and sediment removal.	EPA Green Infrastructure: https://www.epa.gov/green-infrastructure; WEF Stormwater Institute: https://www.wef.org/resources/for-the-public/Stormwater; 1-3
Permeable Pavement	0.1–0.3	Stabilize	Phosphorus ↓ 20–60%, Nutrients ↓ 30–60%, Sediment ↓ 50–80%	Permeable pavement filters runoff, reducing phosphorus loads to streams. Maintenance includes vacuum sweeping and inspection for clogging.	EPA Green Infrastructure: https://www.epa.gov/green-infrastructure; 2,13-17
Tree Planting/Urban Forestry	0.2–0.4	Stabilize	Phosphorus ↓ 10–30%, Nutrients ↓ 20–40%, Sediment ↓ 30–50%, Temperature ↓ 2–6°F	Urban trees intercept rainfall and promote infiltration. Leaf litter management (e.g., street sweeping) can further reduce phosphorus export.	USDA Forest Service Urban Forestry: https://www.fs.usda.gov/managing-land/urban-forests/ucf; 18-20

[1] Dunne et al. (2015), [2] Janke et al. (2023), [3] Li et al. (2025), [4] Obeid (2005), [5] Weiss et al. (2016), [6] Strong (2015), [7] Folorunso (2020), [8] Xiao et al. (2017), [9] EPA (2022), [10] Ramler et al. (2022), [11] Rudra (2003), [12] Fox & Penn (2013), [13] Olsen (2017), [14] Frost et al. (2019), [15] USGS (2019), [16] Kamali et al. (2017), [17] Luo et al. (2024), [18] Metson et al. (2015), [19] Selbig et al. (2020), [20] Zhou et al. (2024)

Phosphorus pollution in surface waters primarily originates from agricultural and urban activities (Carpenter et al., 1998). Major sources include fertilizers, manure, and urban runoff (Easton & Petrović, 2008; Yuan et al., 2011). Fertilized lawns and urban barren areas contribute to phosphorus loading, with fertilized lawns having higher dissolved phosphorus losses on runoff-prone soils (Easton & Petrović, 2008). The AWRC's analyses showed average TP concentration (mg/L) across all sampling locations in the watershed was 0.09 mg/L, which is more than double the 0.04 mg/L reference value (Evans-White et al., 2014). However, 43% of monitoring sites were also found to have an average TP less than 0.04mg/L. Subwatersheds with elevated Phosphorus priority were all located below the Interstate 30 corridor and the fall line separating the Ouachita Mountains Ecoregion to the north and South Central Coastal Plain Ecoregion to the south. A map of soil drainage classes (Figure 2.8) shows that soils in these areas are generally poorly drained, which can contribute to increased runoff of TP and other nutrients. Given the location of these subwatersheds downstream of growing urban areas in the watershed, along with the generally limited livestock and row crop agriculture within the watershed, it is likely that urban activities are the primary contributor to these elevated TP loads.

Managing non-point source phosphorus pollution in the Upper Saline River watershed will require an integrated approach, combining reduced consumption, source management, and nutrient criteria (Haque, 2021). Nature-based solutions like bio-retention ponds, constructed wetlands, vegetative filter strips and swales, and porous pavements have all shown effectiveness in removing TP from urban runoff (Dutta et al., 2021). While measured Phosphorus concentrations in the watershed have decreased since their highs in the mid-2000s and remain low compared to many other watersheds in the state, the recent increases over the past few years are concerning. Monitoring and management activities should focus on ensuring that Phosphorus concentrations are steady or declining across a majority of the subwatersheds.

4.3.2 Sedimentation and Turbidity

Sedimentation and turbidity in streams were identified as primary concerns by watershed stakeholders. AWRC water quality modeling for total suspended sediments (TSS) and Turbidity showed the proportion of riparian forest cover within 30m of streams along with evergreen forest cover and unpaved road density were all influential factors in the CART models. Specifically, monitoring sites with 30 m riparian forest cover < 75% and > 20% evergreen had higher TSS concentrations. Sites with higher unpaved road density and evergreen forest cover also had higher sediment concentrations.

Unpaved roads can deliver sediment and nutrients directly into streams at crossings, or indirectly by overland flow or gullies. Estimates from several watersheds in the Ozark Mountains ecoregion in Arkansas suggest that 20-30% of sediment in rivers comes from unpaved roads (Inlander et al., 2007). Road sediment is being targeted because, compared to other non-point sources of pollution such as runoff from pastures, sediment from roads is more realistic to identify and manage for successful short-term reduction. Thus, assessment and implementation dollars spent to reduce sedimentation can be maximized in the short run by investing in watershed roads assessments and prioritization, training programs, and hands-on demonstrations of the implementation of best management practices on gravel roads. Monitoring and evaluation tools like the Water Erosion Prediction Project (WEPP) model can assist managers in prescribing effective BMPs to reduce sediment loads leaving unpaved roads and riparian buffers. When implementing WEPP modeling to predict event-based sediment yield and runoff from unpaved roads and compare roads with and without BMP installation, an estimated 30% to 70% reduction in sediment loading can be achieved where BMP installation has occurred (Efta and Chung 2014).

In September 2023, in partnership with TNC and Natural Resources Division, the Saline County Road Department successfully completed road crossing construction activities and unpaved road BMP implementation at three sites in the Alum Fork headwaters. WEPP assessment and modeling demonstrated a large decrease in the volume of sediment being mobilized annually from the road surface. Pre-construction WEPP surveys estimated an average annual soil loss of 8.13 tons/acre or approximately 4 kg/m2 during a 20-year modeling period. Post-construction WEPP surveys over the same 20-year modeling window showed estimated average annual soil loss has been reduced to 2.63 tons/acre or 0.59 kg/m2 following BMP implementation and significant improvements to the unpaved roadbed and adjacent ditches. It is estimated the three combined BMP installation projects reduced soil loss rates from 24.38 tons/acre/year pre-implementation to 7.89 tons/acre/year post-implementation. This equates to an average estimated sediment load reduction of 16.49 tons/acre/year, a decrease of nearly 68% compared to pre-implementation sedimentation rates (TNC, 2024).

4.4 Element 3 – Non-Point Source Management Measures Needed

4.4.1 Section1: Data Collection Needs

Additional data collection for tributaries to get a clearer picture of geomorphology, water quality and aquatic habitat.

Intermittent and ephemeral streams play a significant role in hydrologic, chemical, and ecological connectivity, delivering nutrients and sediments to larger bodies of water. Even small, non-perennial tributaries can significantly increase sediment yield in main-stem river, along with delivering higher concentrations of bioavailable nutrients, potentially fueling algal blooms and other water quality declines (Marteau et al., 2017). The impact of these smaller watersheds and tributaries on water quality and availability is often underestimated, as monitoring efforts typically focus on larger tributaries. Expanding monitoring efforts to include smaller tributary streams could help watershed managers better understand and mitigate these impacts.

Hire one additional hydrological or biological sampling technician each at ADEQ and AGFC focused on the Upper Saline River and other Interior Highlands streams.

Hydrologic monitoring needs include observations such as (1) stage, discharge, and the magnitude, frequency, time, duration of extreme high- and low-flow events, (2) channel cross sections, longitudinal profiles, (3) trend analysis of channel platform and bedform changes, and (4) river bank and bed erosion rates. Biological monitoring needs include Index of Biotic Integrity (IBI) monitoring for benthic macroinvertebrates and fish communities.

Develop a watershed map indicating areas of land that if developed would increase the river's vulnerability to increased sedimentation and channel instability and areas that could withstand low impact development.

Watershed development and urbanization can significantly impact stream channel stability and sedimentation by altering flow regimes and increasing storm runoff. Increased imperviousness can potentially destabilize streams even at low levels of 10-20% imperviousness (Bledsoe & Watson, 2001). Development of a multi-factorial approach that combines geoprocessing methods for land use analysis and in situ evaluations using rapid assessment protocols, provides a comprehensive assessment of watershed environmental conditions. Watershed classifications can help predict resistance and resilience to the effects of urbanization based on physiographic characteristics like catchment area, storage capacity, channel slope, soil permeability, baseflow index, riparian forest cover, and land use change. Remote sensing and GIS techniques can further provide a rapid and cost-effective tool for watershed planning and aid spatial planning and assessment of riparian zone vulnerability to development. Watershed vulnerability maps would provide valuable tools for urban planners and watershed managers to identify and prioritize vulnerable areas and implement appropriate conservation and management practices in watershed and riparian zones to protect aquatic ecosystems and communities.

Continuation of Water Quality Monitoring in key areas of the watershed -highest priority is monitoring pH and dissolved oxygen in 303d listed segments.

Low pH and dissolved oxygen (DO) have been observed by within the Upper Saline Watershed. Low dissolved oxygen in the watershed can stem from high nutrient levels in the water. Potential causes for nutrient loading in the watershed were listed as unknown in the 2022 303d list (ADEQ 2023). The critical dissolved oxygen standard for watersheds greater than 10 square miles in the Ouachita Mountains is 6 mg/L and if not continued throughout a 24 hour period conditions can lead to stream impairment for aquatic life. For the Upper West Gulf Coastal Plain the critical D.O. standard for watersheds greater than 10 square miles is 3 mg/L. Additional Water Quality monitoring needs include establishing baseline and annual monitoring of sediment fluxes and water quality parameters, particularly for prioritized sub-basins, water temperature, turbidity, conductivity, total dissolved and suspended solids, and bedload. Sampling analysis for nitrates, phosphorus, pesticides, and herbicides are needed on a periodic basis.

Hire one additional water quality technician to work closely with local stakeholders including SRWA

There is a need in the Upper Saline watershed to continue water quality monitoring in a way that maximizes past and current data collection, but does not duplicate efforts (see Element 9 "Monitoring" for more information on current and past water quality monitoring efforts). The Arkansas Natural Resource Division (Natural Resources Division) is currently dedicating efforts to establishing additional water quality monitoring stations within the Upper Saline Watershed. To locate the most appropriate locations for the addition of permanent monitoring stations, a watershed survey is needed for the Upper Saline Watershed. By conducting a "snapshot" survey in which grab samples are taken throughout the watershed within the same day, surveyors will be able to get a "picture view" of water quality conditions on an average day. This approach, combined with data analysis from all other available data sources, will help determine the most effective locations for citing new permanent water quality monitoring stations.

This effort by the Natural Resources Division to extend water quality monitoring in the Upper Saline will support the long-term monitoring goals for the watershed and establish meaningful data that compliments and builds upon water quality data being produced by other organizations and agencies. With the establishment of two new permanent monitoring stations in the short term (1-5 years) for the Upper Saline, communication regarding collection efforts should be emphasized between data collection agencies and local watershed groups and county conservation districts to cross-reference with restoration efforts and determine if there is an opportunity to associate collected water quality data with pre- and post- BMP implementation efforts.

Every 5 years: Repeat inventory of the top three identified priority sub-watersheds of the Saline to determine annual sediment loading from various sources in the watershed.

A detailed inventory of the top three sub-watersheds targeted for sediment reduction efforts should be conducted at least every 5-years. This watershed inventory should include a detailed geomorphic assessment of the stream. Surveys should include cross-section evaluation of all representative reaches of the mainstem and a bank erosion hazard index (BEHI) inventory to locate additional problem areas. Land uses that contribute sediment to the priority watersheds should be identified and evaluated. Sediment loading delivered to the river should be estimated for each major source using GIS data, available environmental and field collected data, published export coefficients, and/or simple to complex models or relationships. Work should include (but is not limited to) a detailed evaluation of eroding streambanks; watershed erosion prediction curves; and characterization of bank materials. Also, WEPP (water erosion prediction project) modeling modules could be used to evaluate source loadings, particularly for sedimentation from gravel roads. A detailed assessment similar to this should be prioritized for the long term for evaluating nutrient concentrations for priority sub-watersheds.

Expansion of biological assessments: fish and macroinvertebrate population studies and related community changes.

There is a need to increase or expand biological data collection in the Upper Saline Watershed, particularly in conjunction with BMP implementation projects in order to identify any pre- and post-project changes to these populations (see Element 9 “Monitoring” for an overview of current biological monitoring in the USW). Following the prioritization of the top three sub-basins of the Upper Saline Watershed, it is recommended to conduct fish and macroinvertebrate sampling at two strategically placed sites per each priority sub-watershed, bi-annually for at least two years as an independent project focused solely on expanding biological monitoring within the watershed. Pre- and post-project collection of biological data should also be incorporated into site specific 319 implementation projects. At least two 319 projects implemented in the watershed over the next five years should include a biological monitoring component. In either case, sampling sites should be chosen, when possible, in conjunction with other BMP implementation projects in the watershed to monitor biological community reaction to the project efforts. This type of strategic monitoring will be essential for success comparison of different nonpoint source pollution reduction measures.

<u>Implementation of Municipal Stormwater Pollution Prevention Programs</u>

There is a continued need in the watershed to coordinate between local watershed groups, larger cities/municipalities, local schools, and Cooperative Extension Service Offices to insure that information is being disseminated to county road departments, county homebuilder associations, construction companies, and the general public to understand the effects of stormwater runoff and new approaching stormwater requirements. The City of Benton updated and renewed its Stormwater Management Plan (SWMP) plan in 2019 of action for the short term (1-5 years) to minimize the effects of stormwater runoff from the growing urban area. The geographic area covered by this SWMP includes approximately 22.9 square miles and has two major drainage routes, Saline River and Depot Creek including the tributaries of these streams. This progressive plan should be used as a model for other growing cities within the Upper Saline Watershed.

The City of Benton's measurable goals for minimizing effects to the Saline River Watershed from urban stormwater runoff include the following Minimum Control Measures:

1) **Public Education and Outreach on Storm Water Impacts**

a. The City has approximately 12,000 water customers. The City will produce and distribute a utility insert on stormwater and what the public can do to prevent stormwater impacts. This City will begin installing the inserts during Year 1 and repeat once every six months thereafter. Benton's goal is to make 20,000 impressions per year via a utility insert program.

b. A minimum of 50 percent of all school children (K-12) will be educated every two years on stormwater pollution by providing the School Districts in the jurisdiction of the City with materials such as videos, brochures, live presentations, and other media.

c. Provide local video and written materials for use in a wide array of home and business education for family members and employees.

2) **Public Involvement/Participation**

a. The City will coordinate with all citizen groups that initiate a new program's "Adopt A Street" Group for recurring cleanup and clearing of drainage systems working with citizen group "Benton Matters". The "KEEP IT CLEAR TO THE RIVER" initiative is an integral component of the "ADOPT A STREET" and "BENTON MATTERS" and various Church and Community Programs.

b. The City of Benton will seek to involve volunteers and establish a record to notify the City staff when stormwater drainage problems exist or anyone may be causing a potential issue, ensure a response, and monitor results of citizen complaints through the Citizenserve automated system and working with Utility departments and Aldermen.

c. Establish relationship with each existing POA within City Limits and extended contacts to Planning to improve direct linkages with communities and groups that already exist and have a vested interest in improving and maintaining their neighborhoods and their surrounding areas/environment.

d. The City of Benton conducts an Initial review with developers, engineers and builders referencing requirements within Storm Water Discharge Ordinance 48 of 2019, and created a checklist to validate discussions and that a plan is developed prior to approvals being made. These actions as intended to increase awareness of BMPs regarding erosion and sediment control & storm water discharge education for developers and Contractors on all projects. This is targeted to all land development operations, homeowners, businesses/operations to ensure on-site practices are improved, requirements are understood and clarify enforcement actions during inspections.

3) **Illicit Discharge Detection and Elimination**

a. The City of Benton completed a GIS mapping study of its storm sewer system map in fall of 2018. These data were incorporated into its tools for monitoring storm water and to identify and remove illicit discharges.

b. An Illicit Discharge Detection and Elimination was developed and implemented following ADEQs requirements for measuring flows and loading at outfalls to detect and address non-storm water discharges, including illegal dumping, to the storm water system

c. Surveys during dry weather of 20% of outfalls checked for flow annually. Additionally, two specified sites will be check quarterly for flow and TDS. Non-stormwater discharges are monitored to confirm industries are in compliance of state and federal regulations.

4) **Construction Site Runoff Control**

a. City regulatory and enforcement mechanisms are in place to ensure that BMP measures are implemented. Erosion Control Planning, silt fence placement/building, and SWPPP reports and maintenance/monitoring are stressed at Pre-submission meetings and documents are shared with code enforcement & other departments.

b. The City of Benton has set goals to achieve a 100% response rate to all filed complaints, review of all site & development plans, inspection of all construction sites, and enforcement actions are carried out on all violations. The City's Street & Drainage Department is the responsible party with support from Community Development for CWRC-5 handling new permitted development and conducting construction site inspections.

5) **Post-Construction Storm Water Management Development/Redevelopment**

a. Benton has substantial existing development and many new developments are still growing The City revised its Storm Water Discharge Ordinance 48 of 2019 to include references to post-construction management requirements. Ordinances and regulatory mechanisms ensure that BMP measures are implemented, including use silt fences & erosion control until ground cover is established. Additional stormwater staff with code enforcement credentials are being added and stormwater fee per resident is being increased.

b. The City of Benton requires that all yards in new residential developments must be in place prior to issuance of Certificate of Occupancy to alleviate the need for post-construction requirements on areas under construction. The City has set additional post-construction goals, including: reviewing all construction site plans to verify that proper site planning was implemented to minimize the impact on the City's storm sewer system; inspecting all sites to verify procedures for post-construction were completed; all violation letters and enforcement actions are responded to; and all long-term site plans developed and agreed on.

6) **Pollution Prevention/Good Housekeeping for Municipal Operations**

a. As part of its Employee Training Program, the City of Benton developed an annual pollution prevention workshop for all municipal employees whose duties have a direct impact on the city's MS4 at public facilities. Once per year, the City will hold an additional workshop for new employees, crew managers, and all other employees whose day-to-day work activities have the potential to impact stormwater quality. The workshop will emphasize the benefits of recycling organic material; reducing the use and planning the timing of application of chemicals and water; selecting native vegetation to reduce water, nutrient, and maintenance demand; and achieving cost savings through reduced labor and material inputs.

b. Goal to achieve a 40% reduction in fertilizer and pesticide use and a 25% reduction in water use after 3 years. Presently the City has a design for a wash bay for all city vehicles.

4.4.2 Section 2: Restoration & BMP Implementation Needs*:*

Streambank Restoration/ Riparian Re-forestation

Riparian forest cover significantly improves stream water quality and ecosystem health. A developed funding priority system on the County Conservation District level should give particular preference to sites that would restore rapidly eroding streambanks and re-connect forested riparian areas. This Best Management Practice (BMP) is considered a very high priority for the Upper Saline Watershed. Priority should also be given to the development of conservation plans for farms that previously have had no plans or are in need of updating. Annual status reviews to ensure BMP's have been installed and are functioning as designed should be emphasized within County Conservation Districts. Following development of this funding priority system, the County Conservation Districts should submit to the Natural Resources Division for approval. Numerous benefits to the landowner have been identified for restoring riparian vegetation including the establishment of wildlife corridors increasing habitat for recreational
hunting and the reduction of sedimentation to the stream establishing good habitat for recreational fishing. These benefits and the cost-share assistance programs available should be clearly communicated and emphasized to landowners within the watershed through continued outreach by the Conservation District and local watershed groups. It is a short term goal of this plan that at least two riparian restoration projects be implemented in priority areas of the Upper Saline watershed (1-5 years). Riparian restoration projects will require assistance of government agencies and non-profit organizations in the form of cost-share funding, time, and expertise to

be feasible for landowners and to reduce implementation costs. Volunteer efforts and publicity outreach should be incorporated into these projects.

Demonstration and implementation of Best Management Practices (BMP's) for land conversion activities (i.e. erosion control measures).

Forestry: The Arkansas Forestry Commission (AFC) is responsible for a variety of programs related to silvicultural nonpoint source pollution management including; the development of recommended Best Management Practices (BMPs), the collection of BMP monitoring data, investigation of pollution complaints from silvicultural activities, and technical assistance for landowners in applying for cost-share assistance programs. The AFC also collaborates with forest industry associations, the Cooperative Extension Service, and the Arkansas Forestry Association (AFA) to provide training and technical assistance to help loggers, landowners and forest managers implement recommended silvicultural BMPs to control nonpoint sources of pollution. Found in the table below are numbers recorded for selected parameters in BMP monitoring conducted by the Arkansas Forestry Commission (AFC) in counties that fall within the Upper Saline watershed boundaries.

Training sessions and workshops will be critical to the continued adherence to, and expansion of, responsible erosion control practices in the Upper Saline Watershed. At least two trainings per year held throughout the Upper Saline watershed should be targeted for the short term covering topics including ways to minimize soil disturbance, prevent erosion, how to best care for streamside management areas, and available cost share assistance programs for riparian forest enhancement projects. In addition, at least one stakeholder tour of BMP demonstration sites held each year. Due to the credible establishment and documented success of silvicultural BMP trainings, when possible, these should be coordinated with other sediment reduction workshops in the watershed including trainings for road and stream crossing maintenance, and construction best management practices. Citizens, landowners, and watershed group members should be encouraged to attend as well.

Road Maintenance: A good example for a workshop applicable to the local area and local watershed issues would be "Unpaved Road Maintenance Best Management Practices implemented on USFS lands in the Winona Wildlife Management Area". Potential partners could include The Nature Conservancy, the Ouachita National Forest Service, and the Natural Resources Division. Integration of agency personnel, such as ADEQ Water Quality Division or the Arkansas Game & Fish Commission, into trainings would be beneficial for insight into particular aquatic protection programs and recent research/study results conducted in the watershed. Attendance numbers for these trainings should be entered into an accessible database for the Natural Resources Division to track outreach efforts regarding nonpoint source pollution reduction.

Private Land Management: Lands owned by nonindustrial, private owners make up a significant portion of the forests in the Upper Saline watershed and are vital to the long-term sustainability of forest coverage in the watershed. Many studies show that as tract size declines, owners become less likely to actively manage their forests. With the increasing pressure on non-industrial private landowners to produce a multitude of goods and services from their forest lands, and/or to sell or convert forest land to development in the area, it is more important than ever to provide incentives and assistance to reinvest in, reforest, and manage these lands. Benefits received from implementation of particular conservation practices on forest or pasture managed lands include reduced wind and soil erosion, establishment of alternative watering sources for livestock, enhanced water quality and wildlife habitat, as well as assurance of a reliable future supply of timber. These benefits should be emphasized to landowners in the Upper Saline watershed through continued public education and outreach.

The Nature Conservancy (TNC) has had success in generating landowner interest in the TNC Conservation Forestry program which focuses on ecologically sustainable and economically viable forest enhancement projects. Through conservation easements, landowners can still gain economic benefit from ecological thinnings that improve the health of an overly dense forest. Re-introducing prescribed burns to fire-suppressed areas can also enhance plant and animal habitat immensely. It is a goal of this plan to enroll two to five new landowners across the Upper Saline watershed in forest and riparian enhancement projects each year for the next five years through various cost-share programs such as the NRCS Healthy Forests Reserve Program (HFRP), Wildlife Habitat Incentive Program (WHIP), Conservation Reserve Program (CRP), and/or Environmental Quality Incentive Program (EQIP). WHIP, CRP, and EQIP are applied for and administered through the County Conservation Districts. Although each program differs slightly, the goal to enhance and sustain long-term productivity of timber and non-timber resources through a variety of forest and riparian management practices is a component of each one of these program objectives. The following conservation practices qualify for each of the three programs: planting site preparation, hardwood or pine tree planting, prescribed burning, forest stand improvement to remove undesirable species, planting wildlife food plots, and erosion control measures such as water bars, wing ditches, stream crossings, etc.
Urban Development: Riparian areas under residential development should also be prioritized for erosion protection measures as development continues to move towards riparian corridors, particularly in the increasing urban areas of Benton, Bryant and Hot Springs Village. BMP implementation in these areas could include the installation of rain gardens or catchment and filter systems on residential properties, particularly in riparian areas with slopes greater than 30%. Growing municipalities should investigate opportunities to implement sensible zoning requirements for residential and industrial areas located in streamside management zones through local ordinances or city codes. Federal and state funding should support the development of nature trails, public access points, and organized tree plantings near riparian areas of the river to increase local interest, involvement in, and appreciation for the protection of the local natural resources.

It is recommended at least two urban restoration projects be implemented in the Upper Saline watershed in the next one to five years. The Urban and Community Forestry Program provides technical assistance and grants for urban forestry through a cooperative agreement with the USDA Forest Service. Communities, non-federal government agencies, educational institutions, and 501(c)3 non-profit organizations may apply for these competitive grants.

This funding source could be particularly useful in the growing urban areas of the Upper Saline Watershed. In the past, funding of this type has been utilized by municipalities in many areas for hiring an urban watershed coordinator to work with local governments, watershed groups, and citizens to implement urban forestation and restoration projects.

Repair/update high impact crossings in the watershed. Implement BMP's on all sites identified in the roads analysis of the top three priority sub-watersheds of the Upper Saline.

Many culverts, dikes, water diversions, dams, and other artificial barriers have been constructed in the Upper Saline watershed to impound and/or redirect water, all changing natural features of rivers and streams. Culverts that funnel water beneath roads are in many cases no longer serving their original purpose due to poor design. Many culverts and bridges serve as barriers preventing natural fish migrations thus keeping them from important habitats for spawning and growth. There are innovative ways to design such bridges and culverts to allow for flood control, fish passage, and functional motor passageways while maintaining the natural dimension, pattern, and profile of the stream. In the short term, following a detailed road survey of the top three priority watersheds within the Upper Saline, funding should be directed towards implementation and restoration of identified inefficient bridge and culvert crossings, and degraded road segments and ditches.

Development of a Conservation Easement Program for the Upper Saline Watershed

Conservation easements and fee-title programs are two approaches to land protection in watersheds. Conservation easements are legal agreements that restrict development on private land, providing ecological benefits and tax incentives for landowners. In contrast, fee-title programs involve outright land ownership, allowing for direct management and public access. Both approaches contribute to open space connectivity and water quality protection in watersheds (Benez-Secanho & Dwivedi, 2020). The choice between conservation easements and fee-title programs depends on specific conservation goals, land characteristics, and available resources. To establish conservation easements programs, land trusts or other local non-profits can use landscape-level conservation features and policy criteria to prioritize parcels for easement recruitment. Concurrent implementation of best management practices with conservation easements can help to increase the protection of water quality in rapidly urbanizing watersheds (Gitau et al., 2010).

It is recommended that a conservation easement program be established by a local 501 c(3) organization in the next 1-5 years for lands within the Upper Saline Watershed. Conservation easements can help to protect existing riparian hardwood forests, thereby giving landowners the opportunity to preserve their forested lands and still retain financial benefit. This approach could also protect lands within the watershed from encroaching development that would result in further non-point source pollution. Such a program would first identify priority areas within the Upper Saline Watershed, particularly riparian areas, that will best assist in water quality and instream habitat protection downstream of the site. Following identification of priority areas, groups should concentrate on development of an outreach program to inform the public regarding incentives from conservation easement sale or donation. Effective communication about conservation easements is crucial and can ideally be led through in-person outreach from conservation experts who are also community members. Local easement organizations should focus on increasing awareness-level educational efforts to promote conservation easement adoption among landowners. There is potential to develop this type of program in coordination with local watershed groups in the Upper Saline Watershed, like the Saline River Watershed Alliance. Technical assistance could be provided for the establishment of a conservation easement program by the Natural Resources Division or other watershed groups like the Bayou Bartholomew Alliance, Beaver Watershed Alliance, and Illinois River Watershed Partnership, which have extensive experience in the development of such programs.

<u>Establish new/expand existing Private Burn Association (PBA) to include counties in the Upper Saline Watershed</u>

Responsible implementation of prescribed fire can help maintain and restore forests to their historical conditions, helping to protect wildlife, reduce the risks of wildfire, pests and disease to improve ecosystem resilience. Since the early 1990's, one million acres of wooded habitat has been restored across Arkansas and another 400,000 are improving with the implementation of prescribed fire and forest management practices to restore high quality forests (TNC 2024, *personal communication*). Prescribed burns promote establishment of deep root systems, which can help can improve water quality by improving riparian vegetation condition and stabilizing soils to reduce soil erosion and reducing stormwater runoff into streams and ponds.

In the 1960s-late 1990s, landowners in the Upper Saline River watershed conducted communal burns to improve wildlife habitat and control the encroachment of shrubs into pastures and hay fields. However, the frequency of landowners implementing communal burns in the watershed have declined over the past two decades as use of herbicide applications increased (Cross, *personal communication*, 2025 USRW Streamside Management Workshop). Prescribed Burn Associations (PBAs) are typically groups led by landowners who form partnerships to pool their knowledge, equipment, and other resources to conduct prescribed fires. Once a PBA is established, it is possible to receive training and apply for a burn trailer and other equipment provided in partnership by the Arkansas Game

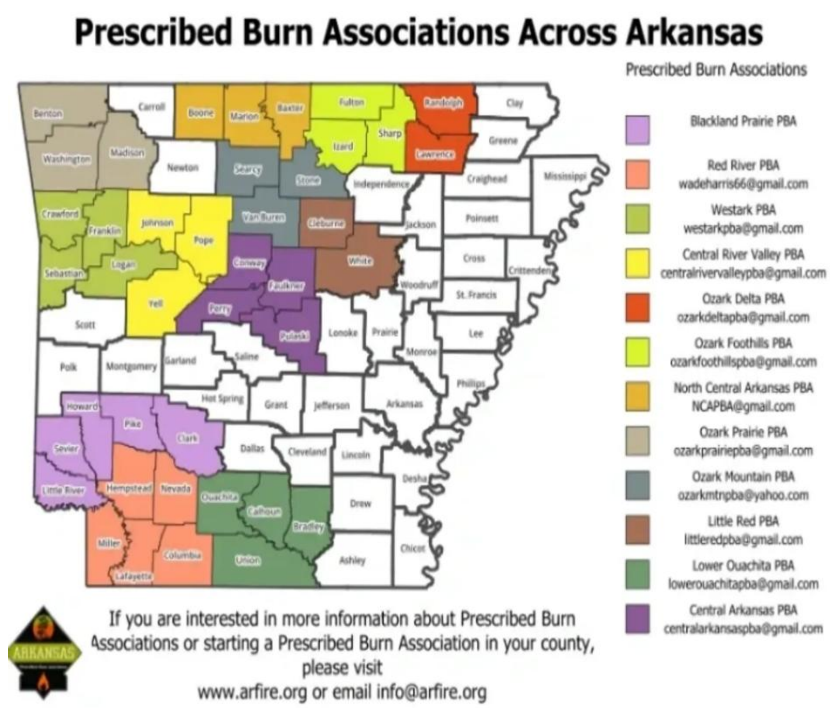

Figure 4.4.1. Map of PBAs across Arkansas as of April 2025 (Source: https://arfire.org/local-pba-chapters).

and Fish Commission, Quail Forever, and United States Fish and Wildlife Service. The Arkansas Prescribed Burning Act (Act 695) provides landowners liability protection when qualified burns are conducted.

Increasing interest in the ecological and wildlife habitat benefits of prescribed fire has resulted in the recent establishment of several new PBAs across Arkansas, including the Blackland Prairie, Red River, and Westark PBAs (Figure 4.4.1). Explore landowner interest for starting a new Private Burn Association (PBA) or joining an existing PBA. The Central Arkansas PBA currently includes the neighboring counties of Perry and Pulaski, along with Conway and Faulkner Counties.

There are many potential partners who can provide technical assistance to landowners who are interested in developing and implementing prescribed fire plans. Partners who can assist in establishing a PBA, include the Arkansas Game & Fish Commission, U.S. Forest Service, U.S. Fish and Wildlife Service, The Nature Conservancy, Quail Forever, University of Arkansas Cooperative Extension Service, Arkansas Prescribed Burn Association, and others who utilize "good fire" to restore wooded habitats and enhance the diversity and quality of Arkansas' forest habitats.

The AGFC currently hosts a PBA Interest Form: https://docs.google.com/forms/d/e/1FAIpQLSdKIL_4WxM-rUHVcZcd9Wd3B8B-jWQn2PJQ79GeUvEqI9Aoag/viewform)

4.5 Element 4 –Financial and Technical Assistance

The following is an attempt to estimate costs for implementation of the guidelines set forth in this plan. Several parameters have been considered for these estimations including; necessary technical assistance, type of BMP's with associated costs for installation and maintenance, and costs associated with implementation. A comprehensive list of estimated costs for nature-based solutions and green infrastructure to reduce the impacts of flooding and streambank erosion and to provide benefits like improved water quality, recreation, and fish and wildlife habitat are included in Table 4.5.5 below. The identified best management practices and associated costs listed are intended for implementation in the short term, over the next five years. It is assumed that once these tasks are complete for the priority sub-watersheds of the Saline, prioritization of sub-basins will be re-assessed and implementation efforts will begin for other sub-basins of high priority. This plan is intended to be a living document and will need adjustment as new tools and data become available. Estimates of costs for implementing activities identified in this watershed management plan are provided below. Actual costs may differ from these estimates.

4.5.1 Unpaved Roads Best Management Practices

In 2015, Act 898 of the 90th General Assembly officially established the Arkansas Unpaved Roads Grant Program (AURP) funding at $300,000 per year. Since its establishment, increasing applicant interest for submitting proposals under the AURP has significantly exceeded the available program funds. There is a demonstrated need based on the number of applicants seeking funding for unpaved roads BMP projects to significantly increase the current funding levels of the AURP. Extreme weather events are increasingly putting stress on older infrastructure. A comparable unpaved roads program in Pennsylvania provides for the allocation of $35,000,000 for the Dirt and Gravel Road Maintenance Program (https://www.pa.gov/agencies/pda/about-pda/boards-commissions/state-conservation-commission/dirt-gravel-low-volume-road-maintenance-program.html). Of that total amount, $7,000,000 is allocated directly to the Bureau of Forestry for maintaining the dirt and gravel roads in their jurisdictions. The Pennsylvania State Conservation Commission is responsible for allocating the remaining $28,000,000 to the 64 County Conservation Districts who participate in the Dirt and Gravel Road Maintenance Program, including up to $8,000,000 for the maintenance of low-volume roads. Pennsylvania has more than 25,000 miles of unpaved roads, while in comparison Arkansas has more than 52,000 miles of unpaved roads. The Arkansas Association of County Judges and roads managers are among the most effective advocates for increasing funding to the AURP and, along with the input of other watershed stakeholders, will be integral to any future legislative policy initiatives for increasing program funding.

The cost of implementing unpaved roads BMPs can be highly project dependent but frequently ranges between $65-80/foot for county roads departments (Arkansas Association of Counties, personal communication, 2025). An analysis of 38 projects funded through the Arkansas Unpaved Roads Program between 2019-2023 indicated an average cost of $70/foot based on implementation of 174 BMPs in 22 counties and watersheds throughout Arkansas (Natural Resources Division, 2023). Each unpaved roads program project is estimated on average to reduce sediment loading in streams by 967 tons and save participating counties $18,000 per year on road maintenance costs (Natural Resources Division, 2023). The estimated costs for unpaved roads BMP implementation on public road segments in the Upper Saline River watershed with an average grade greater than 5 degrees (8.75%) that intersect a surface water feature (see Figure 3.6.2) are included in Table 4.5.1.

Table 4.5.1. Estimated cost to implement BMPs on the highest priority unpaved road segments in HUC12 subwatersheds and counties in the Upper Saline based on an expense of $70/ft., the average cost across 38 projects and 174 BMPs implemented since 2019 through the Arkansas Unpaved Roads Program (AURP).

County and HUC12	Number of Priority Road Segments	Estimated Road Distance for BMP Implementation (Feet)	Estimated BMP Implementation Cost
Garland County	**30**	**153,504**	**$10,745,280.00**
Cedar Creek-South Fork Saline River	12	59,721	$4,180,470.00
Headwaters Middle Fork Saline River	5	19,777	$1,384,390.00
Mill Creek-South Fork Saline River	8	47,085	$3,295,950.00
Outlet Middle Fork Saline River	1	2,193	$153,510.00
Tenmile Creek-South Fork Saline River	4	24,729	$1,731,030.00
Hot Spring County	**4**	**10,020**	**$701,400.00**
Tenmile Creek-Francois Creek	3	9,605	$672,350.00
Thunder Branch-Big Creek	1	415	$29,050.00
Saline County	**34**	**129,212**	**$9,044,840.00**
Big Creek-Alum Fork Saline River	1	1,960	$137,200.00
Depot Creek-Saline River	1	4,514	$315,980.00
Headwaters Alum Fork Saline River	1	2,683	$187,810.00
Little Alum Fork-Alum Fork Saline River	3	8,873	$621,110.00
Logan Creek-Hurricane Creek	1	398	$27,860.00
Lower North Fork Saline River	4	20,520	$1,436,400.00
Middle North Fork Saline River	13	70,700	$4,949,000.00
Mill Creek-South Fork Saline River	2	3,402	$238,140.00
Moccasin Creek-Saline River	4	10,798	$755,860.00
Outlet Middle Fork Saline River	4	5,364	$375,480.00
Total	**68**	**292,736**	**$20,491,520.00**

4.5.2 Conservation Easement Program

The costs of establishing land conservation programs can vary widely depending on the program and its location. There is no certainty that any landowner is actually willing to sell or convey a conservation easement. These numbers do not include any closing costs, due diligence, surveys, staff time etc., and at least an estimated 15-20% should be included on top of land values to cover those expenses. The Alum Fork of the Saline River, located in Saline County, was identified as a highest priority for conservation by a majority of watershed stakeholders. It is designated by the

State of Arkansas as both an Extraordinary Resource Waterbody (ERW) and an Ecologically Sensitive Waterbody, reflecting its exceptional water quality, scenic value, and ecological importance. Flowing through largely forested landscapes of the Ouachita Mountains ecoregion, the Alum Fork supports a diverse array of aquatic life, including numerous state-listed species of greatest conservation need (SGCN) and the Arkansas fatmucket (*Lampsilis powellii),* a federally threatened freshwater mussel that is endemic to only a few streams in the Ouachita Mountains. The estimated acreage and associated costs for establishing a conservation easement program on private lands in the HUC12 subwatersheds of Alum Fork-Saline River are included in Table 4.5.2. These estimates are intended to provide a starting point for developing conservation easement programs in other priority subwatersheds, including the North Fork, Middle Fork and South Fork-Saline River.

Table 4.5.2. Estimated acreage and costs associated with establishing a conservation easement program for the Alum Fork – Saline River.

Landowner	Estimated Acres	Estimated Value CE/acres	Estimated Value Fee	Totals
City/County	225	$2,000		$450,000
Green Bay	205	$1,500		$307,500
Smaller private landowners willing to sell CE	300	$1,500		$450,000
Smaller private landowners willing to sell fee	500		$4,000	$2,000,000
Total				**$3,207,500**

4.5.3 Riparian Restoration/Reforestation

To aid development of a subwatershed-based implementation strategy that identifies and prioritizes areas for riparian restoration and protection projects within the watershed, TNC mapped stream reaches in HUC12 subwatersheds with less than 45% riparian forest cover within 100m of the stream channel. Riparian forest cover includes the combined land area classified as deciduous, mixed, coniferous forest, and woody wetlands cover in the 2019 National Land Cover Database (NLCD) (Figure 4.5.3). Estimated financial costs of implementing reforestation and riparian restoration in these areas are listed by HUC12 subwatersheds in Table 4.5.3 below.

Table 4.5.3. Estimated costs associated with reforestation of riparian areas within 100m of stream channel classified as having <45% combined deciduous, mixed, and coniferous forest and woody wetlands cover in the 2019 National Land Cover Database (NLCD 2019). The Restoration Target (Acres) and estimated costs are for 25% of the total prioritized riparian forest acreage (Riparian Forest <45%) based on a maximum cost of $800/acre (NRCS 2025).

Subwatershed	HUC12 (last 4 digits)	Riparian Forest <45% (Acres)	Restoration Target (Acres)	Estimated Cost Restore Riparian Buffer (Forest)
Middle North Fork Saline River	0304	86.9	21.7	$17,376
Lower North Fork Saline River	1509	173.1	43.3	$34,629
Cedar Creek-South Fork Saline River	8032	533.5	133.4	$106,695
Mill Creek-South Fork Saline River	0776	326.5	81.6	$65,305
Headwaters Middle Fork Saline River	4865	4.9	1.2	$974
Headwaters Alum Fork Saline River	9698	0.6	0.2	$128
Little Alum Fork-Alum Fork Saline River	4979	44.2	11.0	$8,836
Outlet Middle Fork Saline River	0073	432.4	108.1	$86,487
Big Creek-Alum Fork Saline River	0562	127.6	31.9	$25,511
Little Hurricane Creek-Hurricane Creek	0168	1652.1	413.0	$330,419
Logan Creek-Hurricane Creek	3719	53.4	13.3	$10,680
Simpson Creek	6202	69.9	17.5	$13,971
Mud Creek-Hurricane Creek	3918	78.6	19.6	$15,716
Ray Creek-Hurricane Creek	7937	204.6	51.1	$40,911
White Oak Creek-Hurricane Creek	9817	9.5	2.4	$1,898
Johnson Creek-Derrieusseaux Creek	4939	2.7	0.7	$539
Panther Creek-Derrieusseaux Creek	1762	10.9	2.7	$2,184
Brushy Creek	0184	65.8	16.4	$13,156
Tenmile Creek-Francois Creek	4999	216.0	54.0	$43,194
Thunder Branch-Big Creek	9742	161.9	40.5	$32,386
Big Creek-Francois Creek	0274	5.5	1.4	$1,102
Moccasin Creek-Saline River	0008	83.8	20.9	$16,759
Depot Creek-Saline River	0036	896.2	224.1	$179,240
Trace Creek-Saline River	0034	373.9	93.5	$74,774
Jordan Creek-Saline River	0212	328.1	82.0	$65,626
Graves Creek-Lost Creek	0573	55.5	13.9	$11,105
Little Lost Creek-Lost Creek	2955	95.2	23.8	$19,047
Flat Creek-Lost Creek	9954	37.1	9.3	$7,413
Brush Creek	1899	2.1	0.5	$410
Cox Creek	9539	342.9	85.7	$68,582
Mud Creek-Saline River	3155	821.7	205.4	$164,345
Chapel Creek-Saline River	1258	112.9	28.2	$22,580
Little Creek-Saline River	0714	17.5	4.4	$3,509
Steep Creek-Saline River	9796	0.4	0.1	$89
Pine Bridge Creek-Saline River	8403	7.0	1.7	$1,394
Total		**7434.8**	**1858.7**	**$1,486,969**

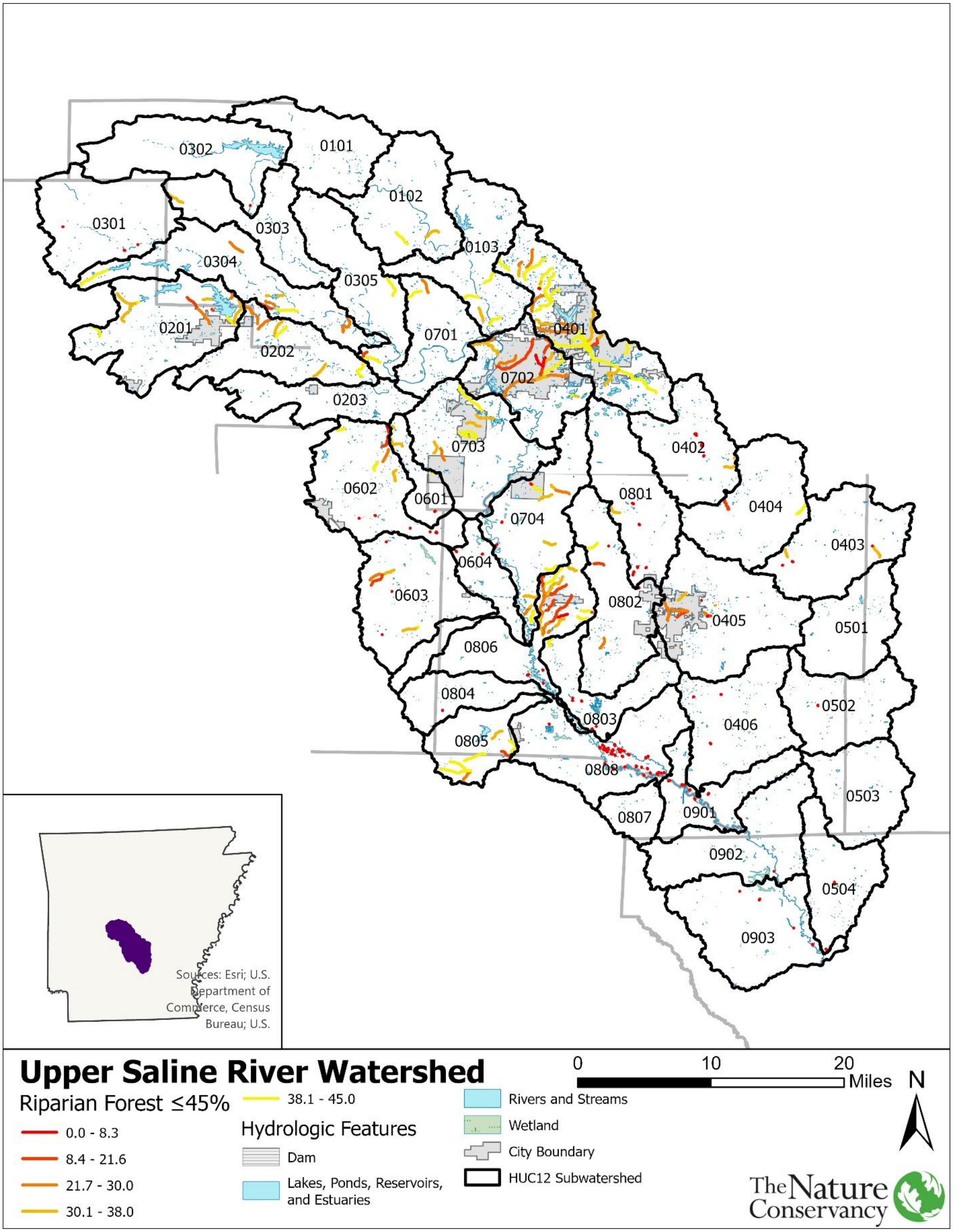

Figure 4.5.3. Riparian areas within 100m of stream channel classified as having <45% combined deciduous, mixed, and coniferous forest and woody wetlands cover in the 2019 National Land Cover Database (NLCD 2019).

4.5.4 NRCS Stream and Wetland Restoration and Nature-Based Solutions

The cost of implementing BMPs to reduce nonpoint source pollution can be variable, depending on materials markets and site conditions. Different practices have different payment rates based on their complexity and cost of implementation. Table 4.5.4 lists available cost information for selected BMPs identified in the management plan. NRCS EQIP reimbursement allocations do not reflect the actual cost of implementing the practice but provide an idea of relative costs. Local communities may also greatly benefit from creating nature-based solutions and green infrastructure to reduce the impacts of flooding and streambank erosion and to provide benefits like improved water quality, recreation, and fish and wildlife habitat. Table 4.5.5 below was adapted from the National Oceanic and Atmospheric Administration (NOAA 2020) and provides cost estimates for common nature based solutions from a variety of sources, which can be found in NOAA's Green Infrastructure Effectiveness Database ((https://coast.noaa.gov/digitalcoast/training/gi-database.html).

Table 4.5.4. NRCS EQIP reimbursements and reported implementation costs for selected riverine, riparian, and wetland BMPs applicable in the Upper Saline River watershed.

Practice Name	Practice Code	Unit	2025 EQIP 75% reimbursement per unit	Purpose	Implementation
Riparian Herbaceous Cover	390	Acres	$270.68 - $324.82	Filter pollutants from runoff, reduce erosion, provide wildlife habitat.	Planting native grasses and forbs, managing existing vegetation, ensuring adequate cover.
Riparian Forest Buffer	391	Each/Acres	$0.40 - $1.63 cuttings/bare root seedlings; $511.60 - 786.84 per acre	Create shade, improve riparian habitat, reduce sediment and nutrient runoff, enhance carbon sequestration.	Planting native trees and shrubs, managing existing vegetation, ensuring adequate buffer width.
Filter Strip	393	Acres	$176.55 - $678.72	Reduce sediment and contaminants in runoff, protect water quality.	Establishing a strip of herbaceous vegetation to filter overland flow from fields or disturbed areas.
Stream Habitat Improvement and Management	395	Acres	$9,144.26 - $32,901.48	Enhance or restore physical, chemical, and biological functions of a stream for aquatic species.	Modifying stream channel dimensions, installing in-stream structures, managing riparian vegetation, and controlling erosion to improve habitat.
Aquatic Organism Passage	396	SqFt/CuYd/Each	$181.90 bridge SqFt; $656.62 low water crossing CuYd; $28,695 - $49,319 culvert Each; $82,408 Fishway	Improve or restore the ability of aquatic organisms to move freely within streams and rivers.	Removing or modifying barriers such as culverts, dams, and weirs to allow for fish and other aquatic species passage.
Stream Crossing	578	SqFt/DialnFt/Each	$72.36 bridge SqFt; $3.76 culvert DialnFt; $6.06 - $17.46 low water crossing SqFt	Provide safe and controlled access across a stream for people, livestock, or equipment while minimizing environmental impacts.	Constructing bridges, culverts, or fords that minimize disturbance to the streambed and banks and allow for fish passage.
Streambank and Shoreline Protection	580	Ft/CuYd/Each	$13.21 - $282.10	Reduce sediment input into waterways, protect property, enhance aquatic habitat.	Utilizing bioengineering techniques, structural measures, or both to stabilize banks.
Structure for Water Control	587	Each/DialnFt/Ton Ft/CuYd/In	Refer to NRCS payment schedule	Control the direction, velocity, and/or elevation of water for various purposes, including irrigation, drainage, or erosion control.	Installing weirs, dams, diversions, or other structures to manage water flow and levels.
Wetland Restoration	657	Each/Acres	Refer to NRCS payment schedule	Restore wetland hydrology, vegetation, and wildlife habitat to a close approximation of pre-disturbance conditions.	Re-establishing abiotic conditions such as hydrology and topography on drained or degraded wetlands.
Wetland Creation	658	Acres	$29,91.72 wildlife pond	Enhance biodiversity, filter pollutants, store water, provide habitat for wetland-dependent species.	Establishing appropriate hydrology, planting native wetland vegetation, managing the site to ensure wetland function.
Wetland Enhancement	659	Acres	$431.39 riverine channel and floodplain restoration	Enhance biodiversity, filter pollutants, store water, provide habitat for wetland-dependent species.	Establishing appropriate hydrology, planting native wetland vegetation, managing the site to ensure wetland function.

Table 4.5.5. Cost estimates for common nature-based solutions adapted from the National Oceanic and Atmospheric Administration (NOAA 2020). More information on these and other nature-based conservation practices can be found in NOAA's Green Infrastructure Effectiveness Database (https://coast.noaa.gov/digitalcoast/training/gi-database.html).

Nature-Based Solution	Average Cost	Maintenance Cost	Cost Considerations
Land Preservation or Restoration	Varies based on land value and method of preservation	Varies based on land value and method of preservation	Ecological baseline assessment, land acquisition, removal of existing structures, design, engineering, permitting, and maintenance including controlling pollution, invasives, erosion, and visitation.
Forestry: Forest Preservation	Varies based on land value and method of preservation	Varies based on land value and method of preservation	Plant materials, installation (watering, backhoe, shovels, mulch, seedlings), maintenance materials (bucket truck, chipper, chainsaws), and maintenance including, pruning (especially near power lines), watering, pest control, removal and disposal of hazardous trees, and fringe landscaping.
Tree Box Filters	\$70-\$600 per sq. foot	\$3-\$14 per sq. foot	Plant materials, installation (watering, backhoe, shovels, mulch, seedlings), maintenance materials (bucket truck, chipper, chainsaws), and maintenance including, pruning (especially near power lines), watering, pest control, removal and disposal of hazardous trees, and fringe landscaping.
Tree Planting	\$13-\$288 per tree	\$15-\$81 per tree	Plant materials, installation (watering, backhoe, shovels, mulch, seedlings), maintenance materials (bucket truck, chipper, chainsaws), and maintenance including, pruning (especially near power lines), watering, pest control, removal and disposal of hazardous trees, and fringe landscaping.
Green Streets	Varies based on the combination of practices used	Varies based on the combination of practices used	Considerations are based on a combination of practices used but may include removing sediment, leaves, or trash that can impede water flow, replacing plants, and watering. Costs are reduced if projects are part of an existing street improvement program.
Bioretention: Rain Garden	\$5-\$16 per sq. foot	\$.31-\$.61 per sq. foot	Design, engineering, permitting, materials (e.g., rocks, plants mulch), installation, and maintenance including watering, pruning, weeding, controlling invasive species, raking mulch, removing litter, and clearing flow pathways at least twice per year and after major storm events.
Bioswales	\$5.50-\$24 per sq. foot	\$.06-\$.21 per sq. foot	Design, engineering, permitting, materials (e.g., rocks, plants mulch), installation, and maintenance including watering, pruning, weeding, controlling invasive species, raking mulch, removing litter, and clearing flow pathways at least twice per year and after major storm events.
Vegetated Filter Strips	\$.03-\$3 per sq. foot	\$.07 per sq. foot	Design, engineering, permitting, materials (e.g., rocks, plants mulch), installation, and maintenance including watering, pruning, weeding, controlling invasive species, raking mulch, removing litter, and clearing flow pathways at least twice per year and after major storm events.

Table 4.5.*5 (*continued).

Nature-Based Solution	Average Cost	Maintenance Cost	Cost Considerations
Green Roofs	$9-$31 per sq. foot	$.02-$.41 per sq. foot	Design, engineering, permitting, structural reinforcement, waterproofing (40 year life expectancy), installation, plants, soil, and maintenance including watering, controlling invasive species, and yearly inspections removing problematic shrubs and reducing the potential for leaks to develop.
Permeable Pavement: Pavers	$5-$12 per sq. foot	$.01-$.23 per sq. foot	Design, engineering, permitting, materials, installation, and maintenance including sweeping or vacuuming, reducing sand and salt usage in cold climates, and maintaining soil under pavers to allow for infiltration.
Porous Asphalt	$5.50-$8 per sq. foot	$.09-$.23 per sq. foot	Design, engineering, permitting, materials, installation, and maintenance including sweeping or vacuuming, reducing sand and salt usage in cold climates, and maintaining soil under pavers to allow for infiltration.
Porous Concrete	$5.50-$12 per sq. foot	$.09-$.23 per sq. foot	Design, engineering, permitting, materials, installation, and maintenance including sweeping or vacuuming, reducing sand and salt usage in cold climates, and maintaining soil under pavers to allow for infiltration.
Gravel	$1.70-$6 per sq. foot	$.02-$.05 per sq. foot	Design, engineering, permitting, materials, installation, and maintenance including sweeping or vacuuming, reducing sand and salt usage in cold climates, and maintaining soil under pavers to allow for infiltration.

4.6 Technical Assistance

This section describes state and federal agencies and organizations that can provide technical assistance for implementation of the activities recommended in this plan. This is not intended to be a complete listing of all available programs that can provide technical assistance.

4.6.1 Implementing Best Management Practices

There are many agencies and organizations that provide technical assistance for installing, operating, and maintaining BMPs identified in the watershed management plan. Examples of these agencies and organizations along with associated BMPs are summarized in Table 4.6.1 and are discussed in further detail below.

Table 4.6.1. Examples of technical assistance available for BMPs recommended for the Upper Saline River watershed.

Practice	NPS 319(h) Grant Program	Partners for Fish and Wildlife	Acres for Widlife	Arkansas State Revolving Loan Fund	Agriculture Water Quality Loan Program	Arkansas Wetland and Riparian Tax Credit Program	Stream Habitat Program	Conservation Reserve Program	Riparian Restoration Program	EPA Green Infrastructure Program	Conservation Stewardship Program (CSP)	Env. Quality Incentive Program (EQIP)	Regional Conservation Partnership Program (RCPP)	National Fish and Wildlife Foundation (NFWF)	National Fish Passage Program (NFPP)
Low impact design and green infrastructure	X			X						X				X	
Rain gardens	X			X						X				X	
Retrofit detention basins	X			X					X	X	X				
Permeable pavement	X			X						X					
Bioswale	X			X						X					
Green roof	X									X					
Green streets	X									X					
Urban tree canopy										X				X	
Roof runoff structure	X									X					
Filter strip	X							X		X	X	X	X		
Grassed waterway	X											X	X		
Septic system upgrades				X											
Solid waste disposal facility	X			X											
Wetland restoration and protection	X	X		X		X				X		X	X	X	
Flood control infrastructure	X			X						X		X	X		
Land conservation		X	X					X				X	X		
Riparian buffer restoration	X	X	X	X		X	X	X	X	X	X	X	X	X	
Road-stream crossing remediation	X											X	X	X	X
Culvert replacement	X											X	X		X
Full or partial dam removal	X													X	X
Installation of fishways or ladders	X														X
Stream habitat restoration and management	X	X	X			X	X						X		X
Floodplain restoration and reconnection	X	X	X			X				X		X	X	X	X
Streambank protection	X	X	X			X	X			X	X	X	X	X	
Natural channel design	X	X								X		X	X		
Constructed wetland	X	X	X							X		X	X	X	
Prescribed fire		X						X			X	X	X	X	
Livestock access control	X	X			X				X		X	X	X		
Livestock stream crossing	X	X	X						X			X	X		
Amendments for treatment of agriculture waste	X											X	X		
Composting facility	X											X	X		
Critical area planting	X		X									X	X		
Heavy use area protection	X											X	X		
Pasture & hay planting	X	X	X									X	X		
Prescribed grazing and grazing management	X				X				X		X	X	X		
Waste storage facility	X				X							X	X		
Watering facility	X	X			X				X		X	X	X		

Arkansas Game and Fish Commission (AGFC)

The AGFC is a state wildlife agency focused on conserving aquatic and terrestrial habitats. AGFC Private Lands Biologists can provide free, site-specific technical assistance and habitat consultations and wildlife management plans, and BMP recommendations to landowners and tenants. AGFC administers several cost-share and incentive programs to support private lands habitat restoration, waterfowl habitat creation, upland game habitat, invasive species control, and water quality improvements. AGFC plays a central role in stream habitat conservation and restoration across the state and in the Upper Saline River Watershed through their Stream Habitat Conservation and Stream Team Programs, which offers professional development and training for educators. AGFC also hosts workshops, field days, and youth programs to promote stream ecology and conservation, and engages communities in watershed stewardship through volunteer opportunities and citizen science.

Arkansas Water Resources Center (AWRC)

The Arkansas Water Resources Center (AWRC) is the state's designated Water Resources Research Institute. AWRC is certified by the Arkansas Department of Environmental Quality and operates as a unit of the University of Arkansas Division of Agriculture. AWRC leverages the expertise and facilities of campuses throughout the University of Arkansas System and collaborates with other state colleges and universities to conduct applied and basic research on water quality, watershed management, and aquatic ecosystems. AWRC's Water Quality Laboratory provides analytical services for researchers, students, and the public, supporting projects funded through programs like the EPA's 319 Nonpoint Source Pollution initiative. AWRC also administers competitive seed grants through the U.S. Geological Survey's Section 104(b) program, fostering early-career research and student training in areas such as water scarcity, ecosystem function, and water technology. The AWRC plays a crucial scientific and technical role in stream habitat conservation within the Upper Saline River watershed and was actively involved in updating the 9-Element Watershed Management Plan through rigorous water quality monitoring and data analysis to identify and prioritize critical sub-watersheds for conservation activities.

County Conservation Districts

County Conservation Districts in Arkansas, including those within the Upper Saline River Watershed (such as the Saline Conservation District), are local, non-regulatory government entities dedicated to the conservation of soil, water, and related natural resources. In the Upper Saline River Watershed, Conservation Districts play a key role in stream habitat conservation by working directly with private landowners, farmers, and forest managers to implement BMPs that reduce erosion, improve water quality, and restore riparian buffers. These practices often include streambank stabilization, native vegetation planting, livestock exclusion fencing, and sediment control on unpaved roads. Conservation Districts can assist with cost-share programs and help landowners access funding through partnerships with the USDA NRCS and the Natural Resources Division. Conservation Districts are also active in education and outreach, hosting workshops, field days, and youth programs to raise awareness about watershed health and conservation practices. In the Upper Saline, they collaborate with organizations like The Nature Conservancy, AGFC, and the Saline River Watershed Alliance to support watershed-scale planning and restoration efforts. Their local knowledge and trusted relationships with landowners make them essential partners in implementing conservation strategies that protect the ecological integrity of the Saline River and its tributaries.

Saline River Watershed Alliance (SRWA)

The Saline River Watershed Alliance (SRWA) is a Saline County-based 501(c)(3) nonprofit organization dedicated to the conservation, protection, enhancement, and maintenance of the Saline River Watershed as a biologically rich aquatic and wildlife habitat and a source of recreational and scenic value. SRWA plays a pivotal role in stream habitat conservation by engaging local landowners, businesses, and agency partners in collaborative restoration efforts. Through partnerships, technical support, and community engagement, the Saline River

Watershed Alliance exemplifies grassroots conservation in action, working to ensure that the Upper Saline River remains one of Arkansas's healthiest and most biologically significant watersheds.

The Nature Conservancy

The Nature Conservancy (TNC) plays a leading role in stream habitat conservation in Arkansas through a combination of science-based restoration, land protection, and collaborative watershed planning. TNC's work in the Upper Saline River Watershed includes riparian and stream habitat restoration to address severe bank erosion, sedimentation, and aquatic habitat degradation. In addition to partnering with the AWRC and SRWA to update the Upper Saline River Watershed-Based Management Plan, TNC addresses nonpoint source pollution from unpaved roads, which are a major contributor to sedimentation in the watershed. TNC holds conservation easements and manages protected areas like the Alum Fork Natural Area, which safeguards over a mile of high-quality stream habitat and supports rare plant and mussel species. Through its integrated partner-driven approach—combining land protection, habitat restoration, scientific research, and community partnerships—TNC helps to ensure the long-term health of Arkansas's most biologically significant river systems.

USDA Natural Resources Conservation Service (NRCS)

USDA NRCS is the primary federal agency responsible for delivering technical and financial assistance to private landowners for the conservation of natural resources, including stream habitat conservation. NRCS plays a role in restoring and protecting stream ecosystems through a combination of science-based planning, voluntary partnerships, and cost-share programs. NRCS's Conservation Technical Assistance (CTA) Program, provides free, voluntary support to landowners interested in improving water quality, reducing erosion, and enhancing aquatic habitat. NRCS conservationists work directly with landowners to assess stream conditions, develop conservation plans, and design site-specific BMPs. These practices may include streambank stabilization, riparian buffer establishment, livestock exclusion fencing, alternative watering systems, and in-stream habitat structures. One of the most widely used tools for stream conservation is the Environmental Quality Incentives Program (EQIP), which offers financial incentives to implement conservation practices that address sedimentation, nutrient runoff, and aquatic habitat degradation. In Arkansas, EQIP has been used extensively to support streambank restoration projects, especially in priority watersheds like the Upper Saline River. NRCS also supports stream habitat work through the Conservation Stewardship Program (CSP), the Agricultural Conservation Easement Program (ACEP), and the Regional Conservation Partnership Program (RCPP), which fosters collaboration among local, state, and non-profit partners.

US Environmental Protection Agency (USEPA)

The cost of implementing The U.S. Environmental Protection Agency (EPA) plays a foundational role in stream habitat conservation by providing funding, regulatory guidance, and scientific tools to support watershed-scale restoration and nonpoint source pollution control. In the Upper Saline, the EPA has designated the watershed as a priority area due to its ecological significance. EPA funding has supported the development and update of the Upper Saline River Watershed-Based Management Plan through the Clean Water Act Section 319(h) Nonpoint Source Management Program, administered by the Natural Resources Division. The EPA's support enables water quality monitoring, watershed modeling, and prioritization of sub-watersheds for conservation action. EPA also provides a suite of scientific tools and frameworks through its Healthy Watersheds Program, which helps local partners assess ecological conditions, identify stressors, and plan restoration efforts. These resources are essential for guiding data-driven decisions and ensuring that conservation investments yield measurable improvements in stream health.

US Fish and Wildlife Service (USFWS)

The U.S. Fish and Wildlife Service (USFWS) plays a critical role in stream habitat conservation in the Upper Saline River Watershed, with a particular focus on protecting threatened and endangered aquatic species and restoring the ecological integrity of stream systems. USFWS contributes to conservation in the watershed through both regulatory and voluntary programs. Under the Endangered Species Act, the agency conducts biological assessments, mussel surveys, and habitat evaluations to ensure that stream restoration and development projects do not harm listed species or their habitats. USFWS provides technical expertise and funding through its Section 6 grant program and the Partners for Fish and Wildlife Program. USFWS actively collaborates with partners such as the AGFC, The Nature Conservancy, and local watershed groups to implement stream restoration projects that benefit both wildlife and water quality. Their work includes long-term monitoring, species recovery planning, and public education about the importance of conserving freshwater biodiversity

US Forest Service (USFS)

The U.S. Forest Service (USFS) plays a significant role in stream habitat and floodplain conservation in Arkansas, particularly in forested watersheds like the Upper Saline River, which originates in the Ouachita National Forest. Through its stewardship of forested headwaters, technical expertise, and interagency partnerships, the USFS plays a foundational role in maintaining the ecological integrity of the Upper Saline River Watershed and ensuring the long-term resilience of its stream habitats. The headwaters of the Saline River's four major forks—South, Middle, Alum, and North—flow through largely forested landscapes managed by the

USFS. These forests provide critical ecosystem services, including natural filtration of runoff, erosion control, and habitat connectivity for aquatic and terrestrial species. In the Upper Saline, the USFS collaborates with agencies like AGFC, U.S. FWS, and The Nature Conservancy to protect sensitive aquatic species like the Arkansas fatmucket mussel (*Lampsilis powellii*) and the Ouachita madtom (*Noturus lachneri*), which depend on clean, free-flowing streams with stable substrates.

U of A Division of Agriculture Extension (UADA)

The University of Arkansas Division of Agriculture Cooperative Extension Service plays a vital educational and technical role in stream habitat conservation across Arkansas, including in the Upper Saline River Watershed. As a land-grant institution, the Extension Service bridges science and community action by providing research-based information, training, and outreach to landowners, local governments, and conservation professionals. The Arkansas Watershed Stewardship Program was developed in partnership with the Natural Resources Division and offers in-person and online training covering topics such as nonpoint source pollution, streambank erosion, riparian buffer functions, and BMPs for land and water stewardship. Extension water quality educators also provide direct support to watershed groups and local governments by facilitating workshops, conducting field assessments, and helping communities develop and implement watershed-based management plans.

Quail Forever

Quail Forever is a national non-profit conservation organization dedicated to the protection and restoration of upland wildlife habitat, with a strong presence in Arkansas. Founded in 2005 as a division of Pheasants Forever, Quail Forever focuses on conserving bobwhite quail, pheasants, and other grassland-dependent species through habitat improvements, public access initiatives, education, and conservation advocacy. In the Upper Saline River Watershed, Quail Forever plays an important role in stream habitat conservation by promoting land management practices that benefit both upland wildlife and aquatic ecosystems. Through partnerships with the USDA NRCS, AGFC, and other agencies, Quail Forever employs Farm Bill biologists who provide free technical assistance to private landowners. These biologists help design and implement conservation plans that often include native grassland restoration, riparian buffer establishment, prescribed fire, and invasive species control, all of which contribute to improved water quality and reduced sedimentation in nearby streams.

4.7 Element 5 – Information/Educational Outreach

Hire 1 Water Quality technician specific to the Upper Saline watershed to work towards increasing utilization of cost-share programs

Technical assistance should be increased within the Upper Saline watershed for accelerating the utilization of cost-share programs. Concentrated efforts should be geared towards priority sub-watersheds of the Saline to accelerate conservation planning in light of limited participation in these programs that has characterized the watershed to date. NRCS EQIP Program funded practices for Garland County in FY2024 are included in Table 4.7.1.

Natural Resources Division has provided state funding in the past to local conservation districts for water quality technicians. A Water Quality Technician would be responsible for reviewing geomorphological assessments of the priority sub-watersheds of the Saline to help identify areas in most need of restoration. The Technician could then incorporate these priority areas into a funding priority system and submit for review to the Arkansas Natural Resource Division. The Water Quality Technician would also be responsible for partnering with local agencies and non-profits conducting research within the watershed to act as a liaison between agencies and local landowners. Pamphlets should be developed by the Water Quality Technician identifying local watershed conditions, research findings, and programs applicable and pertinent to the area for cost-share assistance in restoration.

Specifically, the technician could focus on educating landowners about programs that will assist in pasture and hay management, alternative watering sources for livestock, riparian re-forestation, and fencing. The Technician would also work on annual practice reviews and evaluations of implemented conservation practices. Computer hardware and Geographic Information Systems (GIS) software and training are needed for the county districts to track progress in conservation planning, particularly by HUC12 subwatershed of the Upper Saline to best prioritize future applications for funding. Financial assistance geared towards funding this type of position will be instrumental in increasing participation in important cost-share programs in the Upper Saline Watershed.

Table 4.7.1. NRCS-funded practices for Garland County in FY2024.

Programs

> **Total eligible/pending applications received for FY 2024**

Garland - 18

> **New contract approvals for FY 2024**

Garland (contracted)	9	$107,797
Garland (in progress)	0	$0
Total to Date	9	$107,797

> **Program practice implementation so far in CY 2024**

Practice	Items	Extent	Units
Ag Energy Management Plan	1	1.0	No
Brush Management			Ac
Waste Storage Facility			No
Animal Mortality Facility			No
High Tunnel System	2	4,800.0	SqFt
Prescribed Burning			Ac
Critical Area Planting			Ac
Waste Facility Closure			No
Roofs and Covers			No
Energy Efficient Ag Operation			No
Pond			No
Fence	12	13,732.0	Ft
Firebreak			Ft
Mulching			Ac
Tree/Shrub Site Preparation			Ac
Pasture and Hay Planting			Ac
Livestock Pipeline	4	2,822.0	Ft
Pumping Plant			No
Heavy Use Area Protection	6	2,400.0	SqFt
Tree/Shrub Establishment			Ac
Watering Facility	6	6.0	No
Water Well			No
Energy Efficient Lighting			No
Energy Efficient Building			No
Forest Stand Improvement	1	7.1	Ac
Prescribed Grazing	3	20.1	Ac
Annuals for Grazing	1	11.2	Ac
Conservation Cover	1	2.1	Ac
Stream Crossing	2	2.0	No

Hire 1 Watershed Coordinator to assist and increase the capacity of local watershed conservation groups like the Saline River Watershed Alliance to create and share information on the ecological and historical significance of the Upper Saline Watershed.

As positive watershed awareness grows throughout the Upper Saline, the potential for more public involvement could increase the number of local watershed groups throughout the Upper Saline area. As local groups begin to organize, it is often difficult to find focus and develop a plan of action for involvement within the watershed. The first step taken by many watershed groups is to seek out funding to hire a watershed coordinator. Many watershed groups throughout the country have been successful in receiving grant money to hire a watershed coordinator anywhere from a one to six-year term. Taking this step to establish a full-time person educated in watershed management efforts can save a lot of time and confusion for groups that are ready to learn and get involved in restoration activities but need focused guidance. Since information and educational outreach will be the most useful tools in changing the cumulative negative impacts to local natural resources, it is beneficial to hire someone to devote the necessary time to fully research issues and develop a successful outreach program to involve stakeholders across the watershed. Duties that a watershed coordinator could perform include (but are not limited to): grant research, writing, and development of reports; development of fact sheets, quarterly newsletters, and an informational website; networking with agencies, organizations, news media, and citizens on a multi-county basis; coordination of fundraising, monthly or quarterly public meetings, watershed tours and workshops; working closely with a Water Quality Technician for the Upper Saline; and identifying, planning, and/or leading habitat restoration projects.

4.8 Element 6 – Schedule of Implementation

The successful implementation of the Upper Saline River Watershed Management Plan relies on a well-defined framework of schedules and milestones, and follows an adaptive management process. 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, along with success indicators, 2030 milestones, and implementation partners is summarized in Table 4.8.1.

Table 4.8.1. Implementation schedule for the Upper Saline River watershed management plan.

Data Collection and Monitoring	Start	Anticipated Completion	2030 Milestone	Success Indicator	Implementation Partners
Additional data collection for priority tributaries/subwatersheds to get a clearer picture of geomorphology, water quality and aquatic habitat	2026	Expected to continue indefinitely	At least one year of additional water quality data collected	Number of monitoring sites; number of sampling events; water quality reports; trend analysis	AGFC, ADEQ, USGS, TNC, USFS, USFWS, University research partners
Maintain long term biological assessments: fish and macroinvertebrate population studies and related community changes	2026	Expected to continue indefinitely	At least 1 fish and 1 aquatic macroinvertebrate survey	Number of locations surveyed; Number of sampling events	AGFC, ADEQ, USGS, USFS USFWS
Develop a watershed map indicating areas of land that if developed would increase the river's vulnerability to sedimentation and channel instability and areas that could withstand low impact development	2026	2027	Watershed vulnerability map available and in use by watershed stakeholders	Watershed vulnerability map produced	AGFC, TNC, University research partners
Conduct continuous monitoring and assessment of critical season dissolved oxygen and pH in 303(d) listed stream reaches	2026	2028	Completed monitoring and assessment of critical season dissolved oxygen and pH in 303(d) listed reaches	Number of monitoring sites; number of sampling events; water quality reports; trend analysis	Natural Resources Division, AWRC, ADEQ
Repeat AWRC water quality analysis during high flow conditions	2026	2028	Water quality report for high flow conditions completed	Number of monitoring sites; number of sampling events; water quality reports; trend analysis	AWRC, Natural Resources Division
Repeat AWRC baseflow water quality analysis to see if concentrations are changing over time, as well as 10 sites pulled from ADEQ monitoring sites list to do site specific trends	2030	Expected to repeat every 5 years	Water quality report for base flow conditions completed; site specific trends analyzed	Number of monitoring sites; number of sampling events; water quality reports; trend analysis	AWRC, ADEQ
Inventory of the top three identified priority sub-watersheds of the Saline to determine annual sediment loading from various sources in the watershed	2030	Expected to repeat every 5 years	Inventory reports for sediment loading completed	Number of monitoring sites; number of sampling events; sediment loading reports	USGS, TNC, AGFC, ADEQ, USFS, University research partners

Restoration and BMP Implementation					
Conduct riparian re-forestation/restoration in priority subwatersheds, sites upstream of rapidly eroding streambanks and areas where existing riparian forest can be reconnected	Ongoing	Expected to continue indefinitely	1-2 new projects to restore riparian forest and streambanks	Acres of riparian forest restored	TNC, State agencies, local municipalities, Green Bay Packaging, NRCS, SRWA, local partners
Development of Municipal Stormwater Pollution Prevention Programs and sensible urban zoning to help slow stormwater runoff velocity and reduce direct connections between impervious areas and waterways	Ongoing	Expected to continue indefinitely	Stormwater pollution prevention program developed	Number of stormwater BMPs implemented	Local municipalities, local partners, TNC, SRWA
Establishment of "trash management areas" along portions of the I-30 corridor and other main travel corridors and parking lots where inputs of aquatic litter have been identified as being an issue	Ongoing	Expected to continue indefinitely	1-2 Trash management areas established adjacent to priority streams and heavy use travel corridors	Number of trash management areas	Local municipalities, ARDOT, SRWA, local partners
Demonstration and implementation of Best Management Practices (BMP's) for land conversion activities, improving erosion and sediment control measures, and reducing long term maintenance costs on unpaved roads	Ongoing	Expected to continue indefinitely	At least 1 BMP training workshop and 1 stakeholder tour of BMP demonstration sites held each year	Number of BMPs implemented; Number of demonstration tours and workshops held; Number of attendees	TNC, NRD, conservation districts, county roads departments
Implement BMP's on sites identified in unpaved roads analysis of the top three priority sub-watersheds of the Upper Saline	Ongoing	Expected to continue indefinitely	Implement 1-2 unpaved roads BMP projects per year	Number of BMPs implemented; sediment load reductions from pre- and post-construction surveys	TNC, Green Bay Packaging, NRD, County Roads Dept.
Establish 1-2 additional County trash collection sites in rural areas to reduce illegal trash dumping	2026	Expected to be maintained indefinitely	At least 1 new rural collection site established in watershed	New collection site(s) established	Local counties

Repair/update high impact road/stream crossings in the watershed	Ongoing	Expected to continue indefinitely	Remove/remediate at least 1 high impact road stream crossing per year	Number for crossings removed/remediated	TNC, State agencies, NRCS, USFWS, Green Bay Packaging
Development of a Conservation Easement Program for the Upper Saline Watershed	Ongoing	Expected to continue indefinitely	Conservation easement program be established by a local 501 c(3) organization in the next 1-5 years for lands within the watershed	Acres of land in conservation easements/ landowner conservation agreements	TNC, AGFC, ANHC, City of Benton, local partners
Restore wetland areas and encourage conservation practices to prevent future degradation	2026	2028	At least 1 wetland area identified for habitat restoration	Acres of wetlands restored	TNC, AGFC, NRCS, Extension Services, Conservation Districts, local partners
Invasive Species Management utilizing prescribed fire and other tools	Ongoing	Expected to continue indefinitely	Re-establish native plants and remove invasive species in new projects	Area treated/burned; reduced invasive species populations	TNC, ANRC, AGFC, Conservation Districts, local partners
Nutrient Management Practices	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	NRCS, Conservation Districts, Extension Services
Establish new/expand existing Private Burn Association (PBA) to include counties in the Upper Saline Watershed	2026	Expected to continue indefinitely	PBA established or expanded to include at least 1 county in the watershed	New/existing PBA established/expanded in watershed	Local partners

Outreach and Education					
Community education and outreach	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	SRWA, TNC, state agencies, local partners
Hire 1-2 Watershed/Water Quality Technicians/Coordinators specific to the Upper Saline to work with landowners and municipalities to increase utilization of cost-share programs and uptake of nature-based solutions (NBS) to reduce NPS pollution	2026	2028	1-2 additional watershed/water quality technicians/coordinators working in the watershed	Additional technicians/coordinators working in the watershed	AGFC, ADEQ, NRD, SRWA
Landowner-focused outreach about programs that will assist in riparian re-forestation, pasture and hay management, streambank management, wildlife habitat improvements, alternative watering sources for livestock, and fencing	Ongoing	Expected to continue indefinitely	At least 1 landowner outreach event each year	Number of outreach events and attendees	SRWA, state agencies, local partners
Work with and improve capacity of watershed conservation organizations like the Saline River Watershed Alliance and other community-based conservation groups to create and share information on watershed conditions, research findings, and programs applicable and pertinent to the area for cost-share assistance in restoration	Ongoing	Expected to continue indefinitely	Saline River Watershed Alliance and other watershed conservation organizations have the technical resources and capacity to implement education and outreach and other conservation initiatives in the watershed	Established and operating local watershed organization	SRWA, TNC, state agencies, local partners
Update Management Plan					
Update watershed management plan	2030	2032	Initiate preparations for update	Updated watershed management plan completed and accepted by EPA, stakeholders involved	State agencies, SRWA, TNC, local partners

4.9 Element 7 - Milestones and Re-evaluation/Measures of Success

Setting milestones for this watershed plan, or identified deliverables for a particular recommended project, will assist in determining if implementation efforts are being carried out in a timely and efficient manner during the next five years of implementation. The following items should be monitored for completion on an annual basis to ensure the appropriate progression of each project is taking place:

1. Completed maps depicting sub-watershed prioritization.
2. Sediment loading estimations per land use for inventoried priority watersheds.
3. Detailed map and restoration plan for "hot spots", or rapidly eroding streambanks, identified within priority sub-watersheds.
4. Biological monitoring data and reports for four new sampling sites within the Upper Saline Watershed.
5. Maps and a priority list of roads with the highest potential for contributing sediment. A list of unpaved road culvert segments and low water crossings identified for repair or replacement.
6. Water quality monitoring results and a developed nutrient criteria plan for nutrient impacted streams in the Upper Saline Watershed.
7. Pre- and post-project biological and/or water quality monitoring data and before and after photos taken from streambank restoration projects in the watershed.
8. Attendance lists and a developed inventory database identifying numbers of people that attend BMP trainings and workshops in the watershed on an annual basis.
9. Documentation of the number of conservation easement donations across the Upper Saline Watershed.
10. Number of positive news articles released regarding stakeholder efforts for conservation and restoration in the watershed.
11. Attendance numbers for field tours within the watershed.
12. Number of seed plantings for riparian areas in the watershed.
13. Number of conservation plans developed for farms and ranches throughout the watershed.
14. Number of forest enhancement projects completed within the watershed.
15. Total number of stakeholder meetings held throughout the watershed.

4.10 Element 8 – Performance Criteria Success

The main objective identified for this watershed is to restore a functional and sustainable hydrologic and sediment regime throughout the entire watershed by promoting the abatement of excessive sedimentation and non-point source pollution, restoration of identified critical sites, and the development of sustainable water management practices. These broad measures address and take into account the overall goal of sustaining a healthy population of aquatic species, protecting the integrity of the full range of natural habitats, and maintaining the economic needs of the citizens living in the watershed.

It is important to monitor the success of a watershed plan by identifying if progress is occurring within the outlined objectives. A set of criteria is needed to identify improvements in the watershed including important indicators that are more easily detected by trends rather than a set numeric value. The following criteria will assist state agencies and land managers in determining if implementation efforts are proving effective in reducing loads to the watershed. It will also help determine if significant changes need to be made to the objectives, following a short-term review of the plan, in order to achieve the desired goals.

1. Biological monitoring (fish, macroinvertebrate) shows an increasing trend in populations from pre- to post-BMP implementation in at least 50% of prioritized project sites in the watershed.
2. Storm water inspections of construction and industrial sites show at least an 85% annual compliance rate with the installation and diligent maintenance of appropriate erosion control measures minimizing the impact to both ephemeral and perennial streams.
3. Short term (5 years) of water quality monitoring shows a reversing (declining) trend in turbidity values during storm events in Big Creek (reach 904) and total dissolved solids (TDS) in the Saline River (reach 010). Mean 75th percentiles total Nitrogen (mg/L) and total Phosphorus show declining trend or no net increase.
4. Land use change within the riparian areas of the watershed show a reversed trend of an increase in the deciduous/mixed woods matrix and a decrease in urban, roads, and dominant pine industrial forest matrix over the next five years.
5. BMP compliance rates for monitored forestry practices rises to above 95% and total number of surveyed tracts without an adequate Streamside Management Zone (SMZ) reduces to less than five for lands in the Upper Saline watershed in the next five years.
6. Water quality monitoring ceases to show dissolved oxygen impairments for Big Creek (reach 904), Lockett Creek (reach 922), North Fork (reach 011), Alum Fork (reach 014, 018) and the Middle Fork Saline River (reach 019) over the next five years.

In order to monitor these criteria, there is a need to continue and expand rigorous water quality, macro-invertebrate, and fish population monitoring regimes particularly at all sites chosen for restoration or BMP implementation. Coordination with agency and non-profit organization partners is needed prior to each potential project to ensure the evaluation of success or non-success through coordination of monitoring efforts.

4.11 Element 9 – Monitoring Requirements to Assess Criteria

A high priority for this watershed is maintaining existing and establishing new long-term ecological, hydrological, and geomorphological monitoring sites. This should include the development of a long-term monitoring plan that targets: the expansion of monitoring sites in high priority sub-watersheds of the Upper Saline, the prioritization of new monitoring sites with proposed and existing BMP implementation project areas, and coordination between data collection agencies to maximize monitoring efforts. A summary of conservation projects completed in the watershed since 2006 are included in Appendix B.

Hydrologic monitoring needs include observations such as (1) stage, discharge, and the magnitude, frequency, time, duration of extreme high- and low-flow events, (2) channel cross sections, longitudinal profiles, (3) trend analysis of channel platform and bedform changes, and (4) riverbank and bed erosion rates. Biological monitoring needs include Index of Biotic

Integrity (IBI) monitoring for benthic macroinvertebrates and fish communities. A water quality monitoring, modeling and subwatershed prioritization for the USRW was completed in 2024 by the AWRC and established a baseline for comparing future annual monitoring data of sediment fluxes and water quality parameters such as: nitrates, phosphorus, turbidity, conductivity, and total dissolved solids. Recommendations for continued monitoring include repeating these analyses and update water quality models every 5 years, as well as on a near monthly basis to see if water chemistry is changing over time. This may include pairing data to compare sites across time. In subwatersheds where extensive logging activities occur, monitoring should be timed to target areas that are clear cut, especially in priority headwaters as these subwatersheds may be more sensitive to the effects of land use and landcover changes.

Additional monitoring is also recommended at 10 sites selected from those regularly monitored by ADEQ to examine site specific trends, focusing on tracking 75% percentile of median concentrations over time. There also remains a need for annual monitoring of key water quality constituents during high flow conditions, as well as expanded monitoring of in stream pH, DO, water temperature, and bedloads. Sampling analysis for pesticides, and herbicides are also needed on a periodic basis. While this plan is focused on NPS, monitoring efforts should also focus on point sources within the basin to track Nitrogen and Phosphorus discharge over time.

Hydrologic & Water Quality Monitoring

Currently there are six active and one discontinued USGS streamflow gaging stations in the Upper Saline watershed (Table 4.11.1) The USGS currently maintains only a single water quality and water temperature monitoring station installed by the USGS on Alum Fork Saline River at Winona Dam at Reform, AR, and there remains a need to establish additional water quality monitoring stations in other areas of the watershed, particularly in high priority subwatersheds.

Table 4.11.1 USGS streamflow monitoring gages in the Upper Saline River Watershed.

USGS Gage ID	Location	Type	Status	Period of Record
7362579	S. Alum Creek near Jessieville, AR	Hydrology, Precipitation	Active	2009-05-16 - present
7362587	Alum Fork Saline River near Reform, AR	Hydrology	Active	1989-09-14 - present
7362591	Alum Fork Saline River at Winona Dam at Reform, AR	Hydrology, Temp., Water Quality	Active	2007-10-01 - present
7363000	Saline River at Benton, AR	Hydrology	Active	1950-10-01 - present
7363054	Saline River near Shaw, AR	Hydrology	Active	2017-09-19 - present
7363400	Hurricane Creek below Sheridan, AR	Hydrology, Precipitation	Active	1995-10-01 - present
7363200	Saline River near Sheridan, AR	Hydrology, Precipitation	Discontinued	2000-10-01 - 2024-10-07

Biological Monitoring

The ADEQ has utilized bioassessments, in addition to water quality monitoring, since the 1970's as a technique to evaluate and monitor water quality and ecological health of aquatic systems. Currently, the ADEQ is the primary constituent involved in macroinvertebrate data collection in the Upper Saline Watershed. The ADEQ and the Arkansas Game & Fish Commission (AGFC) are the two state agencies collecting and distributing fish population data within the watershed. Central Arkansas Water (CAW) also conducts seasonal fish and macroinvertebrate sampling throughout the watershed. AGFC currently does not plan to resample previously sampled sites in the Upper Saline River watershed in the short term (within 3 years). The ADEQ completed their latest fish sampling in the Upper Saline in 2016 (North Fork, Cedar Creek, Lockett Creek, Alum

Fork) and 2017 (South Fork) but currently do not have plans of staffing capacity to resample those sites

Best Management Practices Monitoring

The Arkansas Forestry Commission collects and analyzes survey data on the implementation of recommended forestry BMPs in Arkansas' non-point water source silvicultural program. The ADEQ is responsible for routinely inspecting the use of BMPs associated with construction sites to reduce stormwater runoff of sediment into local waterways. The local County Conservation Districts are responsible for monitoring the adherence to BMPs implemented.

What is Needed: Re-evaluation of monitoring needs

Several efforts have been outlined and discussed within this plan to evaluate and expand the monitoring necessary for the short term, including expansion of water quality monitoring, macroinvertebrate and fish population monitoring, and establishing a geomorphological monitoring plan starting with identified priority sub-watersheds. Monitoring efforts should be re-evaluated following five years of implementation of this plan, and as needed with the addition of new data and analysis. This evaluation should address and change, if necessary, the identified monitoring needs for this watershed.

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Appendix A: Attendance summaries for public stakeholder meetings and streamside management landowner workshop

The following tables show the number and type of stakeholders that attended each stakeholder meeting for the update of the Upper Saline River Watershed Management Plan.

The meeting schedule was as follows:

- First Stakeholder Meeting – August 1, 2023
- Second Stakeholder Meeting – May 14, 2024
- Third Stakeholder Meeting – October 17, 2024
- Fourth Stakeholder Meeting – April 3, 2025
- Landowner Workshop – April 19, 2025

First Stakeholder Meeting: August 1, 2023 – Benton County Fairgrounds

Organization/Category	Number of Attendees
Saline River Watershed Alliance	2
Arkansas Game and Fish Commission	1
Natural Resouce Conservation Service	2
Benton County	1
Interested citizens	3
The Nature Conservancy	1
University of Arkansas Division of Agriculture	1

Second Stakeholder Meeting: October 17, 2023 – Benton First United Methodist Church

Third Stakeholder Meeting: May 14, 2024 – Benton First United Methodist Church

Organization/Category	Number of Attendees
Arkansas Game and Fish Commission	1
University of Arkansas	2
Interested citizens	2
Saline River Watershed Alliance	2
Benton County	1
Green Bay Packaging	1
Arkansas Natural Resoures Division	3
The Nature Conservancy	1

Fourth Stakeholder Meeting: April 3, 2025 – Benton First United Methodist Church

Organization/Category	Number of Attendees
Saline River Watershed Alliance	3
Saline River Canoe	2
Green Bay Packaging	1
Arkansas Natural Resoures Division	4
Interested citizens	3
Benton County	1
City of Hot Springs	1
Central Arkansas Water	1
Arkansas Game and Fish Commission	2
University of Arkansas	1
The Nature Conservancy	1

Streamside Management Landowner Workshop: April 19, 2025 – Star Valley Farms, Benton

Organization/Category	Number of Attendees
Arkansas Game and Fish Commission	3
Interested citizens	17
Saline River Canoe	2
Quail Forever	1
Fish and Wildlife Service	1
Natural Resouce Conservation Service	1
Arkansas Natural Resoures Division	2
University of Arkansas	1
Saline River Watershed Alliance	3
Green Bay Packaging	1
The Nature Conservancy	1

<u>Appendix B</u>: Selected list of completed conservation projects in the Upper Saline watershed 2006-2024.

Projects & Activities	Location & Description	Year	Partners
Don Ray project	**160' of streambank stabilization**, Lockett Creek, Garland County,	2012	AGFC
Ed Lindsey project	**930' of streambank stabilization**, South Fork Saline River, Garland County	2014	AGFC
Middle Fork Barrens Natural Area owned by Arkansas Natural Heritage Commission (ANHC)	**260' streambank stabilization project,** Middle Fork Saline River, property obtained in 2004; 206 acres.	2018	ANHC
Alum Fork Natural Area owned by ANHC	Conserves over a mile of the Alum Fork of the Saline River in Saline County. Obtained in 520 acres.	2018	ANHC, TNC
Buckhorn Ranch LLC (Brian Nalley) project	**1,250' of streambank stabilization**, Alum Fork Saline River, Saline County, October	2019	AGFC, TNC
Williams Creek tree planting project	690 containerized seedlings covering 900' of streambank, Williams Creek, Saline County	2019	AGFC
Saline River Watershed Alliance (SRWA)	Creation of the board of directors and non-profit status	2019	
Central Arkansas Water $31.8 million green bond	Purchase of 4,500 acres 4,500 acres of forestland to conserve as portions of the Lake Maumelle and Lake Winona watersheds	2020	CAW, USFS, USEPA, World Resources Institute (WRI)
Saline River Estates Development	North Fork Saline River, Best Management Practices and Guidelines for Construction	2020	AGFC and Brian Nalley
Saline River Riparian Landowner Guide	Development and writing of landowner guide	2021	AGFC, SRWA, Kings River Watershed Partnership, TNC, and AGFC Stream Team. 2021.
Streamside Landowner Workshop	Sponsored event on the Alum Fork Saline River at Brian Nalley's property. 50	2021	SRWA, AGFC, Greenway John Deere, Farmers, Simmons Bank,

	streamside landowners in attendance.		Everett, AGFC Stream Team, and TNC
Lockett Creek Mitigation project by Arkansas Department of Transportation (ArDOT)	10,857' (2+ miles) of restoration	2021	
Wolf Creek and Alum Fork	Two tributary barrier removals	2021	ANHC, TNC, AGFC, and USFS
Arkansas Fatmucket freshwater mussel stockings		2021	AGFC and USFWS
Goat's Beard Bluff Natural Area	Conserves 0.75 mile of the Alum Fork and 3 miles of unnamed tributary streams; 540 acres.	2022	ANHC
Lyle Park Access Area Improvements		2023	City of Benton and AGFC
Clark and Carrie McWilliams project	**428' of streambank stabilization**, North Fork Saline River, Saline County	2024	AGFC
Jordan Qualls project	**605' of streambank stabilization**, South Fork Saline River, Garland County	2024	AGFC
Stream Teams (**water quality monitoring and litter pick-ups**)	Shining Stars 4H Club (#850), Fountain Lake Public School, Lake Hamilton High School, Diamond Lakes Master Naturalists (#1141), Clean Saline (#1194), Saline River Watershed Alliance (#1220), National Park College (#1224), and River Run (#1231). Various years and events.	Various years	

**Numerous other site visits and streambank stabilization plans have been written that have not been implemented yet. Data would be very difficult to retrieve.

** America the Beautiful Challenge grant FY2025 – 5 streambank stabilization projects and 8 barrier removals -unfunded.

Appendix C: Detailed descriptions of the National Land Cover Database (NLCD) land use and landcover categories.

11	**Open Water**- areas of open water, generally with less than 25% cover of vegetation or soil.
21	**Developed, Open Space**- areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
22	**Developed, Low Intensity**- areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.
23	**Developed, Medium Intensity** -areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
24	**Developed High Intensity**-highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.
31	**Barren Land (Rock/Sand/Clay)** - areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover
41	**Deciduous Forest**- areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
42	**Evergreen Forest**- areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.
43	**Mixed Forest**- areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.
52	**Shrub/Scrub**- areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions
71	**Grassland/Herbaceous**- areas dominated by gramanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
81	**Pasture/Hay**-areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
82	**Cultivated Crops** -areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.
90	**Woody Wetlands**- areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
95	**Emergent Herbaceous Wetlands**- Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Appendix D: Land use and landcover summaries by HUC8 and HUC12 subwatershed

Table D1. Summary of NLCD land use and landcover in the HUC8 Upper Saline River watershed in 2006 and 2021.

NLCD Landcover Category	Year	Area acres	Area Sqkm	Area Sqmi	% of Watershed
11_Open Water	2006	8311	33.6	13.0	0.8
21_Developed_Open Space	2006	47331	191.5	74.0	4.3
22_Developed_Low Intensity	2006	30406	123.0	47.5	2.8
23_Developed, Medium Intensity	2006	7304	29.6	11.4	0.7
24_Developed High Intensity	2006	2326	9.4	3.6	0.2
31_Barren Land	2006	2621	10.6	4.1	0.2
41_Deciduous Forest	2006	167774	679.0	262.1	15.2
42_Evergreen Forest	2006	397215	1607.5	620.6	35.9
43_Mixed Forest	2006	66212	268.0	103.5	6.0
52_Shrub/Scrub	2006	64416	260.7	100.7	5.8
71_Grassland/Herbaceous	2006	61049	247.1	95.4	5.5
81_Pasture/Hay	2006	69477	281.2	108.6	6.3
82_Cultivated Crops	2006	2371	9.6	3.7	0.2
90_Woody Wetlands	2006	175227	709.1	273.8	15.9
95_Emergent Herbaceous Wetlands	2006	3245	13.1	5.1	0.3
11_Open Water	2021	8162	33.0	12.8	0.7
21_Developed_Open Space	2021	46482	188.1	72.6	4.2
22_Developed_Low Intensity	2021	31627	128.0	49.4	2.9
23_Developed, Medium Intensity	2021	10268	41.6	16.0	0.9
24_Developed High Intensity	2021	2990	12.1	4.7	0.3
31_Barren Land	2021	3569	14.4	5.6	0.3
41_Deciduous Forest	2021	146163	591.5	228.4	13.2
42_Evergreen Forest	2021	419831	1699.0	656.0	38.0
43_Mixed Forest	2021	63012	255.0	98.5	5.7
52_Shrub/Scrub	2021	64612	261.5	101.0	5.8
71_Grassland/Herbaceous	2021	60484	244.8	94.5	5.5
81_Pasture/Hay	2021	66260	268.1	103.5	6.0
82_Cultivated Crops	2021	2394	9.7	3.7	0.2
90_Woody Wetlands	2021	171270	693.1	267.6	15.5
95_Emergent Herbaceous Wetlands	2021	8149	33.0	12.7	0.7

Table D2: National Land Cover Database (NLCD) classifications of land use and landcover in 2021 in the Upper Saline River HUC12s arranged in descending order by subwatershed area (km^2).

HUC12_Name	HUC12 Area (km^2)	HUC12 Area (mi^2)	11 Open Water	21 Developed Open Space	22 Developed Low Intensity	23 Developed, Medium Intensity	24 Developed High Intensity	31 Barren Land	41 Deciduous Forest	42 Evergreen Forest	43 Mixed Forest	52 Shrub/ Scrub	71 Grassland/ Herbaceous	81 Pasture/ Hay	82 Cultivated Crops	90 Woody Wetlands	95 Emergent Herbaceous Wetlands
Ray Creek-Hurricane Creek	168.1	64.9	0.3	4.7	5.3	1.7	0.6	0.2	4.5	44.6	1.7	4.9	7.8	3.2	0.1	19.2	1.2
Little Hurricane Creek-Hurricane Creek	153.8	59.4	2.6	8.4	7.9	5.6	1.7	2.1	19.2	17.6	6.7	4.5	2.3	19.5	0.0	1.8	0.3
Pine Bridge Creek-Saline River	150.5	58.1	0.3	1.6	2.4	0.2	0.0	0.0	1.0	52.2	0.5	2.1	2.9	0.2	0.5	35.0	1.1
Cedar Creek-South Fork Saline River	148.2	57.2	4.0	13.0	6.0	2.4	0.4	0.7	27.2	17.3	12.2	5.7	3.6	7.5	0.0	0.0	0.0
Chapel Creek-Saline River	142.6	55.1	0.4	1.7	2.0	0.6	0.1	0.1	1.4	36.4	0.7	2.7	3.4	2.4	0.3	47.2	0.8
Outlet Middle Fork Saline River	141.4	54.6	2.0	11.3	4.2	1.4	0.2	0.3	20.8	28.8	11.0	6.1	6.9	6.9	0.0	0.1	0.0
Trace Creek-Saline River	139.8	54.0	0.6	5.8	3.7	1.6	0.3	0.2	12.0	24.6	4.0	2.9	3.3	12.2	0.1	27.5	1.3
Headwaters Alum Fork Saline River	137.8	53.2	3.3	4.2	0.3	0.0	0.0	0.0	20.1	42.9	24.5	2.6	1.5	0.5	0.0	0.1	0.0
Headwaters Middle Fork Saline River	136.3	52.6	0.0	5.7	1.6	0.4	0.1	0.1	23.1	32.8	17.5	10.5	4.7	3.5	0.0	0.0	0.0
Thunder Branch-Big Creek	135.3	52.2	0.1	3.0	2.0	0.4	0.1	0.1	5.7	58.2	3.3	6.0	5.8	6.6	0.3	8.3	0.1
Steep Creek-Saline River	132.5	51.1	0.3	1.9	1.8	0.1	0.1	0.0	1.5	44.3	1.1	2.8	3.9	0.3	0.1	40.6	1.3
Jordan Creek-Saline River	132.0	51.0	0.3	3.1	2.3	0.2	0.0	0.1	5.8	34.1	2.9	4.9	5.2	7.7	0.4	31.5	1.5
White Oak Creek-Hurricane Creek	131.7	50.8	0.2	2.3	2.1	0.3	0.0	0.0	2.4	42.4	1.0	4.6	5.5	5.6	0.7	30.9	1.9
Tenmile Creek-Francois Creek	131.0	50.6	0.4	3.8	2.2	1.2	0.1	0.4	20.5	32.5	7.4	5.6	5.8	12.2	0.0	7.3	0.5
Little Lost Creek-Lost Creek	129.7	50.1	0.2	2.7	2.6	0.2	0.0	0.1	4.9	51.7	1.4	3.9	6.5	8.1	0.0	16.9	0.8
Simpson Creek	126.3	48.8	0.1	2.8	2.5	0.4	0.0	0.1	6.7	55.1	2.6	8.3	7.2	1.5	0.0	12.0	0.7
Mud Creek-Hurricane Creek	126.2	48.7	0.1	2.5	2.3	0.2	0.0	0.0	4.7	62.0	1.5	4.6	4.1	3.6	0.0	13.7	0.6
Middle North Fork Saline River	125.5	48.4	0.2	3.1	0.9	0.2	0.0	0.1	30.1	33.7	10.4	8.3	8.3	4.4	0.0	0.2	0.0
Lower North Fork Saline River	124.4	48.0	1.1	5.2	1.9	0.7	0.1	0.3	42.3	17.5	9.3	7.8	4.7	8.9	0.0	0.2	0.0
Graves Creek-Lost Creek	119.8	46.3	0.5	2.8	2.5	0.2	0.0	0.8	6.2	55.9	2.3	7.5	9.9	1.5	0.0	9.1	0.7
Big Creek-Alum Fork Saline River	116.1	44.8	0.1	2.3	1.1	0.2	0.0	0.1	28.8	30.8	7.0	13.5	10.1	5.6	0.0	0.3	0.0
Depot Creek-Saline River	112.4	43.4	2.2	10.1	13.7	7.4	2.8	1.4	14.3	13.6	8.3	1.9	2.4	10.8	0.1	10.5	0.4
Mud Creek-Saline River	110.5	42.7	0.2	3.0	2.5	0.3	0.1	0.0	2.6	31.7	0.5	7.3	3.0	16.2	0.7	30.8	1.2
Johnson Creek-Derrieusseaux Creek	105.0	40.5	0.1	2.4	1.7	0.2	0.0	0.1	3.6	57.5	1.3	6.0	6.9	1.4	0.1	18.2	0.6
Mill Creek-South Fork Saline River	104.6	40.4	0.3	5.6	3.1	0.9	0.1	0.4	28.3	22.4	9.6	7.2	9.0	13.0	0.0	0.0	0.0
Logan Creek-Hurricane Creek	103.0	39.8	0.1	5.0	3.4	0.4	0.1	0.2	9.7	45.7	3.4	5.1	6.8	5.4	0.0	13.7	1.0
Little Alum Fork-Alum Fork Saline River	100.0	38.6	0.1	3.7	1.6	0.3	0.0	0.1	15.5	39.8	8.1	16.2	10.5	4.1	0.0	0.0	0.0
Upper North Fork Saline River	99.4	38.4	0.1	3.5	1.0	0.2	0.0	0.1	29.7	37.5	19.9	2.4	2.1	3.6	0.0	0.0	0.0
Allgood Creek-Derrieusseaux Creek	97.3	37.5	0.1	2.1	1.7	0.1	0.0	0.0	2.8	46.1	1.2	7.5	9.6	0.5	0.2	26.3	1.7
Little Derrieusseaux Creek-Derrieusseaux Creek	94.4	36.4	0.3	2.5	2.1	0.3	0.0	0.8	5.3	59.1	2.2	9.7	5.4	2.1	0.0	10.0	0.2
Panther Creek-Derrieusseaux Creek	87.1	33.6	0.2	1.8	1.9	0.1	0.0	0.0	1.2	46.7	1.1	3.9	5.5	0.7	0.3	34.4	1.9
Moccasin Creek-Saline River	82.9	32.0	0.6	4.6	1.1	0.3	0.0	0.2	36.8	19.2	8.4	10.1	8.4	9.8	0.0	0.3	0.0
Tenmile Creek-South Fork Saline River	80.5	31.1	0.3	4.7	1.6	0.5	0.1	0.4	52.0	11.9	10.1	3.8	4.6	10.0	0.0	0.0	0.0
Little Creek-Saline River	77.2	29.8	0.4	2.0	2.0	0.3	0.1	0.0	1.3	28.1	0.5	4.0	3.5	1.5	1.6	52.1	2.9
Flat Creek-Lost Creek	75.4	29.1	0.7	2.0	2.3	0.3	0.3	0.5	1.3	39.3	0.6	2.9	4.9	8.8	1.4	33.4	1.4
Cox Creek	68.7	26.5	1.2	2.1	2.0	0.2	0.1	0.0	7.0	46.6	2.4	13.3	7.1	3.2	0.1	14.1	0.7
Big Creek-Francois Creek	67.8	26.2	0.2	2.9	1.7	0.2	0.1	0.0	2.4	27.6	1.2	3.1	2.5	5.7	0.4	49.4	2.7
Brush Creek	58.6	22.6	0.1	2.3	2.3	0.2	0.0	0.0	4.8	49.4	1.2	5.1	7.0	8.0	0.0	19.2	0.3
Brushy Creek	36.3	14.0	0.3	3.3	2.4	0.9	0.2	0.4	11.3	50.4	4.0	4.4	4.9	8.7	0.0	7.5	1.4
Beech Creek-Cow Head Creek	33.2	12.8	0.0	1.6	1.6	0.1	0.0	0.0	0.7	70.1	1.2	0.8	0.7	0.0	0.1	22.9	0.3

Figure D3: National Land Cover Database (NLCD) classifications of land use and landcover in 2006 and 2021 in the Upper Saline River HUC12s arranged in descending order by subwatershed area (km^2).

Table D4: Land use/landcover change within the Upper Saline River Watershed between 2006 and 2021 based on analysis of the National Land Cover Database (NLCD) at 30m spatial resolution. Change classes indicate the starting (2006) and ending (2021) land cover classes. The vast majority (91%, 1574 sq. mi.) of the watershed land area did not undergo and detectible changes over the observation period. The influence of commercial timber harvesting activities in watershed is evident in the extensive change from Evergreen Forest to Grassland/Herbaceous cover and the successional transition to Shrub/Scrub and back to Evergreen Forest.

Change Class	Change Area (Acres)	Change Area (km^2)	Change Area (mi^2)
No Change	1007398.16	4076.8	1574.05
Evergreen Forest->Grassland/Herbaceous	22981.8	93	35.91
Grassland/Herbaceous->Shrub/Scrub	21133.93	85.53	33.02
Shrub/Scrub->Evergreen Forest	20515.67	83.02	32.06
Evergreen Forest->Shrub/Scrub	6207.25	25.12	9.7
Deciduous Forest->Grassland/Herbaceous	3125.53	12.65	4.88
Shrub/Scrub->Deciduous Forest	2529.74	10.24	3.95
Shrub/Scrub->Mixed Forest	1349.93	5.46	2.11
Woody Wetlands->Emergent Herbaceous Wetlands	1323.91	5.36	2.07
Shrub/Scrub->Grassland/Herbaceous	1174.69	4.75	1.84
Deciduous Forest->Shrub/Scrub	1013.9	4.1	1.58
Emergent Herbaceous Wetlands->Woody Wetlands	978.98	3.96	1.53
Pasture/Hay->Shrub/Scrub	965.86	3.91	1.51
Mixed Forest->Grassland/Herbaceous	851.77	3.45	1.33
Shrub/Scrub->Pasture/Hay	425.44	1.72	0.66
Mixed Forest->Shrub/Scrub	373.62	1.51	0.58
Grassland/Herbaceous->Pasture/Hay	283.55	1.15	0.44
Grassland/Herbaceous->Evergreen Forest	268.65	1.09	0.42
Deciduous Forest->Developed Open Space	253.31	1.03	0.4
Pasture/Hay->Developed Open Space	211.27	0.86	0.33
Deciduous Forest->Pasture/Hay	205.71	0.83	0.32
Pasture/Hay->Developed Low Intensity	204.6	0.83	0.32
Developed Open Space->Developed Medium Intensity	198.82	0.8	0.31
Pasture/Hay->Grassland/Herbaceous	197.04	0.8	0.31
Emergent Herbaceous Wetlands->Evergreen Forest	189.04	0.77	0.3
Deciduous Forest->Developed Low Intensity	160.12	0.65	0.25
Deciduous Forest->Evergreen Forest	150.34	0.61	0.23
Emergent Herbaceous Wetlands->Pasture/Hay	136.55	0.55	0.21
Emergent Herbaceous Wetlands->Shrub/Scrub	131.88	0.53	0.21
Evergreen Forest->Developed Open Space	126.1	0.51	0.2
Pasture/Hay->Developed Medium Intensity	118.98	0.48	0.19
Mixed Forest->Evergreen Forest	113.64	0.46	0.18
Grassland/Herbaceous->Developed Open Space	112.09	0.45	0.18
Deciduous Forest->Developed Medium Intensity	109.64	0.44	0.17
Grassland/Herbaceous->Developed Low Intensity	108.97	0.44	0.17
Evergreen Forest->Pasture/Hay	98.74	0.4	0.15

Grassland/Herbaceous->Developed Medium Intensity	93.63	0.38	0.15
Developed Open Space->Developed Low Intensity	77.84	0.32	0.12
Mixed Forest->Developed Open Space	72.28	0.29	0.11
Evergreen Forest->Developed Low Intensity	71.17	0.29	0.11
Cultivated Crops->Emergent Herbaceous Wetlands	68.72	0.28	0.11
Pasture/Hay->Deciduous Forest	64.94	0.26	0.1
Shrub/Scrub->Developed Low Intensity	60.94	0.25	0.1
Shrub/Scrub->Developed Open Space	60.71	0.25	0.09
Mixed Forest->Developed Low Intensity	58.04	0.23	0.09
Pasture/Hay->Cultivated Crops	54.93	0.22	0.09
Emergent Herbaceous Wetlands->Grassland/Herbaceous	53.6	0.22	0.08
Grassland/Herbaceous->Deciduous Forest	49.59	0.2	0.08
Pasture/Hay->Evergreen Forest	49.59	0.2	0.08
Evergreen Forest->Developed Medium Intensity	47.15	0.19	0.07
Shrub/Scrub->Developed Medium Intensity	43.81	0.18	0.07
Developed Low Intensity->Developed Medium Intensity	40.25	0.16	0.06
Pasture/Hay->Open Water	39.14	0.16	0.06
Open Water->Barren Land	35.81	0.14	0.06
Deciduous Forest->Mixed Forest	35.36	0.14	0.06
Barren Land->Developed Medium Intensity	34.92	0.14	0.05
Open Water->Grassland/Herbaceous	34.47	0.14	0.05
Open Water->Woody Wetlands	33.36	0.14	0.05
Mixed Forest->Deciduous Forest	33.14	0.13	0.05
Open Water->Evergreen Forest	31.36	0.13	0.05
Cultivated Crops->Shrub/Scrub	31.36	0.13	0.05
Woody Wetlands->Open Water	30.25	0.12	0.05
Barren Land->Open Water	29.58	0.12	0.05
Mixed Forest->Pasture/Hay	29.13	0.12	0.05
Mixed Forest->Developed Medium Intensity	28.69	0.12	0.04
Shrub/Scrub->Woody Wetlands	27.58	0.11	0.04
Developed Low Intensity->Developed High Intensity	27.35	0.11	0.04
Evergreen Forest->Mixed Forest	27.13	0.11	0.04
Evergreen Forest->Deciduous Forest	26.91	0.11	0.04
Grassland/Herbaceous->Emergent Herbaceous Wetlands	25.58	0.1	0.04
Open Water->Emergent Herbaceous Wetlands	25.35	0.1	0.04
Open Water->Deciduous Forest	24.91	0.1	0.04
Grassland/Herbaceous->Open Water	24.91	0.1	0.04
Woody Wetlands->Shrub/Scrub	24.02	0.1	0.04
Pasture/Hay->Developed High Intensity	23.8	0.1	0.04
Evergreen Forest->Emergent Herbaceous Wetlands	23.13	0.09	0.04
Evergreen Forest->Cultivated Crops	22.24	0.09	0.03
Grassland/Herbaceous->Barren Land	21.79	0.09	0.03
Shrub/Scrub->Open Water	21.35	0.09	0.03
Developed Open Space->Developed High Intensity	19.79	0.08	0.03
Open Water->Shrub/Scrub	19.57	0.08	0.03

Barren Land->Developed Low Intensity	14.23	0.06	0.02
Emergent Herbaceous Wetlands->Cultivated Crops	14.23	0.06	0.02
Grassland/Herbaceous->Mixed Forest	13.57	0.05	0.02
Evergreen Forest->Open Water	12.9	0.05	0.02
Deciduous Forest->Emergent Herbaceous Wetlands	12.68	0.05	0.02
Deciduous Forest->Open Water	11.56	0.05	0.02
Pasture/Hay->Mixed Forest	11.34	0.05	0.02
Pasture/Hay->Emergent Herbaceous Wetlands	11.34	0.05	0.02
Emergent Herbaceous Wetlands->Deciduous Forest	11.34	0.05	0.02
Shrub/Scrub->Barren Land	11.12	0.05	0.02
Open Water->Developed Open Space	10.9	0.04	0.02
Woody Wetlands->Pasture/Hay	10.45	0.04	0.02
Deciduous Forest->Developed High Intensity	10.23	0.04	0.02
Shrub/Scrub->Developed High Intensity	10.01	0.04	0.02
Emergent Herbaceous Wetlands->Open Water	10.01	0.04	0.02
Deciduous Forest->Barren Land	9.79	0.04	0.02
Woody Wetlands->Evergreen Forest	9.34	0.04	0.01
Barren Land->Developed Open Space	9.12	0.04	0.01
Barren Land->Developed High Intensity	8.9	0.04	0.01
Shrub/Scrub->Emergent Herbaceous Wetlands	8.67	0.04	0.01
Grassland/Herbaceous->Developed High Intensity	7.78	0.03	0.01
Barren Land->Grassland/Herbaceous	7.34	0.03	0.01
Evergreen Forest->Barren Land	6.67	0.03	0.01
Cultivated Crops->Evergreen Forest	6.67	0.03	0.01
Pasture/Hay->Barren Land	6.45	0.03	0.01
Evergreen Forest->Developed High Intensity	6.23	0.03	0.01
Mixed Forest->Open Water	6.23	0.03	0.01
Pasture/Hay->Woody Wetlands	6.23	0.03	0.01
Woody Wetlands->Grassland/Herbaceous	6.23	0.03	0.01
Open Water->Developed Low Intensity	5.78	0.02	0.01
Barren Land->Pasture/Hay	5.78	0.02	0.01
Woody Wetlands->Barren Land	5.56	0.02	0.01
Open Water->Mixed Forest	5.34	0.02	0.01
Shrub/Scrub->Cultivated Crops	4.67	0.02	0.01
Grassland/Herbaceous->Woody Wetlands	4.67	0.02	0.01
Evergreen Forest->Woody Wetlands	4.45	0.02	0.01
Deciduous Forest->Woody Wetlands	4.23	0.02	0.01
Open Water->Pasture/Hay	3.34	0.01	0.01
Woody Wetlands->Developed Open Space	2.89	0.01	0
Developed Medium Intensity->Developed High Intensity	2.67	0.01	0
Mixed Forest->Developed High Intensity	2.67	0.01	0
Woody Wetlands->Developed Medium Intensity	2.67	0.01	0
Emergent Herbaceous Wetlands->Mixed Forest	2.22	0.01	0
Barren Land->Evergreen Forest	2	0.01	0
Barren Land->Shrub/Scrub	2	0.01	0

Mixed Forest->Barren Land	2	0.01	0
Open Water->Developed Medium Intensity	1.78	0.01	0
Barren Land->Deciduous Forest	1.78	0.01	0
Deciduous Forest->Cultivated Crops	1.33	0.01	0
Woody Wetlands->Cultivated Crops	1.33	0.01	0
Woody Wetlands->Developed Low Intensity	1.11	0	0
Barren Land->Mixed Forest	0.89	0	0
Emergent Herbaceous Wetlands->Developed Low Intensity	0.89	0	0
Emergent Herbaceous Wetlands->Developed Medium Intensity	0.89	0	0
Mixed Forest->Cultivated Crops	0.67	0	0
Cultivated Crops->Open Water	0.67	0	0
Cultivated Crops->Barren Land	0.67	0	0
Cultivated Crops->Pasture/Hay	0.67	0	0
Cultivated Crops->Woody Wetlands	0.67	0	0
Emergent Herbaceous Wetlands->Developed Open Space	0.44	0	0
Open Water->Cultivated Crops	0.22	0	0
Barren Land->Woody Wetlands	0.22	0	0
Mixed Forest->Emergent Herbaceous Wetlands	0.22	0	0
Grassland/Herbaceous->Cultivated Crops	0.22	0	0
Cultivated Crops->Developed Low Intensity	0.22	0	0
Cultivated Crops->Developed Medium Intensity	0.22	0	0
Cultivated Crops->Developed High Intensity	0.22	0	0
Cultivated Crops->Grassland/Herbaceous	0.22	0	0
Woody Wetlands->Mixed Forest	0.22	0	0
Emergent Herbaceous Wetlands->Barren Land	0.22	0	0

Appendix E: Arkansas Department of Environmental Quality (ADEQ) water quality stations and available sampling data for sites in the Upper Saline River Watershed.

StationID	Latitude	Longitude	County	EcoRegion	Description	ADEQPlSeg	StationTypeNew	WaterSource	#_WQSamples
AFS0001	34.616402	-92.749199	Saline	Ouachita Mountains	Alum Fork Saline River at Hwy 5 E. of Crows	2C	Surface Water	River	408
NFS0004	34.605	-92.618301	Saline	Ouachita Mountains	N. Fork Saline River @ Hwy 5 bridge	2C	Surface Water	River	395
NFS0001	34.7686	-92.752197	Saline	Ouachita Mountains	N. Fork Saline River off Hwy 9 east of Paron,AR on 12th St.	2C	Surface Water	River	393
NFS0002	34.7458	-92.703598	Saline	Ouachita Mountains	N. Fork Saline River 1/2 mi upstream of Trukey CR. confl.	2C	Surface Water	River	386
NFS0003	34.6597	-92.6344	Saline	Ouachita Mountains	N. Fork Saline R. 3 mi W. of Congo 1/2 mi above Boot Cr.	2C	Surface Water	River	361
SFS0002	34.577251	-92.811592	Saline	Ouachita Mountains	South Fork of the Saline River on Owensville Cutoff/CR268	2C	Surface Water	River	297
MFS0001B	34.615078	-92.778831	Saline	Ouachita Mountains	Middle Fork Saline River at SR5 Bridge	2C	Surface Water	River	238
OUA0116	34.32	-92.3417	Grant	South Central Plains	Hurricane Creek at Hwy. 270 Bridge 3 mi east of Sheridan, AR	2C	Surface Water	River	226
LOUA014A	34.6189	-92.5306	Saline	Ouachita Mountains	Hurricane Lake - NE of Benton	2C	Surface Water	Lake	225
FRO027	34.79231	-92.69909	Saline	Ouachita Mountains	Saline County Domestic Well 027	2C	Groundwater	Well	223
MFS0001	34.597374	-92.74295	Saline	Ouachita Mountains	Middle Fork Saline River 2 mi SE Crows,AR on Narrows Rd	2C	Surface Water	River	96
LOUA021A	34.1744	-92.6228	Grant	South Central Plains	Cox Creek Lake below AG&F Boat Ramp.	2C	Surface Water	Lake	58
FRO006	34.70195	-92.57403	Saline	Ouachita Mountains	Saline County Domestic Well 006	2C	Groundwater	Well	45
OUA0227	34.223339	-92.488136	Grant	South Central Plains	Lost Creek off of Grant CR8, ~ 2 miles E of Hwy 46, at Sheri	2C	Surface Water	River	43
OUA0197	34.616653	-92.914978	Garland	Ouachita Mountains	Lockett Creek on HWY 5 in Fountain Lake	2C	Surface Water	River	41
OUA0216	34.755009	-92.873497	Saline	Ouachita Mountains	Alum Fork Saline River on FR24000/WH W of Paron	2C	Surface Water	River	40
NFS0001A	34.7789	-92.756897	Saline	Ouachita Mountains	N. Fork Saline River @ Hwy 9 bridge N. of Paron,AR	2C	Surface Water	River	38
SFS0001	34.554699	-92.762802	Saline	Ouachita Mountains	S. Fork Saline River off Hwy. 70 near Nance on Narrows Rd	2C	Surface Water	River	36
OUA0248	34.103489	-92.434326	Dallas	South Central Plains	Cow Head Creek on SR48 E of Carthage; US reach	2C	Surface Water	River	33
OUA0247	34.205097	-92.232353	Jefferson	South Central Plains	Johnson Creek on CR Grant 29 W of Pine Bluff; DS reach	2C	Surface Water	River	31
OUA0228	34.546139	-92.597595	Saline	South Central Plains	Depot Creek off Richard St. just S of Benton. Park in vacant	2C	Surface Water	River	30
OUA0167	33.728001	-91.954803	Cleveland	South Central Plains	Hudgens Creek on SR35 E of Rye	2C	Surface Water	River	24
OUA0018	34.289398	-92.370003	Grant	South Central Plains	Big Creek below Sheridan,AR on CR204	2C	Surface Water	River	23
LOUA011A	34.7986	-92.8475	Saline	Ouachita Mountains	Lake Winona -	2C	Surface Water	Lake	23
OUA0171H	34.466408	-92.793402	Hot Spring	Ouachita Mountains	Reyburn Creek upstream of the confluence with Skull Creek	2F	Surface Water	River	23
OUA0171G	34.466572	-92.793015	Hot Spring	Ouachita Mountains	Skull Creek US of confl. with Reyburn Creek on Darby Ln (CR7	2F	Surface Water	River	23
OUA0171J	34.466028	-92.791351	Hot Spring	Ouachita Mountains	Reyburn Creek about 50 yards below Skull Creek confluence	2F	Surface Water	River	23
OUA0171K	34.461536	-92.779657	Hot Spring	Ouachita Mountains	Reyburn Creek at Darby Lane	2F	Surface Water	River	23
OUA0220	34.810558	-93.008087	Saline	Ouachita Mountains	S Alum Creek on CR5/Reform Rd W of Lake Winona	2C	Surface Water	River	20
NFS0003A	34.6611	-92.6347	Saline	Ouachita Mountains	N. Fork Saline River 3 mi W. of Congo, AR above Boot Cr conf	2C	Surface Water	River	20
MFS0004E	34.687881	-92.970337	Saline	Ouachita Mountains	Mill Creek below Hot Springs Village WWTP near Cortez Rd	2C	Surface Water	River	16
FRO010	34.6618	-92.5462	Saline	Ouachita Mountains	Saline County Domestic Well 010	2C	Groundwater	Well	16
MFS0004	34.680382	-92.924004	Saline	Ouachita Mountains	Middle Fork Saline River at Danville Road low water bridge	2C	Surface Water	River	15
MFS0004B	34.69532	-92.94399	Saline	Ouachita Mountains	Middle Fork Saline River off of Devaca Way	2C	Surface Water	River	15
OUA0182B	34.560501	-92.465202	Saline	South Central Plains	Hurricane Creek near Sardis on S Sardis Road	2C	Surface Water	River	14
FRO023	34.78081	-92.70889	Saline	Ouachita Mountains	Saline County Domestic Well 023	2C	Groundwater	Well	13
OUA0182A	34.5751	-92.495102	Saline	South Central Plains	Hurricane Creek near Bryant on SR183 (S Reynolds Rd)	2C	Surface Water	River	11
OUA0031	34.511101	-92.415001	Saline	South Central Plains	Hurricane Creek near Sardis,AR on S Sardis Rd	2C	Surface Water	River	6
OUA0026	34.562801	-92.615303	Saline	Ouachita Mountains	Saline River near Benton,AR on SR229	2C	Surface Water	River	5
MFS0003	34.671638	-92.889816	Saline	Ouachita Mountains	Middle Fork Saline River on Antioch Rd	2C	Surface Water	River	4
OUA0042	34.115398	-92.405602	Grant	South Central Plains	Saline River near Sheridan,AR on Hwy 167	2C	Surface Water	River	2
MFS0005	34.702919	-92.986183	Garland	Ouachita Mountains	Middle Fork Saline River at Talley Cemetery Road	2C	Surface Water	River	2
FRO024	34.7938	-92.6916	Saline	Ouachita Mountains	Saline County Unused Spring 024	2C	Groundwater	Spring	2
OUA0214	34.652664	-92.94783	Saline	Ouachita Mountains	Cedar Creek on Minorca Rd BL Lake Coronado in Hot Springs Vi	2C	Surface Water	River	2
OUA0196	34.61433	-92.892937	Garland	Ouachita Mountains	Cedar Creek on Hwy 5 in Whittington S of Lake Balboa	2C	Surface Water	River	2
OUA0041	34.498806	-92.571587	Saline	Ouachita Mountains	Saline River below Benton,AR on Shaw Bridge Rd.	2C	Surface Water	River	1
MFS0002	34.63026	-92.826729	Saline	Ouachita Mountains	Middle Fork Saline River at Vance Road Bridge	2C	Surface Water	River	1
OUA0226	34.441341	-92.610649	Saline	South Central Plains	Clift Creek on CR291 2.5 mi E of Traskwood	2C	Surface Water	River	1

Appendix F: Arkansas Department of Environmental Quality (ADEQ) fish sampling data and linked reports for the Upper Saline River Watershed

SampleID	Collection Date	Stream Name	County	Eco Region	Seg.	WQ Station	Notes
2c042 Collection Rpt Habitat Sum Rpt	7/11/2008	**Little Alum Fork** Hunting Lease	Saline	Ouachita Mountains	2C		Little Alum Fork Icthyofauna survey (R18W T1N S16)
2C043 Collection Rpt Habitat Sum Rpt	8/29/2008	**Little Alum Fork** Upstream of Mt. Ida Rd bridge	Saline	Ouachita Mountains	2C		
2C048 Collection Rpt Habitat Sum Rpt	7/16/2009	**Alum Fork Saline River** at Hwy. 9 bridge. S1 T1S R17W	Saline	Ouachita Mountains	2C	AFS0002	Nutrient criteria development study
2C051 Collection Rpt Habitat Sum Rpt	7/16/2009	**Little Alum Fork** LAF01 at Mt. Ida Rd. bridge. S14 T1N R18W	Saline	Ouachita Mountains	2C		Nutrient criteria development study
2C053	7/27/2009	**South Fork Saline River** SFS@Hwy 128 brige. S34 T1S R18W	Garland	Ouachita Mountains	2C		Nutrient criteria development study

Collection Rpt Habitat Sum Rpt							
2C054 Collection Rpt Habitat Sum Rpt	7/27/2009	**South Fork Saline River** South Fork at Highway 5. S6 T2S R18W	Garland	Ouachita Mountains	2C		Nutrient criteria development study
2C052 Collection Rpt Habitat Sum Rpt	8/4/2009	**North Fork Saline River** at Hwy. 9 bridge. S14 T1N R18W	Saline	Ouachita Mountains	2C	NFS0001	Nutrient criteria development study
2C055 Collection Rpt Habitat Sum Rpt	8/4/2009	**North Fork Saline River** 0.1 mi N of end of Belle Ln. S15 T1N R16W.	Saline	Ouachita Mountains	2C	NFS0002	Nutrient criteria development study
2C050 Collection Rpt	8/13/2009	**Middle Fork Saline River** at Narrows Rd. bridge. S32 T1S R16W	Saline	Ouachita Mountains	2C	MFS0001	Nutrient criteria development study

Habitat Sum Rpt							
2C056 Collection Rpt Habitat Sum Rpt	8/13/2009	**Middle Fork Saline River** MFS02. at Vance Rd. bridge. S21 T1S R17W	Saline	Ouachita Mountains	2C	MFS0002	Nutrient criteria development study
2C044 Collection Rpt Habitat Sum Rpt	8/14/2009	**Alum Fork Saline River** 3 mi w of Hwy 9 on Sulphur SpringsRd. S2 T1S R17W	Saline	Ouachita Mountains	2C		Nutrient criteria development study
2C046 Collection Rpt Habitat Sum Rpt	8/14/2009	**South Fork Saline River** SFS02. at Owensville Cutoff Rd. S3 T2S R17W	Garland	Ouachita Mountains	2C		Nutrient criteria development study
2C045	8/17/2009	**North Fork Saline River** NFS03--at Steel Bridge Road crossing. S8 T1S R15W	Saline	Ouachita Mountains	2C	NFS0003	Nutrient criteria development study

Collection Rpt Habitat Sum Rpt							
2C047 Collection Rpt Habitat Sum Rpt	8/17/2009	**North Fork Saline River** at Hwy. 5. bridge. S28 T1S R15W	Saline	Ouachita Mountains	2C	NFS0004	Nutrient criteria development study
2C059 Collection Rpt	7/18/2016	**North Fork Saline** 12th Street Crossing off Hwy 9, 0.5 Miles SE of Paron	Saline	Ouachita Mountains	2C	NFS0001A	
2C061 Collection Rpt	8/4/2016	**Cedar Creek** On Hwy 5 in Whittington, SE of Lake Balboa	Garland	Ouachita Mountains	2C	OUA0196	
2C062 Collection Rpt	8/4/2016	**Lockett Creek** On Hwy 5 in Fountain Lake	Garland	Ouachita Mountains	2C	OUA0197	
2C064	8/9/2016	**Alum Fork Saline** On FR 24000/ Weyerhaeuser Road,	Saline	Ouachita Mountains	2C	OUA0216	

Collection Rpt		6 Miles W of Paron					
2C058 Collection Rpt	8/11/2016	**Middle Fork Saline** Tally Cemetery Road Crossing, 4.5 Miles E of Jessieville	Garland	Ouachita Mountains	2C	MFS0005	
2C065 Collection Rpt	8/30/2017	**South Fork Saline** South Fork of the Saline River on Owensville Cutoff/CR 268	Saline	Ouachita Mountains	2C	SFS0002	

Appendix G: Agency and literature sources for water quality constituent reference values listed in Table 4.7.1.

Ammonia-N (mg/L): 2013 EPA ammonia toxicity level for Fatmucket mussels (a threatened mussel group found within the watershed) was 0.34 mg/L.

- https://www.epa.gov/sites/default/files/2015-08/documents/aquatic-life-ambient-water-quality-criteria-for-ammonia-freshwater-2013.pdf

Chloride: Chloride standard determined from Arkansas's least-disturbed ecoregion reference streams and are considered to be the maximum naturally occurring levels based on Pollution Control and Ecology Commission Rule 2.

- https://www.adeq.state.ar.us/regs/files/rule02_final_220128.pdf

Conductivity: On average, ecoregional background estimates based on the 75th percentile of least disturbed station medians are: 105 uS/cm in the Ouachita Mountains and 134 uS/Cm in the South Central Plains

- Document Display | NEPIS | US EPA

Nitrate: "recent nationwide study found that concentrations over 1 mg/l nitrate indicate human activity"

- Estimated Nitrate Concentrations in Groundwater Used for Drinking | US EPA

SRP: SRP threshold of 0.021-0.042 mg/L for nutrient-sensitive organism groups (macrophytes and phytobenthos); study done in Europe

- https://www.sciencedirect.com/science/article/pii/S1470160X20309560

TN: reference values represent the 25th percentile of stream TP and TN nutrient criteria for chlorophyll-a within the watersheds ecoregion that is suggested by the USEPA

- Evans-White M.A., Haggard, B.E., & Scott, J.T. (2014). A review of Stream Nutrient Criteria Development in the United States. Environmental Quality, 42, 1002-1014. https://doi.org/10.2134/jeq2012.0491

TP: reference values represent the 25th percentile of stream TP and TN nutrient criteria for chlorophyll-a within the watersheds ecoregion that is suggested by the USEPA

- Evans-White M.A., Haggard, B.E., & Scott, J.T. (2014). A review of Stream Nutrient Criteria Development in the United States. Environmental Quality, 42, 1002-1014. https://doi.org/10.2134/jeq2012.0491

TSS: Big creek listed on the 2004 303(d) list & EPA investigated the best TMDL for the creek. TSS criteria developed for Big creek is 10 mg/L.

- https://www.adeq.state.ar.us/downloads/webdatabases/water/tmdl/pdfs/turbidity_for_seven_stream_2008_03_27.pdf

Turbidity: Base flow standards based on Pollution Control and Ecology Commission Rule 2.

- https://www.adeq.state.ar.us/regs/files/rule02_final_220128.pdf

Appendix H: Final report on constituent water quality sampling and analysis for prioritization of Upper Saline River HUC12 subwatersheds by the University of Arkansas's Water Resources Center (AWRC)

FINAL REPORT

HUC-12 Prioritization using Classification and Regression Tree Analysis (CART) Within the Upper Saline River Watershed, Arkansas

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319 Nonpoint Source Program

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Introduction

Water quality plays a vital role in both ecosystem and organism health, and water quality monitoring is critical for management decisions as well as identifying pollution sources (Chapman & Sullivan, 2022). Water quality is impacted by both natural and anthropogenic sources such as effluent discharge, sewage leakage, pesticide, fertilizer, and manure applications (Khatri & Tyagi, 2014). Pollutants such as these can lead to decreased water quality, increasing the need to monitor water quality to locate pollution sources, as well as implement watershed management plans and strategies to improve water quality (Shi et al., 2020).

As the human population continues to increase, one of the most critical stressors on water quality is land use and conversions of natural and forested areas to anthropogenic uses, such as urban and agricultural areas (Winkler et al., 2021). Increasing human populations and the conversion of natural areas to anthropogenic uses increase non-point source (NPS) pollutants, which threaten stream water quality, by increasing nutrient concentrations and transport, accelerating eutrophication (Lei et al., 2021). Non-point sources remain problematic as they can come from various sources and paths across the landscape, making their origin hard to identify and quantify. Therefore, exploring the relationship between stream water quality and LULC is important to create informed strategies to reduce NPS and improve water quality (Gergel, 2005).

NPS can be mitigated through the implementation of nutrient management strategies, conservation practices, and best management practices however to make the most efficient use of conservation or restoration resources it has been recommended to first identify areas where efforts will be most effective (Niraula et al., 2013). To identify priority areas for conservation or restoration within a watershed water quality monitoring and/or modeling can be used.

The Arkansas Department of Agriculture – Natural Resources Division has previously identified the Upper Saline River watershed as a 319 NPS priority watershed with concerns about the watershed's sedimentation, chloride, sulfate, pH, mercury, and dissolved oxygen levels in stream (Natural Resources Division, 2022). Also previously, The Nature Conservancy (TNC) established a nine-element watershed management plan for the Upper Saline River watershed in 2006 (TNC, 2006). However, this watershed management plan is due for an update.

To address the water quality issues and help TNC revise the previous 9-element watershed management plan, we conducted monthly water quality monitoring at 29 sites and identified HUC-12 priority areas within the Upper Saline River Watershed. The main objectives of this study were to 1) assess trends in stream water quality using historical monitoring data, 2) evaluate correlations between stream water quality and catchment land use across sites representing different catchment areas, and 3) evaluate the influence of watershed metrics on stream water quality using Classification and Regression Tree (CART) analysis. Water pollution is a growing threat to ecosystems, and water quality monitoring presents an opportunity to identify current pollutants, leading to conservation and restoration efforts and minimizing future degradation.

Site Description

The Upper Saline River watershed (HUC 8) drains a 4,454 km^2 area, of which 63% is forested, 16% is wetland, 12% is agricultural, 8% is urban, and < 1% is water (NLCD, 2021). The watershed has been experiencing land use conversions over the past two decades, where slight increases in urban development and decreases in forest and agriculture cover have occurred. As of 2010, approximately 140,000 people live in the watershed, with the population in the upper portion rapidly growing (U.S. Census Bureau, 2021). For example, Saline County experienced a 15.1% increase in population from 2010 to 2020 (U.S. Census Bureau, 2021).

The watershed lies within the Ouachita River Basin, with the watershed's main river, the Saline River, flowing south into the Lower Saline Watershed (HUC 8). The Upper Saline River watershed includes four major streams: the South, Middle, Alum, and North Forks. The main tributaries to the Saline River and its forks are Cedar Creek, Derrieuseaux Creek, Francois Creek, Hurricane Creek, Huskey Creek, Lost Creek, and Simpson Creek. The Alum, Middle, and North Forks have been designated as Extraordinary Resource Waterbodies (ERWs) by the State of Arkansas, characterized by scenic beauty, high water quality, and broad recreation potential (APCEC, 2022). Yet, several stream reaches in the watershed have been identified as impaired on recent 303(d) lists (ADEQ, 2023) (Table 1).

Table 1: Impaired stream reaches within the Upper Saline River watershed on the draft 2022 303(d) list as defined by the Arkansas Department of Energy and Environment (ADEE, 2023).

Watershed	Stream	Reach	Miles	Non-Attained Standards[1]	Source[2]
8040203	Saline River	001	1.50	Hg	UN
8040203	Lost Creek Ditch	008	21.3	pH	AG
8040203	Saline River	010	27.64	TDS	UN
8040203	North Fork Saline River	011	37.5	DO	UN
8040203	Alum Fork Saline River	014	19.3	DO, pH	UN
8040203	Alum Fork Saline River	018	7.7	pH, DO	UN
8040203	Middle Fork Saline River	019	37.1	DO	UN
8040203	Cedar Creek	021	1.2	DO	UN
8040203	South Fork Saline River	022	13.6	Biological Integrity-Fish & Macroinvertebrates	UN
8040203	Skull Creek	824	0.5	pH	IP, RE
8040203	Big Creek	904	15.60	DO, Turbidity	AG, SE
8040203	Saline River	913	10.20	TDS	UN
8040203	Lockett Creek	922	8.8	DO, pH, Biological Integrity-Fish	UN
8040203	Reyburn Creek	924	8.1	pH	IP, RE

[1]Hg=Mercury, TDS=Total Dissolved Solids, DO=Dissolved Oxygen, [2]AG=Agricultural Activities, IP=Industrial Source Point, RE=Resource Extraction, UN=Unknown, SE=Surface Erosion.

Methods

Historical Data Analysis

Changes in nutrient concentrations over time at the watershed (HUC-8) and site level were also assessed. Water quality monitoring data from sites within the Upper Saline River watershed was gathered from January 1, 1990, to December 31, 2023, using the Arkansas Department of Energy and Environment ambient water quality monitoring database accessed via the water quality monitoring data portal. Focus constituents were TN and TP. N+N and total Kjeldahl nitrogen (TKN) were used to calculate TN for sites with no direct TN measures. Data was screened and flagged for non-numeric information included with the observation values, data below detection limits, outliers that were an order of magnitude out of range of typical values for that parameter, and 0 or negative values. Data reported below the detection limit with a specific concentration was used as recorded in the data portal, while data recorded with a less than sign was used in the analysis as the detection limit (i.e. data reported as <0.02 was used as 0.02).

To analyze watershed level trends, the yearly median of TN and TP at each selected site was calculated. The 75th percentile of median TN and TP concentrations for each year was then calculated across monitoring sites within the basin each year. Mann-Kendell tests (MK) were then used to detect monotonic changes in the nutrient concentrations over time using R (version 4.3.2). The statistical significance for the MK test was as follows: for $p \geq 0.20$, trend was unlikely; for $0.10 \geq p < 0.20$ trend may exist, for $0.05 \geq p < 0.10$ trend was likely, and for $p < 0.05$ trend was very likely. The Sen line slope was also calculated; a positive slope showed increasing nutrient concentrations, while a negative slope showed decreasing nutrient concentrations. A slope with a magnitude less than 0.01% in either direction was considered not changing, regardless of significance. The LOESS line was also calculated to show the moving central tendency of the nutrients through time.

Field Sampling and Water Quality Analysis

Samples were collected at 29 sites within the Upper Saline River Watershed, and water samples were collected monthly from January 2023 to November 2023 (Fig. 1; Table 2). Sites were selected to represent a broad range and mix of urban, agricultural, and forested areas to evaluate how LULC affects water quality within the watershed.

Water samples were collected from public access bridges using an alpha style horizontal sampler or a pole sampler from the vertical centroid of flow, where the water is actively moving downstream near the deepest part of the channel visually. At each site, a clear 500 mL and 250 mL high density polyethylene (HDPE) bottle was filled and stored on ice in the dark until arrival at the Arkansas Water Resource Center (AWRC) water quality labs. All samples were analyzed for anions (chloride (Cl), fluoride (F), and sulfate (SO_4)), dissolved nutrients (soluble reactive phosphorus (SRP), ammonia (NH_3-N), nitrate plus nitrite (NO_3-N + NO_2-N)), total nutrients (TN and TP), total suspended solids (TSS), turbidity, and conductivity.

The analytical methods and equipment included:

- Anions analysis using a Dionex Ion Chromatography System 1600, including Cl, F, and SO_4 via EPA method 300.0.
- NO_2-N analysis using a Beckman Spectrophotometer via APHA method 4500.
- Dissolved nutrient analysis using a Skalar San++ System Wet Chemistry Autoanalyzer, including SRP via EPA method 365.1, NH_3-N via EPA method 351.2, and NO_3-N + NO_2-N via EPA method 353.2.
- Total nutrients using a Skalar San++ System Wet Chemistry Autoanalyzer via APHA method 4500-P J and EPA method 353.2.

- TSS analysis by filtering 100 mL of sample, drying the filter, and weighing the filter using a Mettler Toledo AX205 Balance via EPA method 160.2.
- Conductivity analysis using a VWR Symphony B10C via EPA method 120.1.

Water sample collection and analysis were conducted following an approved quality assurance project plan (QAPP, QMP #22-404), and water samples were analysed using standard methods at the certified AWRC water quality labs.

Figure 2. Upper Saline River watershed boundary and sample sites with the surrounding Arkansas counties.

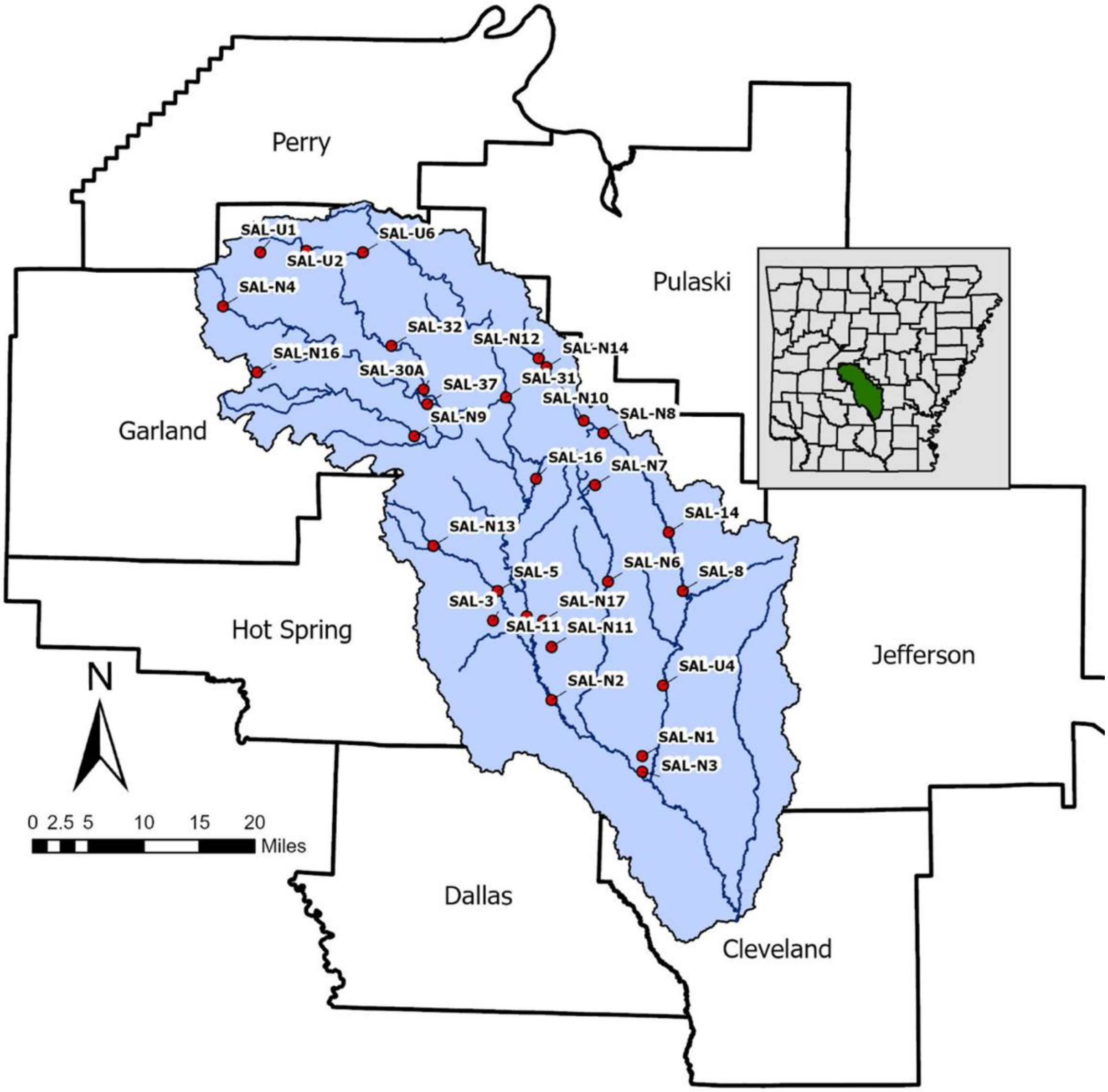


Table 2. Monitoring sites with latitude (Lat N) and longitude (Long W), catchment areas, and 2021 land use percentages in the Upper Saline River Watershed.

Site ID	Lat N	Long W	Area (km^2)	HUC 12 ID	Stream Name	U (%)[1]	F (%)[2]	A (%)[3]
SAL-11	34.319	-92.587	1770	80402030704	Saline River	10.7	70.3	12.6
SAL-14	34.429	-92.362	256	80402030402	Hurricane Creek	19.0	54.3	17.9
SAL-16	34.499	-92.572	1510	80402030702	Saline River	11.1	74.7	12.3
SAL-3	34.314	-92.64	84.0	80402030603	Big Creek	5.4	74.5	10.9
SAL-30A	34.616	-92.749	314	80402030305	Alum Fork Saline River	4.7	84.3	9.4
SAL-31	34.605	-92.619	343	80402030103	North Fork Saline River	5.5	83.0	10.9
SAL-32	34.673	-92.799	234	80402030303	Alum Fork Saline River	5.0	85.7	7.3
SAL-37	34.597	-92.743	276	80402030304	Middle Fork Saline River	12.8	75.1	11.0
SAL-5	34.353	-92.632	174	80402030604	Francois Creek	7.5	65.2	17.1
SAL-8	34.352	-92.341	382	80402030404	Hurricane Creek	14.4	60.5	14.6
SAL-N1	34.136	-92.405	7.60	80402030901	Gamble Creek	5.4	42.8	28.4
SAL-N10	34.575	-92.495	98.4	80402030401	Hurricane Creek	30.4	42.7	23.9
SAL-N11	34.28	-92.548	21.7	80402030806	Polk Creek	5.3	71.0	20.6
SAL-N12	34.657	-92.566	26.6	80402030401	Hurricane Creek	8.4	63.0	11.6
SAL-N13	34.412	-92.734	24.9	80402030602	Reyburn Creek	7.3	70.2	18.3
SAL-N14	34.645	-92.554	1.70	80402030401	Hurricane Creek	31.8	45.6	22.0
SAL-N16	34.639	-93.012	1.50	80402030201	Cedar Creek	6.7	47.9	45.4
SAL-N17	34.314	-92.561	10.2	80402030806	Herbert Creek	10.3	33.4	54.3
SAL-N2	34.21	-92.548	2310	80402030806	Saline River	9.6	67.5	13.3
SAL-N3	34.116	-92.406	2902	80402030901	Saline River	5.7	57.7	13.8
SAL-N4	34.725	-93.066	18.3	80402030301	Middle Fork Saline River	4.9	89.1	5.9
SAL-N6	34.364	-92.458	104	80402030801	Lost Creek	6.5	73.8	11.3
SAL-N7	34.491	-92.478	6.40	80402030801	Wet Lost Creek	13.8	71.7	9.0
SAL-N8	34.558	-92.464	121	80402030401	Hurricane Creek	28.7	42.7	24.9
SAL-N9	34.555	-92.764	247	80402030202	South Fork Saline River	17.7	64.4	15.3
SAL-U1	34.795	-93.007	13.7	80402030302	South Alum Creek	5.0	94.6	0.4
SAL-U2	34.797	-92.934	69.6	80402030302	Alum Fork Saline River	4.2	94.5	1.3
SAL-U4	34.229	-92.373	27.9	80402030405	Hurricane Creek	14.7	59.9	14.9
SAL-U6	34.795	-92.844	115	80402030302	Alum Fork Saline River	4.1	91.0	0.9

[1]Urban includes developed open space, low intensity, medium intensity, high intensity, and barren land. [2]Forest includes deciduous, evergreen, mixed forests, and shrub/scrub. [3]Agriculture includes cultivated crops, pasture/hay, and grasslands.

Watershed Metrics Development

Model My Watershed was used to delineate each site's catchment areas (Stroud Water Research Center, 2017). The catchment LULC percentages above each site were calculated in ArcGIS Pro using the 2001, 2011, and 2021 National Landcover Database (NLCD) raster (Dewitz, 2023) (Table 3). Land use percentages were then calculated. The 2021 LULC percentages were used for statistical analysis.

Several watershed metrics were also gathered. ArcGIS Pro tools were used to find the urban, forest, agriculture, and wetland LULC classes within the 30 m and 90 m riparian areas along the “Medium Resolution: National Hydrology Dataset Flowline Feature” stream corridor layer from the Arkansas GIS office for 2001, 2011, and 2021. The 2021 riparian LULC was used for statistical analysis. The catchment area stream density, total road density, and unpaved road density were analyzed by using the “Medium Resolution: National Hydrology Dataset Flowline Feature” layer and the “Roads All” layer from the Arkansas GIS office divided by the site’s catchment area. The Nature Conservancy provided a stream road crossing layer. All land use metrics used in statistical analyses are described in Table 3.

Table 3. Watershed metrics that will be used and their descriptions.

Watershed Metric	Units	Definition
% Forested	%	The sum of deciduous, evergreen, mixed forests, and shrub/scrub covers within a catchment area divided by the total catchment area.
% Natural Forest	%	The sum of deciduous and mixed forests covers within a catchment area divided by the total catchment area.
% Evergreen Forest	%	The sum of evergreen forest cover within a catchment area divided by the total catchment area.
% Urban	%	The sum of developed open space, low intensity, medium intensity, high intensity urban, and barren covers within a catchment area divided by the total catchment area.
% Agriculture	%	The sum of cultivated crops, pasture/hay, and grasslands covers within a catchment area divided by the total catchment area.
% Human Development Index (HDI)	%	The sum of urban and agriculture LULC % categories within a catchment area divided by the total catchment area.
% Forested Riparian buffer (30 m & 90 m)	%	The sum of forest land use categories within a 30 m, 60 m, and 90 m buffer area divided by total buffer area.
% Urban Riparian Buffer (30 m & 90 m)	%	The sum of urban land use categories within a 30 m, 60 m, and 9 0m buffer area divided by total buffer area.
% Agriculture Riparian buffer (30 m &90 m)	%	The sum of agriculture land use categories within a 30 m, 60 m, and 90 m buffer area divided by total buffer area.
% Human Development Index (HDI) Buffer (30 m & 90 m)	%	The sum of urban and agriculture LULC % categories within a 30 m, 60 m, and 90 m buffer area divided by total buffer area.
Stream Density	km/km^2	Total length of stream within the catchment area divided by the total catchment area.
Stream Road Crossings	$\#/km^2$	The number of stream road crossings within the catchment area divided by the total catchment area.
Total Road Density	km/km^2	Total length of roads within the catchment area divided by the total catchment area.
Unpaved Road Density	km/km^2	Total length of gravel roads within the catchment area divided by the total catchment area.

CART Analysis

Concentrations reported as zeros were changed to represent the lowest detected concentration for each constituent. This allowed for the geometric mean to be calculated for each site's water quality constituent data in R (version 4.3.2). The geometric mean of the constituents was chosen because geometric means are less sensitive to low and high values than arithmetic means, which is needed when working with variable environmental data.

The point source (PS) discharge density within each site's catchment area was calculated to remove sites substantially influenced by PS pollutants so that analysis would focus on non-point source (NPS) pollutants. Model My Watersheds point source estimations were delineated for each site and then divided by the site's catchment area (Stroud Water Research Center, 2017). Model My Watershed lists the point source discharges within the catchment areas that are registered with the US EPA's National Pollution Discharge Elimination System (NPDES) (Stroud Water Research Center, 2017). These NPDES-permitted discharges are primarily from large municipal and industrial wastewater treatment plants (Stroud Water Research Center, 2017). The geometric mean of each site's water quality constituent was run against the gathered PS discharge density using a non-parametric change point analysis. The non-parametric change point analysis gives a threshold where a significant shift occurs in pollutant levels. The produced threshold for each water quality constituent was then averaged together, giving a value of 23.27 $L/d/m^2$. Sites with a PS discharge density above the 23.27 $L/d/m^2$ threshold were predicted to influence water chemistry and, therefore, removed. Sites SAL-N8 and SAL-N10 were removed from the analysis.

Classification and regression tree (CART) analysis is a tree-based classification technique that can be used for predictive modeling (Uddameri et al., 2020). It has the ability to predict the category a value may fall into when data is non-linear and has been used to find meaningful relationships between watershed metrics and water quality (McCarty et al., 2018; Uddameri et al., 2020). Classification and regression tree analysis gives the data structure through multiple threshold splits, giving first a primary threshold, then secondary, tertiary, and so on. The CART analyses were performed using the constituent's geometric means with all watershed metrics (Table 3) using R (version 4.3.2). To avoid overpredicting, the CART analysis trees were pruned so that a minimum of three sites is within each threshold split. Each threshold split also had to explain more than or equal to 5 percent variability or have a complexity factor increase by 0.05.

The 30 m and 90 m riparian areas LULCs were highly correlated, so only one riparian size was applied to each water quality constituents CART analysis. The 30 m riparian area LULCs were applied to the sediment water quality constituents, while the 90 m riparian area LULCs were applied to the nutrient water quality constituents. This was chosen because sediments likely come from the stream bank area within the buffer, while nutrients can be transported across the larger riparian zone to the stream channel.

Several CART analyses produced threshold splits that were statistically significant but did not make conceptual sense. If this occurred, the next best statistically significant split was chosen if the split still explained more than or equal to 5 percent variability or had a complexity factor increase by 0.05.

HUC-12 Watershed Prioritization

HUC-12 areas within the Upper Saline River watershed were gathered from the Arkansas GIS office's "12 Digit Watershed Boundary Dataset 2017" layer (USGS, 2023) (Fig. 2). All watershed metrics were found for each HUC-12 area using the same methods as previously described (Table 3).

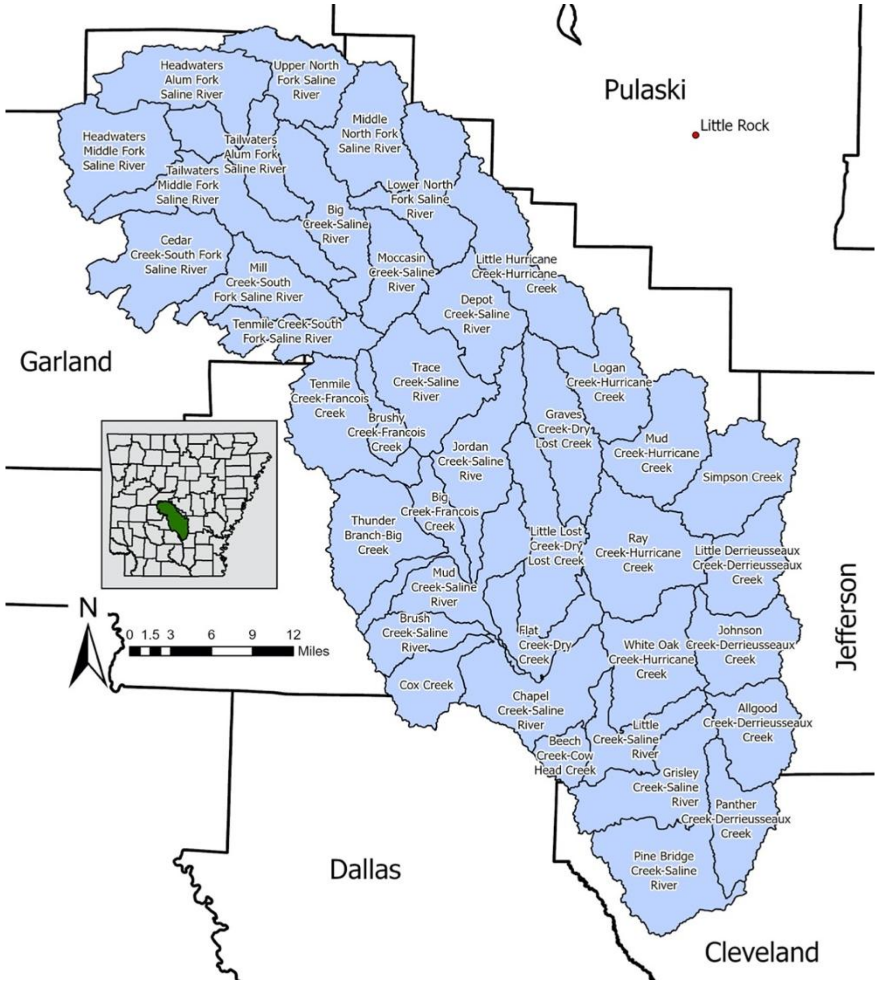
The CART analyses using the geometric means of the water quality constituents were used to build HUC-12 watershed prioritization maps because CART explained the greatest variation in the data when compared to simple linear regression. The given CART watershed metric thresholds for each water quality constituent were applied to each of the HUC-12 watersheds. Using the given thresholds, prioritization maps detailing areas of high, medium, and low priority areas for conservation and protection for each water quality constituent were created in ArcGIS Pro.

To address the chemical constituents carrying most of the prioritization weight, chemical constituents maps were combined into four main groups: nitrogen, phosphorus, sediments, and human influence. To do this, the high, medium, and low-priority HUC-12s were ranked as 5, 3, and 1 for each priority map. Then, each HUC-12 ranking for each map was added together. HUC-12s were then re-ranked based on the HUC-12 sums. HUC-12s falling with a rank of 10 were high priority, HUC-12s ranked between 6-9 were medium priority, and HUC-12s with a rank of 5 or below were low priority.

A separate map was made to address 303(d) listed streams. If a HUC-12 area included a 303(d) listed stream within its boundaries, it was ranked as a high priority, while if no listed stream was present, it was ranked as a low priority. Two more maps were made to address forest landcover change. The forest landcover change from 2001 to 2021 was calculated for each HUC-12s' 90 m riparian buffer and HUC-12 area. If a 90 m riparian buffer area or HUC-12 area lost more than 1% of its forest cover, then it was ranked as a high priority, while if less than 1% was lost, it was ranked as a low priority. The two forest cover change maps HUC-12 areas were then ranked using the same methods as the chemical constituents, where a high priority area had a rank of 5, a medium priority had a rank of 3, and a low priority area had a rank of 1.

To calculate a final HUC-12 prioritization map, we took the sum of each HUC-12's ranks and added them together. We then calculated the 1/3rd and 2/3rd percentiles to split the HUC-12s into three groups. The 1/3rd percentile was 17, while the 2/3rd percentile was 24. If a HUC-12 had a sum between 7 and 16, it was ranked as a low priority, a sum between 17 and 23 was ranked as medium priority, and a sum between 24 and 35 was ranked as high priority.

Figure 2. Upper Saline River watershed HUC-12's and surrounding Arkansas counties.



Results

Historical Data Analysis

Between 1990 and 2023, the annual 75th percentile median TP concentrations within the Upper Saline River watershed ranged from 0.020 to 0.175 mg/L. The TP concentrations within the watershed showed a general decreasing trend between 1990 and 2023 (Fig. 3). Specifically, the MK results showed a decrease of 1.5%/yr on average across the watershed ($p=0.04$). The resulting p-value of 0.041 falls within our significance level of the trend being likely. However, the LOESS line shows variation within the data (Fig. 3). Specifically, there has been a general decrease in the annual 75th percentile median TP concentrations until 2014, while after 2014, there has been a general increase.

Annual 75th median percentile TN concentrations within the watershed ranged from 0.35 to 1.44 mg/L between 1990 and 2023. Like TP, the TN concentrations within the watershed showed a general decreasing trend (Fig. 4). Specifically, the MK results showed an average annual TN concentration decrease of 2.6%/yr across the watershed ($p<0.01$). However, the TN concentration trends were more significant than TP's, falling within our very likely significance category. Also like TP, TN's LOESS line showed variation within the data with a general annual 75th percentile median TN concentration decrease until 2014, where after 2014, TN began to increase again (Fig. 4).

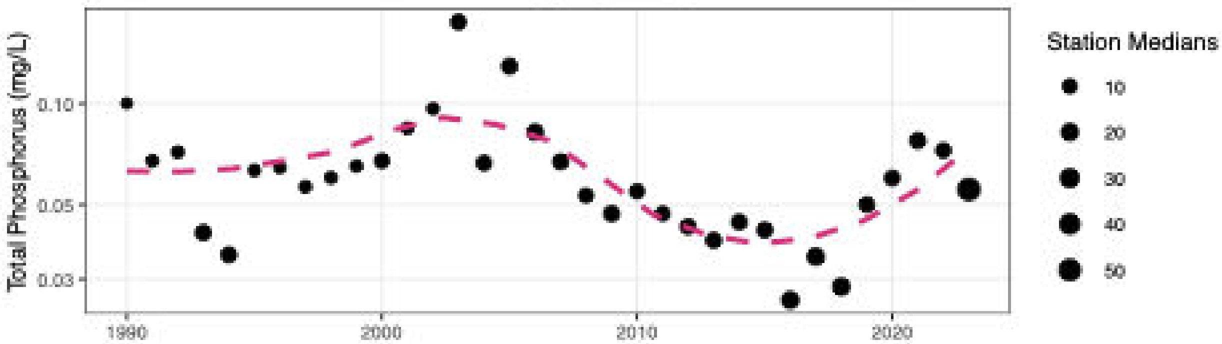


Figure 3. Mean of the sites 75th percentile TP concentrations within the Upper Saline River Watershed through time. The red dashed line represents the LOESS relationship. Dot sizes change based on how many monitoring sites were considered for each year (MK p=0.04) (MK slope = -1.5 %/yr).

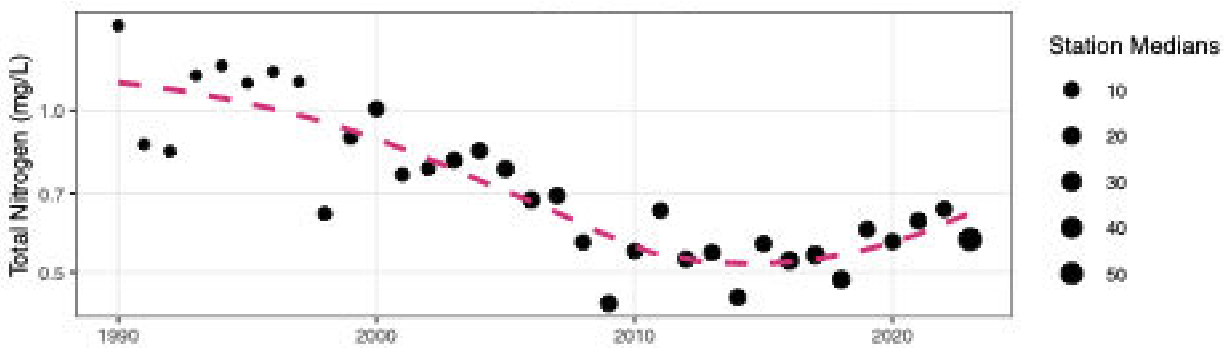


Figure 4. Mean of the sites 75th percentile TN concentrations within the Upper Saline River Watershed through time. The red dashed line represents the LOESS relationship. Dot sizes change based on how many monitoring sites were considered for each year (MK p<0.01) (MK slope = -2.6 %/yr).

Human Influence

Chloride

Geometric mean chloride concentrations ranged from 1.0 to 18.1 mg/L across all 29 sites within the Upper Saline River Watershed. Two forested watershed metrics showed structure within the CART analysis and explained the most variation within the data when predicting chloride concentrations (r^2=0.59) (Fig. 5). The primary split with 90 m forested riparian buffer showed a threshold response at 58% (partial r^2=0.48); sites with less than 58% forest cover within the 90 m riparian buffer area had a mean chloride concentration of 4.7 mg/L (i.e. predicted high category) (Fig. 5). A secondary threshold response was seen with the catchment forest cover (partial r^2=0.11); site catchments that exceed a catchment forest cover of 79% had a mean chloride concentration of 1.5 mg/L (i.e. predicted low category), while sites below the 79% threshold had a mean of 2.8 mg/L (i.e. predicted medium category) (Fig. 5). When the CART thresholds were applied to the HUC-12 watershed metrics 22 were ranked within the high category, 9 in the medium, and 9 in the low (Fig. 5).

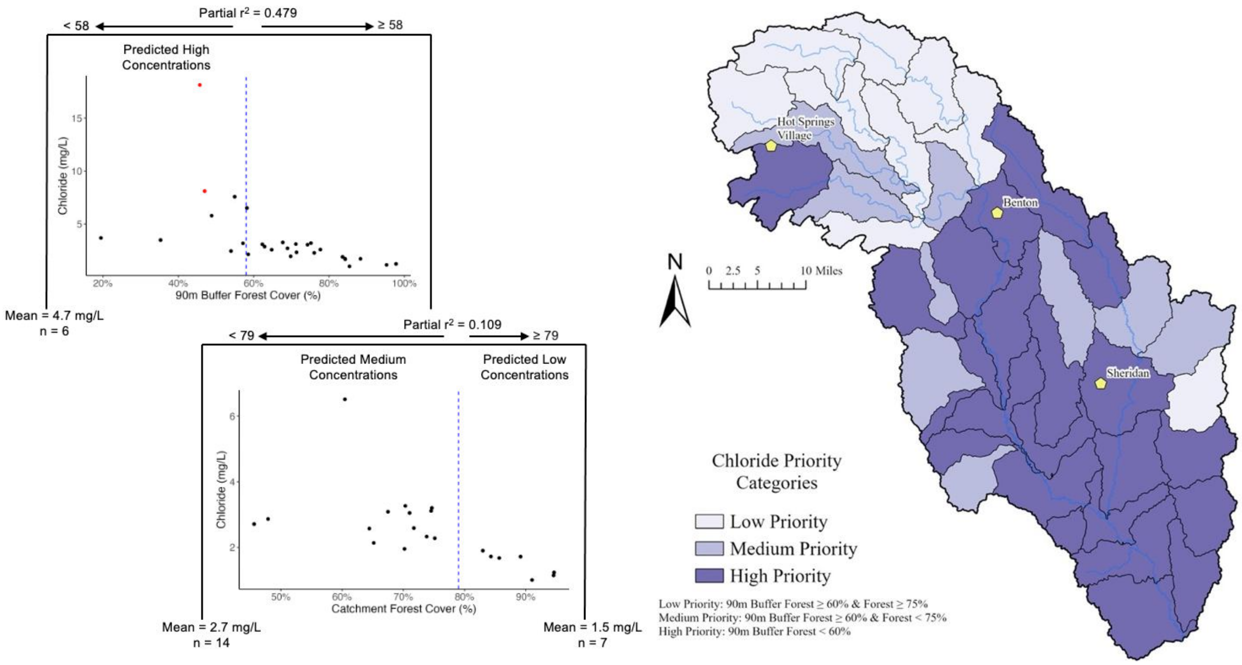


Figure 5. The CART results for chloride and the corresponding watershed metric predictors. Vertical blue dashed lines represent the change points (CP). Red dots show sites SAL-N8 and SAL-N10, which were not used in the statistical analysis. The HUC-12s were ranked in low, medium, and high priority categories based on the chloride CART analysis.

Conductivity

Geometric mean conductivity ranged from 12 to 346 µS/cm across all 29 sites within the Upper Saline River Watershed. Two 90 m riparian buffer watershed metrics showed structure within CART and explained the most variation within the data when predicting conductivity (r^2=0.62) (Fig. 6). The primary split with 90 m urban riparian buffer showed a threshold response at 7.5% (partial r^2=0.53); sites with more than 7.5% urban cover within the 90 m riparian buffer area had a mean conductivity of 150 µS/cm (i.e. predicted high category) (Fig. 6). A secondary threshold response was seen with the 90 m HDI riparian buffer cover (partial r^2=0.09); site catchments that exceed a catchment HDI cover of 10% had a mean conductivity of 71 µS/cm (i.e. predicted medium category), while sites below the 10% threshold had a mean of 26 µS/cm (i.e. predicted low category) (Fig. 6). When the CART thresholds were applied to the HUC-12 watershed metrics 4 were ranked within the high category, 17 in the medium, and 19 in the low (Fig. 6).

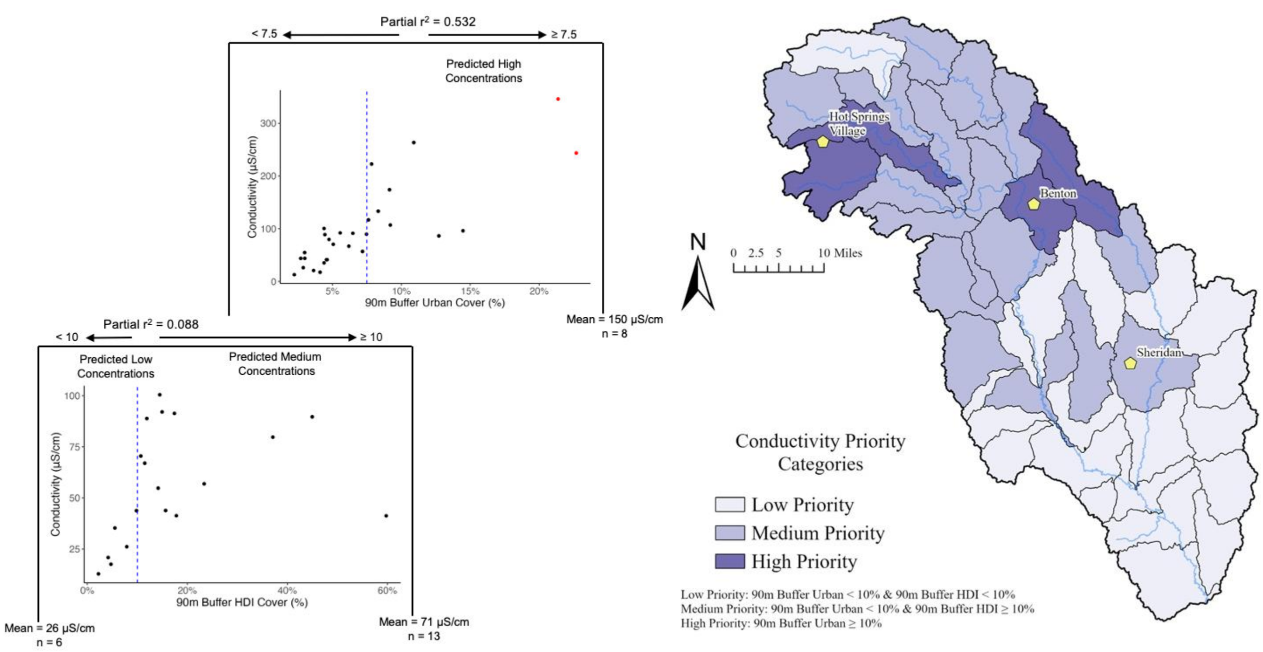


Figure 6. The CART results for conductivity and the corresponding watershed metric predictors. Vertical blue dashed lines represent the change points (CP). Red dots show sites SAL-N8 and SAL-N10, which were not used in the statistical analysis. The HUC-12s were ranked in low, medium, and high priority categories based on the conductivity CART analysis.

Overall Human Influence Priority

The two human influences water quality constituents, chloride and conductivity, HUC-12s were ranked based on the priority category each HUC-12 area fell into. The two maps were added together to create one human influence priority map. The overall human influence priority map has 3 HUC-12 areas within the high priority category, 24 within the medium, and 13 within the low (Fig. 7).

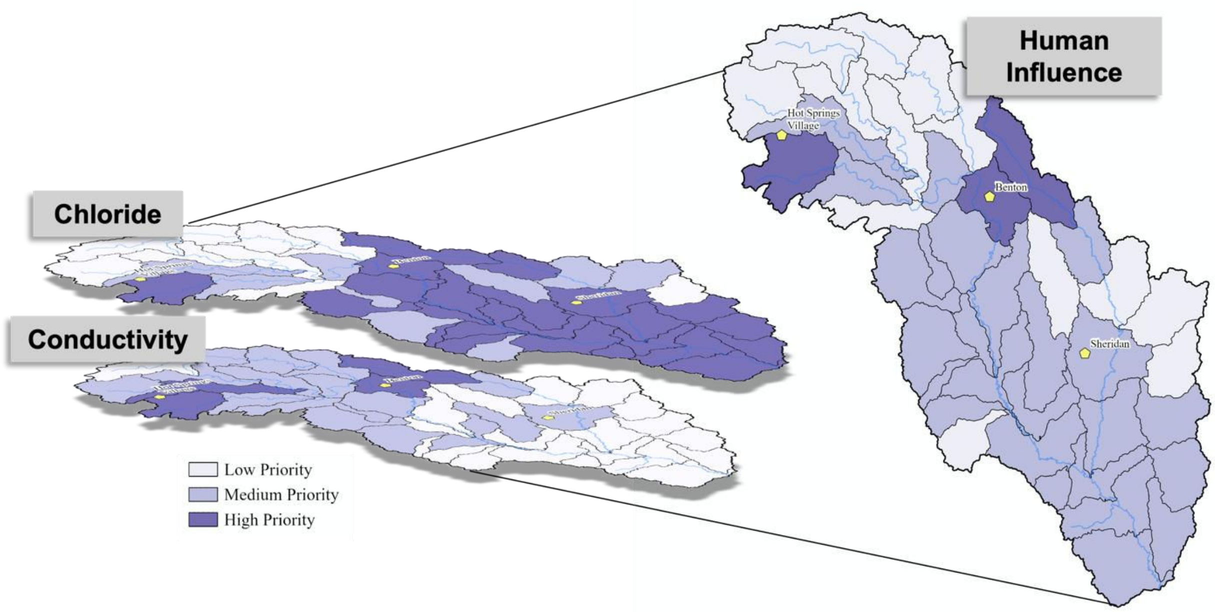


Figure 7. Potential prioritization of HUC-12 watersheds within the Upper Saline River Watershed based on chloride and conductivity water quality constituents. Priority varies from lightest (low priority) to darkest (high priority).

Phosphorus

Soluble Reactive Phosphorus

Geometric mean SRP concentrations ranged from 0.002 to 0.150 mg/L across all 29 sites within the Upper Saline River Watershed. Watershed metrics showed structure within CART when predicting SRP concentrations, explaining the most variation within the data (r^2=0.60) (Fig. 8). The primary split was with natural forest cover (partial r^2=0.51); sites with less than 8.4% catchment natural forest cover had a mean SRP concentration of 0.024 mg/L (i.e. predicted high category) (Fig. 8). A secondary threshold response was seen with the catchment agricultural landcover (partial r^2=0.09); site catchments that exceeded an agriculture landcover of 11% had a mean SRP concentration of 0.009 mg/L (i.e. predicted medium category), while sites below the 11% threshold which had an SRP concentration of 0.003 mg/L (i.e. predicted low category) (Fig. 8). When SRP's CART thresholds were applied to the HUC-12 watershed metrics 22 HUC-12 areas were ranked within the high category, 6 in the medium, and 12 in the low (Fig. 8).

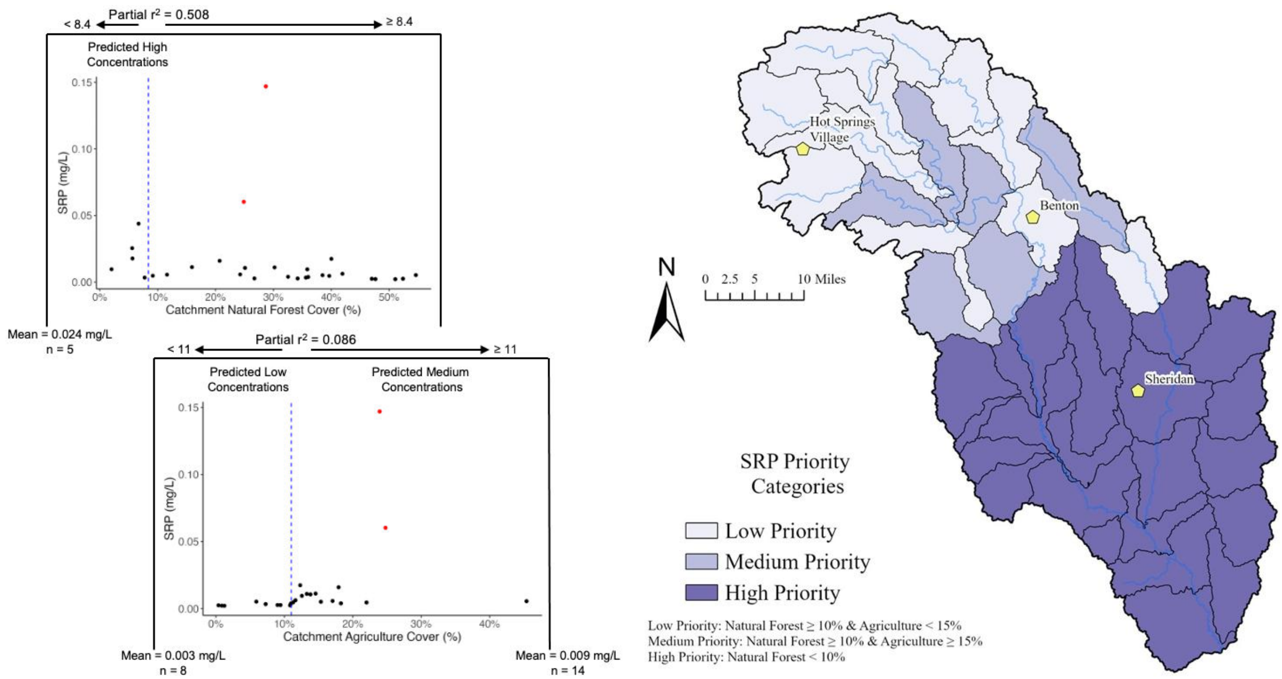


Figure 8. The CART results for SRP and the corresponding watershed metric predictors. Vertical blue dashed lines represent the change points (CP). Red dots show sites SAL-N8 and SAL-N10, which were not used in the statistical analysis. The HUC-12s were ranked in low, medium, and high priority categories based on the SRP CART analysis.

Total Phosphorus

Geometric mean TP concentrations ranged from 0.006 to 0.320 mg/L across all 29 sites within the Upper Saline River Watershed. The watershed metrics showed structure when predicting TP concentrations with CART, explaining the most variation within the data (r^2=0.65) (Fig. 9). The primary split, like SRP, was with natural forest cover (partial r^2=0.45); sites with less than 7.2% catchment natural forest cover had a mean TP concentration of 0.095 mg/L (i.e. predicted high category) (Fig. 9). A secondary threshold response was seen with the catchment stream density (partial r^2=0.20); site catchments that exceeded a stream density of 1.1 km/km^2 had a mean TP concentration of 0.046 mg/L (i.e. predicted medium category), while sites below the 1.1 km/km^2 threshold had a mean of 0.012 mg/L (i.e. predicted low category) (Fig. 9). When the TP CART thresholds were applied to the HUC-12 watershed metrics 22 HUC-12 areas were ranked within the high category, 9 in the medium, and 9 in the low (Fig. 9).

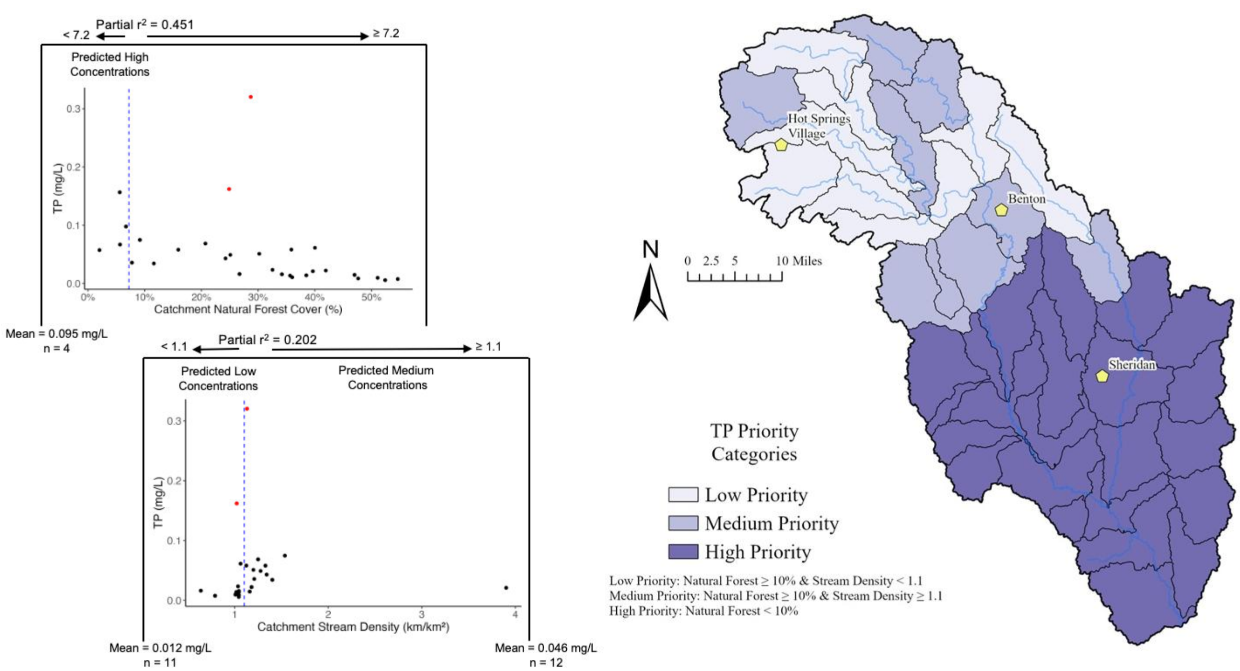


Figure 9. The CART results for TP and the corresponding watershed metric predictors. Vertical blue dashed lines represent the change points (CP). Red dots show sites SAL-N8 and SAL-N10, which were not used in the statistical analysis. The HUC-12s were ranked in low, medium, and high priority categories based on the TP CART analysis.

Overall Phosphorus Priority

The two phosphorus water quality constituents, SRP and TP, HUC-12s were ranked based on the priority category each HUC-12 area fell into. The two maps were added together to create one phosphorus priority map. The overall phosphorus priority map has 22 HUC-12 areas within the high priority category, 3 within the medium, and 15 within the low (Fig. 10).

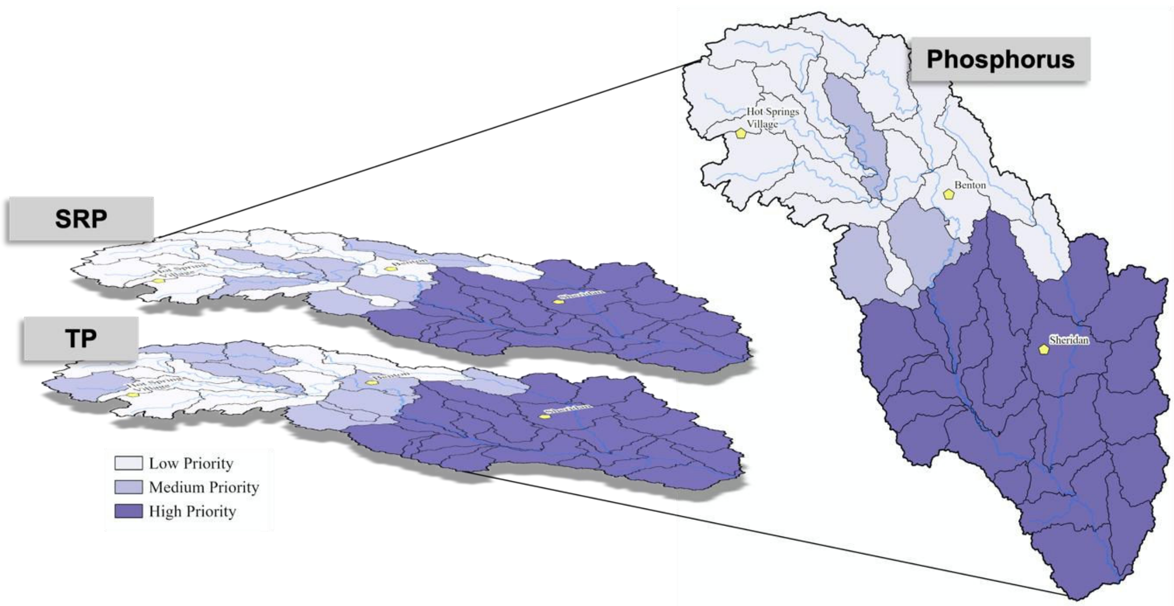


Figure 10. Potential prioritization of HUC-12 watersheds within the Upper Saline River Watershed based on phosphorus water quality constituents. Priority varies from lightest (low priority) to darkest (high priority).

Nitrogen

Nitrate

Geometric mean nitrate concentrations ranged from 0.004 to 0.778 mg/L across all 29 sites within the Upper Saline River Watershed. Only one watershed characteristics with CART showed structure when predicting nitrate concentrations, explaining the most variation within the data (r^2=0.55) (Fig. 11). The primary split was with catchment urban cover; sites with less than 10% catchment urban cover had a mean nitrate concentration of 0.036 mg/L (i.e. predicted low category) while sites below the threshold had a mean of 0.140 mg/l (i.e. predicted high category (Fig. 11). When the nitrate CART thresholds were applied to the HUC-12 watershed metrics, 7 HUC-12 areas were ranked within the high category, and 33 were in the low category (Fig. 11).

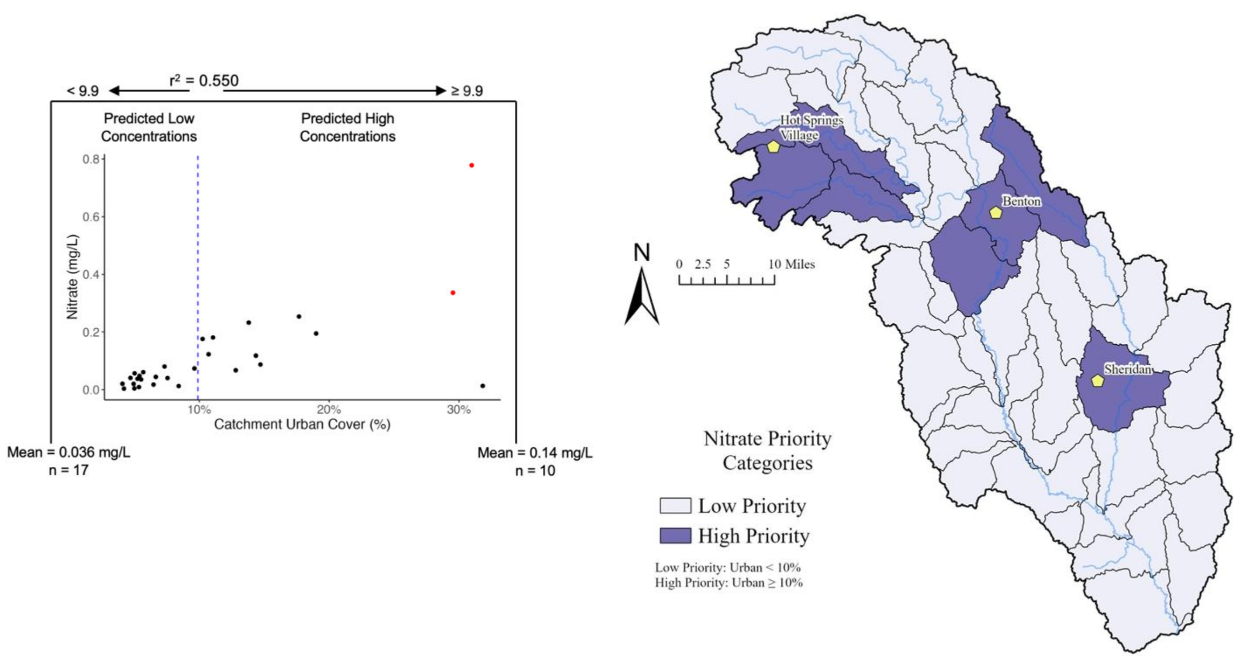


Figure 11. The CART results for nitrate and the corresponding watershed metric predictors. Vertical blue dashed lines represent the change points (CP). Red dots show sites SAL-N8 and SAL-N10, which were not used in the statistical analysis. The HUC-12s were ranked in low, medium, and high priority categories based on the nitrate CART analysis.

Ammonia-N

Geometric mean ammonia concentrations ranged from 0.003 to 0.082 mg/L across all 29 sites within the Upper Saline River Watershed. Watershed metrics showed structure with CART when predicting ammonia concentrations, explaining the most variation within the data (r^2=0.87) (Fig. 12). The primary split was with natural forest cover (partial r^2=0.59); sites with more than 25% catchment natural forest cover had a mean ammonia concentration of 0.006 mg/L (i.e. predicted low category) (Fig. 12). A secondary threshold response was observed with the 90 m forested riparian buffer cover (partial r^2=0.28); catchments with more than 58% 90 m forested riparian buffer cover had a mean ammonia concentration of 0.014 mg/L (i.e. predicted medium category). Sites below the threshold had a mean of 0.032 mg/L (i.e. predicted high category) (Fig. 12). When the ammonia CART thresholds were applied to the HUC-12 watershed metrics 21 HUC-12 areas were ranked within the high category, 11 in the medium, and 8 in the low (Fig. 12).

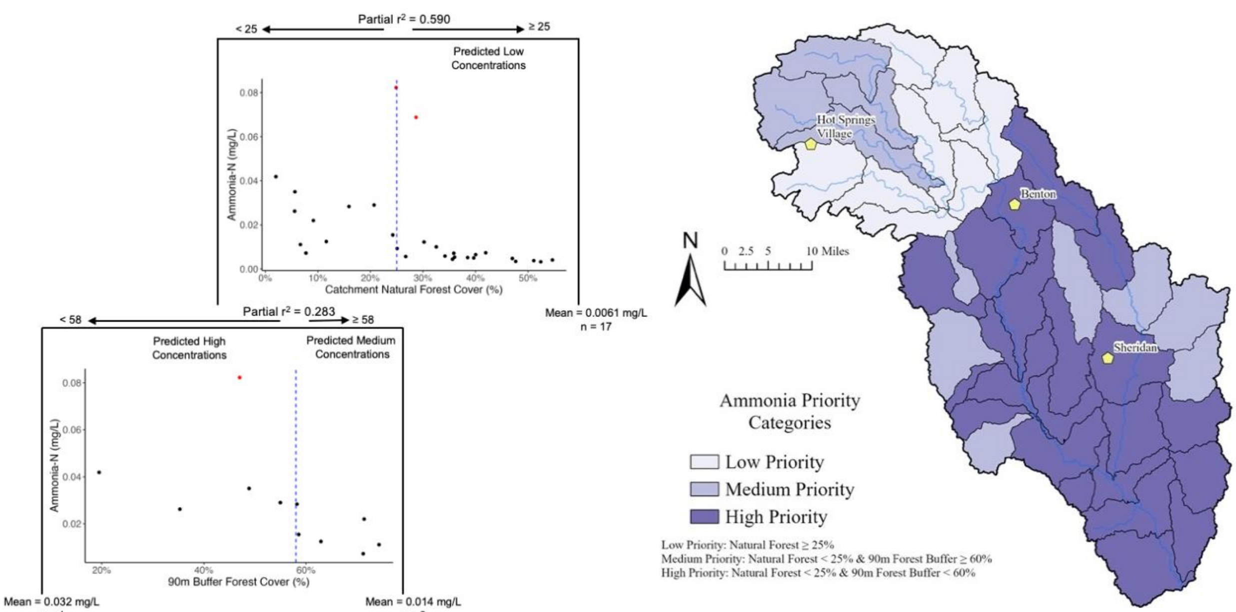


Figure 12. The CART results for ammonia and the corresponding watershed metric predictors. Vertical blue dashed lines represent the change points (CP). Red dots show sites SAL-N8 and SAL-N10, which were not used in the statistical analysis. The HUC-12s were ranked in low, medium, and high priority categories based on the ammonia CART analysis.

Total Nitrogen

Geometric mean TN concentrations ranged from 0.11 to 1.71 mg/L across all 29 sites within the Upper Saline River Watershed. Watershed metrics that showed structure with CART and explained the most variation within the data when predicting TN concentrations included catchment forest and natural forest cover (r^2=0.80) (Fig. 13). The primary split with catchment forest had a threshold response at 75% (partial r^2=0.62); sites with more than 75% catchment forest cover had a mean TN concentration of 0.20 mg/L (i.e. predicted low category) (Fig. 13). A secondary threshold response was seen with the catchment natural forest (partial r^2=0.18); site catchments that exceed a natural forest cover of 6.2% had a mean TN concentration of 0.51 mg/L (i.e. predicted medium category), while sites below the 6.2% threshold had a mean of 0.79 mg/L (i.e. predicted high category) (Fig. 13). When the TN CART thresholds were applied to the HUC-12 watershed metrics 24 HUC-12 areas were ranked within the high category, 7 in the medium, and 9 in the low (Fig. 13).

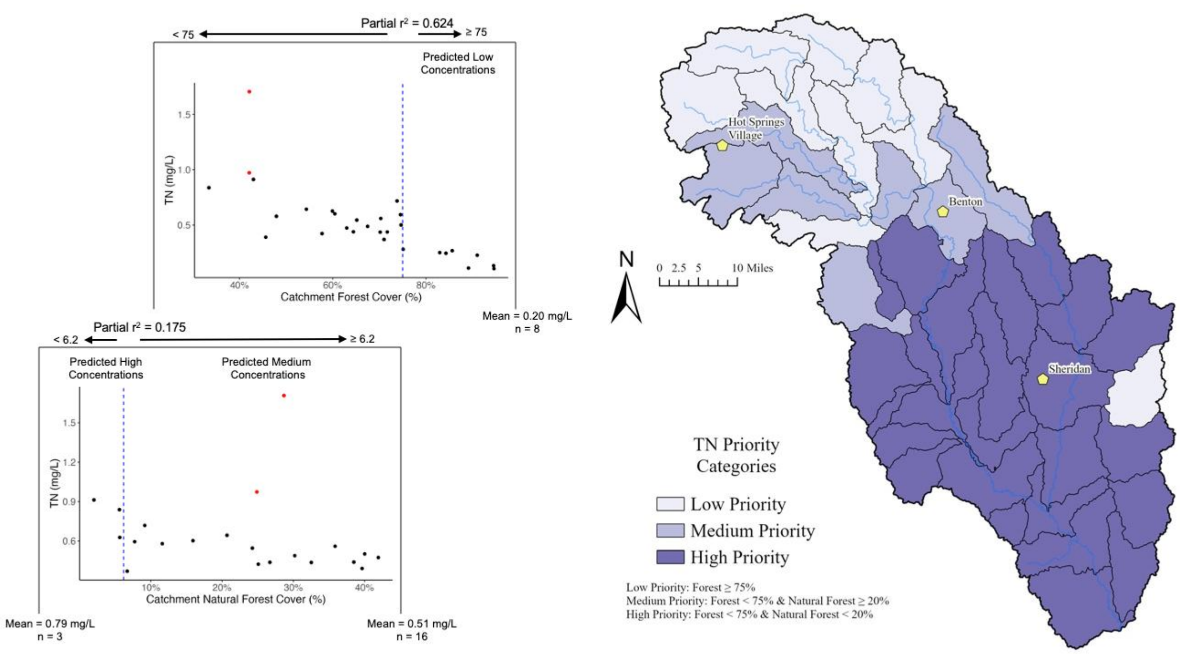


Figure 13. The CART results for TN and the corresponding watershed metric predictors. Vertical blue dashed lines represent the change points (CP). Red dots show sites SAL-N8 and SAL-N10, which were not used in the statistical analysis. The HUC-12s were ranked in low, medium, and high priority categories based on the TN CART analysis.

qOverall Nitrogen Priority

Three nitrogen water quality constituents, ammonia, nitrate, and TN were used for the overall nitrogen priority ranking. Their HUC-12s were ranked based on the priority category each HUC-12 area fell into. The three maps were added together to create one nitrogen map. The overall nitrogen priority map has 21 HUC-12 areas within the high priority category, 9 within the medium, and 10 within the low (Fig. 14).

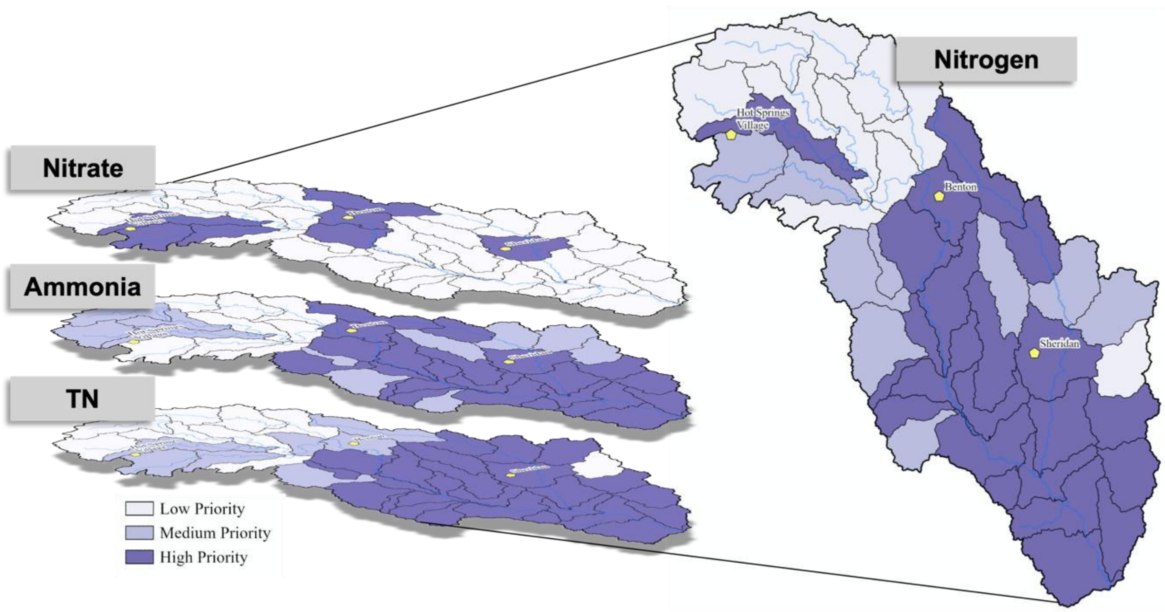


Figure 14. Potential prioritization of HUC-12 watersheds within the Upper Saline River Watershed based on nitrogen water quality constituents. Priority varies from lightest (low priority) to darkest (high priority).

Sediments

Total Suspended Solids

Geometric mean TSS concentration ranged from <1 to 12 mg/L across all 29 sites within the Upper Saline River Watershed. The watershed metrics CART analysis that explained the most variation within the data when predicting TSS concentrations showed the most complex structure out of all the water quality parameters (r^2=0.79) (Fig. 15). A primary split with the 30 m forested riparian buffer area was seen with a threshold response at 72% (partial r^2=0.48). Sites below the 72% threshold had a secondary split with the catchment evergreen forest cover which also showed a threshold response at 20% (partial r^2=0.17) (Fig. 15). Sites below the 20% catchment evergreen forest cover threshold had a mean TSS concentration of 3 mg/L, while sites above the threshold had a tertiary split with catchment unpaved road density (partial r^2=0.09) (i.e. predicted low category) (Fig. 15). Sites with less than or equal to 0.75 km/km^2 catchment unpaved road density had a mean TSS concentration of 6 mg/L (i.e. predicted medium category), and sites above the 0.75 km/km^2 threshold had a mean concentration of 10 mg/L (i.e. predicted high category) (Fig. 15). On the other side of TSS primary split, sites with greater than 72% 30 m forested riparian buffer cover had a secondary threshold split with the catchment forest cover, which also showed a threshold response at 75% (partial r^2=0.06) (Fig. 15). Sites above the 75% threshold had a mean TSS concentration of 3.82 mg/L, and sites below the had a mean of 1.17 mg/L (i.e. predicted low category) (Fig. 15). When the CART thresholds were applied to the HUC-12 watershed metrics 17 HUC-12 areas were ranked within the high category, 10 in the medium, and 13 in the low. (Fig. 15).

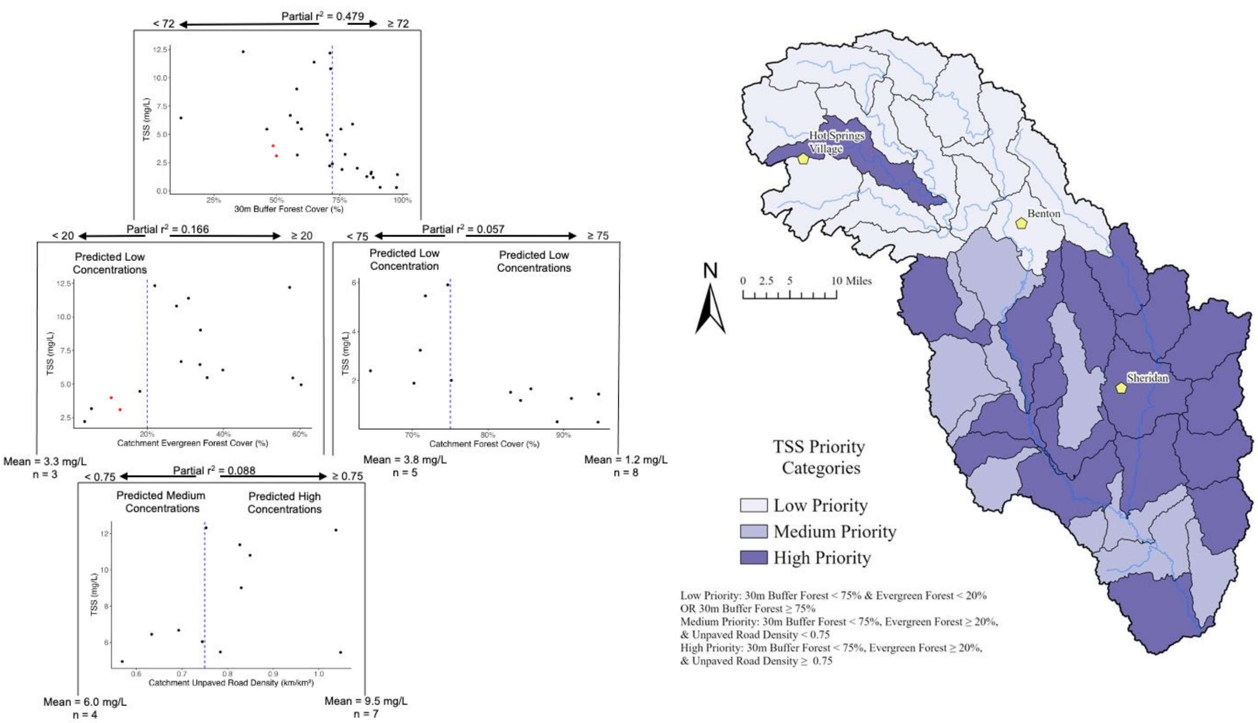


Figure 15. The CART results for TSS and the corresponding watershed metric predictors. Vertical blue dashed lines represent the change points (CP). Red dots show sites SAL-N8 and SAL-N10, which were not used in the statistical analysis. The HUC-12s were ranked in low, medium, and high priority categories based on the TSS CART analysis.

Turbidity

Geometric mean turbidity ranged from 1.8 to 23.6 NTU's across all 29 sites within the Upper Saline River Watershed. Watershed metrics showed structure with CART when predicting turbidity, explaining the most variation within the data (r^2=0.76) (Fig. 16). The primary split was with catchment natural forest cover (partial r^2=0.60). Sites with less than 31% natural forest cover within the catchment area had a secondary threshold split with the 30 m forested riparian buffer cover (partial r^2=0.11), while sites with above the threshold had a mean turbidity of 5.3 NTU's (i.e. predicted low category) (Fig. 16). For the secondary threshold split, sites with less than 71% forest landcover within the 30 m riparian buffer area had a tertiary threshold split with catchment unpaved road density (partial r^2=0.05), while above the 71% threshold sites had a mean turbidity of 9.5 NTU's (i.e. predicted medium category) (Fig. 16). While, for the tertiary threshold split, sites with less than 0.72 km/km^2 catchment unpaved road density had a mean turbidity concentration of 13.7 NTU (i.e. predicted medium category), and sites above the threshold had a mean of 17.6 NTU (i.e. predicted high category) (Fig. 16). When the turbidity CART thresholds were applied to the HUC-12 watershed metrics 18 HUC-12 areas were ranked within the high category, 12 in the medium, and 10 in the low. (Fig. 16).

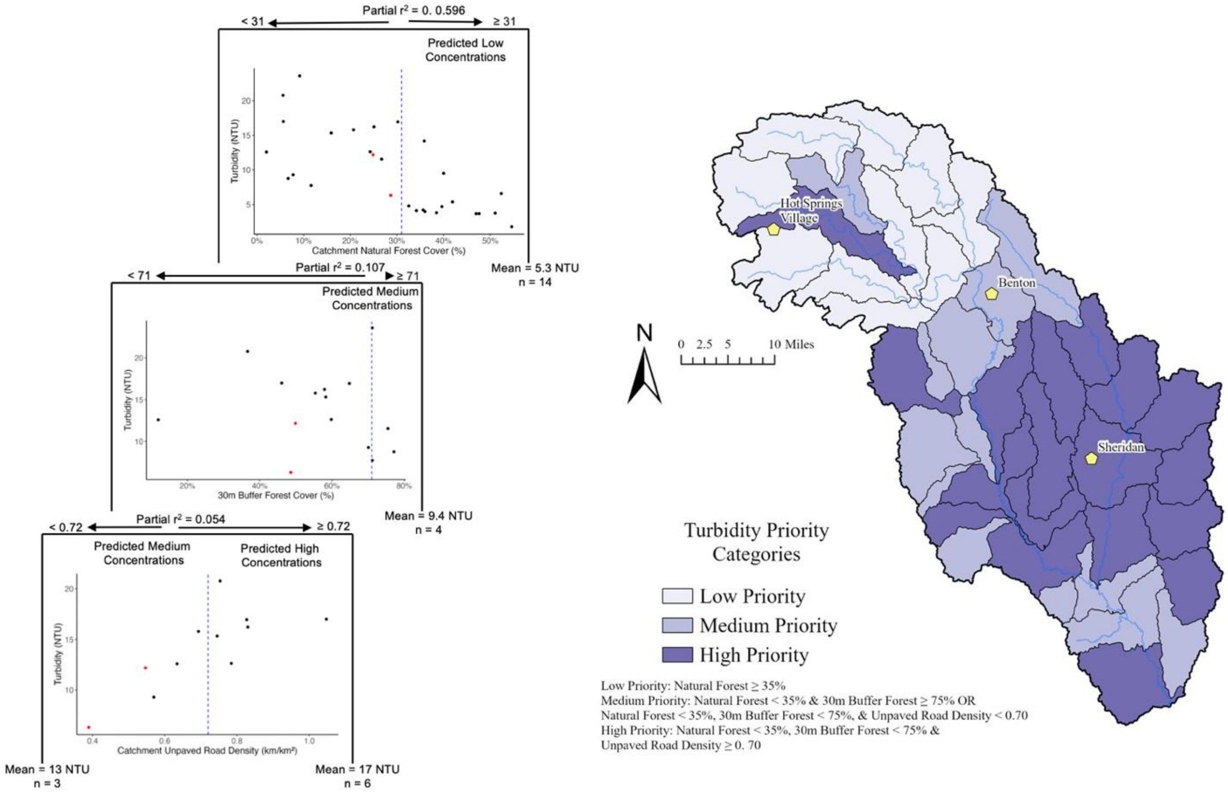


Figure 16. The CART results for turbidity and the corresponding watershed metric predictors. Vertical blue dashed lines represent the change points (CP). Red dots show sites SAL-N8 and SAL-N10, which were not used in the statistical analysis. The HUC-12s were ranked in low, medium, and high priority categories based on the turbidity CART analysis.

Overall Sediment Priority

The two sediment water quality constituents, TSS and turbidity, were used for the overall sediment priority ranking. Their HUC-12s were ranked based on the priority category each HUC-12 area fell into. The three maps were added together to create one sediment map. The overall sediment priority map has 17 HUC-12 areas within the high priority category, 10 within the medium, and 13 within the low (Fig. 17).

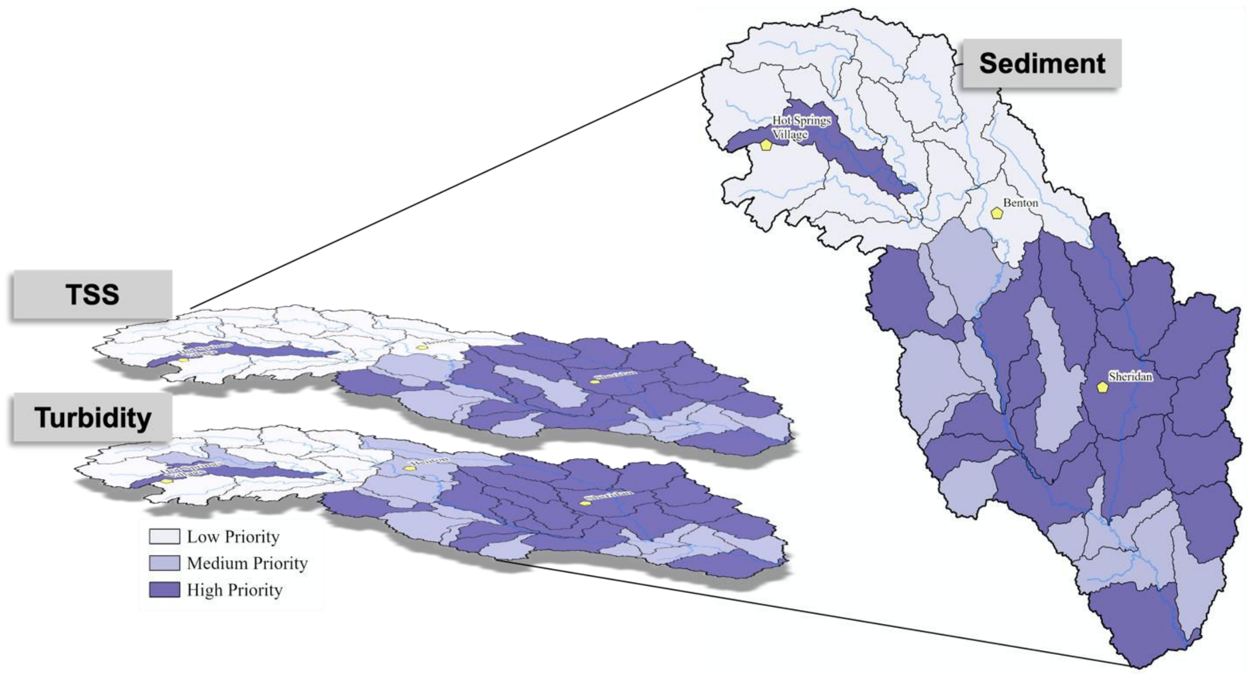


Figure 17. Potential prioritization of HUC-12 watersheds within the Upper Saline River Watershed based on sediment water quality constituents. Priority varies from lightest (low priority) to darkest (high priority).

303(d) Impaired Streams

Several stream reaches within the Upper Saline River watershed have been identified as impaired on recent 303(d) lists (ADEQ, 2023). To ensure that these 303(d) listed streams were addressed in the HUC-12 watershed prioritization, any HUC-12 with an impaired stream within its boundaries was categorized as a high priority, while HUC-12s with no impaired streams were categorized as low priority for conservation and protection. The resulting 303(d) listed streams priority map had 17 HUC-12 areas within the high priority category and 23 within the low category (Fig. 18).

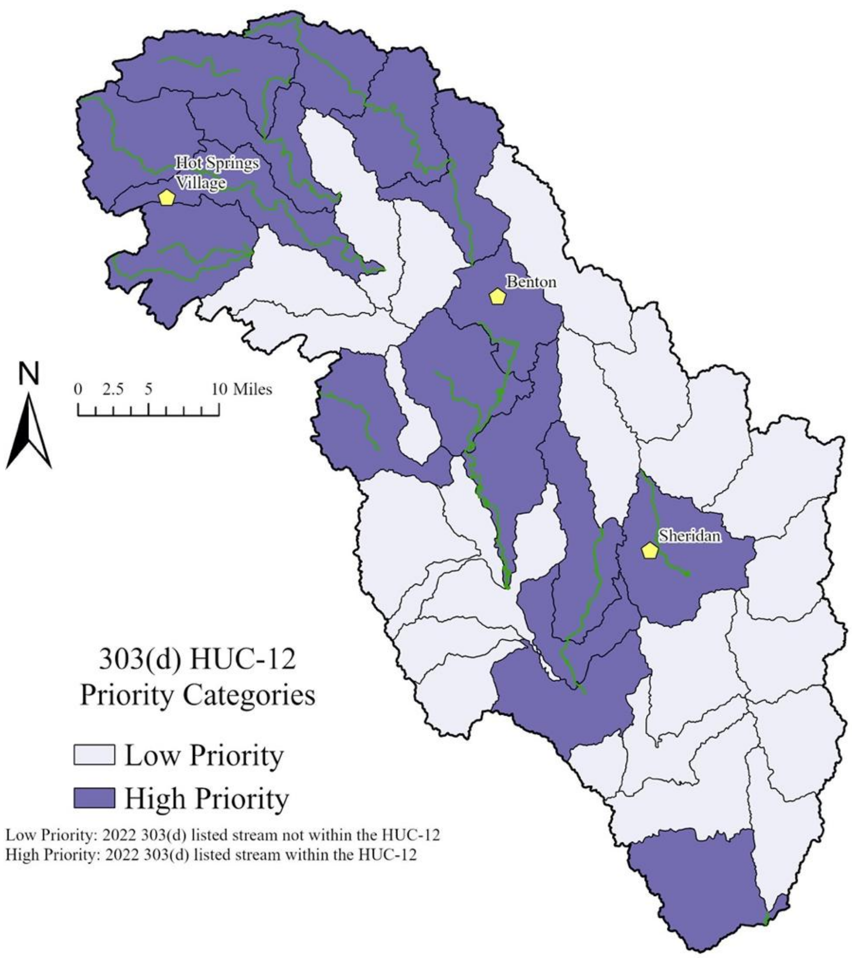


Figure 18. Potential prioritization of HUC-12 watersheds within the Upper Saline River Watershed based on 2022 303(d) listed streams. Priority varies from lightest (low priority) to darkest (high priority). Green stream lines represent the 2022 303(d) listed stream segments.

90m Forest Landcover Change

Landcover change within the riparian areas was a concern within the Upper Saline River Watershed. To ensure that riparian landcover change was addressed in the HUC-12 watershed prioritization the change in forest landcover within the 90 m riparian buffer was calculated from 2001 to 2021. Any HUC-12 area that lost more than 1% of its forest cover within the 90 m riparian buffer area was listed as a high priority area, while HUC-12 areas that lost less than 1% were categorized as low priority areas. The resulting 90 m forest cover change priority map has 21 HUC-12 areas within the high priority category and 19 within the low category (Fig. 19).

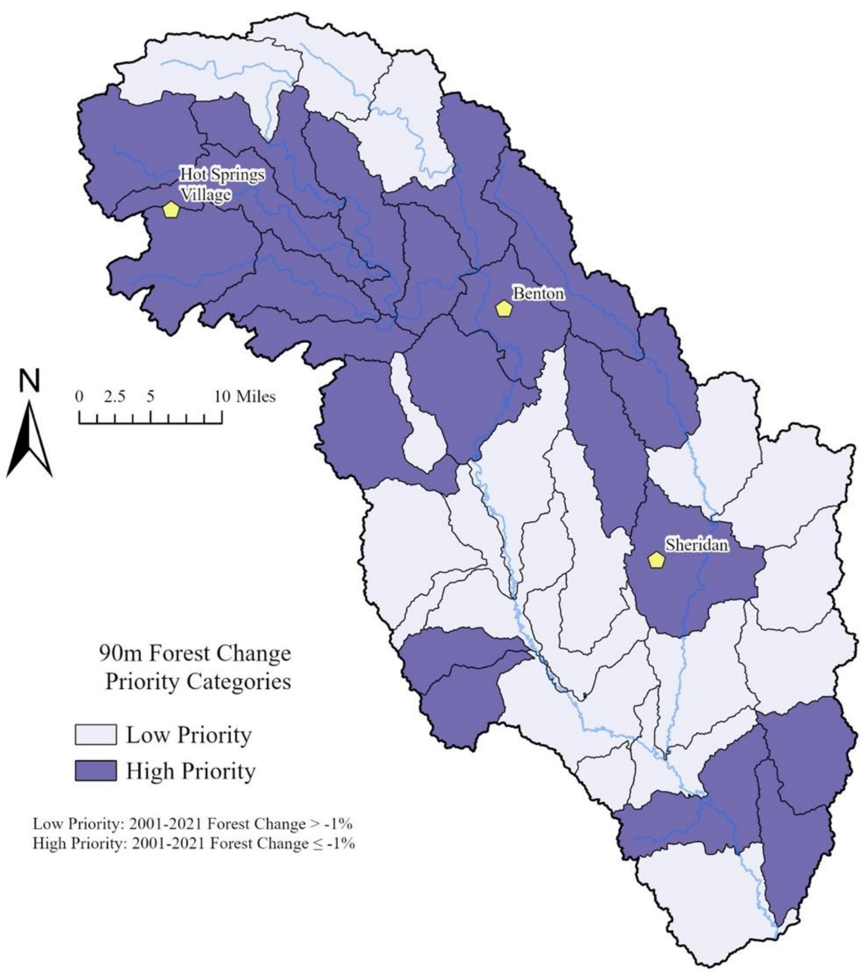


Figure 19. Potential prioritization of HUC-12 watersheds within the Upper Saline River Watershed based on the 90 m forest riparian buffer cover change from 2001 to 2021. Priority varies from lightest (low priority) to darkest (high priority).

HUC-12 Landcover Change

Landcover change within the whole HUC-12 area was also a concern within the Upper Saline River Watershed. To ensure that landcover change was addressed in the HUC-12 watershed prioritization, the change in forest landcover within the HUC-12 area was calculated from 2001 to 2021. Any HUC-12 area that lost more than 1% of its forest cover was listed as a high priority area, while HUC-12 areas that lost less than 1% were categorized as low priority areas. The resulting HUC-12 area forest cover change priority map had 11 HUC-12 areas within the high priority category and 29 within the low category (Fig. 20)

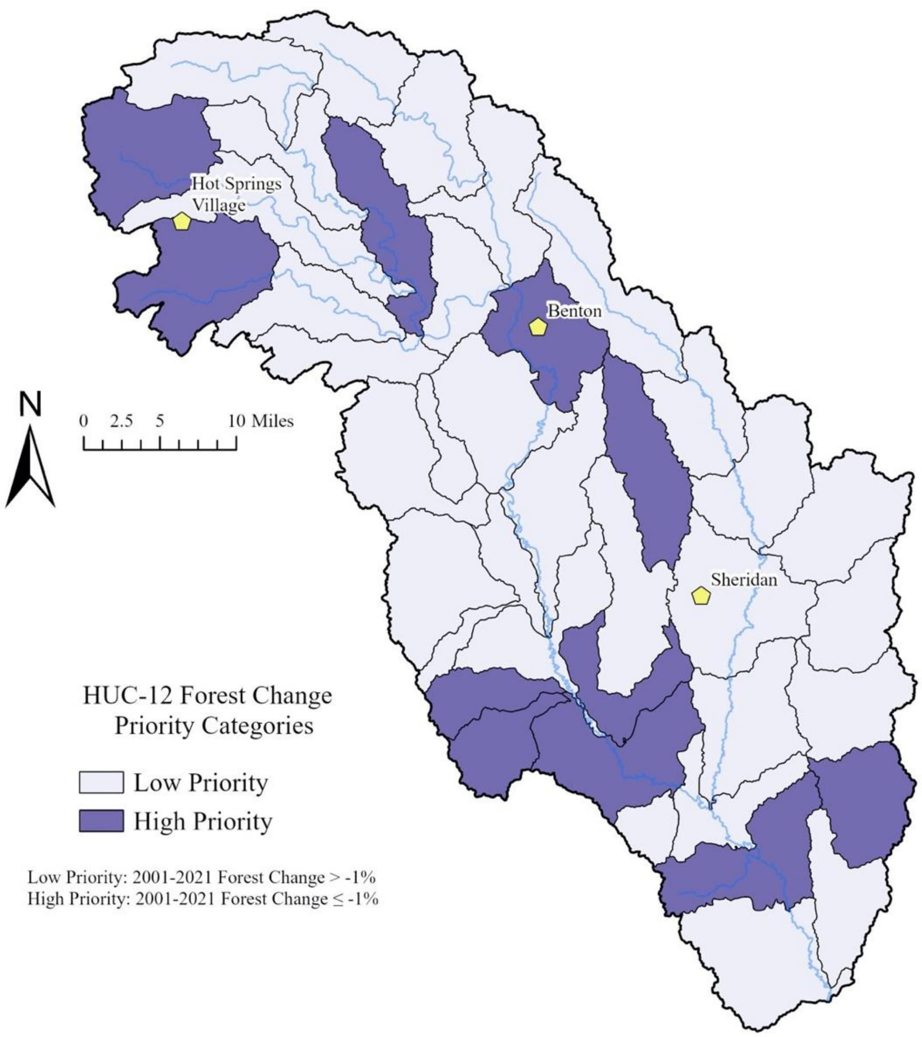


Figure 20. Potential prioritization of HUC-12 watersheds within the Upper Saline River Watershed based on the HUC-12 buffer forest cover change from 2001 to 2021. Priority varies from lightest (low priority) to darkest (high priority).

Final HUC-12 Prioritization

To calculate a final HUC-12 prioritization map for the Upper Saline River Watershed, the sum of each HUC-12's ranks from the final seven priority maps (human influence, phosphorus, nitrogen, sediments, 303(d) listed streams, 90 m forest change, and HUC-12 forest change) was added together. The 1/3rd and 2/3rd percentiles of the overall sums were calculated, splitting the HUC-12s into three groups. If a HUC-12 had an overall between 7 and 16, it was ranked as a low priority, a sum between 17 and 23 was ranked as medium priority, and a sum between 24 and 35 was ranked as high priority. The resulting final prioritization map for the watershed has 14 HUC-12 areas within the high priority category, 16 within the medium priority, and 10 within the low category (Fig. 21; Table 4)

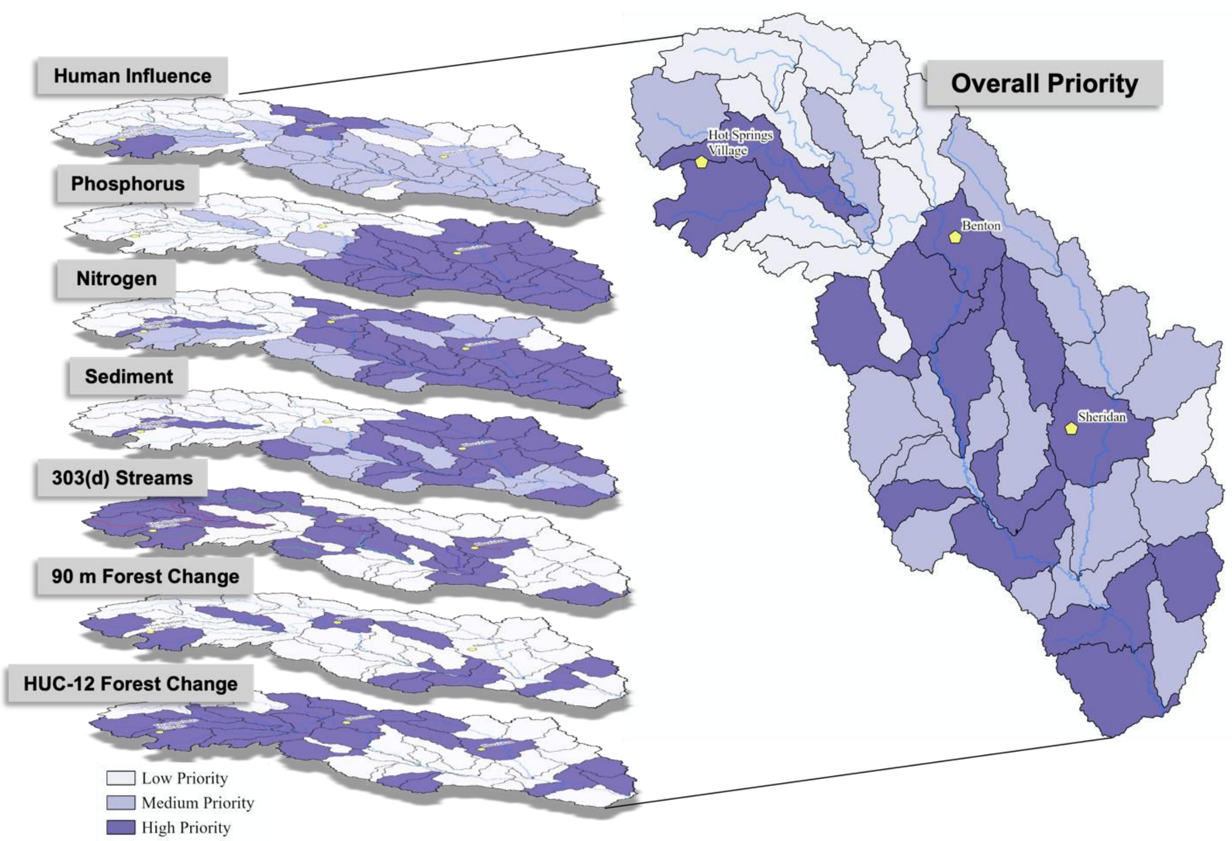


Figure 21. Potential final prioritization of HUC-12 watersheds within the Upper Saline River Watershed based on the seven HUC-12 prioritization maps. Priority varies from lightest (low priority) to darkest (high priority)

Table 4. Upper Saline River watershed HUC-12's and their final potential prioritization category.

HUC-12 Name	Final Sum	Priority Category
Allgood Creek-Derrieusseaux Creek	29	High
Beech Creek-Cow Head Creek	19	Medium
Big Creek-Francois Creek	19	Medium
Big Creek-Saline River	17	Medium
Brush Creek-Saline River	29	High
Brushy Creek-Francois Creek	13	Low
Cedar Creek-South Fork Saline River	25	High
Chapel Creek-Saline River	29	High
Cox Creek	23	Medium
Depot Creek-Saline River	27	High
Flat Creek-Dry Creek	29	High
Graves Creek-Dry Lost Creek	25	High
Grisley Creek-Saline River	27	High
Headwaters Alum Fork Saline River	11	Low
Headwaters Middle Fork Saline River	19	Medium
Johnson Creek-Derrieusseaux Creek	21	Medium
Jordan Creek-Saline River	25	High
Little Creek-Saline River	19	Medium
Little Derrieusseaux Creek-Derrieusseaux Creek	15	Low
Little Hurricane Creek-Hurricane Creek	19	Medium
Little Lost Creek-Dry Lost Creek	23	Medium
Logan Creek-Hurricane Creek	21	Medium
Lower North Fork Saline River	15	Low
Middle North Fork Saline River	11	Low
Mill Creek-South Fork Saline River	15	Low
Moccasin Creek-Saline River	13	Low
Mud Creek-Hurricane Creek	17	Medium
Mud Creek-Saline River	21	Medium
Panther Creek-Derrieusseaux Creek	23	Medium
Pine Bridge Creek-Saline River	25	High
Ray Creek-Hurricane Creek	29	High
Simpson Creek	17	Medium
Tailwaters Alum Fork Saline River	15	Low
Tailwaters Middle Fork Saline River	25	High
Tenmile Creek-Francois Creek	25	High
Tenmile Creek-South Fork Saline River	11	Low
Thunder Branch-Big Creek	17	Medium
Trace Creek-Saline River	25	High
Upper North Fork Saline River	11	Low
White Oak Creek-Hurricane Creek	21	Medium

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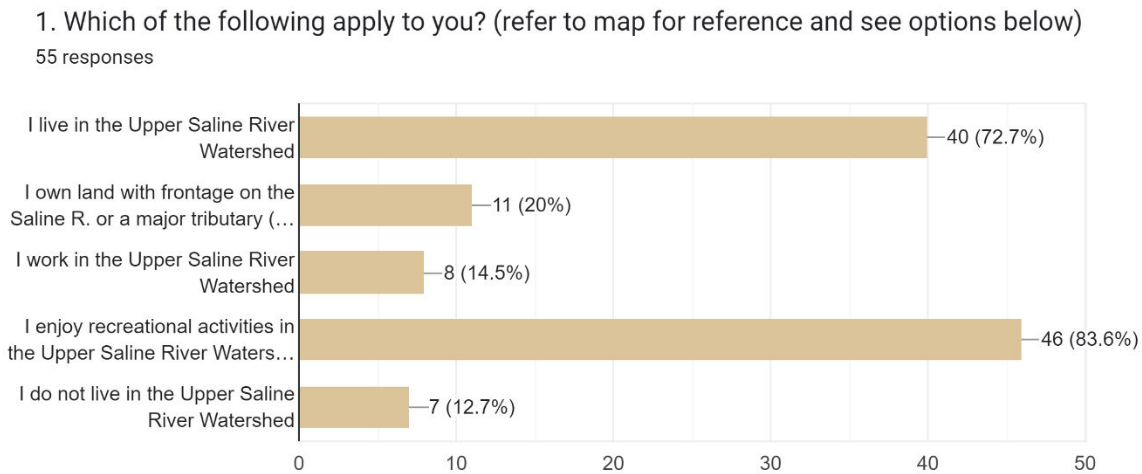
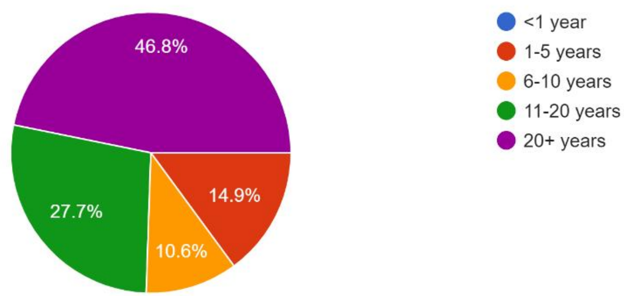
Appendix I: Stakeholder responses to the Upper Saline Watershed Questionnaire consisting of 16 questions about the watershed, activities, and perceptions of water quality.



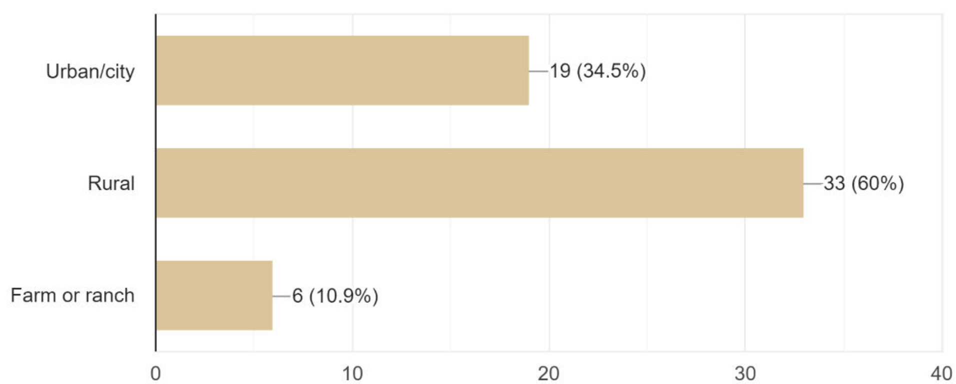
How long have you lived in the Upper Saline Watershed?

47 responses



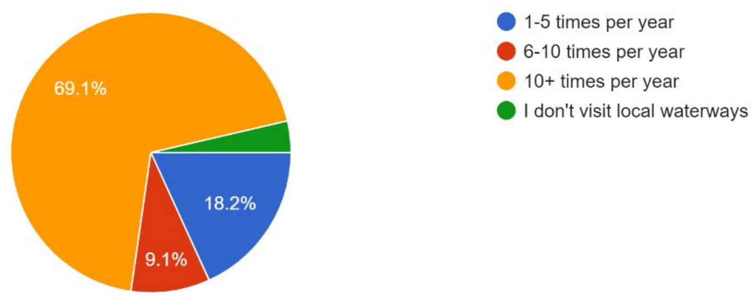
2. Which of the following best describes where you live?

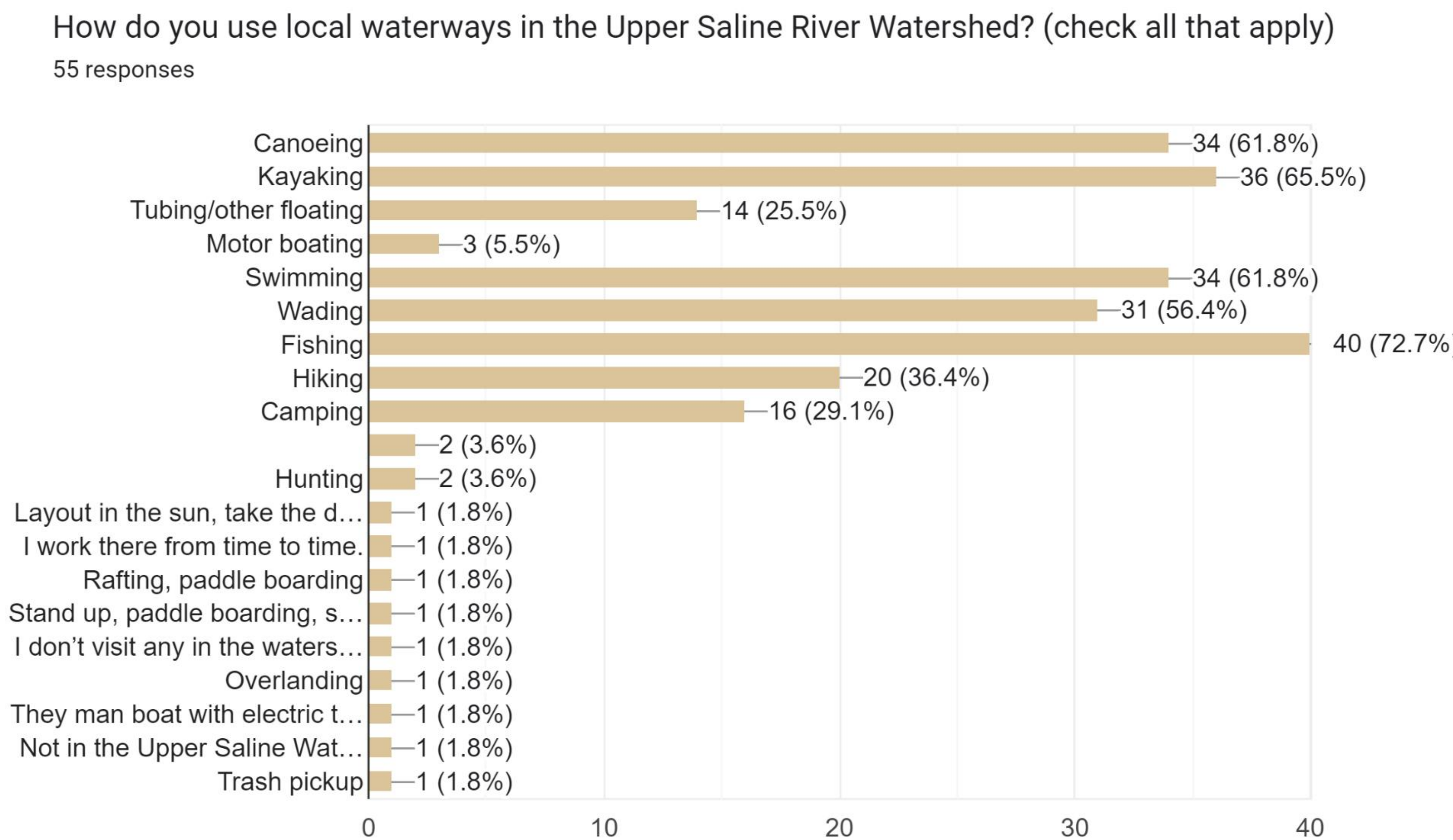
55 responses



How often do you visit local waterways in the Upper Saline River Watershed

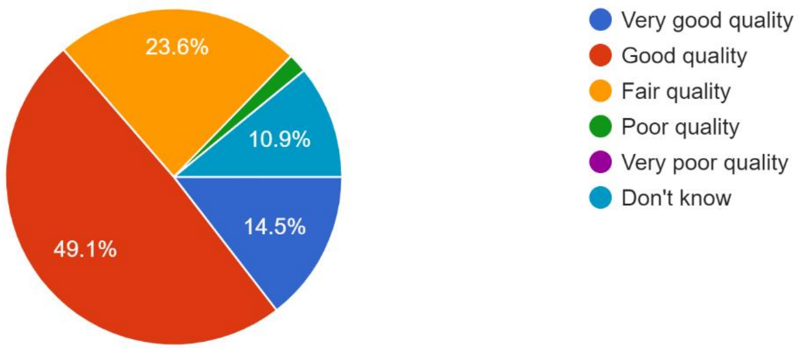
55 responses




How do you use local waterways in the Upper Saline River Watershed? (check all that apply)
55 responses
Canoeing
Kayaking
Tubing/other floating
Motor boating
Swimming
Wading
Fishing
Hiking
Camping
Hunting
Layout in the sun, take the d…
I work there from time to time.
Rafting, paddle boarding
Stand up, paddle boarding, s…
I don’t visit any in the waters…
Overlanding
They man boat with electric t…
Not in the Upper Saline Wat…
Trash pickup
34 (61.8%)
36 (65.5%)
14 (25.5%)
3 (5.5%)
34 (61.8%)
31 (56.4%)
40 (72.7%)
20 (36.4%)
16 (29.1%)
2 (3.6%)
2 (3.6%)
1 (1.8%)
1 (1.8%)
1 (1.8%)
1 (1.8%)
1 (1.8%)
1 (1.8%)
1 (1.8%)
1 (1.8%)
1 (1.8%)
0
10
20
30
40

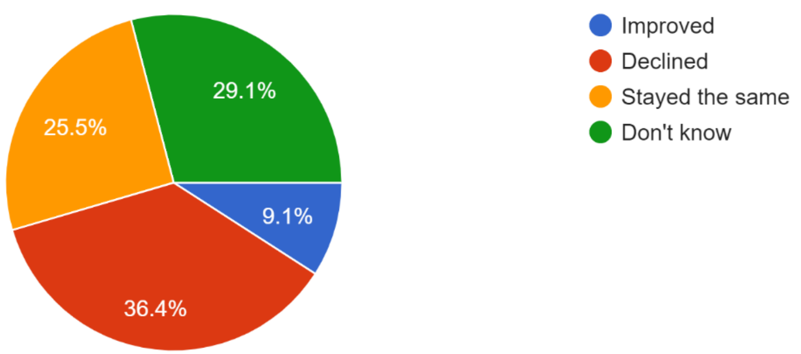
What is your opinion of water quality in the Upper Saline River?

55 responses



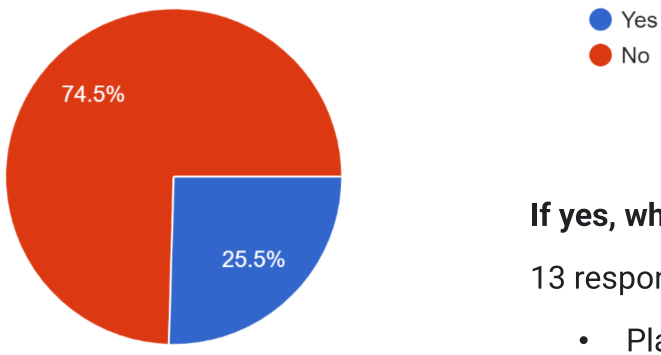
How do you feel water quality in the Upper Saline River has changed over the past 10 years?

55 responses



Have you implemented any conservation practices on your property in the past?

55 responses



If yes, what conservation practices have you adopted?

13 responses

- Planted native plants. Don’t fertilize lawn of weeds.
- Streambank protection
- Cut down vines that choke out trees and kill them, pick up trash.
- I don't use any fertilizer or weed killer.
- No additives to the soil, leaves remain during winter.
- Invasive species removal, planting of native plants, plans to do prescribed burns
- Reforestation
- Rip rap run off ditches
- We clean up historic dumps regularly.
- Native plants and erosion control
- Controlled burns to improve habitat for quail and turkey. Strategic plantings are planned.
- Riparian buffer on an ephemeral stream that flows through our backyard
- Reduce soil erosion from stormwater run off

Are there any streams or changes in the watershed that you are concerned about? Why? - 26 responses:

- No; Not that I'm aware of; I do not know
- Only erosion from new houses
- South Fork Saline; Hurricane
- I’m worried about the coming developments around the 229 a bridge and I30 that will bring more visitors to the river, and by default more trash and erosion.
- The creek by Bishop Park is used regularly for fishing and it floods a lot
- Erosion from rains and urban run off.
- Not that I'm aware of.
- Trash getting in river
- flooding has ripped out huge sections of banks
- I am concerned as to how Benton plans on diverting water for the RV park and soccer field on the old Thomas farm they recently purchased.
- Erosion near Peeler Bend
- Depot Creek has an excessive amount of litter from the stretch along the interstate. This enters the saline river just south of the river street bridge.
- Excessive waste and unawareness of items that end up in the watershed. Too much trash!
- Erosion of banks
- Some livestock practices seem concerning to me
- Seems like the development in the Benton sprawl and greater little rock urbanization are concerning.
- South Fork has a lot of algae.
- I am always concerned about Hurricane Creek when it rains a lot. When it floods, the whole county is affected one way or another.
- Erosion, gravel mining, private land owners and trespassers dumping. I know where one person is dumping sewage from a camper into the south Fork.
- Damage due to interstate and various road projects ; attempts to block access.
- Ten mile creek. There seems to be a lot of trash from swimmers at the lonsdale park, and where highway 70 crosses the creek course to pleasant run rd.

How much of a problem do you feel the following issues are in the Upper Saline Watershed? (Scroll right to view all options)