UPPER WHITE RIVER, AR
WATERSHED MANAGEMENT PLAN



JULY 24, 2025

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WATERSHED MANAGEMENT PLAN

DRAFT

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EXECUTIVE SUMMARY

The **Upper White River Watershed Management Plan (WMP)** is a comprehensive approach to managing and protecting the water quality and natural resources of the Upper White River watershed in Northwest Arkansas. Developed by H2Ozarks, this plan addresses the unique environmental challenges of the region, which includes the White River, West Fork White River, War Eagle Creek, Kings River, and Long Creek. The WMP aims to improve water quality, mitigate pollution sources, and promote sustainable land and water management practices.

The WMP follows the U.S. Environmental Protection Agency's (**EPA) 9-element framework** for comprehensive watershed management:

Element		Description
1.	Identification of Impairment Sources	Identifies causes and sources of pollution.
2.	Expected Load Reductions	Estimation of pollution reductions through activities.
3.	Management Measures	Proposed actions for pollution control and identify critical areas for implementation.
4.	Technical & Financial Assistance	Estimates of amounts of technical and financial support needed for implementation.
5.	Public Education & Participation	Current and future public involvement activities.
6.	Schedule	Schedule for implementation.
7.	Milestones	Measurable, key points of progress.
8.	Evaluation Criteria	Metrics for assessing load reduction and progress toward watershed goals.
9.	Monitoring	Ongoing monitoring to evaluate the effectiveness of efforts for adaptive management.

Upper White River WMP

The Upper White River watershed (HUC8 11010001) is a **vital natural resource** located in Northwest Arkansas. The watershed encompasses drinking water supply Beaver Lake, Extraordinary Resource Waters and Natural and Scenic Waterway designated Kings River, and Ecologically Sensitive Waterbody designated White River, seeps, and springs. The watershed provides drinking water to over 500,000 people, supports local agriculture, and serves as a key cultural, recreational, and ecological asset in the most rapidly growing area of the state. Recognizing its significance, the watershed has been designated as a priority in the Arkansas 2024-2029 Nonpoint Source Priority Watersheds list. With its rich biodiversity, scenic landscapes, and

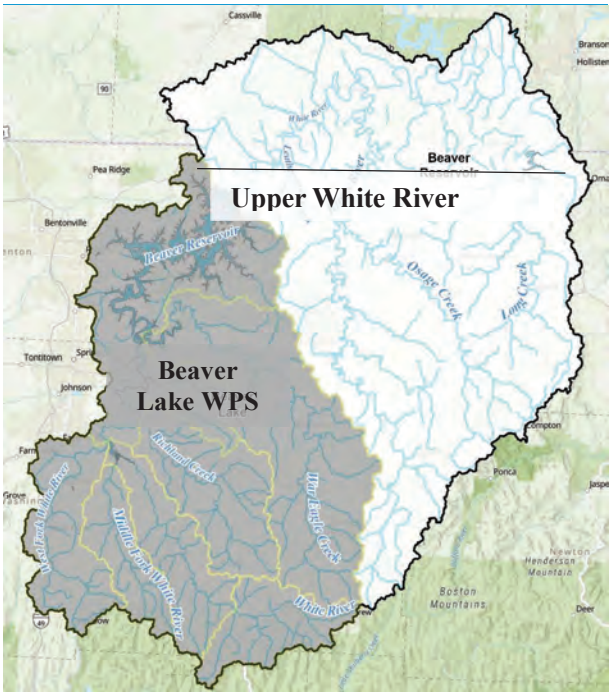
vital water supply, the health of this watershed directly impacts the quality of life for residents and visitors alike. However, the watershed faces increasing pressures from urban development, land use changes, and nutrient and sediment pollution, making its protection a critical priority.

Navigating Overlaps: Coexisting Management Plans

Two watershed plans were developed for the White River watershed in Northwest Arkansas during 2021-2024:

- Upper White River Watershed Management Plan (WMP), developed by H2Ozarks
- Beaver Lake Watershed Protection Strategy (WPS), developed by Beaver Watershed Alliance

Together, these two plans provide a comprehensive approach to watershed management, recognizing the diverse needs and challenges of distinct geographic areas while upholding a unified commitment to environmental stewardship.

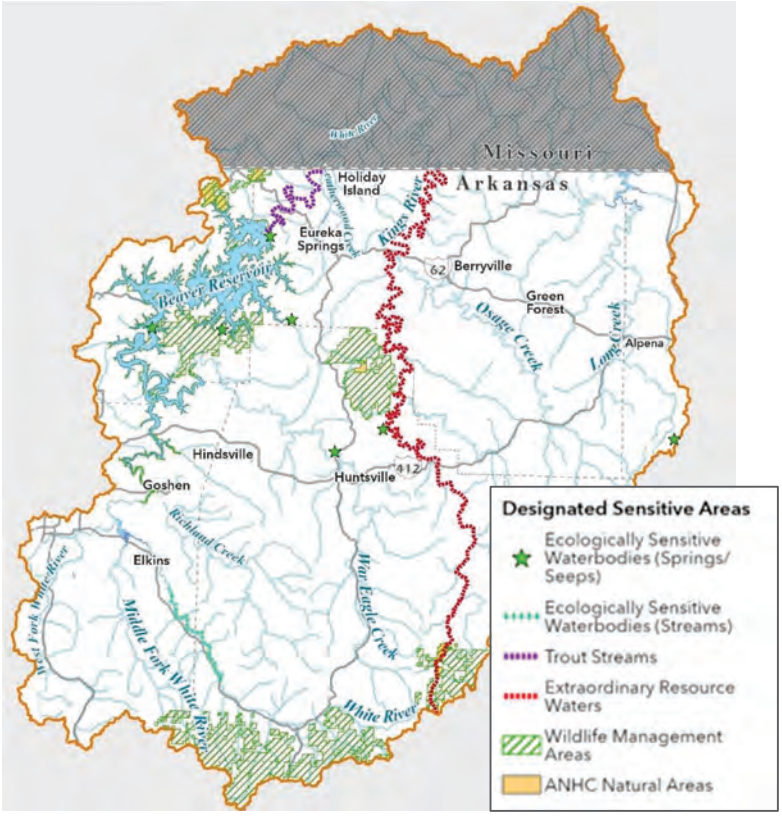


Plan Aspect	Upper White River WMP	Beaver Lake WPS
Geographic Focus	Entire Upper White River Watershed in Arkansas; larger area; more forest/pastureland	Only the Beaver Lake Watershed; smaller, more developed area; higher population density
Priority Areas	Based on presence of impaired waters, five identified water quality issues and threats, and modeled pollutant yields	Based on modeled pollutant yields, flood events, riparian pasture extent, and streambank erosion severity for current and future conditions
Modeling Approach	Models current conditions using SWAT model at HUC12 scale	Models current and future conditions using WaterFALL model at catchment scale
Water Quality Focus	All waterbodies support designated uses	Waterbodies support designated uses with emphasis on Beaver Lake water supply use

Although both plans adhere to the EPA's 9-element framework, differences stem from variations in geographic focus, modeling methodologies, and organizational priorities (see table above). Despite these differences, both plans identify similar issues and concerns, and recommend many of the same practices to address them.

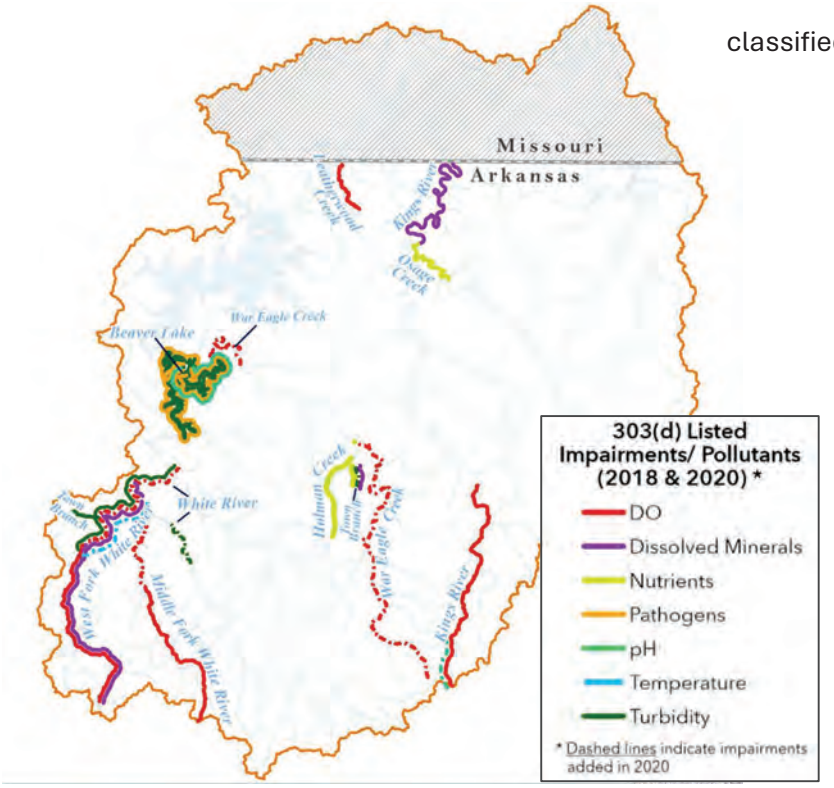
Why the Upper White River HUC8?

- Existing HUC8 Plan over 20 years old
- Presence of Impaired Waterbodies
- Extraordinary Resource Waters, Natural and Scenic Waterways, Ecologically Sensitive Waterbodies
- AR Priority Watershed (2024-2029 NPS Plan)



Totals: 2,700 miles of streams and over 25,600 acres of impounded water in the Upper White River watershed.

Impaired: over 135 miles of streams and over 3,400 acres of Beaver Lake are classified as impaired (ADEQ, 2020).

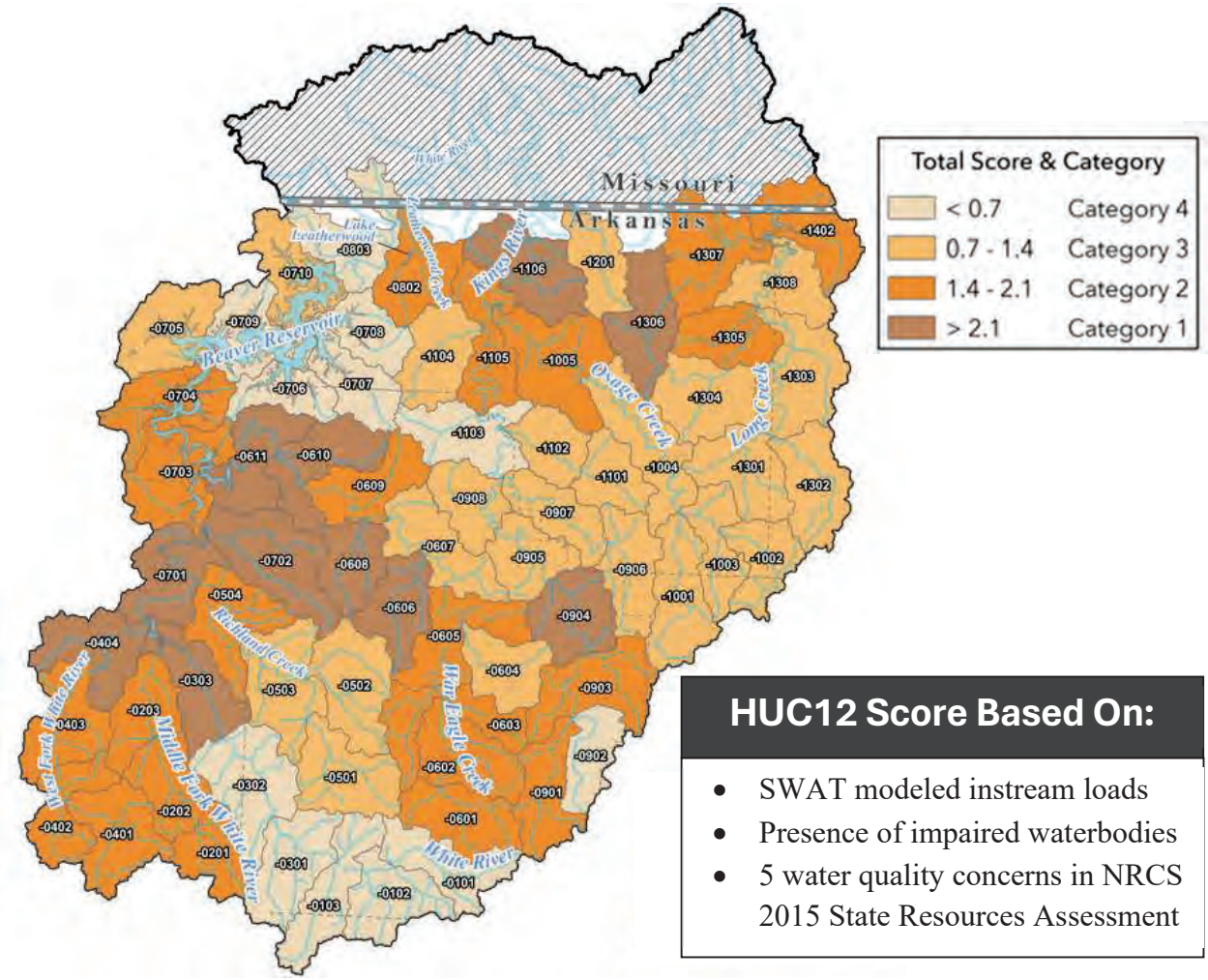


Potential Nonpoint Sources of Pollutants Causing Impairments:

- Runoff from pasture, haylands, developed areas, animal feeding operations
- Failing septic systems
- Unpaved roads
- Streambank and lakeshore erosion
- Sediments
- Livestock and wildlife
- Groundwater, geology, soil characteristics

Management Goals

Eleven HUC12s were selected as priority areas for management activities to reduce nonpoint source pollution, identified as Category 1 sub-watersheds in the map below and listed in the table. However, efforts to control NPS pollution in other sub-watersheds are also encouraged.



HUC12 ID	HUC12 Name	Waterbody
110100010303	Lake Sequoyah	White River
110100010404	Town Branch-West Fork White River	West Fork White River
110100010606	Holman Creek	War Eagle Creek
110100010608	Glade Creek	War Eagle Creek
110100010610	Clifty Creek-War Eagle Creek	War Eagle Creek
110100010611	Beaver Lake-War Eagle Creek	War Eagle Creek
110100010701	Roberts Creek-Beaver Lake	White River
110100010702	Brush Creek-Beaver Lake	White River
110100010904	Spanker Branch-Kings River	Kings River
110100011106	Clabber Creek-Kings River	Kings River
110100011306	Braswell Branch-Yocum Creek	Yocum Creek

Stakeholders set five management goals to achieve the vision of the Upper White River watershed:



Some management practices recommended by stakeholders:

Rural: Environmentally sensitive road maintenance, Riparian buffers, Septic system remediation, Streambank/lakeshore/stream restoration.

Urban: Constructed wetlands, Land conservation, Low impact development, Rain gardens, Retention, detention basins, Riparian restoration, Smart growth, Streambank/stream restoration.

To achieve the WMP goals, reduction targets have been set for pollutants listed in the table below. There was not enough data to set numeric goals for pH, dissolved oxygen, and *E. coli*, which have also been identified as pollutants of concern in the Upper White River watershed.

Category 1 Sub-watersheds		Load Reduction Targets			
HUC12 ID Number	HUC12 Name	Sulfate	Sediment	Total Nitrogen	Total Phosphorus
-0303	Lake Sequoyah	NA	10%	NA	40%
-0404	Town Branch-West Fork White River	40%	60%	25%	50%
-0606	Holman Creek	NA	60%	35%	80%
-0608	Glade Creek	NA	20%	35%	0
-0610	Clifty Creek-War Eagle Creek	NA	20%	40%	50%
-0611	Beaver Lake-War Eagle Creek	NA	50%	*	70%
-0701	Roberts Creek-Beaver Lake	*	50%	30%	25%
-0702	Brush Creek-Beaver Lake	NA	Not enough data	45%	*
-0904	Spanker Branch-Kings River	NA	Not enough data	NA	NA
-1106	Clabber Creek-Kings River	NA	Not enough data	45%	55%
-1306	Braswell Branch-Yocum Creek	NA	Not enough data	40%	15%

NA = This pollutant has not been identified as a nonpoint source concern in this sub-watershed.

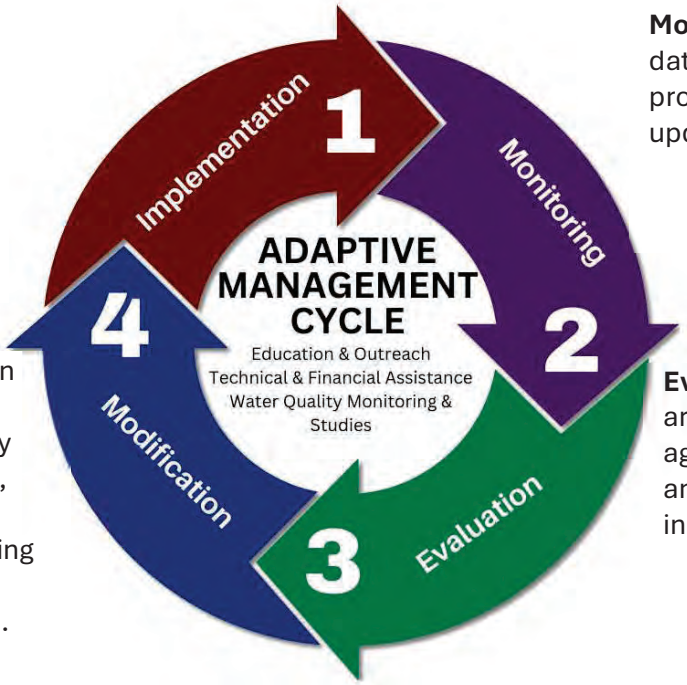
* = Data from 2018-2022 indicate target may be met, however management recommendations for other pollutants will address this pollutant.

Implementation Strategy

The successful implementation of the Upper White River Watershed Management Plan relies on a well-defined framework of schedule and milestones. The WMP includes an overview of the timelines and milestones associated with the ongoing and planned activities aimed at achieving the watershed management goals.

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

Implementation: Practices are put into action, informed by the components of the adaptive management cycle.



Monitoring: Provide data to track progress and inform update of plan goals.

Modification: Based on evaluation, the plan is updated to address any changes in regulations, available assistance programs, understanding of the watershed, or management priorities.

Evaluation: Results are assessed against the goals and criteria outlined in the plan.

This adaptive approach assures that the management plan remains effective and responsive to new information and changing conditions. Education and outreach, and technical and financial assistance, support voluntary stakeholder implementation of practices to provide beneficial outcomes for stakeholders and the watershed. The WMP contains information about appropriate practices; implementation costs and benefits; ongoing and proposed studies, outreach, and management activities; available assistance; and contact information for agencies and other organizations active in the watershed.

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ACRONYMS

AGFC	Arkansas Game and Fish Commission
ARCDC	Arkansas Resource Conservation and Development Council
ATTRA	Appropriate Technology Transfer for Rural Areas
AWRC	Arkansas Water Resources Center
BMP	best management practice
BWA	Beaver Watershed Alliance
BWD	Beaver Water District
°C	degrees Celsius
cfs	cubic feet per second
cfu	colony forming units
CRP	Conservation Reserve Program
CSP	Conservation Stewardship Program
DEQ	Arkansas Department of Energy and Environment Division of Environmental Quality
DO	dissolved oxygen
EPA	United States Environmental Protection Agency
E. coli	Escherichia coli
EQIP	Environmental Quality Incentives Program
°F	degrees Fahrenheit
FTN	FTN Associates, Ltd.
FSA	Farm Services Agency
ha	hectare
HUC12	12-digit hydrologic unit code
IBI	index of biotic integrity
kg	kilogram
KRWP	Kings River Watershed Partnership
LID	low impact development
mg/L	milligrams per liter
mL	milliliter
mm	millimeter
MMI	Multi-metric index of biotic integrity
NCAT	National Center for Applied Technology
NRCS	US Department of Agriculture Natural Resources Conservation Service
NTU	Nephelometric turbidity units
RCPP	Regional Conservation Partnership Program
SARE	Sustainable Agriculture Research and Education
SARP	Southeast Aquatic Resources Partnership
sq km	square kilometer
SRP	soluble reactive phosphorus

ACRONYMS (CONTINUED)

STP	soil test phosphorus
TDS	total dissolved solids
TMDL	total maximum daily load
TSS	total suspended solids
ug/L	micrograms per liter
US	United States of America
USACE	US Army Corps of Engineers
USDA	US Department of Agriculture
USFWS	US Fish and Wildlife Service
USGS	US Geological Survey
WCRC	Watershed Conservation Resources Center
WWTP	wastewater treatment plant (municipal)

1.0 INTRODUCTION

This management plan addresses the Upper White River Watershed (Hydrologic Unit Code HUC 11010001) in Arkansas. The primary focus of this plan is the protection and improvement of surface water quality in the White River, Beaver Lake, Table Rock Lake, Kings River, Long Creek, and their tributaries, through the voluntary management of unregulated nonpoint sources of pollution.

1.1 Plan Need and Mission

The Upper White River watershed is one of the 12 Nonpoint Source Program priority watersheds designated by Arkansas Department of Agriculture Natural Resources Division (FTN Associates, Ltd. 2022). This watershed has been a priority since the beginning of the Nonpoint Source Program. Several stream reaches in the watershed are included on the most recent approved state impaired waters lists (303(d) lists) in part because of pollution from nonpoint sources. In addition, protection of the drinking water supply reservoirs, Beaver Lake and Table Rock Lake, and populations of a threatened cavefish and threatened and endangered mussels present in the watershed are a concern. Given these concerns, the Upper White River watershed was selected by Natural Resources Division for development of a watershed management plan to address water quality impairments, protect drinking water supplies, protect threatened and endangered aquatic species, and meet the agency goal for development of watershed management plans.

The primary focus of this plan is the **protection** and **improvement** of surface water quality in the White River, Beaver Lake, Table Rock Lake, Kings River, Long Creek, and their tributaries through the voluntary management of unregulated nonpoint sources of pollution. The **mission** of the watershed management plan for the Upper White River watershed is: To increase awareness of water quality issues through outreach and education and increase voluntary implementation of effective nonpoint source pollution and water quality management practices. Several agencies and interest groups have active outreach and education programs in the Upper White River watershed (see Section 5.1). These entities work to increase public awareness of

water quality issues in the watershed and encourage practices that address those issues. This plan supports the efforts of these organizations.

1.2 Watershed Vision

The **vision** for the Upper White River watershed is: The desired and designated uses of the White River, including Beaver Lake, and its tributaries, including Kings River and Long Creek and their tributaries, are attained and sustained, resulting in healthy streams that enhance the socioeconomic, agricultural, and natural amenity benefits of the watershed, as visitors, landowners, and local communities work together to protect and improve both water resources and the quality of life throughout the watershed.

Each community, landowner, and producer has their own vision for their part of the watershed. In addition, there are several agencies and other organizations that work within the Upper White River watershed to manage its natural resources. Some of them have developed plans that document their missions, visions and/or goals for the Upper White River watershed. Some of these are summarized in Table 1.1. Overall, the vision above is compatible with, and supportive of, those of other programs and organizations active in the watershed.

Table 1.1. Examples of the visions, goals, and/or objectives published by organizations active in the Upper White River watershed.

Organization	Vision, goal, objectives
Beaver Watershed Alliance	2012 Watershed Protection Strategy Goals (Tetra Tech 2012): • Maintain a long-term, high-quality drinking water supply to meet present needs and continuing growth of the region. • Restore water quality of impaired stream and lake areas. • Minimize additional costs and regulations for people living and working in the watershed.
Beaver Water District	Source Water Protection Plan vision (Beaver Water District 2018): Beaver Water District's mission is to serve our customers' needs by providing high quality drinking water that meets or exceeds all regulatory requirements and is economically priced consistent with our quality standards. Vision for source water protection: Beaver Water District will lead the citizens, businesses, and communities of Northwest Arkansas to cooperatively maintain the quality of Beaver Lake for all generations
H2Ozarks	To protect and improve water in the Ozarks by promoting community commitment, public policy, research, and local solutions.
Kings River Watershed Partnership	Protect the health, purity, and economic viability of the Kings River watershed, now and for future generations (Kings River Watershed Partnership 2023).
U.S. Army Corps of Engineers	Beaver Lake and White River project purposes: • Flood control • Hydropower generation • Drinking water supply • Recreation Protect and manage shorelines of all Civil Works water resource development projects under Corps jurisdiction in a manner which will promote the safe and healthful use of these shorelines by the public while maintaining environmental safeguards to assure a quality resource for use by the public (U.S. Army Corps of Engineers Little Rock District 2018).

1.3 Process

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

1. Building partnerships,
2. Characterizing the watershed,
3. Finalizing management goals and identifying solutions, and
4. Designing an implementation program.

H2Ozarks worked with consultants to develop this watershed management plan, utilizing the input of watershed stakeholders. Four public meetings were held as part of the process of developing the Upper White River watershed management plan. Announcements about the public meetings were emailed to approximately 200 people including state and local lawmakers, state agencies, county conservation districts, county extension offices, county judges, city mayors, watershed groups, water resource managers, agricultural interest groups, and interested individuals. Announcements were also posted on social media and press releases were sent to local newspapers and the Northwest Arkansas Democrat Gazette. In addition, flyers advertising the public meetings were distributed around communities in the watershed.

The purposes of the public meetings were to inform stakeholders of the plan and the process for developing it, and to request and obtain stakeholder input for the plan. 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, U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), Arkansas Department of Health, Arkansas natural resources agencies, University of Arkansas (UofA) Cooperative Extension Service, Beaver Water District, and agriculture and environmental interest groups. Attendance summaries from the meetings are included in

Appendix A. Summaries of the public meetings, including attendees questions and comments, are available on the H2Ozarks website (Upper White River Watershed Management Plan | AR & MO, accessed 5/6/2025).

The draft watershed management plan was provided for public review and comment February 12, 2025 through April 22, 2025. The public comment period was announced using the same methods as for public meetings. Public access to the draft watershed management plan was provided on the H2Ozarks website. Appendix A includes a list of public comments received, with responses.

1.4 Document Overview

This document contains elements recommended by EPA for watershed management plans. Section 2 describes many of the features of the watershed. Section 3 summarizes conditions in the watershed, including water quality, hydrology, and ecology; and nonpoint pollutant sources in the Upper White River watershed. Section 4 identifies sub-watersheds that are the focus of nonpoint source pollutant management and water resources protection in this plan, pollutant load reduction targets, and management strategies for controlling nonpoint source pollution in the identified sub-watersheds. Section 5 outlines the overall implementation plan, with schedule, list of management and outreach activities, and identification of indicators and monitoring to track progress and effects. Section 6 discusses costs and benefits of proposed management, and assistance that is available for implementation of nonpoint source pollution management practices. Watershed 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 1.2 provides a roadmap for where the required planning elements are addressed in this plan.

Table 1.2. The required nine planning elements to manage and protect against nonpoint source pollution, and the location of the elements within this plan.

Element	Report Section(s)
Element A: Identification of Causes of Impairment and Pollutant Sources	
1. Sources identified, described, and mapped	3.4
2. Sub-watershed sources	4.7
3. Data Sources are accurate and verifiable	3.0, 4.0
4. Data gaps	3.1.9, 3.2.5, 3.3.7
Element B: Expected Load Reductions	
1. Load reductions achieve environmental goal	4.5, 4.9
2. Load reductions linked to sources	Appendix N
3. Model complexity appropriate	Appendix N
4. Basis of effectiveness estimates explained	Appendix N
5. Methods and data cited and verifiable	Appendix N
Element C: Management Measures Identified	
1. Specific management measures are identified	4.8
2. Priority areas	4.3, 4.4, Appendix G
3. Measure selection rationale documented	4.0
4. Technically sound	4.0
Element D: Technical and Financial Assistance	
1. Estimate of technical assistance	6.3
2. Estimate of financial assistance	6.1, 6.4, Appendix P
Element E: Education/Outreach	
1. Public education/information	1.3, 5.1
2. All relevant stakeholders are identified in outreach process	1.0, Appendix A, 5.1, 5.2
3. Stakeholder outreach	5.1
4. Public participation in plan development	Appendix A
5. Emphasis on achieving water quality standards	1.1, 1.2, 4.1, 4.2, 4.5, 4.6, 4.9, 5.5, 5.6.3
6. Operation & maintenance of BMPs	5.3, 6.3.3
Element F: Implementation Schedule	
1. Includes completion dates	5.8
2. Schedule is appropriate	5.8
Element G: Milestones	
1. Milestones are measurable and attainable	5.8
2. Milestones include completion dates	5.8
3. Progress evaluation and course correction	5.5, 5.6, 5.7
4. Milestones linked to schedule	5.8

Table 1.2. The required nine planning elements to manage and protect against nonpoint source pollution, and the location of the elements within this plan (continued).

Element	Report Section(s)
Element H: Criteria	
1. Criteria are measurable and quantifiable	4.5, 5.6
2. Criteria measure progress toward load reduction goal	5.6
3. Data and models identified	4.5, 4.6
4. Target achievement dates for reduction	5.6
5. Review of progress toward goals	5.7, 5.8
6. Criteria for revision	5.7, 5.8
7. Adaptive management	5.0, 5.7
Element I: Monitoring	
1.a. Description of how monitoring used to evaluate implementation	5.4, 5.6
1.b. Monitoring measures evaluation criteria	5.4, 5.6
1.c. Routine reporting of progress and methods	5.4, 5.7
2.a. Appropriate parameters	5.4
2.b. Adequate number of sites	5.4
2.c. Adequate sampling frequency	5.4
2.d. Monitoring tied to quality assurance project plan	5.4
2.e. Can link implementation to improved water quality	5.4

2.0 WATERSHED DESCRIPTION

2.1 Geography

The Upper White River watershed is defined for this plan as the Arkansas portion of the 8-digit hydrologic unit code (HUC8) 11010001, Beaver Reservoir Watershed. The Upper White River watershed encompasses 2,171 square miles in northwestern Arkansas (Figure 2.1). Several cities are located within the watershed, including Fayetteville, West Fork, Greenland, Elkins, Goshen, Rogers, Springdale, Eureka Springs, and Berryville. The largest towns are located along the western watershed boundary, Rogers, Springdale, and Fayetteville. U.S. Highways 62, and 412 cross the watershed and small sections of U.S. Highway 65 and Interstate 49 are in the watershed.

The White River and Kings River originate in Madison County. The White River flows northwest into Washington County, then north into Benton County, where it turns northeast into Carroll County and is dammed to form Beaver Lake. From Beaver Lake, the White River flows northeast into Missouri, where it is dammed to form Table Rock Lake. The Kings River flows north, forming a short section of the Madison-Carroll County boundary, before crossing the Arkansas-Missouri border in Carroll County and flowing into Table Rock Lake. Long Creek originates in Boone County and flows north to join Table Rock Lake. Other counties that are part of the watershed are Crawford, Franklin, and Newton counties (Table 2.1). All of Carroll County and most of Madison County are within this watershed and together they account for two-thirds of the watershed area. Portions of Washington and Benton County account for another 25% of the watershed area.



Figure 2.1. Upper White River watershed, Arkansas.

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

Counties	County area, square miles	County area within watershed, square miles	Percent of County within watershed	Percent of watershed within County
Benton	884.1	198.1	22%	9.1%
Boone	601.5	117.7	20%	5.4%
Carroll	638.3	638.3	100%	29%
Crawford	605.4	0.11	0.02%	0.005%
Franklin	619.7	18.9	3.0%	0.9%
Madison	836.5	794.5	95%	37%
Newton	822.7	45.4	5.5%	2.1%
Washington	951.7	357.8	38%	16%
Totals	5,960.0	2,170.8	-	100%

2.2 Socioeconomics

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

2.2.1 Population

In 2020, this watershed was home to over 128,000 Arkansans (US Census Bureau 2021a). Numbers of people reported in the 2020 U.S. Census for the counties with more than 10% of their area within the watershed, and the state of Arkansas are presented in Table 2.2. These counties all experienced population increases between 2010 and 2020 and are expected to continue to see population growth through 2035.

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

Table 2.2. Population information for selected counties associated with Upper White River watershed and Arkansas as a whole. The percent population change from 2010 to 2020 is shown in parentheses.

Area	2010 Total Population[a]	Population Change 2010 to 2020	2020 Total Population[a]	2035 Projection[b]
Benton County	221,339	62,994 (28.5%)	284,333	368,796
Boone County	36,903	470 (1.3%)	37,373	39,066
Carroll County	27,446	814 (3.0%)	28,260	31,825
Madison County	15,717	804 (5.1%)	16,521	16,581
Washington County	203,065	42,806 (21.1%)	245,871	356,468
State of Arkansas	2,915,918	95,606 (3.3%)	3,011,524	3,388,943

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

Additional demographic information for the counties with more than 10% of their area within the Upper White River watershed is listed in Table 2.3. This includes percentages of the population for characteristics of commuting, household structure, age, gender, race, median income, poverty, fields of employment, and education level. In the counties associated with the watershed, about one-third of households are families (i.e., children under 18 living with parents), and most of these households include two parents. In age, race, and education Benton and Washington counties appear different from the other three counties shown in Table 2.3. The population in these two counties is younger, more racially diverse, and more highly educated. This may be because of the influence of the University of Arkansas and the economic growth and opportunities in these counties (see Section 2.2.2). Most people living in the watershed consider themselves white (non-Hispanic). All but one of these counties has a higher percentage of people who identify as Pacific Islanders than the state as a whole. Northwest Arkansas is home to one of the largest communities of Marshallese in the United States.

Table 2.3. Demographic information for selected counties associated with Upper White River watershed and Arkansas as a whole.

Information	Benton County	Boone County	Carroll County	Madison County	Washington County	State of Arkansas
Gender[a]						
Male	49.4%	49.0%	49.4%	50.1%	49.7%	49.0%
Female	50.6%	51.0%	50.6%	49.9%	50.3%	51.0%
Age[a]						
Median Age	35.3	43.0	44.8	42.8	32.0	38.8
Under 20	29.1%	24.5%	23.9%	25.1%	28.0%	26.0%
20 to 24 years	5.9%	5.4%	4.9%	5.0%	11.1%	6.6%
25 to 44 years	28.8%	22.1%	21.3%	22.6%	28.1%	24.9%
45 to 64 years	22.6%	26.4%	26.2%	27.5%	20.7%	24.9%
65 and older	13.6%	21.7%	23.6%	19.8%	12.1%	17.6%
Race/Ethnicity[a]						
White non-Hispanic	67.4%	90.3%	74.9%	85.2%	65.3%	68.5%
Hispanic or Latino	17.8%	2.6%	15.2%	5.4%	18.2%	8.5%
Black non-Hispanic	1.6%	0.3%	0.3%	0.2%	3.4%	14.9%
Native American	1.3%	0.7%	0.9%	1.2%	1.0%	0.7%
Asian	4.8%	0.6%	2.0%	0.6%	2.3%	1.7%
Native Hawaiian and Other Pacific Islander	0.9%	0.1%	1.5%	1.4%	3.6%	0.5%
Other race	0.3%	0.2%	0.3%	0.4%	0.3%	0.3%
More than one race	5.9%	5.2%	4.8%	5.5%	6.0%	4.9%
Education[b]						
Less than High School Graduate	10.4%	11.8%	13.6%	15.5%	14.5%	12.8%
High School Graduate (or Equivalency)	28.9%	34.4%	36.0%	49.0%	26.5%	33.9%
Some College or Associate's Degree	26.2%	36.0%	29.2%	23.4%	25.8%	29.5%
Bachelor's Degree	23.1%	11.3%	14.0%	7.3%	19.3%	15.2%
Graduate Degree	11.4%	6.5%	7.2%	4.8%	13.9%	8.6%

Table 2.3. Demographic information for selected counties associated with Upper White River watershed and Arkansas as a whole (continued).

Information	Benton County	Boone County	Carroll County	Madison County	Washington County	State of Arkansas
Household Structure[a]						
Households with children <18 years	37.2%	27.9%	26.1%	31.0%	31.7%	30.5%
Two parent households with children <18 years	27.9%	18.5%	17.4%	20.9%	22.0%	19.0%
Single parent households with children <18 years	6.2%	5.5%	5.0%	5.1%	6.6%	7.5%
Single person household	22.3%	28.9%	31.0%	26.3%	28.0%	29.2%
Other non-family household	6.2%	5.4%	6.8%	6.1%	8.0%	6.2%

a (U.S. Census Bureau 2022)
b (U.S. Census Bureau 2021c)

2.2.2 Economics

County economic information from the U.S. Census Bureau American Community Survey is summarized in Table 2.4. Compared to the state average, per capita income is higher in Benton and Washington counties, but lower in the other counties with more than 10% of their area in the Upper White River watershed. The same is true for median household income. Madison County has the lowest per capita income and median household income of the counties shown in Table 2.4. Poverty levels and unemployment in Madison County are higher than for the state overall. The relative distribution of the available civilian work force among occupations in the listed counties is similar to that for the state overall. Of the listed counties, Carroll and Madison counties have the highest percentage of self-employed workers and the lowest percentage of workers in Management, Business, Science, and Arts.

Drivers of the economy in the Upper White River watershed include agriculture, manufacturing, retail trade, and tourism. The values of sales and receipts reported in the 2017 U.S. economic census for selected economic sectors, in selected counties of the Upper White River watershed, are summarized in Table 2.5. Manufacturing and retail trade reported the highest revenues in these counties. Benton and Washington counties reported the highest sales income.

Agriculture is not an economic sector reported in the U.S. economic census. However, agriculture contributes value to manufacturing, real estate, wholesale trade, and transportation and warehousing economic sectors (English and Popp 2022). Table 2.6 lists the value of sales of agricultural products reported in the 2017 census of agriculture for five counties of the Upper White River watershed. These five counties account for almost 20% of the value of state agricultural sales. Poultry and egg sales account for most of the agricultural sales value in all five counties listed in Table 2.6. In these counties, hay sales account for most of the crop sales value.

Table 2.4. US Census Bureau American Community Survey economic information for selected counties of the Upper White River watershed (U.S. Census Bureau 2021d).

Information	Benton County	Boone County	Carrol County	Madison County	Washington County	State of Arkansas
Income						
Per Capita Income	$36,597	$24,749	$26,445	$22,733	$29,419	$27,724
Median household income	$71,556	$46,392	$48,249	$41,446	$52,380	$49,475
Families below poverty level	6.7%	10.3%	9.7%	13.3%	10.7%	11.8%
People below poverty level	8.6%	13.7%	15.2%	17.3%	16.0%	16.1%
Employment, Occupation (percent of civilian work force over 16)						
Unemployment rate	2.6%	4.5%	4.5%	7.7%	4.4%	5.2%
Management, business, science, arts	38.7%	33.3%	29.6%	26.7%	40.7%	34.9%
Service	14.2%	16.9%	16.9%	13.5%	15.5%	16.6%
Sales, office	22.7%	23.9%	19.4%	19.6%	19.8%	21.2%
Natural resources, construction, maintenance	8.7%	9.1%	13.5%	18.1%	9.3%	10.1%
Production, transportation, material moving	15.7%	16.8%	20.6%	22.0%	14.7%	17.3%
Self-employed	6.1%	6.7%	11.9%	9.4%	5.6%	6.0%
Employment, Industry (percent of civilian work force over 16)						
Agriculture, forestry, fishing and hunting, and mining	1.4%	2.5%	7.3%	5.4%	1.0%	2.7%
Construction	7.0%	7.2%	8.5%	11.4%	8.0%	6.9%
Manufacturing	13.9%	10.5%	20.8%	17.2%	13.2%	13.4%
Wholesale trade	3.0%	1.8%	0.1%	1.9%	2.4%	2.4%
Retail trade	21.5%	12.6%	10.8%	13.3%	12.2%	13.1%
Transportation and warehousing, and utilities	5.2%	13.2%	3.9%	7.4%	5.6%	5.9%
Information	0.8%	1.6%	2.4%	1.9%	1.1%	1.4%
Finance and insurance, and real estate and rental and leasing	4.6%	3.6%	4.3%	2.9%	4.2%	4.9%
Professional, scientific, and management, and administrative and waste management services	10.2%	6.8%	7.4%	5.1%	9.4%	7.7%
Educational services, and health care and social assistance	17.9%	23.9%	17.0%	20.8%	26.0%	24.6%
Arts, entertainment, and recreation, and accommodation and food services	7.8%	8.0%	9.5%	3.8%	9.3%	7.9%
Other services, except public administration	4.5%	5.3%	5.6%	4.9%	4.7%	4.8%
Public administration	2.3%	3.1%	2.3%	4.1%	2.8%	4.4%

Table 2.5. Value of county sales, shipments, receipts, revenue, or business done ($1,000) reported in the 2017 Economic Census of the U.S. (U.S. Census Bureau 2018).

Industry	Benton County Sales, $1,000 (Percent of Arkansas)	Boone County Sales, $1,000 (Percent of Arkansas)	Carrol County Sales, $1,000 (Percent of Arkansas)	Madison County Sales, $1,000 (Percent of Arkansas)	Washington County Sales, $1,000 (Percent of Arkansas)	Sum of Sales, $1,000	Arkansas Sales, $1,000
Manufacturing	$3,579,265 (6%)	$438,492 (1%)	$796,647 (1%)	$315,196 (1%)	$4,188,127 (7%)	$9,768,937 (17%)	$58,363,748
Wholesale trade	$2,400,075 (3%)	D	$52,274 (<1%)	D	$2,389,244 (3%)	$4,850,064 (6%)	$74,585,556
Retail trade	$3,717,446 (9%)	$622,351 (2%)	$250,069 (1%)	$95,884 <1%)	$3,587,770 (9%)	$8,497,505 (21%)	$40,174,079
Transportation and warehousing	$2,016,005 (25%)	$123,689 (2%)	$15,225 (<1%)	D	$887,626 (11%)	$3,062,188 (38%)	$8,011,461
Real estate and rental and leasing	$302,945 (12%)	$18,401 (1%)	$10,580 (<1%)	D	$319,084 (12%)	$653,019 (25%)	$2,588,174
Professional, scientific, and technical services	$1,250,038 (22%)	$19,212 (<1%)	$197,511 (4%)	D	$527,814 (9%)	$2,004,492 (36%)	$5,564,917
Administrative and support and waste management and remediation services	$331,494 (9%)	$65,459 (2%)	$16,554 (<1%)	$5,115 (<1%)	$346,066 (9%)	$767,600 (21%)	$3,675,744
Educational Services	$22,990 (14%)	D	$822 (1%)	N/A	D	$23,812 (15%)	$161,583
Health care and social assistance	$1,214,805 (6%)	$232,246 (1%)	$75,092 (<1%)	$14,552 (<1%)	$1,795,258 (9%)	$3,387,404 (17%)	$19,845,377
Arts, entertainment, and recreation	$129,927 (12%)	D	D	D	$68,491 (6%)	$198,418 (19%)	$1,056,596
Accommodation and food services	$610,252 (11%)	$58,058 (1%)	$69,869 (1%)	$9,971 (<1%)	$581,703 (11%)	$1,350,882 (25%)	$5,484,783
Other services (except public administration)	$287,856 (10%)	D	$14,207 (<1%)	D	$488,462 (17%)	$794,391 (28%)	$2,873,816
Sum of Sales, $1000	$15,863,098 (7%)	$1,577,908 (1%)	$1,498,850 (1%)	$440,718 (<1%)	$15,179,645 (7%)	$35,358,712 (16%)	222,385,834

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

Table 2.6. Value of county and state sales of agricultural commodities in thousands of dollars (USDA National Agricultural Statistics Service 2017).

Commodity	Benton County, $1,000 (Percent of Arkansas)	Boone County, $1,000 (Percent of Arkansas)	Carrol County, $1,000 (Percent of Arkansas)	Madison County, $1,000 (Percent of Arkansas)	Washington County. $1,000 (Percent of Arkansas)	State of Arkansas, $1,000
All agricultural products	$593,371 (6%)	$164,017 (2%)	$363,617 (4%)	$279,342 (3%)	$509,256 (5%)	$9,651,160
All crops	$7,562 (<1%)	$3,114 (<1%)	$3,409 (<1%)	$6,055 (<1%)	$7,722 (<1%)	$3,624,930
Rice	N/A	N/A	N/A	N/A	N/A	$922,214
Soybeans	$1,012 (<1%)	N/A	N/A	N/A	(D)	$1,717,830
Cotton	N/A	N/A	N/A	N/A	N/A	$342,825
Corn	$429 (<1%)	(D)	$23 (<1%)	(D)	(D)	$386,041
Wheat	$124 (<1%)	(D)	N/A	(D)	(D)	$29,023
Other crops and hay	$3,343 (3%)	$2,248 (2%)	$2,187 (2%)	$3,536 (3%)	$4,212 (4%)	$110,864
Fruit and tree nut	$351 (2%)	$184 (1%)	$658 (3%)	(D)	$602 (3%)	$19,535
Vegetable (including seeds, transplants)	(D)	(D)	$280 (1%)	$175 (<1%)	$598 (1%)	$45,129
All livestock	$585,810 (10%)	$160,903 (3%)	$360,208 (6%)	$273,286 (5%)	$501,534 (8%)	$6,026,230
Cattle and calves	$41,596 (6%)	$53,759 (7%)	$36,949 (5%)	$27,075 (4%)	$42,300 (6%)	$737,961
Poultry and eggs	$536,033 (10%)	$106,494 (2%)	$322,780 (6%)	$244,464 (5%)	$456,508 (9%)	$5,112,242
Hogs and pigs	(D)	(D)	(D)	(D)	(D)	$69,438
Horses, etc.	$298 (3%)	$240 (2%)	$110 (1%)	$168 (2%)	$578 (5%)	$10,525
Sheep, goats products	$346 (8%)	$224 (5%)	$161 (4%)	$92 (2%)	$177 (4%)	$4,190
Aquaculture	(D)	N/A	(D)	(D)	N/A	$71,121

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

The COVID-19 Pandemic caused Arkansas tourism to decline in 2020. From 2020 to 2023 visitor spending increased 65%, exceeding 2019 levels (Arkansas Department of Parks, Heritage, and Tourism 2024a). A summary of 2023 travel-related revenue for selected counties of the Upper White River watershed is provided in Table 2.7.

Table 2.7. Tourism impact data for selected counties of the Upper White River watershed, 2023 (Arkansas Department of Parks, Heritage, and Tourism 2024b).

Industry	Benton County	Boone County	Carrol County	Madison County	Washington County	Sum
Visitor Spending (Millions)	$1,156.1	$83.20	$335.7	$17.3	$768.5	$2,360.80
Labor Income (Millions)	$255.6	$18.70	$82.1	$2.8	$215.2	$574.40
Travel-Generated Employment (Jobs)	8,858	720	3,278	81	6,381	19,318
Travel-Generated State Taxes (Millions)	$81.1	$5.40	$22.3	$1.1	$46.1	$156.00
Travel-Generated Local Taxes (Millions)	$36.0	$1.90	$6.9	$0.6	$15.7	$61.10

The U.S. Army Corps of Engineers (USACE) has estimated the regional economic impact of recreation at Beaver Lake and Table Rock Lake reservoirs. Impacts for fiscal year 2023 to areas around the reservoirs are listed in Table 2.8.

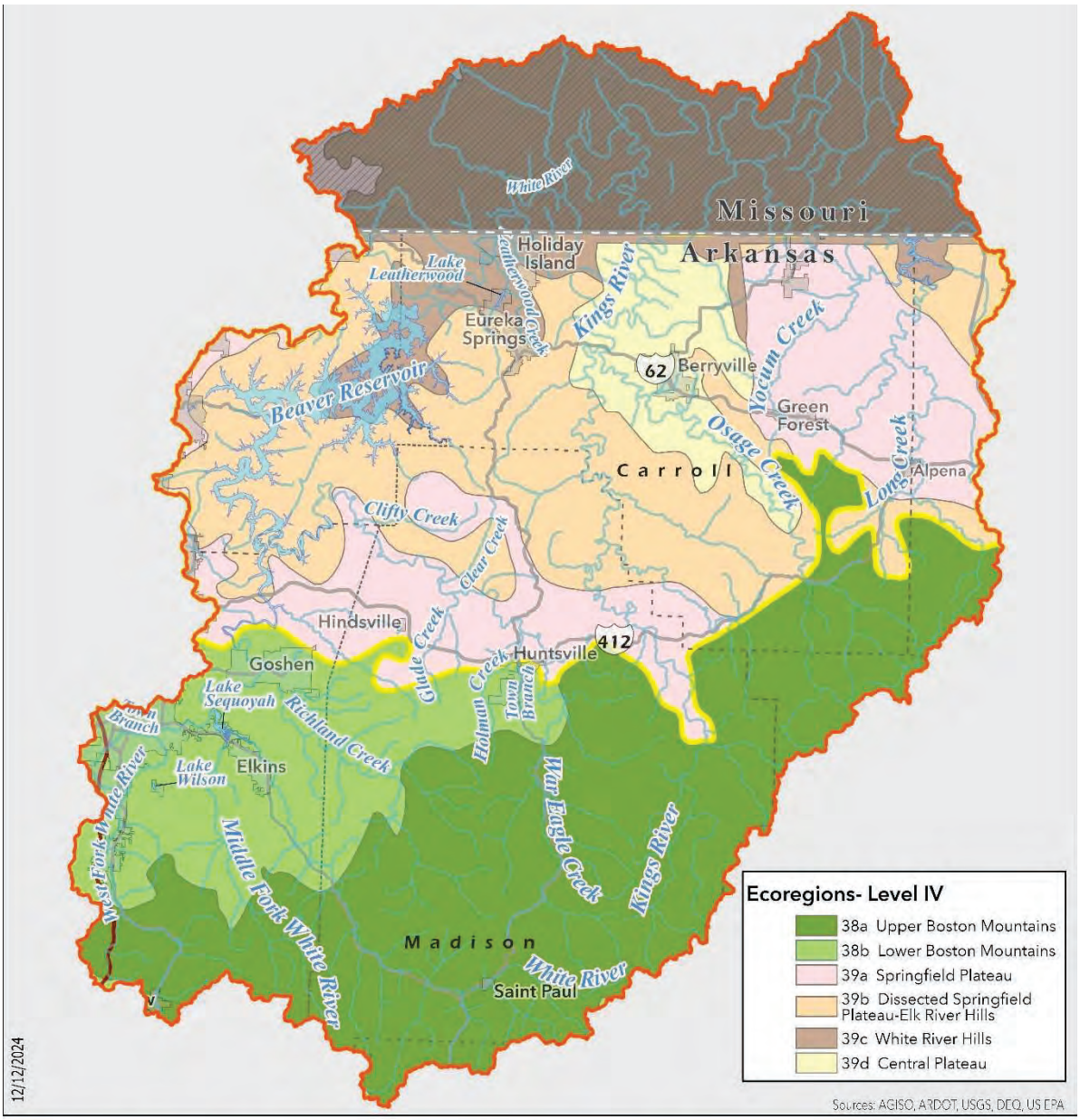
Table 2.8 Fiscal year 2023 economic impacts of recreation at Beaver Lake and Table Rock Lake (USACE Institute for Water Resources 2024).

Commodity	Beaver Lake Economic Impact Within 30 Miles of Reservoir	Beaver Lake Economic Data with Multiplier Effect*	Table Rock Lake Economic Impact Within 30 Miles of Reservoir	Table Rock Lake Economic Data with Multiplier Effect*
Visitor spending	$154,173,461	N/A	$280,352,836	N/A
Sales	$106,190,409	$180,421,814	$169,016,757	$258,621,406
Jobs supported/created	846	1,287	1,323	1,873
Labor income	$37,185,558	$60,911,582	$60,218,569	$86,725,601
Value added	$60,182,341	$99,971,829	$97,866,630	$144,027,647

*The multiplier effect reflects regional, i.e., greater than 30 miles, economic impacts.

2.3 Ecoregions

Two Level III (Boston Mountains and Ozark Highlands), and six Level IV ecoregions occur in the Upper White River watershed (Figure 2.2). Table 2.9 summarizes the characteristics of these ecoregions. These characteristics are described in greater detail in the following subsections.



Upper White River Watershed- Ecoregions, Level IV

tn Associates Ltd

NORTH

0 5 10 Miles

The northern portion of the Upper White River watershed lies in the Central Plateau, Springfield Plateau, Dissected Springfield Plateau-Elk River Hills, and the White River Hills subdivisions of the Ozark Highlands ecoregion. The southern portion of the watershed lies in the Upper and Lower subdivisions of the Boston Mountains ecoregion. The division between the Ozark Highlands and Boston Mountains ecoregions is shown by the yellow line in the map.

(U.S. EPA ecoregions, delineated via methods published by Omernik, 1995).

Figure 2.2. Ecoregions map of the Upper White River watershed (U.S. EPA 2014).

Table 2.9. Characteristics of Level IV ecoregions of the Upper White River watershed (from Woods et al. 2004).

Level III ecoregion code and name	Level IV ecoregion code and name	Topography	Hydrology	Elevation/local relief (feet)	Geology	Common soil series	Mean annual precipitation (inches)	Natural vegetation
38. Boston Mountains	38a. Upper Boston Mountains	Dissected, rugged mountains with steep slopes, sharp ridges, and narrow valleys. Benches on the mountainsides occur and are characteristic.	Summer flow in many streams is zero or near zero but enduring pools fed by interstitial flow occur.	Mostly 1900-2800/ 300-900	Quaternary colluvium and alluvium. Pennsylvanian sandstone, shale, limy sandstone, sandy limestone, and siltstone. Mountaintops: generally capped by resistant sandstone. Side slopes: interbedded sandstone, siltstone, and shale.	Uplands: Enders, Nella, Steprock, Mountainburg, Leesburg, Sidon, Nauvoo; upland soils have low natural fertility. Terraces and floodplains: Spadra, Ceda.	52-54	Potential natural vegetation: oak–hickory forest. Mixed deciduous forest and oak woodlands are native. Today, on upland areas: northern red oak, white oak, pignut hickory, and mockernut hickory. Today, on narrow floodplains and low terraces: sweetgum, willows, birch, American sycamore, hickories, southern red oak, and white oak.
38. Boston Mountains	38b. Lower Boston Mountains	Low mountains, rounded high hills, and undulating plateaus.	Summer flow in many streams is zero or near zero but enduring pools fed by interstitial flow occur.	Mostly 200-1900; up to 2300/ 150-800	Quaternary colluvium and alluvium. Pennsylvanian sandstone, shale, limy sandstone, sandy limestone, and siltstone. Mountaintops are usually capped by resistant sandstone. Side slopes are often underlain by interbedded sandstone, siltstone, and shale.	Uplands: Enders, Nella, Mountainburg, Steprock, Nella, Linker, Sidon; in east, Steprock and Linker are more widespread than in west. On floodplains and terraces: Ceda, Cleora, Razort, Spadra. Upland soils have low natural fertility.	46-52. The east is more moist than the west.	Potential natural vegetation: oak–hickory–pine forest and oak–hickory forest. Mixed oak and oak–pine forests, woodland, or savanna occur on uplands; northern red oak, white oak, post, scarlet, black, blackjack oak, pignut hickory, shagbark hickory, mockernut hickory, and shortleaf pine are native. On lower, drier south- and west-facing sites: shortleaf pine. On narrow floodplains and low terraces: sweetgum, willows, birch, American sycamore, hickories, southern red oak, and white oak.
39. Ozark Highlands	39a. Springfield Plateau	Nearly level to rolling, undissected or slightly dissected portion of the Springfield Plateau. Karst features including caves, sinkholes, and solution valleys occur.	Springs are common and contribute substantially to streamflow in the summer and fall. Many streams flow year-round, but some dry valleys occur.	260-1600; uplands are lowest in the east/ mostly 50-200	Quaternary cherty clay solution residuum and limited amounts of alluvium. Extensive limestone and interbedded chert of the Mississippian Boone Formation.	On uplands underlain by cherty limestone: Noark, Clarksville, Nixa, Captina, Tonti. On uplands underlain by sandstone: Linker, Mountainburg. On floodplains or low terraces: Secesh, Razort.	44-48. Parts are in the rain shadow of the Boston Mountains.	Potential natural vegetation: oak–hickory forest and some oak–hickory–pine forest. Before the 19th century, savanna or tall grass prairies were common and maintained by fire. Native on uplands: mixed deciduous forest (containing black oak, white oak, blackjack oak, post oak, and hickories) with some mixed deciduous–shortleaf pine forest. Native on floodplains and low terraces: willows, maples, hickories, birch, American elm, and American sycamore.
39. Ozark Highlands	39b. Dissected Springfield Plateau-Elk River Hills	Moderately to highly dissected, hilly part of the Springfield Plateau. Gently sloping, narrow ridge tops are separated by steep V-shaped valleys. Karst features occur.	Springs are common and contribute to streamflow in the summer and fall. Streams are usually perennial but some dry valleys occur.	300-1850/ 50-800	Quaternary cherty clay solution residuum, colluvium, and alluvium. On uplands: limestone and interbedded chert of the Mississippian Boone Formation. Along deeply entrenched rivers: early-Mississippian or Devonian Chattanooga Shale and Ordovician Cotter Dolomite. Rock outcrops.	Clarksville, Nixa, Noark, Arkana, Moko, Portia, Estate	44-48. Parts are in the rain shadow of the Boston Mountains.	Potential natural vegetation: oak–hickory–pine forest and oak–hickory forest. Native on uplands: oak–woodland, mixed deciduous forest, or mixed deciduous–pine forest containing black oak, white oak, blackjack oak, post oak, hickories, and shortleaf pine. Native on north-facing slopes and in ravines: mesic forest containing sugar maple, white oak, northern red oak, and beech.
39. Ozark Highlands	39c. White River Hills	Moderately to highly dissected portion of the Salem Plateau containing hills, ridges, karst features, and entrenched,	Streams generally flow year-round, reflecting the influence of	540-1800/ 150-800	Quaternary cherty silty to sandy clay solution residuum, silty sand to sandy silt decomposition residuum, colluvium, and limited amounts of alluvium. Dolomite, chert, and limestone occur and are sometimes	On uplands: Arkana, Moko, Doniphan, Gassville, Nixa, Clarksville, Noark, Estate, Portia. On floodplains: Razort, Elsah.	42-47	Potential natural vegetation: oak–hickory forest, cedar glades, and, in the west, oak–hickory–pine forest. Native on uplands: mixed deciduous forest (containing black oak, white oak, blackjack oak, post oak, and hickories) and also mixed deciduous–shortleaf pine forest. Native on driest sites with shallow, rocky soils over dolomite and limestone: glades consisting of

Table 2.9. Characteristics of Level IV ecoregions of the Upper White River watershed (from Woods et al. 2004) (continued).

Level III ecoregion code and name	Level IV ecoregion code and name	Topography	Hydrology	Elevation/local relief (feet)	Geology	Common soil series	Mean annual precipitation (inches)	Natural vegetation
		narrow valleys. Flat land is uncommon, but benches and bottomlands flank the White River.	ground water, but dry valleys occur.		interbedded with sandstone and shale. Ordovician Cotter Dolomite and Jefferson City Dolomite are common but, near the southern boundary, Mississippian Boone Formation occurs.			eastern redcedar, Ashe juniper, native grasses, and sparse populations of post oak and elm.
39. Ozark Highlands	39d. Central Plateau	Undulating to hilly part of the Salem Plateau containing hollows, ridges, knobs, and karst features including caves and sinkholes; along major rivers, narrow corridors of nearly level bottomland occur. Generally, slightly to moderately dissected, but steep, highly dissected terrain is found near major rivers.	Springs are common in some areas and contribute substantially to streamflow in the summer and fall. On bottomlands, floodwaters rise and recede quickly	Mostly 250-1400; maximum 1700/ 100-600	Quaternary cherty silty to sandy clay solution residuum, silty sand and sandy silt decomposition residuum, colluvium, and alluvium. Dolomite and limestone are extensive and often cherty; interbedded sandstone and shale also occur. Includes Ordovician Jefferson City Dolomite, Cotter Dolomite, Powell Dolomite, Everton Formation, and St. Peter Sandstone.	On uplands underlain by cherty carbonates: Gepp, Doniphan, Arkana, Agnos, Ventris, Gassville, Moko, Captina, Eldon. On cherty ridgetops and upper slopes: Clarksville. On sandstone uplands: Boden, Brockwell, Brocket, Lily, Portia. On floodplains or low terraces: Hontas, Sturkie, Razort. Upland soils are stony, thin, droughty, and shallower than bottomland soils.	44-49. West-facing slopes receive more precipitation than valleys.	Potential natural vegetation: oak–hickory forest, oak–hickory–pine forest, and scattered cedar glades. Forest, savanna, glades, barrens, and upland prairies occurred before the nineteenth century. Native on uplands: mixed forest containing blackjack oak, post oak, black oak, white oak, hickories. On droughty, rocky slopes: post oak, blackjack oak, and shortleaf pine. On thin soils: barrens with sparse tree cover with herbaceous ground cover. Native on north-facing slopes and in hollows: mesic forests containing sugar maple, white oak, northern red oak, and beech. On shallow, rocky, droughty soils underlain by dolomite or limestone: cedar glades. Native on floodplains and low terraces: southern red oak, white oak, American sycamore, willow, eastern cottonwood, maples, birch, and ash.

2.3.1 Climate

Climate normals are 30-year averages of climate data, calculated at individual recording stations for the United States by the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information. The 1991-2020 normal annual precipitation for the Upper White River watershed is between 40 and 60 inches, normal low temperature is between 46 and 49 degrees Fahrenheit, and normal maximum temperature is between 65 and 71 degrees Fahrenheit (RTI International 2023). Climate normal average monthly precipitation and the average monthly minimum and maximum temperatures at Huntsville (station ID USC00033544) are shown on Figure 2.3.

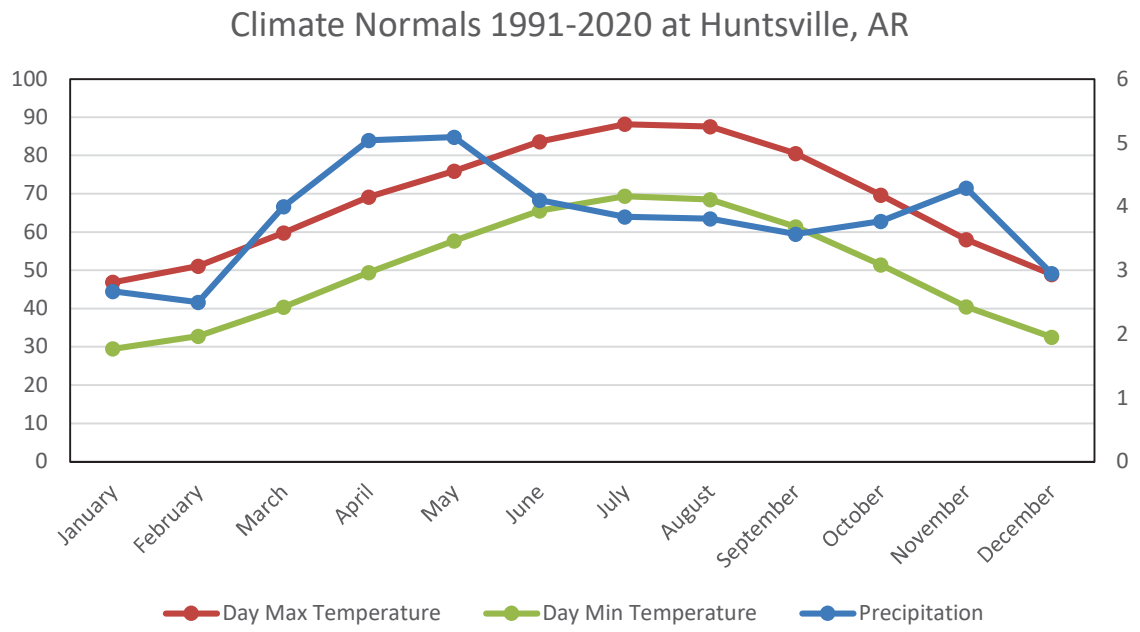


Figure 2.3. Climate normals at Hunstville, 1991-2020 (NOAA 2021).

Climate change expectations in this region are for wetter and warmer summers and fewer days below freezing during the winter. On average, climate change models predict summer precipitation doubling by 2050 and average summer temperature increasing by around six degrees Fahrenheit. In 2050, around 20 fewer days of freezing temperatures are predicted. Climate changes are expected to affect water quality in the Upper White River watershed (RTI

International 2023). A comparison of current climate normals to earlier normals (1980-2010) appear to support these predictions (see Figure 2.4). Current precipitation normals are higher than previous normals during July and August, and in most months, current minimum and maximum temperature normals are higher than previous normals. The greatest change in normal temperatures is seen in December, possibly reflecting a reduction in days of freezing temperatures.

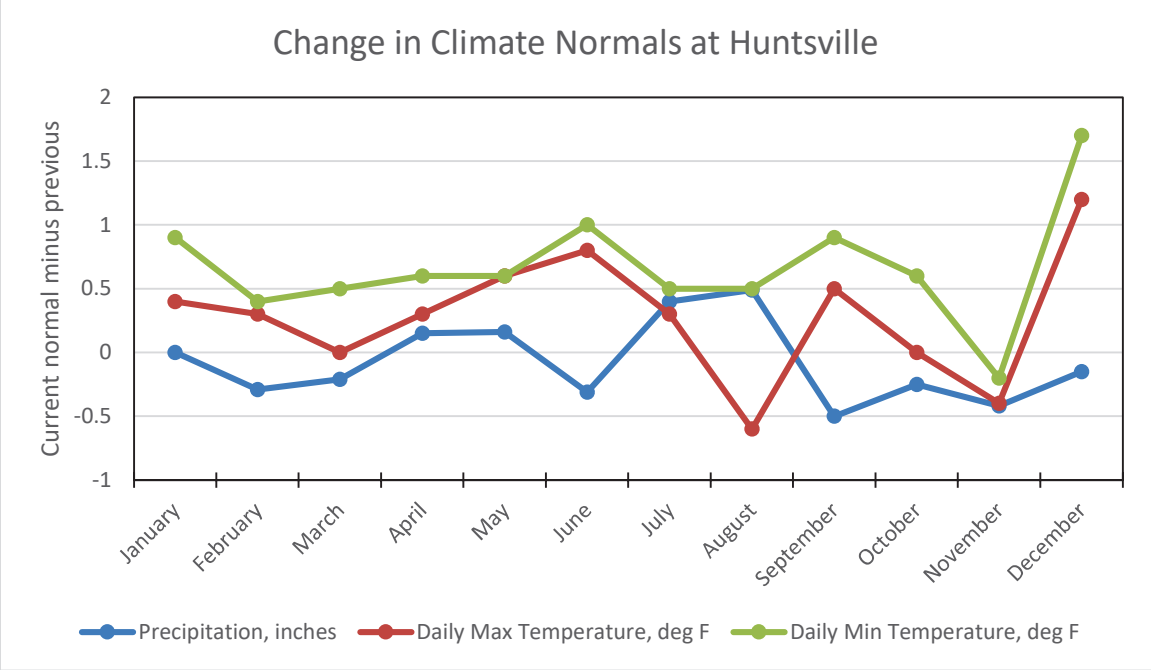


Figure 2.4. Difference in climate normals, current (1991-2020) minus previous (1981-2010) (NOAA 2021).

2.3.2 Geology

The Upper White River watershed includes areas in the Boston Mountains, Springfield, and Salem Plateaus of the Ozark Plateaus physiographic province (Figure 2.5). The Ozark Plateaus are underlain by Paleozoic rocks ranging in age from Ordovician to Pennsylvanian. These formations consists of fairly level layers of primarily sandstone and shale (including the Fayetteville shale), with some chert, dolostone, and limestone (Kilpatrick and Ludwig 1990)

(McFarland 2004). These sedimentary rocks were deposited mostly by shallow marine seas. Caves and sinkholes are common in the Mississippian limestone formations of the Springfield Plateau. These karst features are less common in the Ordovician dolostone formations of the Salem Plateau. Table 2.10 shows the stratigraphy of the geology underlying the watershed.

Table 2.10. Stratigraphy of geology underlying Upper White River watershed (oldest formations at the top, youngest at the bottom) (McFarland 2004).

System	Formation	General Geology
Pennsylvanian	Atoka Formation	Silty sandstone, shale
	Prairie Grove/Bloyd Shale	Shale
	Cane Hill/Hale Formation	Shale, siltstone, sandstone
Mississippian	Pitkin Limestone	Limestone
	Fayetteville Shale	Shale
	Batesville Sandstone	Sandstone
	Boone Formation	Limestone
	St. Joe Limestone	Limestone
Devonian	Chattanooga Shale	Shale
	Clifty Limestone	Limestone
	Penters Chert	Chert
Ordovician	St. Peter Sandstone	Sandstone
	Everton Formation	Dolostone, Sandstone, Limestone
	Powell Dolomite	Dolomite
	Cotter Dolomite	Dolomite
	Jefferson City Dolomite	Dolomite
	Roubidoux Formation	Sandstone
	Gasconade Dolomite	Dolomite
	Gunter Sandstone	Sandstone
	Van Buren Formation	Sandstone

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

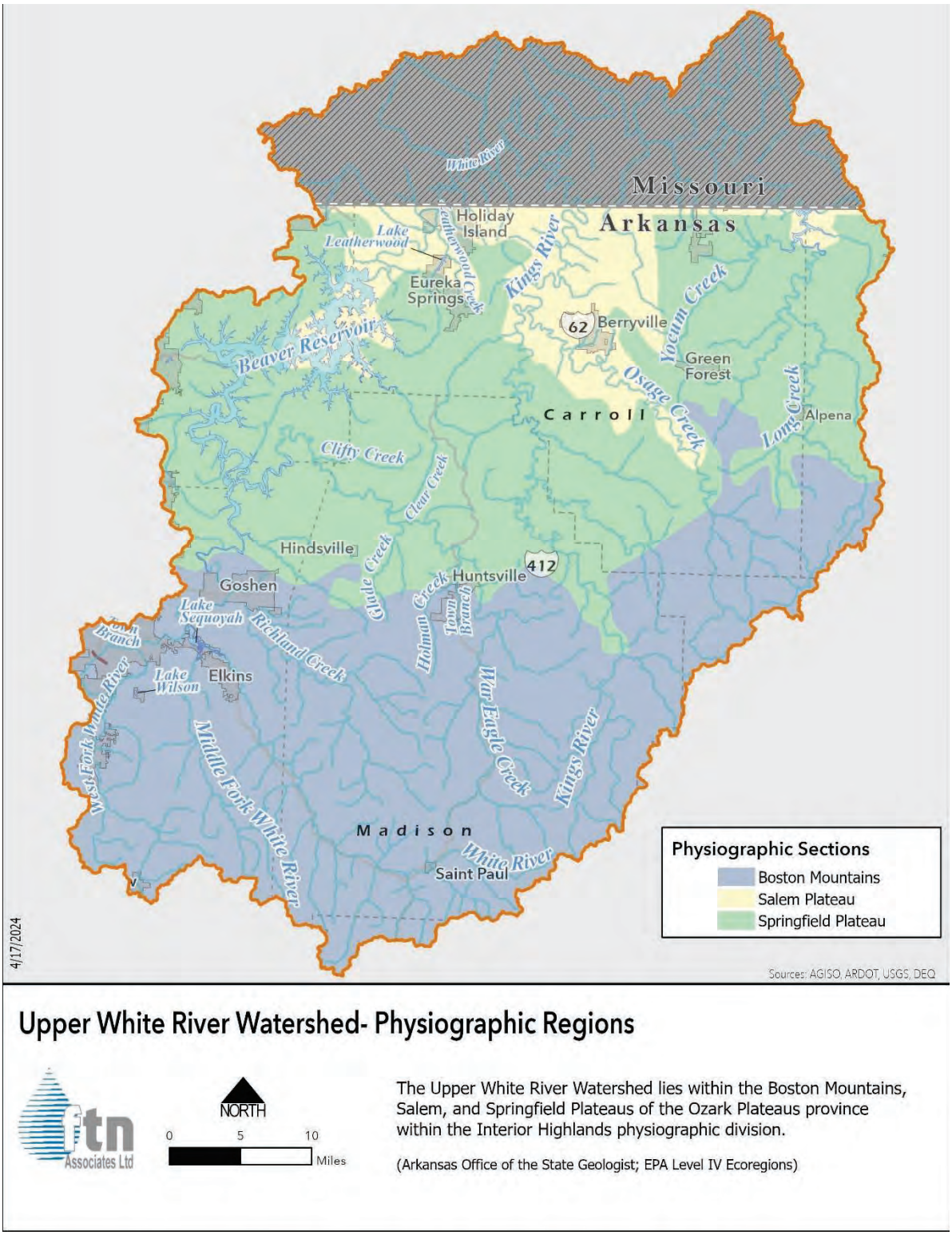


Figure 2.5. Map of physiographic provinces of the Upper White River watershed.

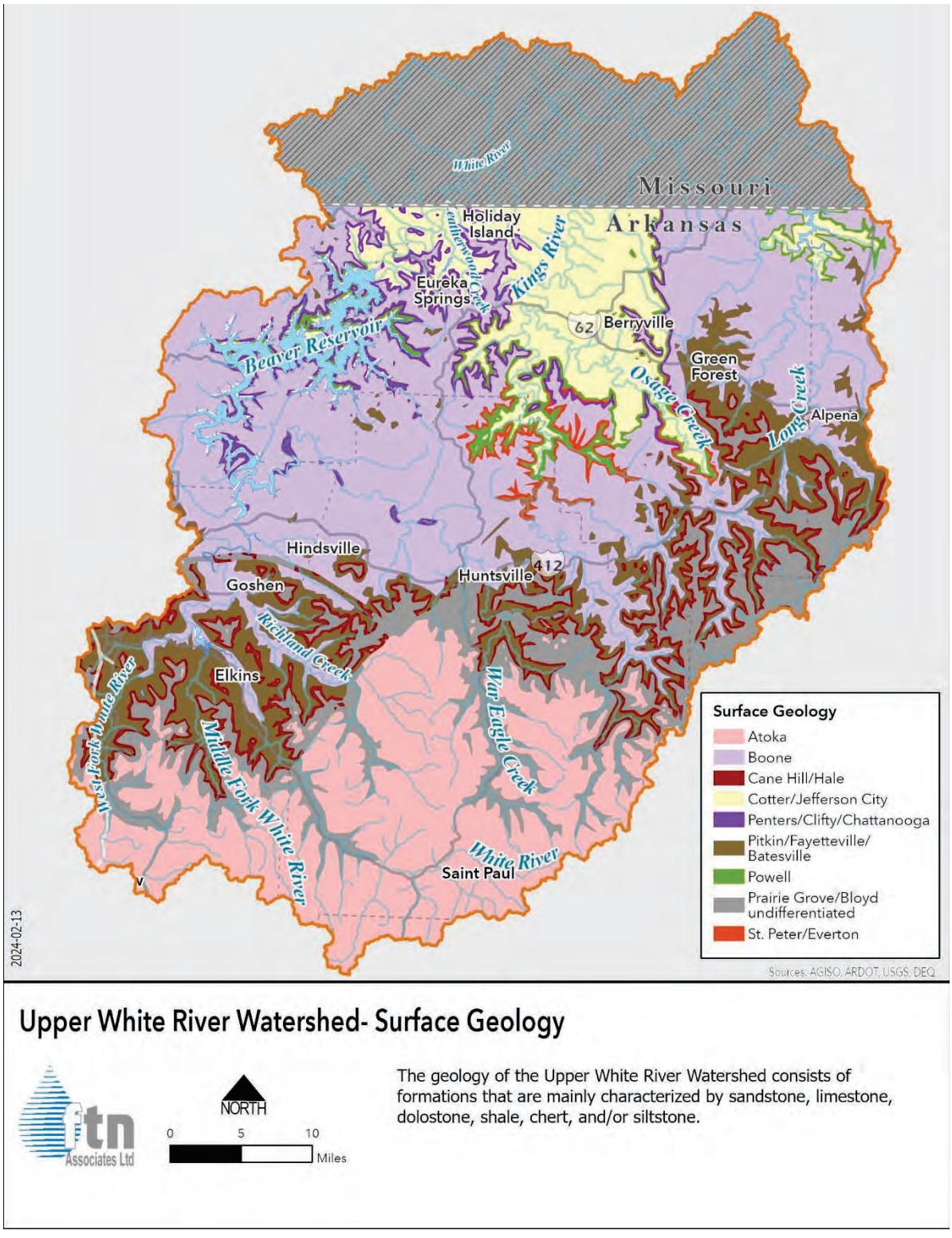


Figure 2.6. Surface geology map of Upper White River watershed.

2.3.3 Topography

The three physiographic subdivisions in the Upper White River watershed are topographically distinct (Figure 2.5). The southern watershed (headwaters) is in the Boston Mountains. The Boston Mountains have the highest elevations of the three subdivisions, and are the most extensively eroded, resulting in rugged terrain characterized by ravines and gorges 500 to 1,200 feet deep. The Springfield Plateau is north of the Boston Mountains. The topography of this division is characterized as gently rolling hills. The Salem Plateau is the most northern division. Topography in this subdivision is characterized as relatively level to gently rolling (Miller 2006).

Elevations within the Upper White River watershed range from 2,490 feet above sea level in the Boston Mountains of the watershed headwaters, to 902 feet above sea level in the lower end of the watershed where Brush Creek (a Table Rock Lake tributary) crosses the Missouri state line (Center for Advanced Spatial Technologies 2006). The gradient of White River from the headwaters to the Missouri state line, 143 miles, is about 10 feet/mile. The gradient of the Kings River from the headwaters to the Missouri state line, 102 miles, is about 15 feet/mile (USGS 2023). Overall, the watershed slopes generally to the north.

Land slopes in the Upper White River watershed range from zero degrees in river valleys and on plateaus, to around 81 degrees (693% grade) on cliff faces and hill sides in the Boston Mountains. Slopes of 14% or more are considered steep and areas with slopes of 7% or less are considered flat lands. Geographic Information System (GIS) analysis indicates that about 68% of the watershed has slopes flatter than 7%. Table 2.11 lists the proportion of the Upper White River watershed considered flat lands, steep, and in between. Figure 2.7 shows a map of the locations of areas within the three slope ranges.

Table 2.11. Slope areas in the Upper White River watershed.

Slope ranges, degrees	Area within the watershed, acres	Percent of watershed
<7%	949,165	68%
7-14%	341,822	25%
>14%	98,949	7%
Total	1,389,936	100%

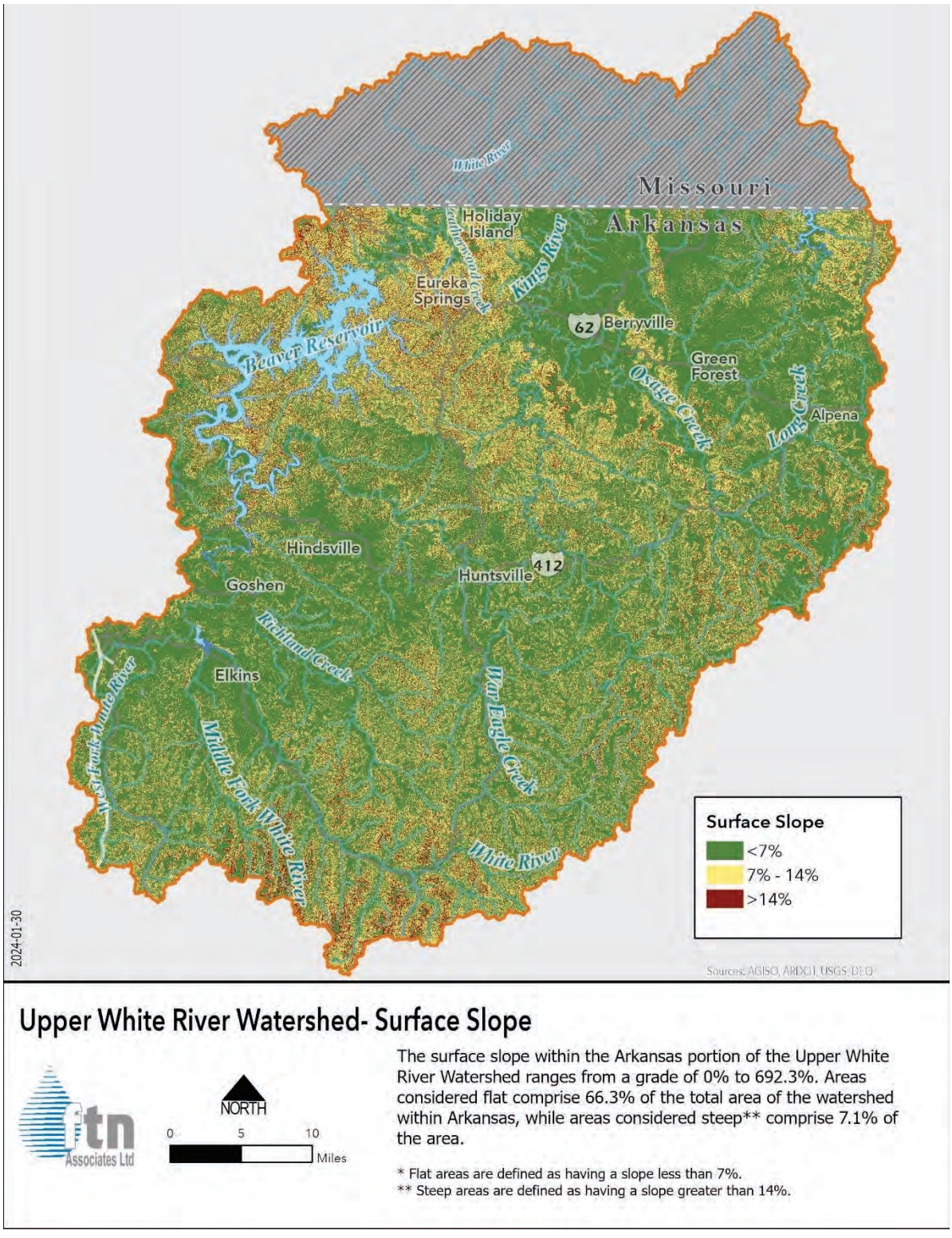


Figure 2.7. Slope map of the Upper White River watershed.

2.3.4 Soils

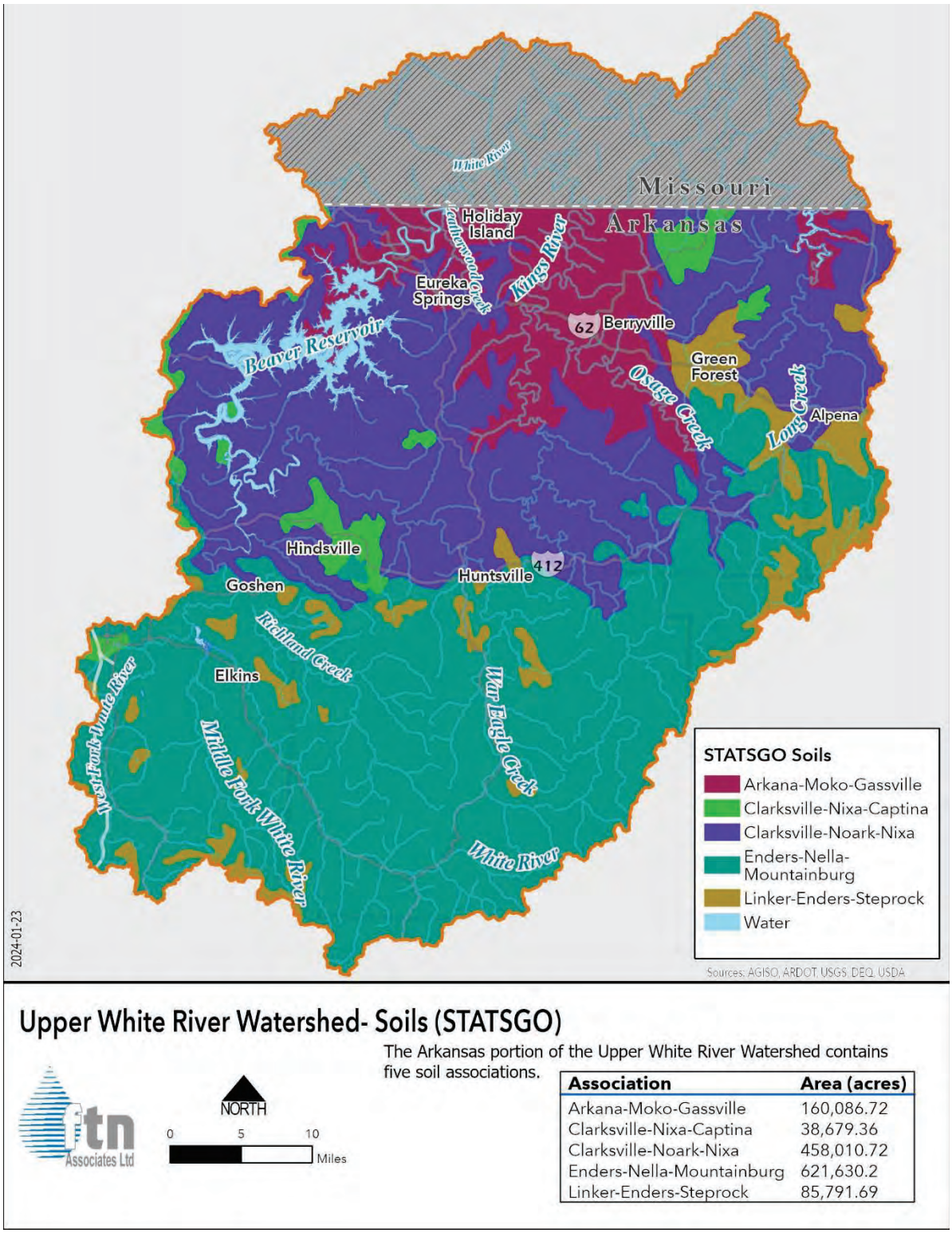
Table 2.12 lists the soil associations present in the Upper White River watershed with selected characteristics. Figure 2.8 shows a map of these soil associations in the watershed. Soils in the watershed are primarily loamy and stony, deep to moderately deep, and well drained.

Table 2.12. Soil associations present in the Upper White River watershed (NRCS 2014).

Soil Association	Drainage	USDA Texture
Arkana-Moko-Gassville	Well drained	Clay to stony silt-loam
Clarksville-Nixa-Captina	Moderately well drained to somewhat excessively drained	Clay to gravelly silt-loam
Clarksville-Noark-Nixa	Moderately well drained to somewhat excessively drained	Clay to gravelly silt-loam
Enders-Nella-Mountainburg	Well drained	Cobbly clay-loam to stony fine sandy-loam
Linker-Enders-Steprock	Well drained	Clay-loam to stony fine sandy-loam

2.3.5 Land Use/Land Cover

Forest is the predominant land use in the Upper White River watershed. Sixty percent of the watershed's land area is forested (Figure 2.9). Most of the forest is in the basin headwaters and around Beaver Lake (Figure 2.10). Twenty-eight percent of the land is pasture, which is concentrated in the northeastern and west central watershed. Six percent of the watershed is urban and suburban, with the largest developed areas around Fayetteville, Berryville, and Green Forest. Three percent of the watershed is in other land uses (barren, herbaceous, and shrub) and less than 1% is wetlands. The remaining area is covered by water, most of which is Beaver Lake.



Association	Area (acres)
Arkana-Moko-Gassville	160,086.72
Clarksville-Nixa-Captina	38,679.36
Clarksville-Noark-Nixa	458,010.72
Enders-Nella-Mountainburg	621,630.2
Linker-Enders-Steprock	85,791.69

Figure 2.8. Map of major soil associations within the Upper White River watershed.

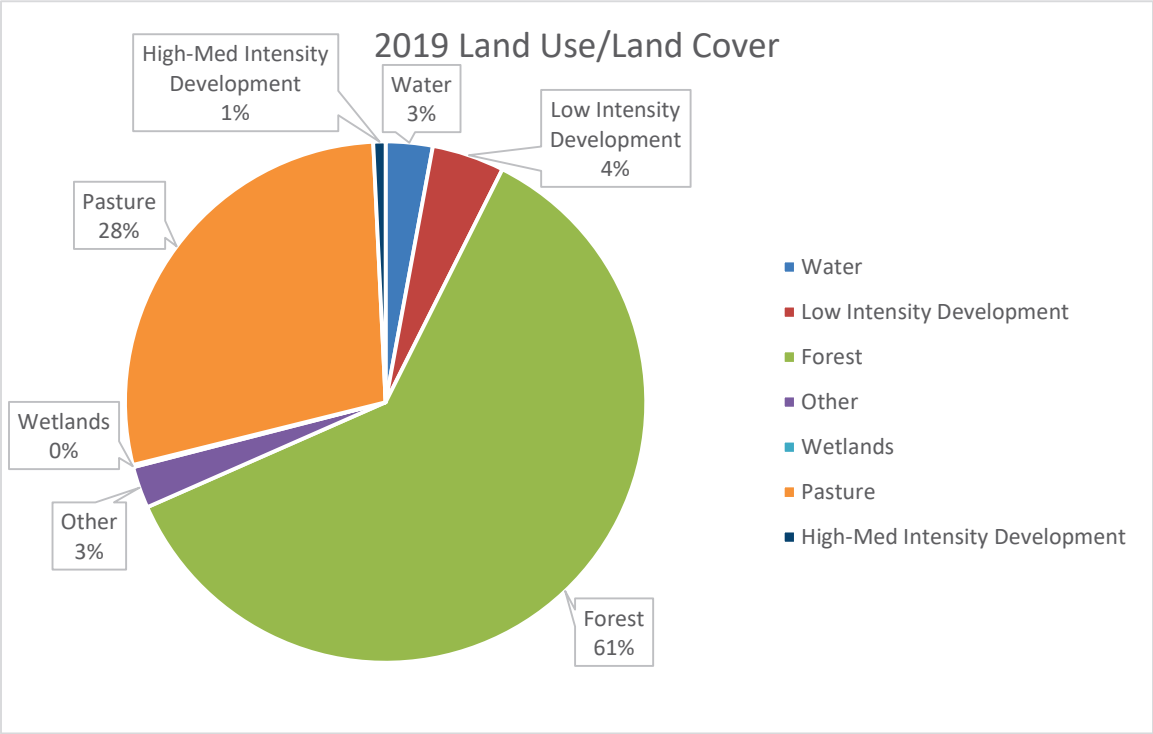


Figure 2.9. Upper White River summary of 2019 land cover (Dewitz and USGS 2021).

Land use change has been identified as a concern in this watershed. Table 2.13 shows a summary and comparison of 2001 and 2019 land cover in the watershed. Land covers that declined from 2001 to 2019 are forest, pasture, crops, and wetlands. While concerns have been raised about increasing areas of development in this watershed, the greatest percent change 2001 to 2019 were in herbaceous and scrub/shrub covers, which account for 1.5% or less of the land area. Medium and high intensity development increased more than other classes of development between 2001 and 2019, both increased 58%. Land cover changes for subbasins of the Upper White River watershed are summarized in Appendix B. Changes in land cover and land use have the potential to affect water quality and quantity in the watershed.

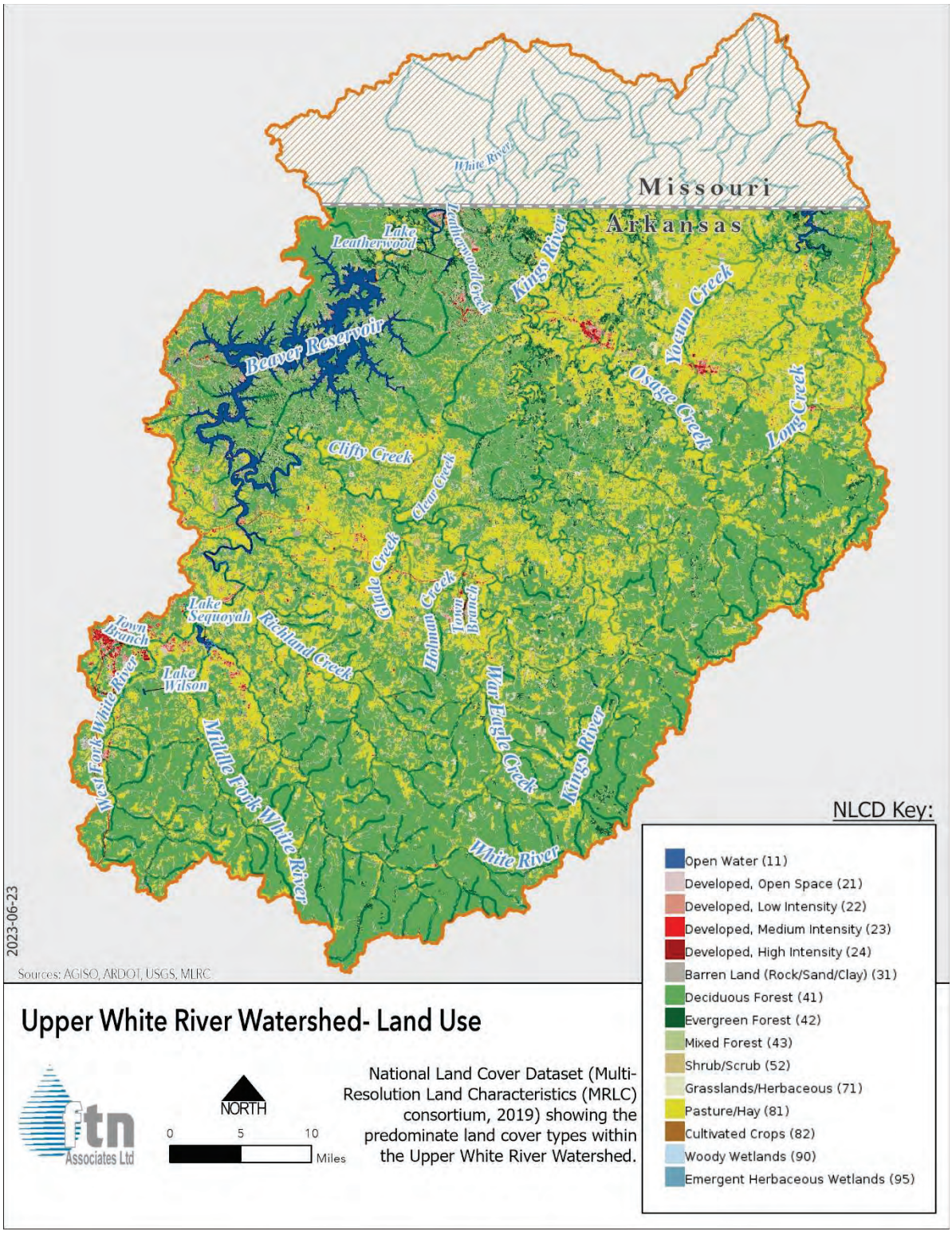


Figure 2.10. Upper White River map of 2019 land cover (Dewitz and USGS 2021).

Table 2.13. Comparison of 2001 land cover to 2019 land cover (Multi-Resolution Land Characteristics Consortium 2022).

Land Cover	2001 Area, acres	2001 % of Watershed	2019 Area, acres	2019 % of Watershed	Area % change (2019-2001/2001)	Percent Difference (2019% - 2001%)
Open Water	61,917	3.79%	64,136	3.93%	3.58%	0.14%
Developed, Open Space	69,800	4.28%	70,102	4.30%	0.43%	0.02%
Developed, Low Intensity	24,384	1.49%	26,414	1.62%	8.32%	0.12%
Developed, Medium Intensity	6,521	0.40%	10,311	0.63%	58.12%	0.23%
Developed, High Intensity	1,458	0.09%	2,299	0.14%	57.63%	0.05%
Barren Land	2,982	0.18%	3,509	0.21%	17.69%	0.03%
Forest	1,012,469	62.04%	988,251	60.55%	-2.39%	-1.49%
Shrub/Scrub	1,841	0.11%	11,815	0.72%	541.69%	0.61%
Herbaceous	5,296	0.32%	24,439	1.5%	361.43%	1.18%
Hay/Pasture	443,001	27.14%	428,602	26.26%	-3.25%	-0.88%
Cultivated Crops	45	0.00%	40	0.00%	-11.27%	-0.01%
Wetlands	2,451	0.15%	2,248	0.13%	-8.28%	-0.02%
Total	**1,632,165**	**99.99%**	**1,632,166**	**99.99%**		

2.4 Water Resources

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

2.4.1 Surface Water

The Upper White River watershed contains over 2,700 miles of streams and over 40 square miles of impounded water (Center for Advanced Spatial Technologies 2006). The longest streamline is 143 miles, from the headwaters of the White River to the Missouri state line.

The White River is impounded by the Beaver Dam at mile 609 in Carroll County. Beaver Lake is a multipurpose reservoir built and managed by the USACE. This reservoir is 49.71 miles long with a surface area of 44 square miles (Wikipedia 2023). When the water level is at 1,120 ft msl the reservoir contains 936,500 acre-feet of water (USACE Little Rock District n.d.). The purposes for which USACE manages the reservoir are primarily flood control, hydropower generation, and water supply with the secondary purpose of fish and wildlife support (USACE n.d.). Four water utilities withdraw water from Beaver Lake (USACE 2017). These utilities sell some of their withdrawals to other water utilities in the region. As a result, over 500,000 people in Arkansas get their drinking water from Beaver Lake. Releases from Beaver Lake are set to meet demands for power generation, and to achieve downstream temperature and dissolved oxygen targets (USACE n.d.).

2.4.2 Groundwater

Two aquifers are present beneath the Upper White River watershed. The Ozark aquifer is present under the entire watershed. This aquifer is unconfined in the Salem Plateau and confined in the Springfield Plateau and Boston Mountains (Figure 2.12). In the Upper White River watershed, the Ozark aquifer consists of Clifty, Penters, St. Peter, Everton, Powell, Cotter, Jefferson City, Roubidoux, Gasconade, and Gunter formations (see Table 2.14). The thickness of this series of water-bearing formations ranges from 2,000 to 3,000 feet (Kresse, et al. 2014)

The Springfield Plateau aquifer is present under the Springfield Plateau and the Boston Mountains. This aquifer is unconfined in the Springfield Plateau region and mostly confined in the Boston Mountains (Figure 2.11). In the Upper White River watershed the Springfield Plateau aquifer is present in the Boone formation (see Table 2.14) (Kresse, et al. 2014).

Table 2.14. Geologic formations in the Upper White River watershed associated with aquifers.

System	Formation	Lithology	Regional Geohydrologic Unit
Pennsylvanian	Atoka Formation	Silty Sandstone, Shale	Western Interior Plains confining system
	Prairie Grove/Bloyd Formation	Shale	
	Cane Hill/Hale Formation	Shale, Siltstone, Sandstone	
Mississippian	Pitkin Limestone	Limestone	
	Fayetteville Shale	Shale	
	Batesville Sandstone	Sandstone	
	Boone Formation	Limestone	Springfield Plateau aquifer
	St. Joe Limestone	Limestone	
Devonian	Chattanooga Shale	Shale	Ozark confining unit
	Clifty Limestone	Limestone	Upper Ozark aquifer
	Penters Chert	Chert	
Ordovician	St. Peter Sandstone	Sandstone	
	Everton Formation	Dolostone, Sandstone, Limestone	
	Powell Dolomite	Dolomite	
	Cotter Dolomite	Dolomite	
	Jefferson City Dolomite	Dolomite	
	Roubidoux Formation	Sandstone	Lower Ozark aquifer
	Gasconade Dolomite	Dolomite	
	Gunter Sandstone	Sandstone	
	Van Buren Formation		

Groundwater wells are common throughout the Western Interior Plains confining system, Springfield Plateau aquiver, and Ozark aquifer. These wells are typically for domestic and livestock supplies and a few small communities, resorts, and parks. Most municipal and regional water district systems within the Upper White River watershed are sourced by surface water.

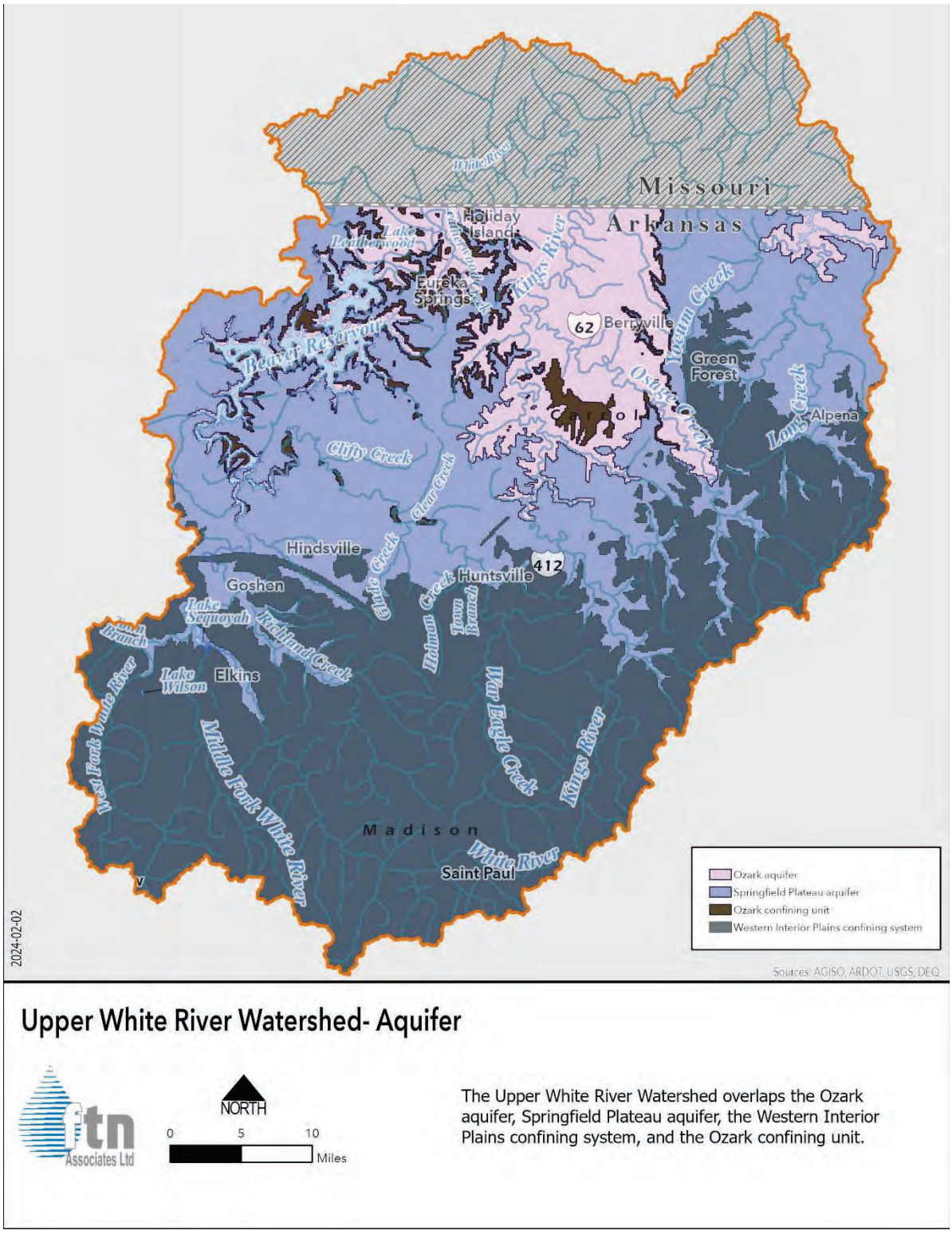


Figure 2.11. Map of aquifers in Upper White River watershed.

2.4.3 Interaction between surface water and groundwater

The interaction between surface- and ground-water flow systems is a function of factors such as geology, soil type, and topography and can differ substantially between basins and between physiographic sections or areas. The Upper White River watershed is located in the Ozark Plateaus Physiographic Province. Karst features are common in the Ozark Plateaus. Dissolution of carbonate rocks along fractures and faults provides a surface water to groundwater connection through cave systems, sinkholes, and natural tunnels.

Streams with sustained dry-season flow (base flow) have a large groundwater contribution to streamflow and streams with little or no dry-season flow receive relatively little groundwater and, in some instances, lose water to the groundwater system.

The amount of surface water and groundwater interaction generally can be characterized by flow-duration curves, dye-tracing, and seepage-run studies, and groundwater level information. In general, interaction between surface water and groundwater is much greater in the Springfield and Salem Plateaus than in the Boston Mountains. Flow-duration curves for streams in the Boston Mountains indicate extremely variable streamflow, largely from surface runoff. No streams in the Boston Mountains are perennial and few springs exist. Flow-duration curves for streams in the Salem and Springfield Plateaus have relatively flat slopes, indicating a well-sustained flow from surface or groundwater storage. Seasonal groundwater level fluctuations typically are greater in the Springfield Plateau, indicating that solution openings are well-developed and that recharge occurs locally (Adamski, et al. 1995). Freiwald (1987), studied streamflow gain and loss for several streams in northern Arkansas, including Kings River. The Kings River was found to be a gaining stream, receiving groundwater inputs primarily from the Boone Formation (Springfield Plateau aquifer). For most of the length of all of the streams evaluated by Freiwald in the Salem and Springfield Plateaus, groundwater contributed to streamflow. Short reaches where the streams recharge the groundwater system through losing stream channels also were identified.

2.5 Wildlife Resources

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

2.5.1 Protected Species

Thirteen animal and one plant species that may be found in the Upper White River watershed are listed as threatened or endangered by the state and/or federal government (Table 2.15). Three of these are threatened aquatic species, one is a candidate for threatened status, and there is one endangered mussel species. No critical habitats for threatened or endangered species have been designated within the Upper White River watershed.

Table 2.15. Listed protected species of the Upper White River watershed (USFWS 2023).

Common Name	Scientific Name	Category	Federal Status	State Status	Counties (streams, if they are listed)
Gray Bat	*Myotis grisescens*	Mammals	Endangered	S2- Imperiled in Arkansas	Benton, Boone, Carrol, Franklin, Madison, Newton, and Washington
Indiana Bat	*Myotis sodalis*	Mammals	Endangered	S1-Critically Imperiled in Arkansas	Benton, Boone, Carrol, Franklin, Madison, Newton, and Washington
Northern Long-eared Bat	*Myotis septentrionalis*	Mammals	Threatened	S1-Critically Imperiled in Arkansas	Benton, Boone, Carrol, Franklin, Madison, Newton, and Washington
Ozark Big-eared Bat	*Corynorhinus townsendii ingens*	Mammals	Endangered	S1-Critically Imperiled in Arkansas	Benton, Boone, Carrol, Franklin, Madison, Newton, and Washington
Tricolored Bat	*Perimyotis subflavus*	Mammals	Proposed Endangered	S5- Secure in Arkansas	Benton, Boone, Carrol, Franklin, Madison, Newton, and Washington
Eastern Black Rail	*Laterallus jamaicensis jamaicensis*	Birds	Threatened	SU- Presumed Extirpated in Arkansas	Benton, Boone, Carrol, Franklin, Madison, Newton, and Washington
Piping Plover	*Charadrius melodus*	Birds	Threatened	S1M- Critically Imperiled Migrant	Benton, Boone, Carrol, Franklin, Madison, Newton, and Washington
Red Knot	*Calidris canutus rufa*	Birds	Threatened	SNA-Not Applicable	Benton, Boone, Carrol, Franklin, Madison, Newton, and Washington
Alligator Snapping Turtle	*Macrochelys temminckii*	Reptiles	Proposed Threatened	S3-Vulnerable in Arkansas	Benton, Boone, Carrol, Franklin, Madison, Newton, and Washington
Ozark Cavefish	*Amblyopsis rosae*	Fish	Threatened	S1-Critically Imperiled in Arkansas	Benton and Washington
Rabbitsfoot	*Quadrula cylindrica cylindrica*	Clam	Threatened	S3-Vulnerable in Arkansas	Benton, Carrol, Madison, Newton, and Washington (White River, War Eagle Creek)
Snuffbox Mussel	Epioblasma triquetra	Clam	Endangered	S1-Critically Imperiled in Arkansas	Carrol
Monarch Butterfly	*Danaus plexippus*	Insect	Candidate	S5B- Secure Breeding Population	Benton, Boone, Carrol, Franklin, Madison, Newton, and Washington
Missouri Bladderpod	*Physaria filiformis*	Flowering Plant	Threatened	S1-Critically Imperiled in Arkansas	Washington

2.5.2 Species of Greatest Conservation Need

Arkansas Game and Fish Commission (AGFC) identifies an additional 80 or so aquatic species of greatest conservation need for the ecobasins[1] of the Upper White River in the Arkansas Wildlife Action Plan (38 for Boston Mountains - White River, 77 for Ozark Highlands – White River) (Fowler and Anderson 2015). Nine aquatic karst species of greatest conservation need listed in the Arkansas Wildlife Action Plan have been identified as present in the watershed (Inlander, Gallipeau and Slay 2011).

2.5.3 Nuisance Species

Non-native species of plants and animals are also present in the Upper White River watershed. Some of these species are considered invasive because they crowd out native species. Non-native aquatic invasive species that have been reported in the Upper White River watershed are listed in Table 2.16. This list includes sport fish species that are stocked in Beaver Lake or the White River cold-water fishery downstream of Beaver Dam. Asian clams have been identified as having the potential to affect populations of native mussels, including protected species present in the Upper White River watershed; Rabbitsfoot and Snuffbox (USFWS 2021, USFWS 2022). Common carp, Grass carp, and brown trout have also been identified as potentially impacting Snuffbox mussel populations (USFWS 2022). In addition to the species listed in Table 2.16, the algae Didymo (*Didymosphenia geminate*) has been reported in the Beaver Lake tailwaters (Arkansas Game and Fish Commission 2023).

[1] Ecobasins are the seven Arkansas Level III ecoregions subdivided by the six major river basins in Arkansas. AGFC defines a total of 18 ecobasins in the Arkansas Wildlife Action Plan.

Table 2.16. Non-native aquatic invasive species reported in the Upper White River watershed (USGS 2023).

Common Name	Scientific Name	Category	Source	Location	Status
Brazilian waterweed	Egeria densa	Plants	Exotic	Lake Lucerne	Established
Curly-leaf pondweed	*Potamogeton crispus*	Plants	Exotic	Benton County	Established
narrow-leaved cattail	Typha angustifolia	Plants	Exotic	Roadside ditch, Carroll County	Unknown
parrot feather	Myriophyllum aquaticum	Plants	Exotic	Eureka Springs	Established
water-cress	Nasturtium officinale	Plants	Exotic	Carroll and Madison counties	Established
Asian clam	Corbicula fluminea	Mollusks-Bivalves	Exotic	Beaver Lake, White River, Kings River, Leatherwood Creek	Established
freshwater jellyfish	Craspedacusta sowerbyi	Coelenterates-Hydrozoans	Exotic	Beaver Lake, White R near Eureka Springs	Unknown
a waterflea	Daphnia lumholtzi	Crustaceans-Cladocerans	Exotic	Beaver Lake	Collected
White River crawfish	Procambarus acutus	Crustaceans-Crayfish	Native Transplant	White River	Established
Brook Trout	Salvelinus fontinalis	Fishes	Native Transplant	White River	Stocked
Brown Trout	Salmo trutta	Fishes	Exotic	Beaver Lake tailwaters (White River)	Stocked, established
Common Carp	Cyprinus carpio	Fishes	Exotic	Beaver Lake, Kings River, Yocum Creek, Richland Creek, War Eagle Creek, White River, West Fork White River	Established
Cutthroat Trout	Oncorhynchus clarkii	Fishes	Native	Beaver Lake tailwaters (White River)	Stocked, established
Flathead Catfish	Pylodictis olivaris	Fishes	Native Transplant	Beaver Lake, War Eagle Creek, White River	established

Table 2.16. Non-native aquatic invasive species reported in the Upper White River watershed (continued).

Common Name	Scientific Name	Category	Source	Location	Status
Goldfish	Carassius auratus	Fishes	Exotic	Beaver Lake, Kings River, Richland Creek	Unknown
Grass Carp	Ctenopharyngodon idella	Fishes	Exotic	Beaver Lake	Unknown
Lake Trout	Salvelinus namaycush	Fishes	Native Transplant	Beaver Lake tailwaters (White River)	Established
Northern Pike	Esox lucius	Fishes	Native Transplant	Beaver Lake	established
Rainbow Trout	Oncorhynchus mykiss	Fishes	Native	Beaver Lake and tailwaters (White River)	Stocked, established
Rock Bass	Ambloplites rupestris	Fishes	Native Transplant	Kings River, Middle Fork White River, War Eagle Creek, White River	Established
Striped Bass	Morone saxatilis	Fishes	Native	Beaver Lake	Stocked, established
Threadfin Shad	Dorosoma petenense	Fishes	Native Transplant	Beaver Lake	Established
unidentified pacu	Colossoma or Piaractus sp.	Fishes	Exotic	Beaver Lake, White River	Failed
Walleye	Sander vitreus	Fishes	Native Transplant	Beaver Lake	Established
Western Mosquitofish	Gambusia affinis	Fishes	Native Transplant	Beaver Lake	Established
Wiper	Morone chrysops × saxatilis	Fishes	Native Hybrid	Beaver Lake	Stocked

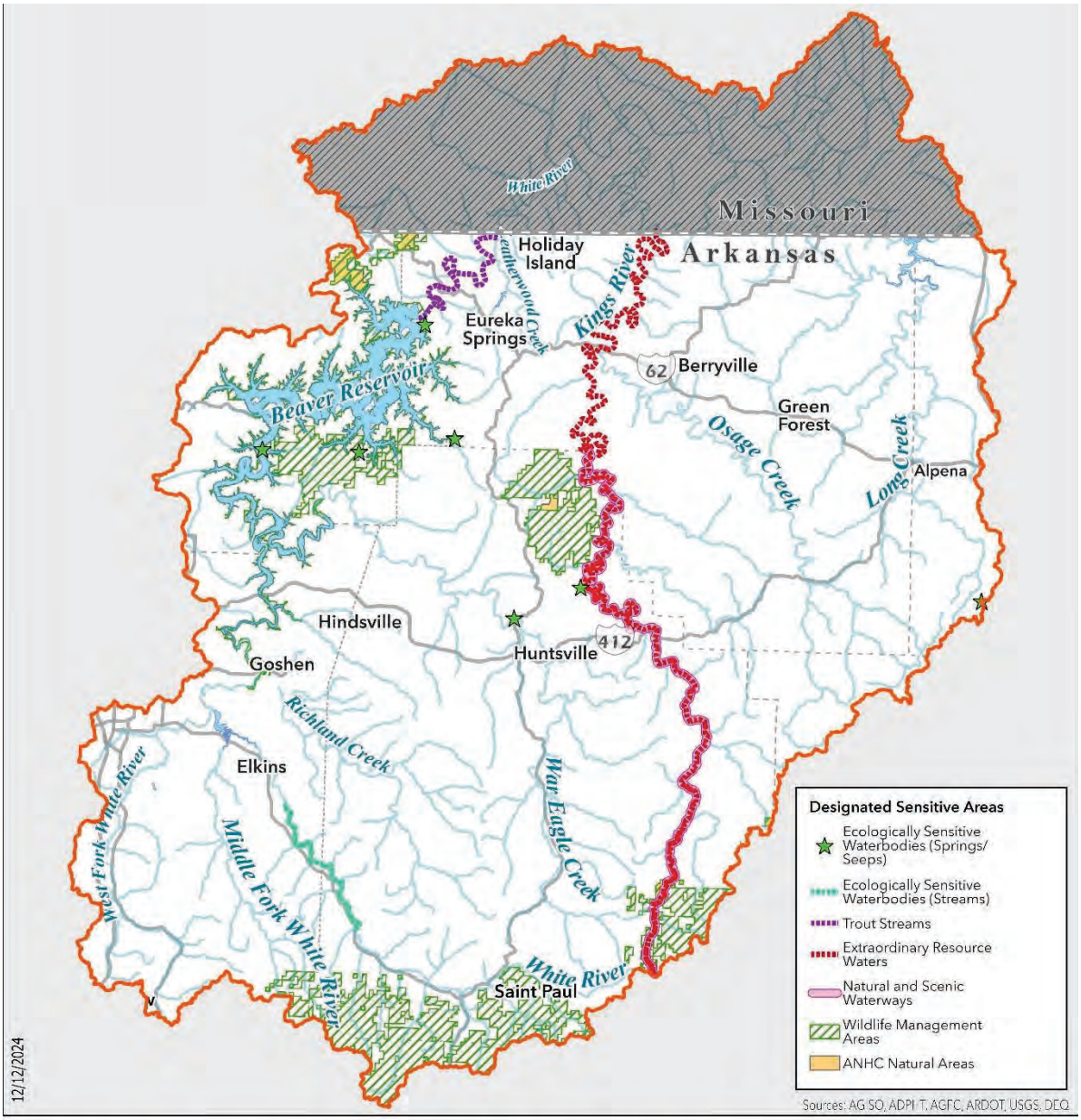
2.5.4 Sensitive Areas

Sensitive areas within the Upper White River watershed include state wildlife management areas, state natural areas, and state designated Trout Waters, Extraordinary Resource Waters, Natural and Scenic Waterways, and Ecologically Sensitive Waterbodies. Figure 2.12 shows the locations of these sensitive areas within the watershed. Table 2.17 Lists designated management areas within the watershed with some descriptive information about these areas.

Table 2.17. Designated conservation and protected areas in the Upper White River watershed.

Name	County	Area, ac	Focus habitat	Owned By
Hobbs State Park Conservation Area and Wildlife Management Area	Benton, Carroll, Madison	12,055	Forest	Arkansas State Parks
McIlroy Madison County Wildlife Management Area	Carroll, Madison	14,536	Forest	AGFC
Kirk Dupps Beaver Lake Wildlife Management Area	Benton, Carroll, Madison, Washington	8,007	Forest	USACE
Bear Hollow Natural Area	Madison	397	Forest, creek	Arkansas Natural Heritage Commission
Devil's Eyebrow Natural Area	Benton	3642.6	Forest	Arkansas Natural Heritage Commission
Withrow Springs State Park	Madison	786	Springs, creek, forest	Arkansas Department of Parks, Heritage, and Tourism

A groundwater quality vulnerability map developed by The Nature Conservancy using the DRASTIK model indicates that groundwater quality is moderately to highly vulnerable to impacts from surface land management activities in the watershed (Inlander, Gallipeau and Slay 2011). The highest vulnerability is primarily in river valleys (Figure 2.13).



Upper White River Watershed- Designated Sensitive Areas

tn Associates Ltd

NORTH

0 5 10 Miles

The Upper White River Watershed contains 10 ecologically sensitive waterbodies (7 springs/seeps and 3 streams), 1 trout stream, 8 extraordinary resource waters (all of which are stream segments), 7 wildlife management areas*, and 4 natural areas**.

*Only portions of White Rock WMA and Buffalo National River WMA are contained within the watershed

**All natural areas in the watershed except one (Bear Hollow Natural Area) overlap with wildlife management areas.

Figure 2.12. Map of sensitive areas within Upper White River watershed.

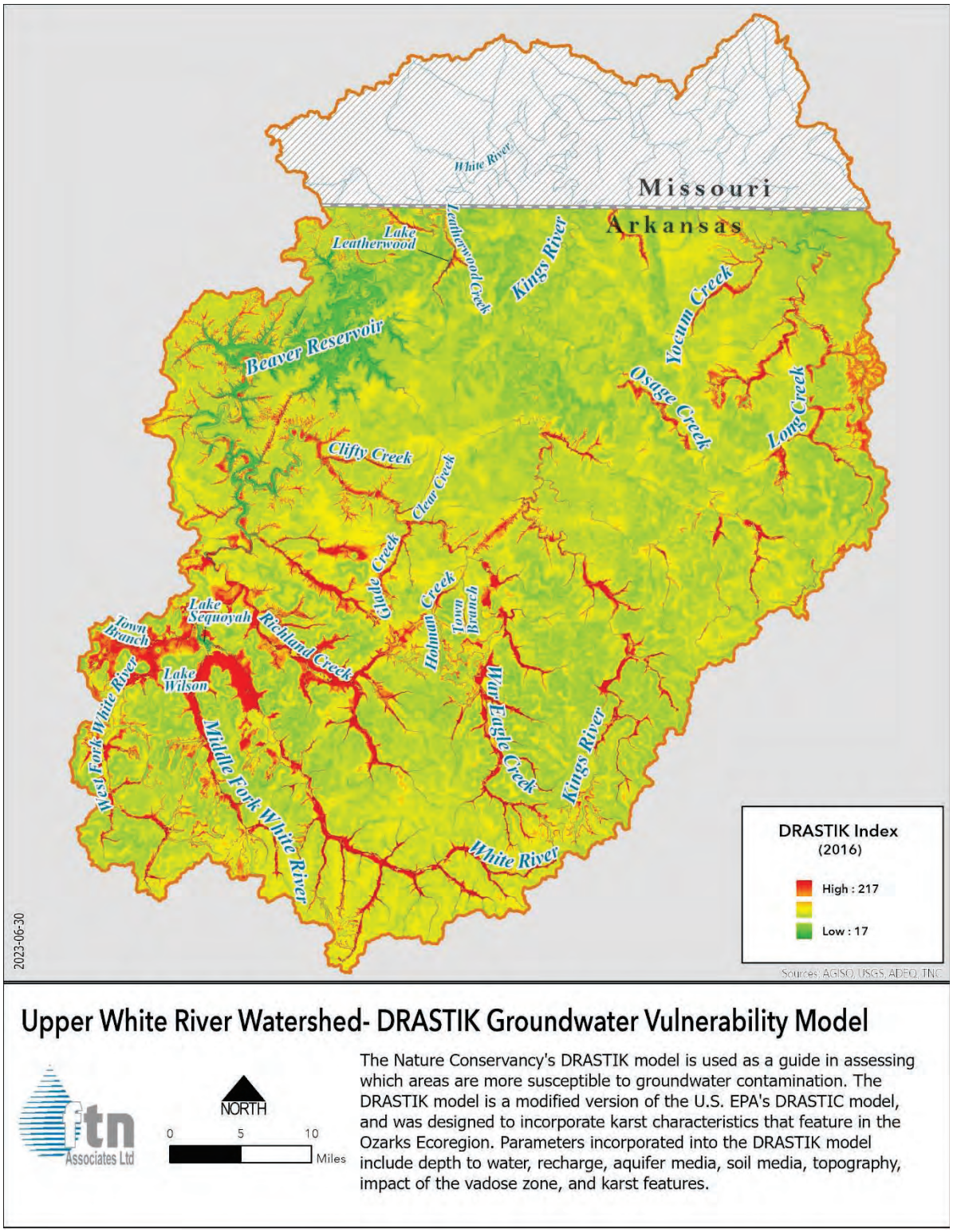


Figure 2.13. Map of groundwater vulnerability in the Upper White River watershed (Inlander, Gallipeau and Slay 2011).

The Nature Conservancy also used the DRASTIK model to evaluate threats groundwater quality and/or quantity issues pose to aquatic cave species. Of the caves studied, most received a low to medium threat ranking. However, several caves on the western edge of the Upper White River watershed received a high overall threat ranking (Figure 2.14).

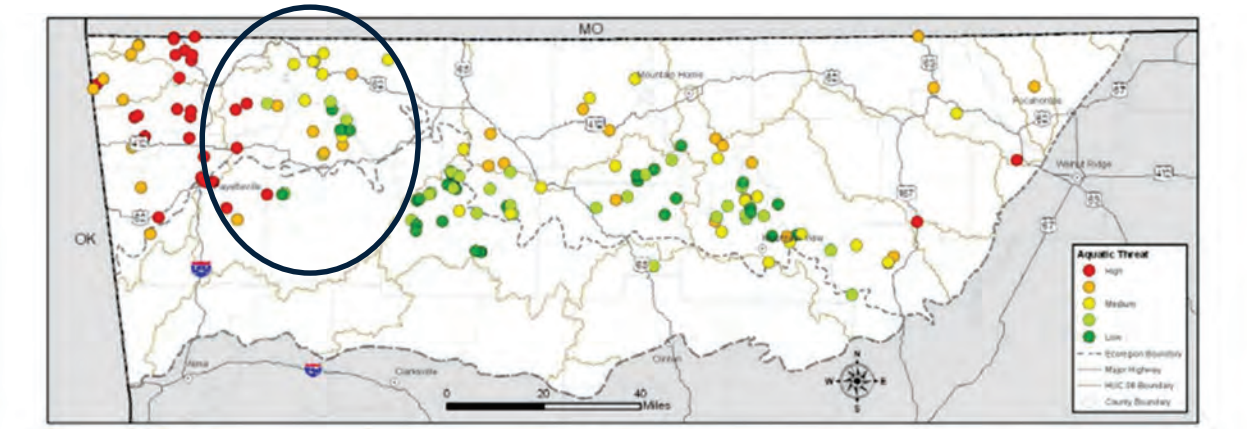


Figure 2.14. Overall threat scores for sites occupied by aquatic cave species (Figure 53 from Inlander, Gallipeau and Slay 2011). The circle encompasses evaluated sites within the Upper White River watershed.

3.0 WATERSHED ASSESSMENT

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

3.1 Surface Water Quality

This subsection describes surface water quality in the Upper White River watershed in terms of measured concentrations of selected parameters. This includes a summary of the water quality standards that apply in the watershed and the water quality monitoring programs active in the watershed. Recent (2018-2022) surface water quality data are summarized and discussed, and trends in long-term water quality data are evaluated.

3.1.1 Surface Water Quality Standards

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

3.1.1.1 Designated Uses

Designated uses of the streams in the watershed are primary contact recreation (watersheds >10 square miles); secondary contact recreation; seasonal aquatic life (watersheds < 10 square miles), and perennial aquatic life (watersheds ≥ 10 square miles and streamflow ≥ 1 cubic feet per second [cfs]). Additionally, almost all streams have Domestic, Industrial and Agricultural Water Supply as a designated use. The domestic water supply use does not apply to portions of Town Branch and Holman Creek downstream of the City of Huntsville wastewater treatment plant (WWTP). Designated uses of lakes and reservoirs in the watershed are primary contact recreation, secondary contact recreation, perennial aquatic life, and Domestic, Industrial and Agricultural Water Supply. The White River downstream of Beaver Dam to the state line is designated as Trout Waters. The Kings River is designated as

Extraordinary Resource Waters, and the portion of the Kings River in Madison County is also designated as a Natural and Scenic Waterway. At least six springs in the watershed are designated as Ecologically Sensitive Waterbodies (Arkansas Pollution Control and Ecology Commission 2022). Figure 2.12 shows Trout Waters, Extraordinary Resource Waters, Natural and Scenic Waterways, and Ecologically Sensitive Waterbodies in the Upper White River watershed.

3.1.1.2 Numeric Criteria

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

Table 3.1. Selected numeric water quality criteria applicable to waterbodies in the Upper White River watershed (Arkansas Pollution Control and Ecology Commission 2022).

Parameter	Season	Location	Conditions	Criteria
Water Temperature	All	Boston Mountains	Non-trout streams/reaches	31°C (87.8°F)
		Ozark Highlands	Non-trout streams/reaches	29°C (84.2°F)
		Trout streams/reaches	All	20°C (68°F)
		Lakes and Reservoirs	1-meter depth	32°C (89.6°F)
Dissolved Oxygen	Primary Season[c]	Boston Mountains and Ozark Highlands	All	6 mg/L
		Ozark Highlands	When water temperature ≤10°C, or March – May when flow ≥ 15 cfs	6.5 mg/L
	Critical Season[d]	Boston Mountains and Ozark Highlands	< 10 square mile watershed	2 mg/L
		Boston Mountains	Watershed ≥10 square mile	6 mg/L
		Ozark Highlands	10-100 square mile watershed	5 mg/L
			>100 square mile watershed	6 mg/L
	All	Lakes and Reservoirs	1-meter depth	5 mg/L
pH	All	All	All	6 – 9 SU
		Lakes and Reservoirs	1-meter depth	
Turbidity	Base Flow[a]	Boston Mountains, Ozark Highlands, Trout Waters	All	10 NTU
		Lakes and Reservoirs	1-meter depth	25 NTU
	Storm Flows[b]	Boston Mountains	All	19 NTU
		Ozark Highlands	All	17 NTU
		Trout Waters	All	15 NTU
		Lakes and Reservoirs	1-meter depth	45 NTU
Chloride	All	White River	from WHI0052 to Missouri state line, including Beaver Lake; and headwaters to Noland WWTP outfall	20 mg/L
		Kings River and West Fork White River	All	20 mg/L
		Holman Creek	from Town Branch to War Eagle Creek	180 mg/L
		Town Branch	from Huntsville WWTP outfall to Holman Creek	223 mg/L
		White River	From WR-02 to WHI0052 (AR_11010001_823)	30 mg/L
		White River	From Noland WWTP outfall to WR-02 (AR_11010001_923)	44 mg/L
		All other waterbodies	All	250 mg/L
Sulfate	All	White River	from WHI0052 to Missouri state line, including Beaver Lake; and headwaters to Noland WWTP outfall	20 mg/L
		Kings River and West Fork White River	All	20 mg/L
		Holman Creek	from Town Branch to War Eagle Creek	48 mg/L
		Town Branch	from Huntsville WWTP outfall to Holman Creek	61 mg/L
		White River	From WR-02 to WHI0052	40 mg/L
		White River	From Noland WWTP outfall to WR-02	79 mg/L
		All other waterbodies	All	250 mg/L

Table 3.1. Selected numeric water quality criteria applicable to waterbodies in the Upper White River watershed (continued).

Parameter	Season	Location	Conditions	Criteria
Total Dissolved Solids (TDS)	All	White River	from WHI0052 to Missouri state line, including Beaver Lake; and headwaters to Noland WWTP outfall	160 mg/L
		Kings River and West Fork White River	All	150 mg/L
		Holman Creek	from Town Branch to War Eagle Creek	621 mg/L
		Town Branch	from Huntsville WWTP outfall to Holman Creek	779 mg/L
		White River	From WR-02 to WHI0052	237 mg/L
		White River	From Noland WWTP outfall to WR-02	362 mg/L
		All other waterbodies	All	500 mg/L
Escherichia coli (E. coli)	Primary Contact[e]	Extraordinary Resource Waters Ecologically Sensitive Waterbodies Reservoirs	Individual sample criterion	298 colonies /100 mL
			Geometric mean	126 colonies /100 mL
		All other waters	Individual sample criterion	410 colonies /100 mL
	Secondary Contact[f]	Extraordinary Resource Waters Ecologically Sensitive Waterbodies Reservoirs20310	Individual sample criterion	1,490 colonies /100 mL
			Geometric mean	630 colonies /100 mL
		All other waters	Individual sample criterion	2,050 colonies /100 mL
Chlorophyll a	May-October	Beaver Lake Hickory Creek site	Geometric mean	8 ug/L
Secchi transparency	All	Beaver Lake Hickory Creek site	Annual average	1.1 meter

[a]Base Flow = June – October
[b]Storm Flows = Entire Year
[c]Primary Season = when water temperature is 22°C or lower, usually mid-September to mid-May
[d]Critical Season = when water temperature is > 22°C, usually mid-May to mid-September
[e]Primary Contact = May 1 to September 31, watersheds > 10 square miles
[f]Secondary Contact = October 1 to April 30

3.1.1.3 Narrative Criteria

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

3.1.2 Current Surface Water Quality Monitoring

The Upper White River watershed is one of the most heavily sampled for water quality in the state. Surface water quality data have been collected by several entities in this watershed, including Arkansas Department of Energy and Environment Division of Environmental Quality (DEQ), U.S. Geological Survey (USGS), U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers, Arkansas Water Resources Center (AWRC), Beaver Water District (BWD), H2Ozarks, Watershed Conservation Resource Center (WCRC), universities, and Arkansas Stream Teams. Over 85 water quality monitoring stations at 71 monitoring locations were sampled during the period 2018-2022 by AWRC, BWD, DEQ, H2Ozarks, and USGS. Several locations were sampled by more than one entity. Table 3.2 lists the monitoring locations and stations sampled 2018-2022, which are mapped in Figure 3.1. Data collected from 2018 through 2022 reflect current water quality conditions in the watershed. Table 3.3 summarizes the water quality parameters that were measured at water quality stations active during 2018-2022. Over 60,000 water quality measurements were collected by AWRC, BWD, DEQ, H2Ozarks, and USGS 2018-2022.

Table 3.2. Surface water quality monitoring stations sampled 2018-2022 in the Upper White River watershed.

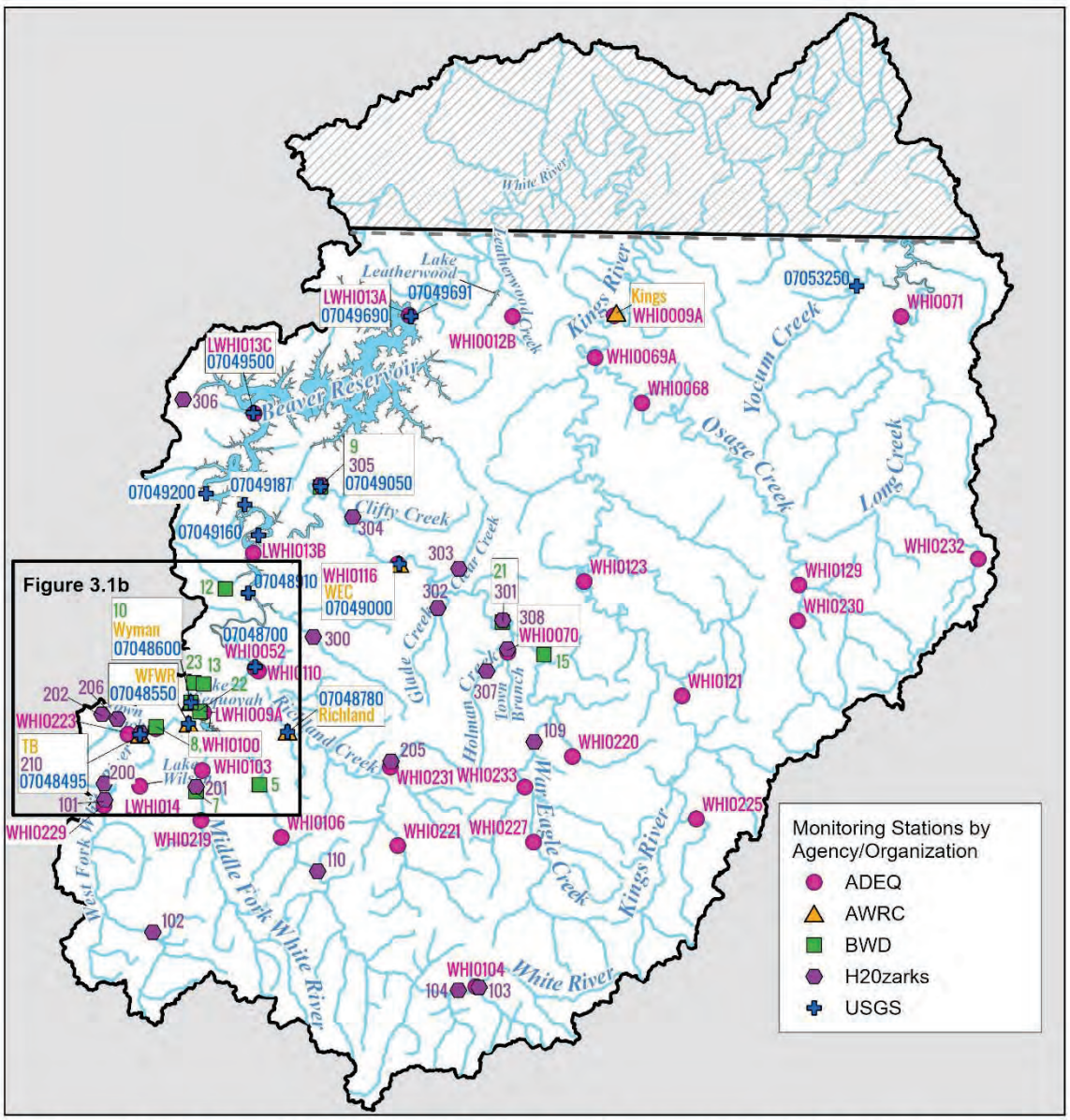
Location description	Agency	Station ID	Begin year (earliest year during target period)	End Year	Number of samples 2018-2022
Baldwin Creek near St. Paul	H2Ozarks	103	2015 (2018)	2021	15
White River on County Road 112 at St. Paul	ADEQ	WHI0104	1992 (2022)	2022	12
White River near St. Paul	H2Ozarks	104	2015 (2018)	2021	15
White River at County Road 6578	H2Ozarks	110	2021	2021	2
White River off State Road 16 on County Road 183 at Durham	ADEQ	WHI0106	1996 (2018)	2022	51
White River at Elkins	BWD	5	2006 (2018)	2022	58
Middle Fork White River bridge on East Black Oak Road 1 mile south of Black Oak	ADEQ	WHI0219	2022	2022	12
Middle Fork White River at County Road 51	BWD	7	2006 (2018)	2022	58
Middle Fork White River at Harris Road	H2Ozarks	201	2014 (2018)	2021	14
Middle Fork White River on County Road 51/South Harris Drive southwest of Elkins	ADEQ	WHI0103	1996 (2018)	2022	53
Lake Sequoyah near dam	ADEQ	LWHI009A	1994 (2020)	2022	9
Lake Sequoyah outflow (White River)	BWD	22	2019	2022	35
West Fork White River (Brentwood Park)	H2Ozarks	102	2014 (2018)	2021	14
West Fork White River at Baptist Ford Bridge	H2Ozarks	101	2014 (2018)	2020	10
West Fork White River bridge on South Main Avenue off U.S. Highway 71, less than 1 mile south of Greenland	ADEQ	WHI0229	2022	2022	13
Ward Slough	H2Ozarks	200	2016 (2018)	2020	10
Lake Wilson	ADEQ	LWHI014	2012 (2020)	2022	12
Mullins Creek at the UofA	H2Ozarks	202	2016 (2018)	2020	8
Spout Spring Branch	H2Ozarks	206	2013 (2018)	2020	10
Town Branch bridge on Morningside Drive off State Road 156/16 in southeast Fayetteville	ADEQ	WHI0223	2022	2022	12
Town Branch at Armstrong Street in Fayetteville, Arkansas	AWRC	TB	2009 (2018)	2022	130
	H2Ozarks	210	2014 (2018)	2021	14
	USGS	7048495	2015 (2018)	2021	24 (1,652 temperature only)
West Fork White River on County Road 55/Dead Horse Mountain Road	BWD	8	2006 (2018)	2022	58
	ADEQ	WHI0100	1992 (2018)	2022	53
West Fork White River east of Fayetteville, Arkansas	AWRC	WFWR	2009 (2018)	2022	129
	USGS	7048550	1974 (2018)	2023	6 (1,685 temperature only)
White River near Fayetteville, Arkansas	BWD	10	2006 (2018)	2022	58
	AWRC	Wyman	2009 (2018)	2022	128
	USGS	7048600	1975 (2018)	2021	14
Underwood Property	BWD	23	2022	2022	11
White River at Bank's Farm	BWD	13	2006 (2018)	2022	47
Drakes Creek bridge on County Road 6245 east of Drakes Creek town	ADEQ	WHI0231	2022	2022	12

Table 3.2. Surface water quality monitoring stations sampled 2018-2022 (continued).

Location description	Agency	Station ID	Begin year (earliest year during target period)	End Year	Number of samples 2018-2022
Hock Creek	H2Ozarks	205	2016 (2018)	2021	14
Lollars Creek bridge on County Road 6261 0.5 miles north of Asher	ADEQ	WHI0221	2022	2022	12
Richland Creek at Tuttle Road near Goshen, Arkansas	AWRC	Richland	2016 (2018)	2022	131
	USGS	7048780	2015 (2018)	2021	13
Richland Creek on State Road 45/West Bowen Boulevard near Goshen	ADEQ	WHI0110	1992 (2022)	2022	12
White River on State Road 45/West Boman Boulevard near Goshen	ADEQ	WHI0052	*1990* (2018)	2022	53
	USGS	7048700	1969 (2018)	2021	19-22
Brush Creek	H2Ozarks	300	2013 (2018)	2021	13
Beaver Lake at Highway 412 bridge near Sonora	USGS	7048910	1984 (2018)	2021	22
Tributary below Parson's Landfill	BWD	12	2006 (2018)	2022	50
Beaver Lake near War Eagle Park - upper site	ADEQ	LWHI013B	1999 (2018)	2019	5
War Eagle Creek on a bridge on Madison County Road 5635 off State Road 23 1.5 miles north of Witter	ADEQ	WHI0227	2022	2022	12
Jackson Creek Bridge on County Road 5675 0.5 miles west of Aurora and State Road 23	ADEQ	WHI0233	2022	2022	12
War Eagle Creek near County Road 6129	H2Ozarks	109	2018	2021	11
Wharton Creek bridge on State Road 74, 2 miles east of Wharton	ADEQ	WHI0220	2022	2022	12
War Eagle Creek at Old Highway 412	BWD	15	2006 (2018)	2022	58
Holman Creek upstream of Huntsville	H2Ozarks	307	2014 (2018)	2021	14
Holman Creek on State Road 23 downstream of Huntsville	ADEQ	WHI0070	*1990* (2018)	2022	53
	H2Ozarks	308	2014 (2018)	2021	14
Withrow Spring at Withrow Springs Cave at Withrow Springs State Park	ADEQ	WHI0209	2016 (2018)	2018	9
War Eagle Creek at Highway 23 bridge	BWD	21	2018	2022	57
	ADEQ	WHI0207	2016 (2018)	2018	9
	H2Ozarks	301	2013 (2018)	2020	9
Glade Creek	H2Ozarks	302	2013 (2018)	2021	13
Clear Creek	H2Ozarks	303	2013 (2018)	2021	15
War Eagle Creek near Hindsville, Arkansas	AWRC	WEC	2009 (2018)	2022	131
War Eagle Creek at State Road 45 north of Hindsville	ADEQ	WHI0116	1992 (2018)	2022	53
Clifty Creek	H2Ozarks	304	2013 (2018)	2021	15
War Eagle Creek at War Eagle, Arkansas	BWD	9	2006 (2018)	2022	58
	H2Ozarks	305	2013 (2018)	2020	9
	USGS	7049050	1975 (2018)	2021	12
War Eagle Creek above White River near Lowell	USGS	7049160	2009 (2018)	2021	22
Beaver Lake downstream of Hickory Creek Landing near Springdale, Arkansas	USGS	7049187	2008 (2018)	2020	10
Beaver Lake near Lowell	USGS	7049200	1977 (2018)	2021	22
Prairie Creek	H2Ozarks	306	2013 (2018)	2020	10

Table 3.2. Surface water quality monitoring stations sampled 2018-2022 (continued).

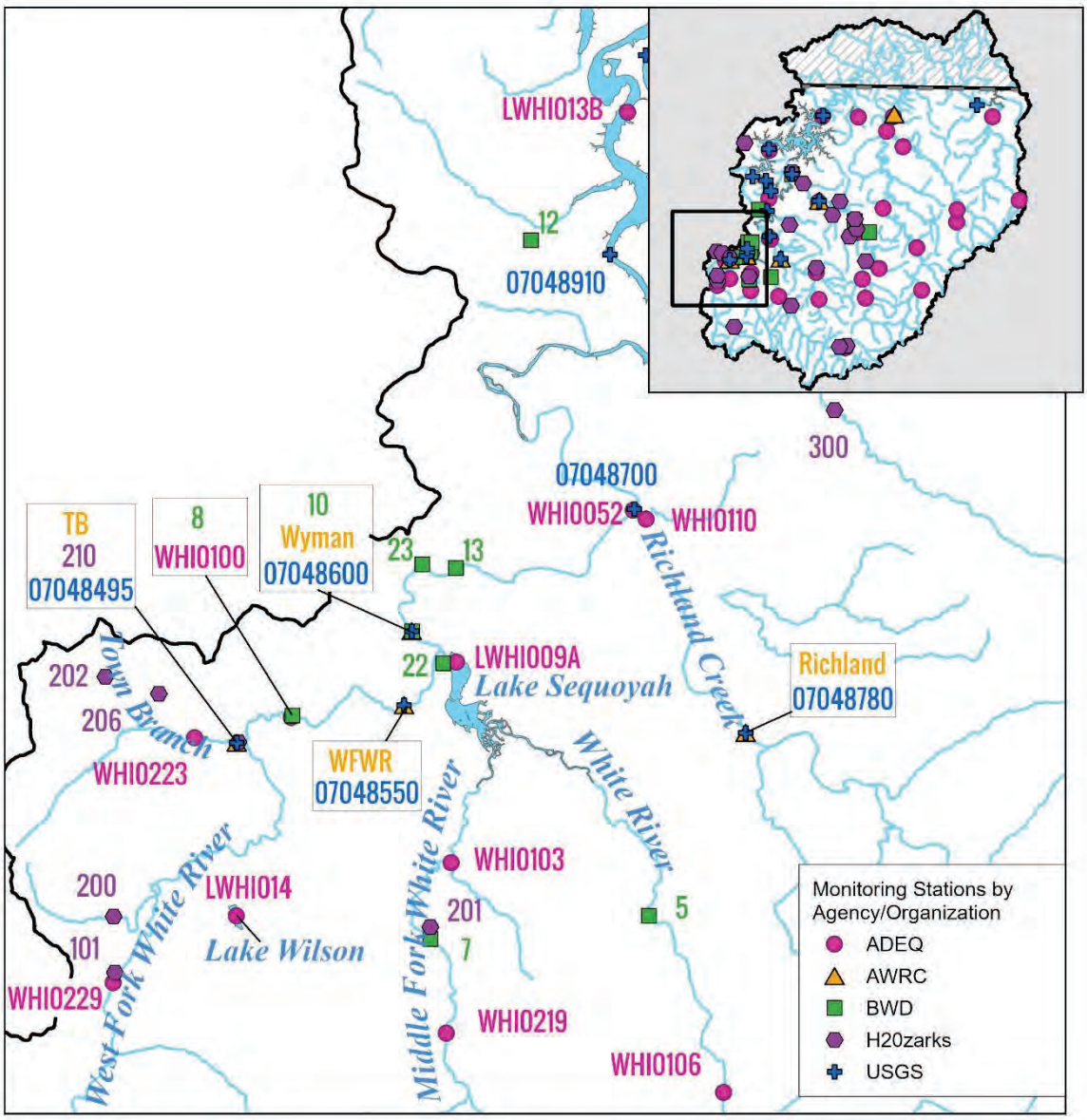
Location description	Agency	Station ID	Begin year (earliest year during target period)	End Year	Number of samples 2018-2022
Beaver Lake at Highway 12 bridge near Rogers, Arkansas	ADEQ	LWHI013C	2011 (2018)	2019	4
	USGS	7049500	1952 (2018)	2021	22
Beaver Lake above dam	ADEQ	LWHI013A	1999 (2018)	2019	5
Beaver Lake near Eureka Springs, Arkansas	USGS	7049690	1973 (2018)	2022	31
White River at Beaver Dam near Eureka Springs	USGS	7049691	1967 (2018)	2022	9
Leatherwood Creek on State Road 23 below Eureka Springs	ADEQ	WHI0012B	2005 (2018)	2022	44
Felkins Creek bridge on County Road 3655, 5 miles south of Kingston	ADEQ	WHI0225	2022	2022	10
Kings River on State Road 21 north of Kingston	ADEQ	WHI0121	1992 (2018)	2022	53
Kings River on County Road 25 north of Alabam	ADEQ	WHI0123	1992 (2018)	2022	53
Kenner Creek bridge on State Road 103, 2 miles south of Osage	ADEQ	WHI0230	2022	2022	11
Osage Creek at Highway 412 northwest of Osage	ADEQ	WHI0129	1992 (2022)	2022	11
Osage Creek on State Road 221 above Berryville	ADEQ	WHI0068	*1990* (2018)	2022	45
Osage Creek on the County Road 306 bridge west of Pleasant Valley	ADEQ	WHI0069A	2016 (2018)	2022	49
Kings River on State Road143 north of Berryville	AWRC	Kings	2018	2018	36
	ADEQ	WHI0009A	*1990* (2018)	2022	50
Yocum Creek near Oak Grove, Arkansas	USGS	7053250	1987 (2018)	2018	2
Terrapin Creek bridge on Creekland Drive 2.5 miles south of Batavia	ADEQ	WHI0232	2022	2022	10
Long Creek on County Road 824 below Denver	ADEQ	WHI0071	*1990* (2018)	2022	49



Upper White River Watershed - Water Quality Sampling Sites (2018-2022)

Between 2018 and 2022, a total of 85 monitoring stations were operated in the watershed by Arkansas Department of Energy and Environment Division of Environmental Quality (DEQ), Arkansas Water Resources Center (AWRC), Beaver Water District (BWD), H2Ozarks, and United States Geological Survey (USGS).

Figure 3.1a. Locations of water quality monitoring stations in the Upper White River watershed that were sampled 2018-2022.



Upper White River Watershed - Water Quality Sampling Sites (2018-2022)

Between 2018 and 2022, a total of 85 monitoring stations were operated in the watershed by Arkansas Department of Energy and Environment Division of Environmental Quality (DEQ), Arkansas Water Resources Center (AWRC), Beaver Water District (BWD), H2Ozarks, and United States Geological Survey (USGS).

Figure 3.1b. Detail view of selected locations of water quality monitoring stations in the Upper White River watershed that were sampled 2018-2022.

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

Parameter	DEQ Ambient	DEQ Roving	DEQ Special Study	DEQ Lake	USGS Streams	USGS lake	BWD	AWRC	H2Ozarks
Alkalinity	M	2-3/yr	B	Q	-	-	-	-	Q
Ammonia	M	M	B	Q	X	-	-	-	-
Biochemical oxygen demand	9-11/yr+	H	-	-	-	-	-	-	-
Chloride	M	2-3/yr	B	Q	S	-	-	F	-
Dissolved oxygen	M	M	B	Q	X	X	-	-	-
Hardness	3-6/yr	2-3/yr	B	Q	S	-		-	-
Metals	4-6/yr	2-3/yr	B	Q	S	-	-	-	-
Nitrate + nitrite	M	2-3/yr	B	Q	S	-	M	F	-
Nitrate	-	-	-	-	X	X	M	F	-
Organics	H	-	-	-	-	-		-	-
Pathogens	H	15-16/yr	-	-	S	-		-	-
pH	M	M	B	Q	X	X	-	-	Q
Soluble reactive phosphorus	-	-	-	-	-	-	M	F	-
Specific conductance	M	M	X	Q	X	-		F	Q
Suspended sediment	-	-	-	-	S	-	-	-	-
Sulfate	M	2-3/yr	B	Q	S	-	-	F	-
Temperature	M	M	B	Q	X	X	M	-	Q
Total dissolved solids	M	2-3/yr	B	Q	S	-	-	-	Q
Total Kjeldahl nitrogen	M	2-3/yr	B	Q	S	-	-	-	-
Total nitrogen	M	2-3/yr	B	Q	S	-	M	F	Q
Total organic carbon	M	2-3/yr	H	Q	-	-		-	-
Total phosphorus	M	2-3/yr	B	Q	S	-	M	F	Q
Total suspended solids	M	2-3/yr	B	Q	-	-	-	F	Q
Transparency	-	-	-	Q	-	X		-	-
Turbidity	M	2-3/yr	B	Q	S	-	M	F	Q (started 2021)

D=daily, M=monthly; B=every two months; H=historically, but not in the last five years; Q=quarterly, X=varies; S=some stations, F = flow dependent

3.1.3 Summary of Current Surface Water Quality

Measurements of selected parameters of concern collected during the period 2018-2022 by Arkansas Department of Environmental Quality (DEQ), Arkansas Water Resources Center (AWRC), Beaver Watershed District (BWD), H2Ozarks, and United States Geological Survey USGS in the Upper White River Watershed were summarized and evaluated to characterize current water quality conditions. Parameters examined included those related to current assessed water quality impairments: bacteria, pH, turbidity, total suspended solids (TSS), total dissolved solids (TDS,) sulfate, temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), and nutrients. Below is a summary of key findings from this evaluation. The details of the water quality analysis and presentation and discussion of all the results is provided in Appendix C.

Available data appear to show that concentrations of some parameters increase from headwaters to downstream reaches, including:

- In the White River: pH, alkalinity, TSS, nitrate+ nitrite, total nitrogen, TDS, and sulfate;
- In War Eagle Creek: pH, alkalinity, TSS, nitrate + nitrite, total nitrogen, TDS, and sulfate;
- In Kings River: pH, alkalinity, TDS, and sulfate;
- In Osage Creek: pH, alkalinity, TDS, and sulfate; and
- In West Fork White River: turbidity, TSS, total phosphorus and TDS.

Town Branch median concentrations of several constituents are significantly higher than median concentrations in the West Fork White River, including alkalinity (Town Branch 119 mg/L versus West Fork White River 22 to 56 mg/L), nitrate + nitrite (0.49 and 0.61 mg/L in Town Branch versus 0.24 to 0.29 mg/L in West Fork White River), total nitrogen (0.73 to 1.06 mg/L in Town Branch versus 0.35 to 0.51 mg/L in West Fork White River), and TDS (209.5 to 265.5 mg/L in Town Branch versus 47.4 to 115.0 mg/L in West Fork White River).

Recent *E. coli* measurements were available only from the White River (two stations), Richland Creek, War Eagle Creek, and Beaver Lake. During 2018-2022 median *E. coli* values from Beaver Lake (0 to 5 cfu/100 mL) were significantly lower than median *E. coli* values from

stream stations (55 to 3,000 cfu/100mL). *E. coli* levels greater than the primary and secondary contact season individual sample criteria were measured at the White River station just below West Fork White River confluence (07048600), in Richland Creek (0748780), and in War Eagle Creek (0749050). These data appear to support concerns about *E. coli* levels in Upper White River streams. However, *E. coli* levels are notoriously variable and the available measurements from these stations are not suitable for evaluating water quality impairment. One *E. coli* measurement from Beaver Lake station 07048910 (Highway 412 bridge) exceeded the primary contact season individual sample criterion.

Generally, pH values tend to be lower in the watershed headwaters in the Boston Mountains (see Appendix C Section 1.3 for identification of stations in the Boston Mountains). This is a function of the underlying geology of the Boston Mountains physiographic region, which has little carbonate rock, and thus lower capacity for neutralizing acidity. As a result, alkalinity values also tend to be lower at Boston Mountain stations. Measurements of pH lower than 6 su were reported at three stream stations 2018-2022, 103 and 104 in the White River headwaters (Boston Mountains), and WHI0100 in the West Fork White River downstream of Town Branch. Values of pH greater than 9 s.u. have only been measured 2018-2022 in reservoirs in this watershed (Beaver Lake and Lake Sequoyah).

Median TDS concentrations, although variable, increase from upstream to downstream in most streams. In at least some instances, higher median TDS concentrations may be associated with municipal WWTP discharge and runoff from development, e.g., Holman Creek (119 to 223 mg/L), Leatherwood Creek (199 mg/L), and Town Branch and its tributaries in Fayetteville (209 to 303 mg/L). The highest TDS concentration measured in the watershed (900 mg/L) was from Holman Creek. Research has shown that geology and anthropogenic activities can influence TDS levels in streams (Scott and Haggard 2021). The lowest median TDS values (26.9 to 7.5 mg/L) are from the upper White River stations (103, WHI0104, and 104). TDS concentrations measured in the reservoirs (ranging from 18 to 120 mg/L) are much less variable than those in streams, which range from 8 to 900 mg/L.

The highest median sulfate concentrations measured in the watershed are at the stations on Town Branch in Fayetteville (47.85 to 63.35 mg/L). Town Branch median sulfate

concentrations are statistically significantly higher than median sulfate concentrations at the other stream stations in the watershed with at least 10 measurements (2.33 to 22.7 mg/L). Research suggest that geology and riparian soils may have significant influence on sulfate in the West Fork White River (Scott and Haggard 2021). Thus, the differences in sulfate levels at headwater stations located in Boston Mountains ecoregion, and the increase in sulfate as rivers run through Ozark Highlands ecoregion may be at least partly the result of differences in geology.

At most of the locations monitored, median Base Flow turbidity values are lower than median Storm Flow turbidity values. Base Flow turbidity measurements for 2018-2022 from turbidity impaired stream segments (White River and West Fork White River) still indicate turbidity impairment under Base Flow conditions. Several also appear to indicate turbidity impairment under Storm Flow conditions. The 2018-2022 data from a few stations located on unimpaired stream segments may indicate turbidity impairment under Base Flow and/or Storm Flow conditions. Beaver Lake turbidity measurements from 2018-2022 from turbidity impaired lake segments do not appear to indicate continued turbidity impairment.

Stations on turbidity impaired sections of the West Fork White River (WHI0100 and WFWR) and White River between West Fork White River and Richland Creek (Wyman and WHI0052) also have the highest median TSS values, 6.4 to 10.9 mg/L. This confirms that erosion and stream sediment load contribute to turbidity impairments. Measurements of suspended sediment concentration (SSC) at five USGS stations where at least 10 samples were collected are not significantly different, although median values range from 6.0 to 412 mg/L.

Water temperatures were consistent across all stations with at least 10 measurements, except the White River station just below the Beaver Lake dam (USGS 07049691), where the median water temperatures (9.20 °C) is significantly lower than median temperatures at the rest of the stream stations with at least 10 measurements, which range between 13.50 and 22.70 °C. This is expected because of the influence of releases from Beaver Lake. Water temperatures above the criteria were measured at stations in each of the major tributary subbasins during 2018-2022. However, in most cases the exceedances are not frequent enough for the streams to

be classified as impaired (see Section 3.1.4). All water temperatures measured in reservoirs 2018-2022 were below the criterion.

In our analysis, DO levels at monitored locations in the Upper White River watershed are mostly supportive of aquatic life, especially during the Primary Season. DO values lower than seasonal criteria were reported at stations on several assessment units with existing or proposed listings of impairment because of low DO, and elsewhere on the White River (07048600), in Wharton Creek (WHI0220), and War Eagle Creek (07049050). No DO values lower than seasonal criteria were reported at station WHI0121 on the DO impaired Kings River assessment unit.

The highest seasonal and overall median DO concentrations from stations with at least 10 measurements were at Holman Creek station WHI0070 (Primary Season = 12.0 mg/L, Critical Season = 9.26 mg/L, overall = 10.8 mg/L). However, these median values are not significantly higher than median values at most of the other stream stations with at least 10 measurements.

Although Beaver Lake releases are managed to support the tailwater trout fishery, DO concentrations below the Trout Waters criterion (6 mg/L) have been reported just downstream of the Beaver Lake dam at station 07049691. However, most of the reported DO concentrations from station 07049691 are above the criterion, so this stream segment has not been classified as impaired. It is interesting that the median DO concentration at station 07049691 (7.6 mg/L) is significantly lower than median DO concentrations at other stream stations with more than 10 measurements (9.21 to 10.8 mg/L).

DO supersaturation, i.e., > 100% and especially over 125%, may be the result of high levels of primary productivity, which may result in poor water quality conditions. Percent DO saturation values greater than 100% were identified from stations on DO impaired assessment units (White River station 07048700, Leatherwood Creek station WHI0012B, and West Fork White River station WHI0100). In addition, over 25% of percent DO saturation are over 100% at the Holman Creek station (WHI0070), which had the highest median seasonal and overall DO concentrations. Percent DO saturation values greater than 125% occurred at the Leatherwood Creek and Holman Creek stations, and in Beaver Lake.

Phosphorus levels measured in the streams are relatively similar throughout the watershed (where more than 10 measurements were taken). Total phosphorus data reported by different organizations are not necessarily comparable to each other. This is likely because of differences in sampling protocols and/or analysis methods among the organizations. Holman Creek (308, WHI0070) and Richland Creek (Richland) have the highest maximum total phosphorus levels from 2018-2022 (5.561, 2.490, and 1.931 mg/L, respectively). However, War Eagle Creek (07049050) and Holman Creek (WHI0070) have the highest median total phosphorus concentrations (0.333 and 0.230 mg/L, respectively).

Almost all ammonia nitrogen measurements are reported as less than the detection limit. The highest reported ammonia nitrogen concentration during 2018-2022 occurred at Osage Creek station WHI0069A (1.09 mg/L). The stations with the highest median ammonia nitrogen concentrations are in reservoirs. The Lake Wilson station (LWHI014) and Beaver Lake station 07049200 both have median ammonia nitrogen values of 0.04 mg/L.

Almost all nitrate + nitrite measurements are below the 10 mg/L drinking water criterion. The highest nitrate + nitrite nitrogen value (11.10 mg/L), and only value above 10 mg/L, during 2018-2022 was measured at Holman Creek (station WHI0070), which is influence by the discharge from the Huntsville WWTP. The 2018-2022 median nitrate + nitrite concentrations at Long Creek (2.05 mg/L) and Holman Creek station WHI0070 (2.20 mg/L) are significantly higher than the median concentrations at the other water quality stations with more than 10 measurements, which range from 0.15 to 1.54 mg/L. Median nitrate + nitrite concentrations in War Eagle Creek downstream of Huntsville (1.08 to 1.54 mg/L) are significantly higher than the median concentration upstream of Huntsville (0.15 mg/L).

For total nitrogen, the highest median total nitrogen concentrations are from Brush Creek (4.21 mg/L) and the War Eagle Creek tributaries Holman Creek, Glade Creek, Clear Creek, and Clifty Creek (2.59 to 3.98 mg/L), which are significantly higher than median values at the other stream stations in this watershed with ten or more measurements. Median total nitrogen concentrations for reservoir stations with at least 10 measurements do not appear to be significantly different from median concentrations for most stream stations. Holman Creek

stations had the highest maximum measurement (13.0 mg/L), which is likely because of the Huntsville WWTP discharge.

3.1.4 Assessed Water Quality Impairments

As of September 2023, the most recent EPA approved state impaired waters list (i.e., 303(d) list) for Arkansas is from 2018. The draft 2020 and 2022 303(d) lists are under review.[2] Impaired waters in the Upper White River watershed from the final 2018 list are listed in Table 3.4 and mapped on Figure 3.2. On the 2018 303(d) list, over 135 miles of streams in the watershed, and over 3,400 acres of Beaver Lake are classified as impaired. Table 3.4 also lists changes in the Upper White River watershed from the 2018 303(d) List that are on the draft 2020 and 2022 303(d) lists. New impairments from the draft 2020 303(d) List are also indicated on Figure 3.2 with dashed lines.

Waterbodies on the 303(d) list are prioritized for corrective action to improve water quality. Corrective action often includes a Total Maximum Daily Load (TMDL) study. In a TMDL study the maximum load of a pollutant that will allow the waterbody to achieve water quality standards is estimated.

[2] The 2020 303(d) list was accepted by EPA September 2023, pending changes to Illinois River impairments. The 2022 303(d) list was accepted by EPA March 2025. The list of waterbody impairments in the Upper White River watershed is the same on the final 2022 303(d) lists as in the draft list. So, the draft 2022 information presented in this document is the same as that on the final 303(d) list. There is one difference between the draft and final 2020 lists of waterbody impairments in the Upper White River watershed, as noted in Table 3.4.

Table 3.4. Impaired waterbodies in the Upper White River watershed from the final 2018 303(d) List for Arkansas (DEQ 2020) with draft 2020 and 2022 303(d) Lists (DEQ 2021b) (DEQ 2023).

Assessment unit number	Assessment unit description	Category[a]	Designated use not supported	Pollutant(s) causing impairment	Monitoring Station	Suspected source(s) of pollutants	Year listing initiated	Draft 2020 listing change from 2018[b]	Draft 2022 listing change from 2018[b]
11010001-024	West Fork White River	5	Not identified	Total dissolved solids, sulfate	WHI0051, WHI0100, Tilly Willy, Dead Horse, Molly Wagon, Harvey Dowell, Stonebridge, Use Attainability Analysis, WHW03, 04, 05	Unknown	2006	+Dissolved oxygen (critical season) and temperature	+Dissolved oxygen (critical season) and temperature
		4a	Not identified	Turbidity	WHI0051	unknown	1998	NC	NA
11010001-624	West Fork White River	5	Aquatic life	Dissolved oxygen, sulfate	WHI0097, WHI0098, Airport	Unknown	2018	NC	NC
11010001-824	Town Branch (Fayetteville)	5	Not indicated	Turbidity	TB62, TBN01, TB	Surface erosion	2018	NC	-Turbidity
11010001-026	Middle Fork White River	Not listed	Not listed	Not listed	WHI0103	Not listed	2020	+Dissolved oxygen (critical season)	+Dissolved oxygen (critical season)
11010001-926	Middle Fork White River	5	Aquatic life	Dissolved oxygen	WHI0101, MFW01	Unknown	2018	NC	NC
11010001-027	White River	Not listed	Not listed	Not listed	--	Not listed	2020	+Turbidity (base flow, 5alt)	NA
11010001-023	White River	5	Aquatic life	Sulfate	WHI0052, WHI0151A, WHI0151B, WR45, Banks farm, Wyman Bridge	Unknown	2006	-Sulfate +Dissolved oxygen (critical season)	-Sulfate +Dissolved oxygen (critical season) and Temperature
		4a	Not identified	Turbidity	WHI0052	Unknown	2002	NC	NA
11010001-823	White river	Not listed	Not listed	Not listed	WHI0052	Not listed	2020	+Dissolved oxygen (critical season)	NC
11010001-823, 923	White river	4a	Not identified	Turbidity	WHI0052	Unknown	2002	NC	NA
11010001-4040	Beaver Lake	5alt	Primary contact	Pathogens	LWHI013B	Surface erosion	2018	NC	NA
			Not identified	Turbidity		Surface erosion	2018	NC	NA
11010001-4041	Beaver Lake	5alt	Primary contact	Pathogens	USGS-07049160	Surface erosion	2018	NC	NA
			Not identified	pH		Unknown	2018	-pH	NA
			Not identified	Turbidity		Surface erosion	2018	NC	NA
11010001-4042	Beaver Lake	5alt	Primary contact	Pathogens	USGS-07049187	Surface erosion	2018	+Chlorophyll a	NA
			Not identified	Turbidity		Surface erosion	2018	NC	NA
11010001-916	Leatherwood Creek	5	Aquatic life	Dissolved oxygen	LC02, WHI0012B	Unknown	2018	NC	NC
11010001- 060	War Eagle Creek	Not listed	Not listed	Not listed	WHI0233	Not listed	2020	+Dissolved oxygen (critical season)	+Dissolved oxygen (critical season)
11010001-959	Town Branch (Huntsville)	5	Drinking water	Total dissolved solids	Use Attainability Analysis study	Industrial, municipal point sources	2014	NC[d]	NC
		4a	Aquatic life	Nitrate	WHI0093	Municipal point source	1998	NC	NA
11010001-059	Holman Creek	4a	Aquatic life	Nitrate	WHI0070	Municipal point source	1998	NC	NA
11010001- 834	War Eagle Creek	Not listed	Not listed	Not listed	--	Not listed	2020	+Dissolved oxygen (critical season)	NC
11010001-442	Kings River	Not listed	Not listed	Not listed	--	Not listed	2020	+pH	+pH
11010001-542	Kings River	5	Aquatic life	Dissolved oxygen	BUFET004, WHI0121	Unknown	2018	NC	NC
11010001-945	Osage Creek	4a	Aquatic life	Total phosphorus	BUFET008; WHI0065; WHI0069; WHI0130	Municipal point source	2002	NC	NA
11010001-037	Kings River	5	Aquatic life[c]	Total dissolved solids	WHI0009A	Unknown	Pre 2006	NC	NC

a Category 4a=water quality standard(s) is not met but a TMDL study has been completed for the listed parameter; Category 5=water quality standard(s) is not met and a TMDL study is needed; Category 5alt=water quality standard(s) is not met but active or planned restoration approaches may be more immediately beneficial or practicable in achieving water quality standards than pursuing a TMDL in the near term.

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

c In the 2018 303(d) list DEQ reports that fish data indicates the fishery is not impaired.

d The draft 2020 303(d) list shows assessment unit 959 as impaired due to turbidity, but the final 2020 303(d) list shows impairment due to TDS. Because both the final 2018 and the draft and final 2022 303(d) lists show this assessment unit impaired due to TDS, we assume the turbidity impairment on the draft 2020 303(d) list is incorrect and show the 2020 impairment to be due to TDS.

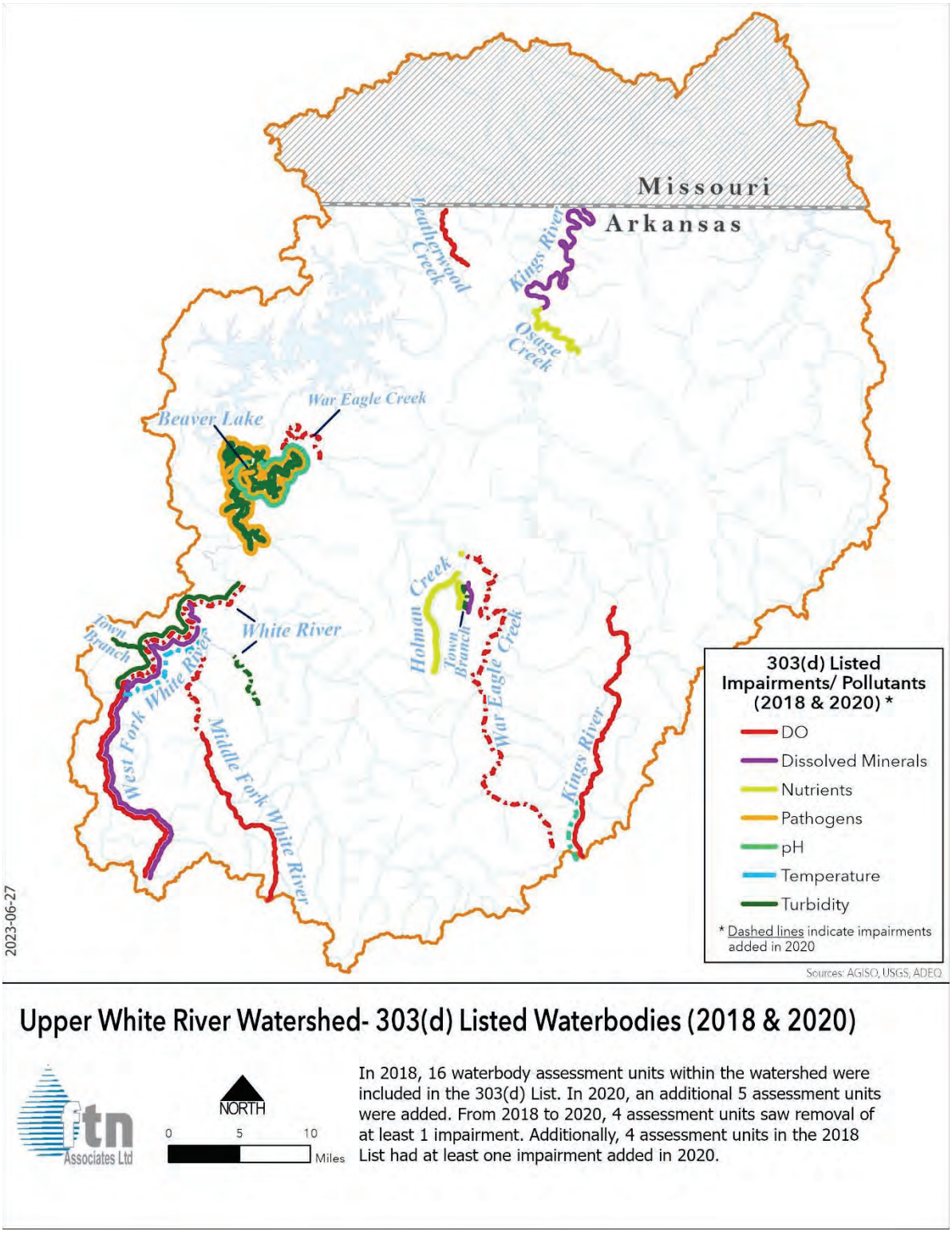


Figure 3.2. Impaired waterbodies in the Upper White River watershed from the final 2018 303(d) List (solid lines) and the draft 2020 303(d) list (solid and dashed lines).

Table Rock Lake in Missouri is classified as impaired for 2020 based on chlorophyll, total nitrogen, and eutrophication bioindicators (MODNR 2020 approved 303(d) list https://dnr.mo.gov/document/2020-epa-approved-section-303d-listed-waters). Sources identified as causing this impairment are municipal point source discharges and various nonpoint sources. All the rivers of the Upper White River watershed empty into Table Rock Lake in Missouri.

3.1.5 Delisted Impaired Assessment Units

Assessment units 11010001-623 and -624 of the West Fork White River, which had previously been considered part of assessment unit 11010001-024, listed as impaired by high turbidity since 1998, were determined to be meeting turbidity standards in the 2018 and 2020 integrated water quality assessments (DEQ 2020, DEQ 2021b). Streambank restoration projects and other erosion reduction practices are credited as the cause of reduced turbidity in these stream segments (Howell 2022).

The following assessment unit and pollutant pairs included on the 2018 303(d) List are not included on the draft 2020 303(d) List:

- 11010001-4041 (Beaver Lake) pH impairment, and
- 11010001-023 (White River) sulfate impairment.

The mineral (including sulfate) criteria for the White River upstream of Beaver Lake were modified in 2017 based on Use Attainability Analyses (DEQ 2017). The change in criteria may have contributed to Assessment Unit 023 being delisted for sulfate impairment.

3.1.6 Water Quality Trends

While it is important to look at current water quality conditions in the watershed, it is also important to determine if water quality is changing over time. Pollutant concentrations that are decreasing over time suggest that water quality is improving and that upstream pollution management practices are providing benefits. Of particular interest in this regard are trends at impaired water bodies. Also of interest are locations where water quality still meets water quality

standards, but long-term trends suggest that water quality standards may not be met in the future if no action is taken.

In this section we present results from trend analyses performed by AWRC on data from their stations in the Beaver Lake watershed. Also presented are results from analysis of data from BWD and DEQ to characterize water quality trends outside of the Beaver Lake watershed.

Grantz and Haggard (2023a) performed trend analysis of flow-normalized concentrations of seven constituents (nitrate nitrogen, total nitrogen, soluble reactive phosphorus (SRP), total phosphorus, total suspended solids (TSS), chloride, and sulfate) collected 2010-2022 at five AWRC water quality monitoring stations; Wyman, WFWR, WEC, TB, Richland, and RC45 (see Figure 3.1 for locations). Statistically significant trends identified are summarized in Table 3.5.

Table 3.5. Summary of results of water quality trend analysis by AWRC on flow-normalized concentrations (Grantz and Haggard 2023a).

Station ID	Stream	Data period	Constituent	Trend direction
WFWR	West Fork White River	2010-2022	Nitrate	Decreasing[a]
			SRP	Decreasing[b]
			Total phosphorus	Decreasing[a]
Wyman	White River	2010-2022	Nitrate	Decreasing[b]
			SRP	Decreasing[a]
			Total phosphorus	Decreasing[a]
RC45	Richland Creek	2010-2014	Total nitrogen	Increasing[b]
Richland	Richland Creek	2016-2022	Total phosphorus	Decreasing[b]
WEC	War Eagle Creek	2010-2022	Chloride	Decreasing[b]
			Total phosphorus	Decreasing[a]

a "very likely" trend, $p<0.05$
b "likely" trend, $p = 0.05$ to <0.10

FTN Associates, Ltd. (FTN) conducted trend analyses on flow-normalized concentration data from BWD and DEQ stations using the same method as described in Grantz and Haggard (2023a). A description of the data and approach used is provided in Appendix D. Our intention was to produce results comparable to those reported in Grantz and Haggard for additional locations. However, we found that differences in the sampling design used by AWRC, compared to that used by BWD and DEQ, may lead to different results from the trend analysis (see discussion in Appendix D). Statistically significant trends identified in BWD and DEQ data are listed in Table 3.6.

Table 3.6. Summary of water quality trend analysis results for flow-normalized concentrations measured by BWD and DEQ.

Station ID	Stream	Data period	Constituent	Trend direction
7	Middle Fork White River (CO Rd 51)	2010-2021	Total nitrogen	Decreasing b
WHI0103	Middle Fork White River (Elkins)	2010-2021	chloride	Decreasing [a]
			sulfate	Decreasing [b]
			Nitrate	Decreasing [b]
			Total nitrogen	Decreasing [b]
			TSS	Decreasing [b]
			DO	Increasing [b]
5	White River (Elkins)	2010-2021	Total nitrogen	Decreasing [b]
WHI0052	White River (Goshen)	2010-2021	chloride	Decreasing [b]
			sulfate	Decreasing [b]
			Nitrate	Decreasing [b]
			Total nitrogen	Decreasing [b]
			Total phosphorus	Decreasing [b]
			TDS	Decreasing [b]
			DO	Increasing [b]
10	White River (Wyman)	2010-2021	Total nitrogen	Decreasing [b]
			Total phosphorus	Increasing [b]
13	White River (Banks Farm)	2010-2021	Total nitrogen	Decreasing [b]
15	War Eagle Creek (old Hwy 412)	2010-2021	Total nitrogen	Decreasing [a]
WHI0070	Holman Creek	2010-2021	TDS	Decreasing [b]
			DO	Increasing [b]
WHI0116	War Eagle Creek (Hindsville)	2010-2021	Chloride	Decreasing [b]
			Sulfate	Decreasing [b]
			Total phosphorus	Decreasing [b]
			DO	Increasing [b]
WHI0123	Kings River (Alabam)	2010-2021	Chloride	Decreasing [b]
			Total phosphorus	Decreasing [b]
			DO	Increasing [b]
WHI0068	Osage Creek	2010-2021	Chloride	Decreasing [b]
			Nitrate	Decreasing [b]
			Total nitrogen	Decreasing [a]
			Total phosphorus	Decreasing [b]
WHI0009A	Kings River (Berryville)	2010-2021	Total nitrogen	Decreasing [a]
			Total phosphorus	Decreasing [a]
			DO	Decreasing [a]
WHI0071	Long Creek	2010-2021	sulfate	Increasing [b]
			Total phosphorus	Decreasing [a]

a "very likely" trend, $p<0.05$
b "likely" trend, $p = 0.05$ to <0.10

The good news is that almost all trends indicate decreasing levels of pollution. Although there is a potential increasing trend in total nitrogen at the AWRC early Richland Creek station, data at the second station, from 2016 to 2022, did not show any trend. The increasing trend in sulfate concentrations at station WHI0071 in Long Creek bears watching. Statistically significant declining trends in total phosphorus concentrations were identified at many of the monitoring locations. Gantz and Haggard (2023a) suggest that the decreasing trends in phosphorus concentrations at most of the AWRC stations result from both improvements in municipal wastewater treatment plants (WWTPs) and nonpoint source pollution management activities. They attribute declining trends in nitrate at their stations in the White River and West Fork White River primarily to improvements in WWTPs.

The increasing trend in DO concentrations identified at several stations may or may not indicate improving water quality. Excessive productivity resulting from nutrient pollution can also cause DO concentrations to increase. Under conditions of excessive productivity, DO saturation values greater than 100% are common, i.e., DO supersaturation. Thus, in some cases, high DO concentrations are an indicator of poor water quality. DO saturation conditions at the stations with increasing DO trends are evaluated in Appendix C.

A few of the monitoring stations evaluated for trends are associated with impaired stream reaches. Table 3.7 summarizes trends in constituents not meeting water quality criteria for water quality stations in impaired stream reaches. In most cases no statistically significant trend was identified for the impairing constituent. However, there is a decreasing trend in sulfate in the White River at station WHI0052. This suggests that the sulfate criterion may eventually be met in this stream reach.

Table 3.7. Trends in pollutants causing impairment of Upper White River stream segments.

Station ID	Stream Name	Assessment Unit ID	Pollutant	Trend
WHI0070	Holman Creek	11010001-059	Nitrate	None
WFWR	West Fork White River	11010001-024	Turbidity	None (TSS)
			Sulfate	None
Wyman	White River	11010001-023	Sulfate	None
WHI0052	White River	11010001-023	Sulfate	Decreasing
		11010001-823, 923, 023	Turbidity	None
WHI0009A	Kings River	11010001-037	TDS	None

3.1.7 Pollutant Loads

There have been several recent efforts to characterize pollutant loads in the Upper White River watershed. AWRC and FTN calculated loads using measured pollutant concentrations and measured (AWRC) or modeled (FTN) flows. FTN, RTI, and USGS estimated loads using water quality models. Results from these efforts are summarized below.

3.1.7.1 Calculated Loads

Grantz and Haggard (2023a) and FTN calculated flow-normalized loads and yields of six constituents (nitrate nitrogen, total nitrogen, total phosphorus, TSS, chloride, and sulfate). AWRC used data they collected at five AWRC water quality monitoring stations; Wyman, WFWR, WEC, Richland, and RC45 (see Figure 3.1 for locations) and daily flows measured at nearby USGS gages. FTN used data collected at six DEQ water quality monitoring stations and daily flows modeled by SWAT for the station locations. Details about data used by FTN are provided in Appendix D. Details about the method used to estimate loads are provided in Grantz and Haggard (2023a). Yields were estimated by dividing the flow-normalized loads by the drainage area for the sampling locations.

Figures 3.3 and 3.4 show loads and yields estimated for 2021 at 9 locations. The locations are graphed for streams located west to east and upstream to downstream. On these graphs, the locations WFWR (West Fork White River), Wyman (White River at Wyman Road bridge), and WEC (War Eagle Creek near Hindsville) were sampled by AWRC. The AWRC sampling program was designed to capture variations in concentrations associated with flow variations (i.e., high flow versus low flow conditions) and season, and the loads reported are for water year. The remaining locations were sampled by DEQ once a month and the loads shown are for the calendar year.

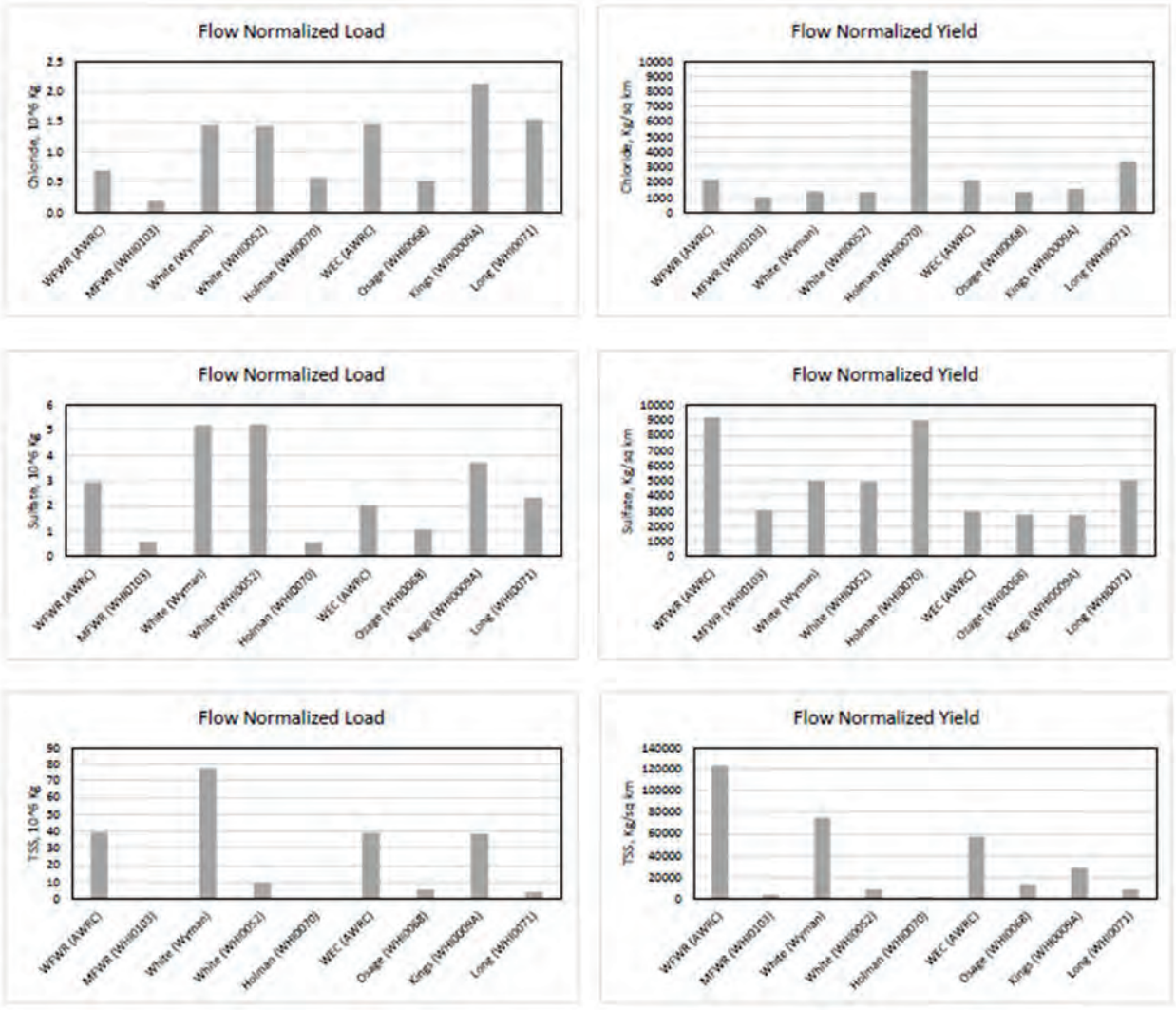


Figure 3.3. Graphs of 2021 chloride, sulfate, and TSS loads and yields estimated by Grantz and Haggard (2023a) and FTN (Appendix D).

Chloride loads seem to vary primarily based on watershed size (Figure 3.3). However, the chloride yields graph shows Holman Creek, the smallest watershed, has a disproportionate chloride yield. This could be because of the influence of the Huntsville WWTP discharge. Note also that Long Creek has a higher chloride yield than the rest of the locations, other than Holman Creek.

Sulfate loads are greatest from the White River, and West Fork White River could be contributing over half of the White River sulfate load (Figure 3.3). Scott and Haggard (2019)

have suggested that underlying geology contributes to high sulfate concentrations in downstream sections of the West Fork White River. Whatever the cause, the West Fork White River has the highest yield of sulfate of the locations evaluated, followed by Holman Creek. The Huntsville municipal wastewater discharge may contribute to sulfate loads in Holman Creek. The West Fork White River at WFWR and the White River at Wyman are on the 2018 303(d) list as impaired by high sulfate levels, however the White River at WHI0052 (on assessment unit 11010001-823) is not.

The AWRC sampling program produces significantly different estimates of TSS load than the DEQ data. Loads estimated for most of the DEQ stations are significantly lower than those from the AWRC stations (Figure 3.3). The AWRC data indicates that the West Fork White River has the highest sediment yield. The White River at both the AWRC (Wyman) and DEQ (WHI0052) sampling locations is designated as impaired by high turbidity, as is the West Fork White River at the AWRC location.

The pattern of loads and yields for nitrate and total nitrogen are similar (Figure 3.4). In general, the highest loads and yields are from the eastern streams. The highest loads are in War Eagle Creek (WEC), Kings River, and Long Creek. The highest yields are from Long Creek and Holman Creek. The Huntsville municipal wastewater discharge likely contributes to the higher nitrogen loads in Holman Creek.

As with TSS loads and yields, the AWRC sampling program results in significantly higher estimates of total phosphorus load and yield than the DEQ data (Figure 3.4). This is likely because much of the phosphorus entering these streams is attached to eroded soil or sediment. Of the AWRC locations, the White River (Wyman) has the highest total phosphorus load, however West Fork White River has the highest total phosphorus yield. Based on the loads estimated from DEQ data at White and Kings stations, it appears that Kings River total phosphorus load is similar to that for the White River. Yields from Holman Creek are on par with those from War Eagle Creek. This may be the result of the influence of the Huntsville municipal wastewater discharge.

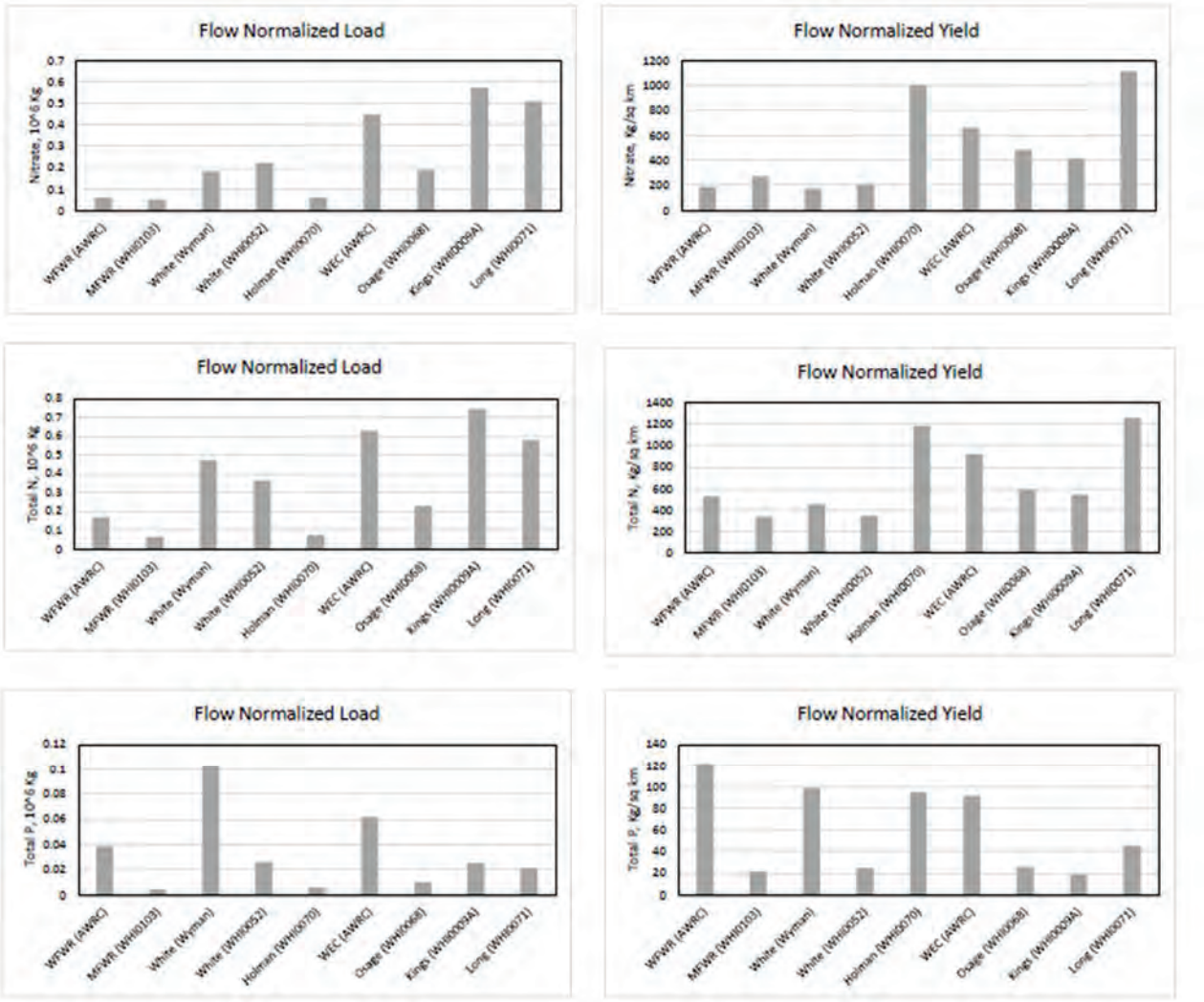


Figure 3.4. Graphs of 2021 nitrate, total nitrogen, and total phosphorus loads and yields estimated by Grantz and Haggard (2023a) and FTN (Appendix D).

3.1.7.2 USGS SPARROW Model Loads

Recently, USGS updated SPARROW modeling of the United States (US) to the period 2000-2014, and estimated streamflow and nitrogen, TSS, and phosphorus yields for 2012 (Robertson and Saad 2019). Estimated 2012 yields from the Upper White River watershed from the updated Midwest SPARROW model are listed in Table 3.8. The estimated Upper White River 2012 total nitrogen and total phosphorus yields are in the second upper quintile for the Midwest. Estimated sediment yields are in the middle quintile for the Midwest (USGS 2019).

Figures 3.5-3.7 show 2012 yields of total nitrogen, total phosphorus, and sediment estimated by the SPARROW model for catchments in the Upper White River watershed.

Table 3.8. Estimated yields from the Upper White River watershed for 2012 using SPARROW model (USGS 2019).

Parameter	Estimated 2012 aggregated yield	Midwest ranking (quintile yield range)
Total nitrogen	780 kg/sq km	Second quintile (580-1,070 kg/sq km)
Total phosphorus	113 kg/sq km	Second quintile (77.8-138 kg/sq km)
Suspended sediment	79.6 metric tons/sq km	Third quintile (72.4-123 metric tons/sq km)
Streamflow	420 mm/year	Second quintile (358-471 mm/year)

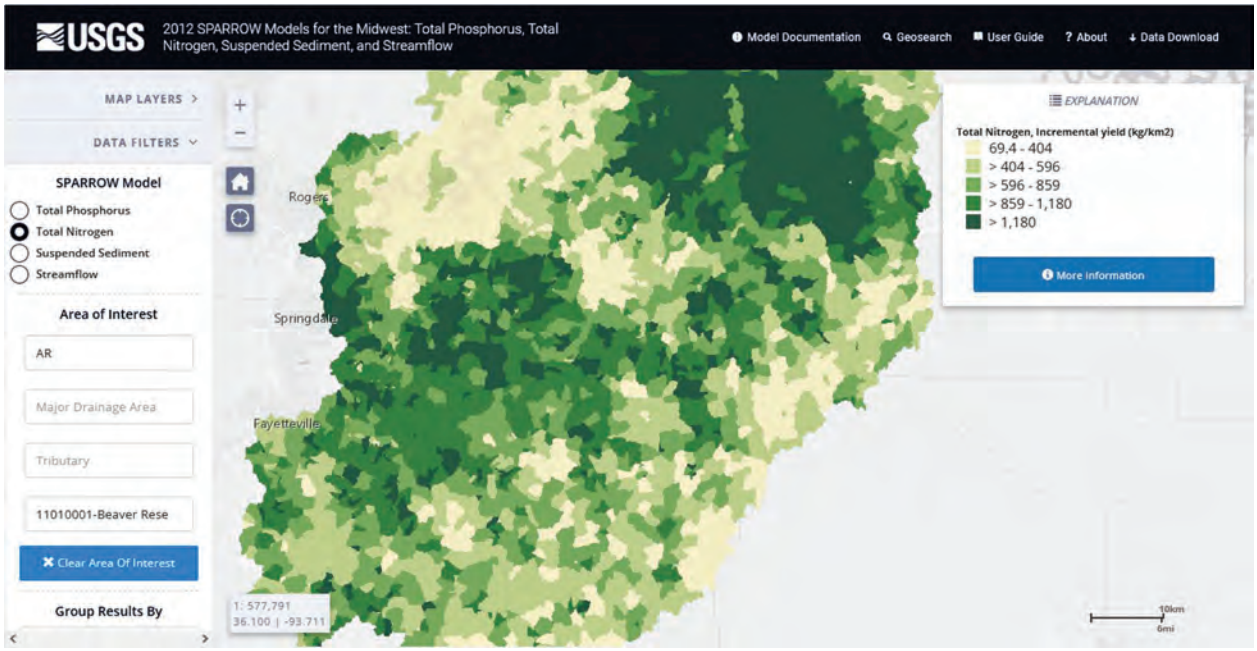


Figure 3.5. Incremental yield of total nitrogen from catchments in the Upper White River watershed estimated for 2012 by the SPARROW model (USGS 2020).

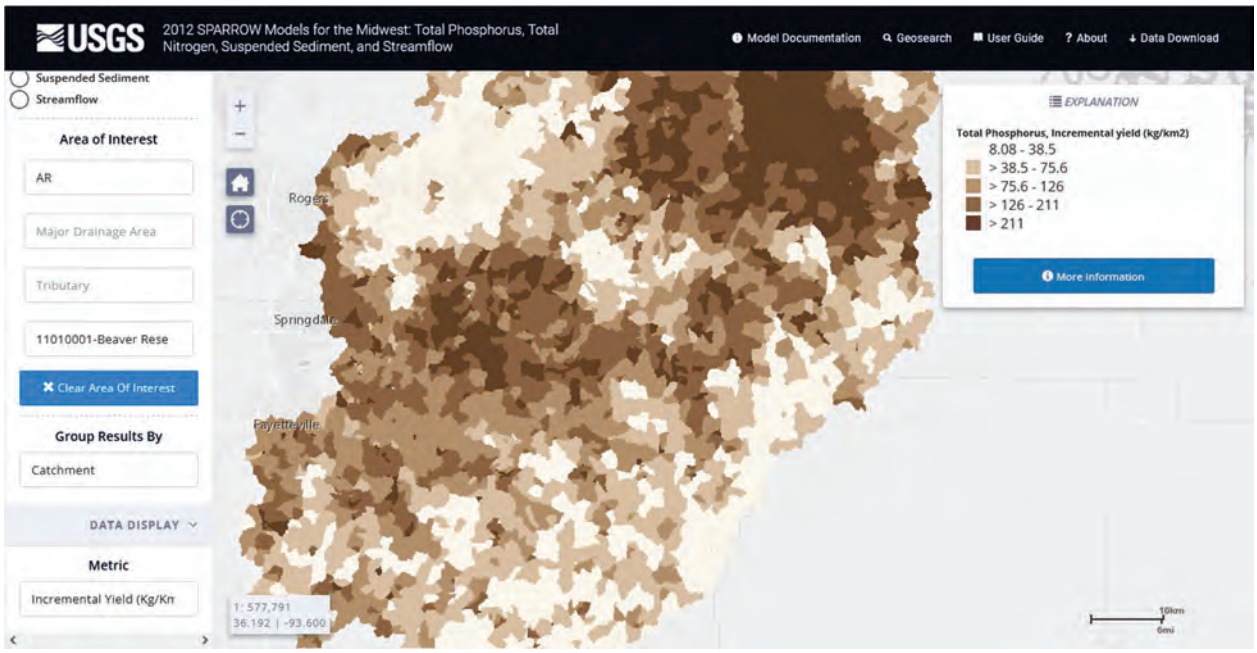


Figure 3.6. Incremental yield of total phosphorus from catchments in the Upper White River watershed estimated for 2012 by the SPARROW model (USGS 2020).

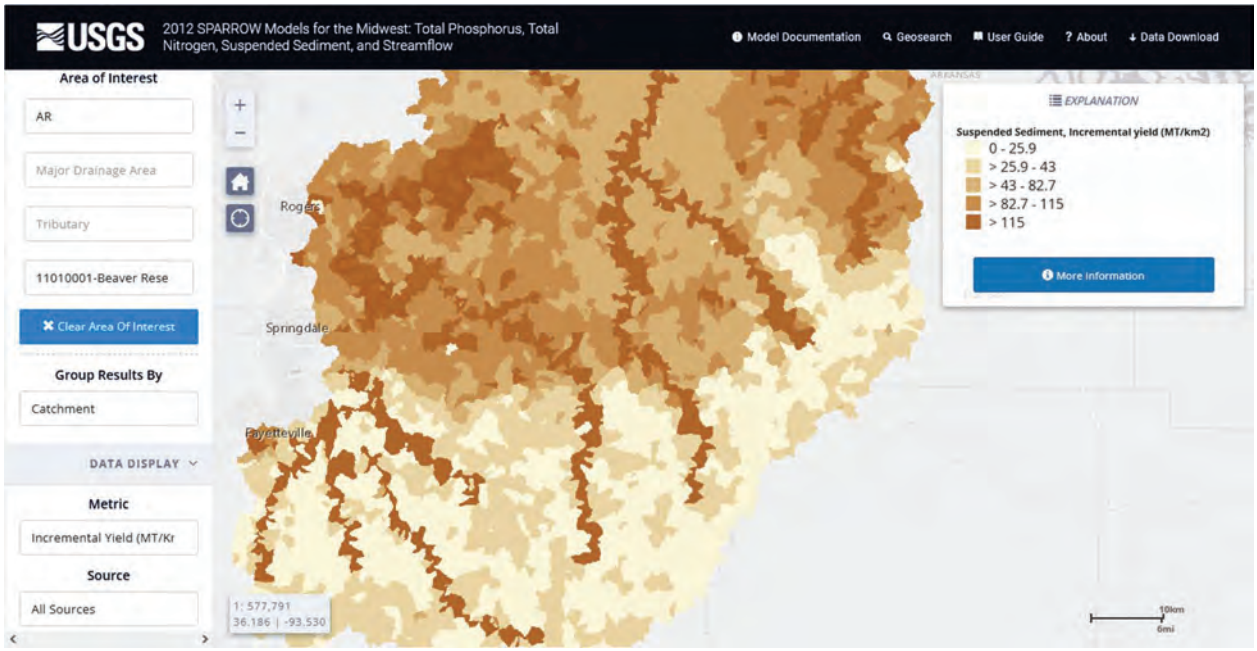


Figure 3.7. Incremental yield of sediment from catchments in the Upper White River watershed estimated for 2012 by the SPARROW model (USGS 2020).

As part of developing the regional SPARROW models, USGS estimated annual loads for over 3,000 water quality monitoring locations in the U.S. (Saad, et al. 2019). Through this effort, 2012 annual loads of nitrogen were developed for eight locations, phosphorus for five locations, and sediment annual loads were developed for two locations within the Upper White River watershed. These loads are listed in Table 3.9.

Table 3.9. USGS estimated 2012 annual nutrient and sediment loads for selected water quality stations (Saad, et al. 2019).

Station	2012 loads		
	Total nitrogen, kg	Total phosphorus, kg	Suspended sediment, metric tons
07048550, West Fork White River E of Fayetteville, AR	218,241 (166,000)*	43,617 (49,700)*	-
07048600, White River near Fayetteville, AR	619,489 (482,000)*	-	107,460 (74,800)*
07048700, White River near Goshen, AR	470,044	75,938	-
07048800, Richland Creek at Goshen, AR	275,926 (207,000)*	-	-
07049000, War Eagle Creek near Hindsville, AR	5,375,125 (568,000)*	69,642 (10,020)*	91,591 (44,000)*
07049160, War Eagle Creek near Lowell, AR	446,150	7,505	-
07050500, Kings River near Berryville, AR	823,229	-	-
07053250, Yocum Creek near Oak Grove, AR	275,541	5,293	390

* Flow-normalized loads calculated by AWRC for 2012 are provided in parentheses for comparison. Note that AWRC "sediment" load is TSS load.

The Midwest SPARROW model estimates load contributions from a variety of sources (Robertson and Saad 2019). Figures 3.7 – 3.9 illustrate the estimated relative load contributions from sources in the Upper White River watershed. The SPARROW model identifies manure and atmospheric deposition as the greatest contributors to total nitrogen yield, manure as the greatest contributor to total phosphorus yield, and agriculture, natural sources, and channel sources as the greatest contributors to sediment yield.

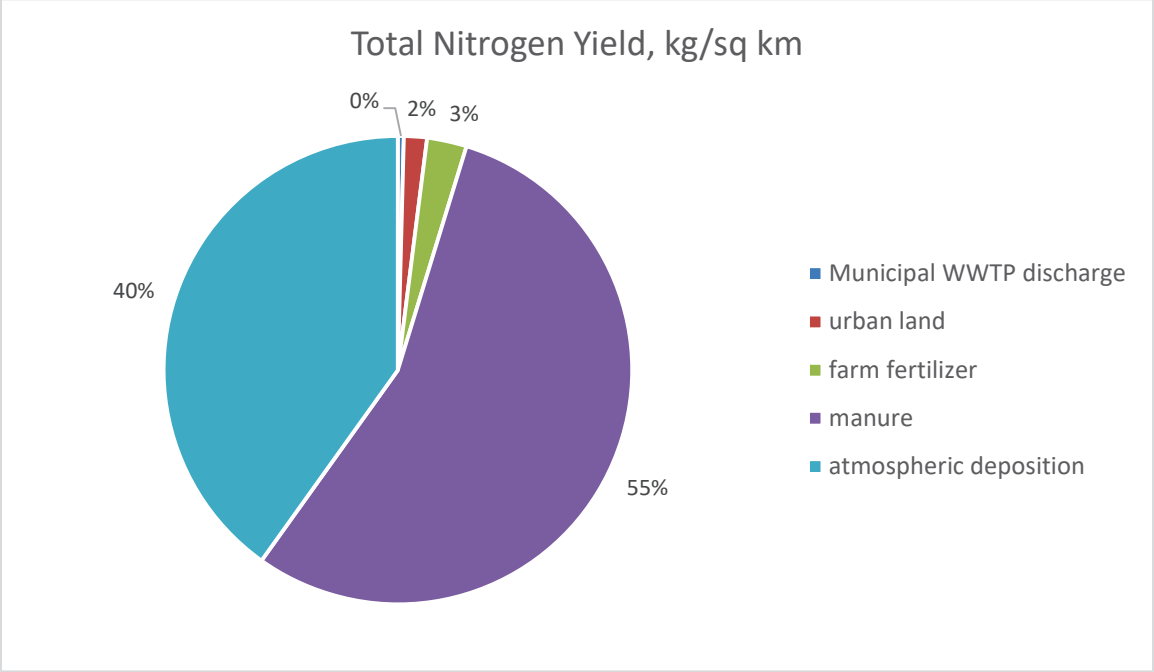


Figure 3.7. SPARROW model sources of total nitrogen yield in the Upper White River watershed.

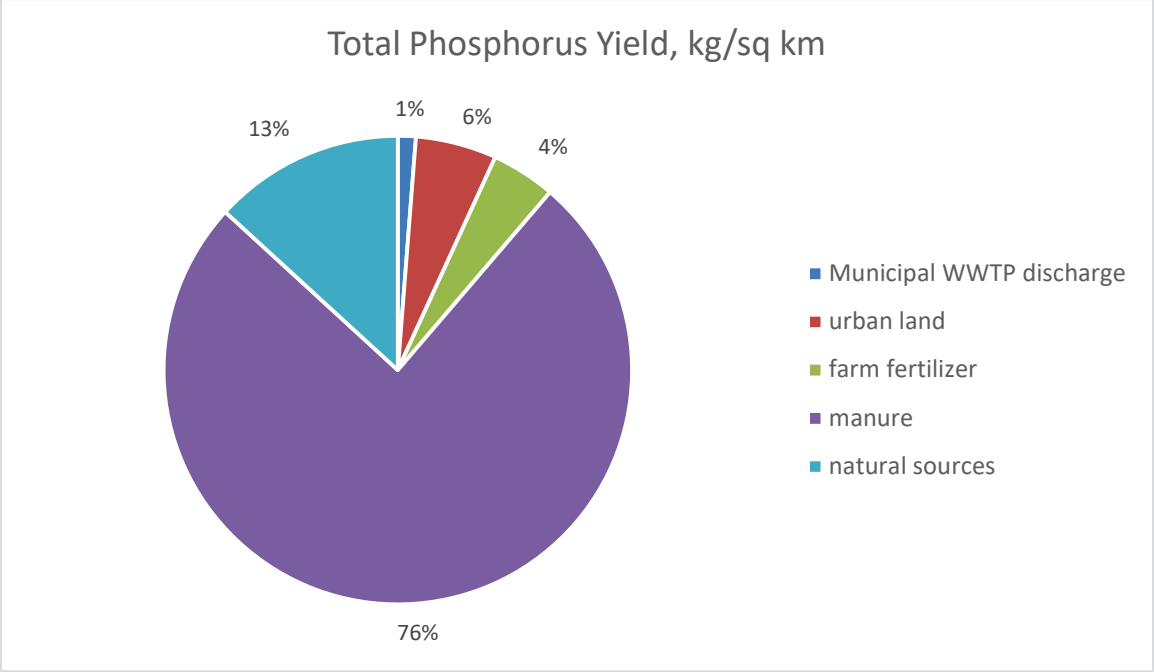


Figure 3.8. SPARROW model sources of total phosphorus yield in the Upper White River watershed.

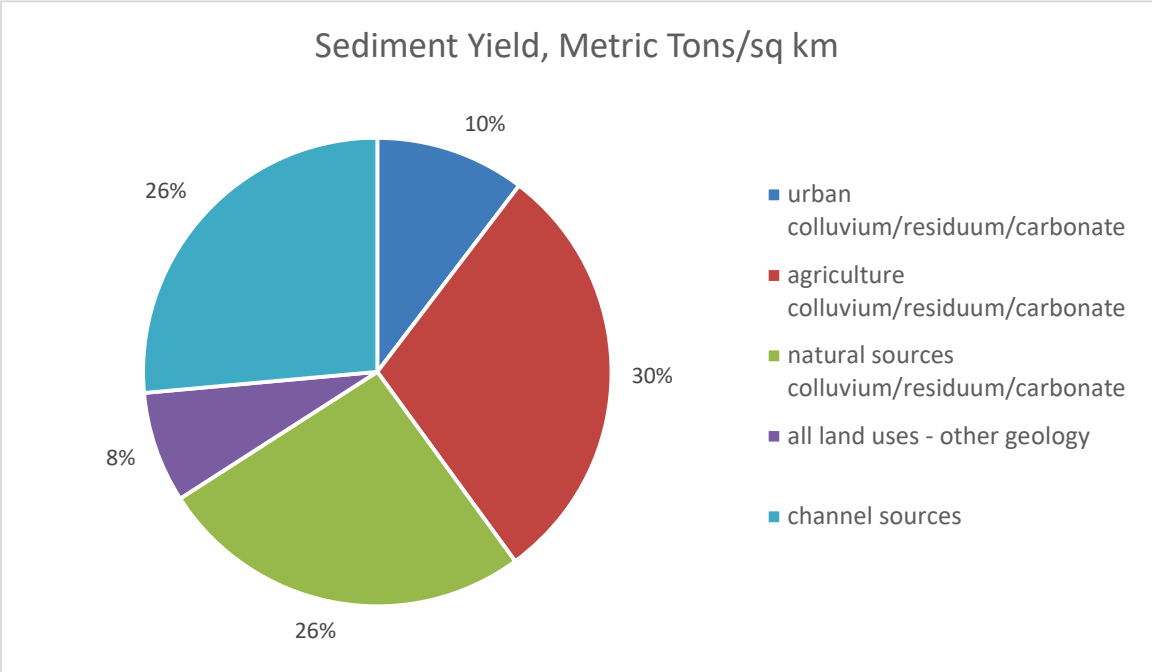


Figure 3.9. SPARROW model sources of sediment yield in the Upper White River watershed.

3.1.7.3 WaterFALL Model

As part of updating the Beaver Lake Watershed Protection Strategy, RTI used the WaterFALL model (Eddy, et al. 2017) to estimate loads of total nitrogen, total phosphorus, and sediment generated in catchments of the Beaver Lake watershed for the period 2007-2021. This modeling effort is described in detail in the Watershed Protection Strategy and associated documents (RTI 2023). Figures 3.10-3.12 show modeled yields from WaterFALL for the Beaver Lake watershed catchments. Modeled yields from WaterFALL tend to be higher in lower War Eagle Creek, Brush Creek, Richland Creek, and White River than other areas of the modeled watershed.

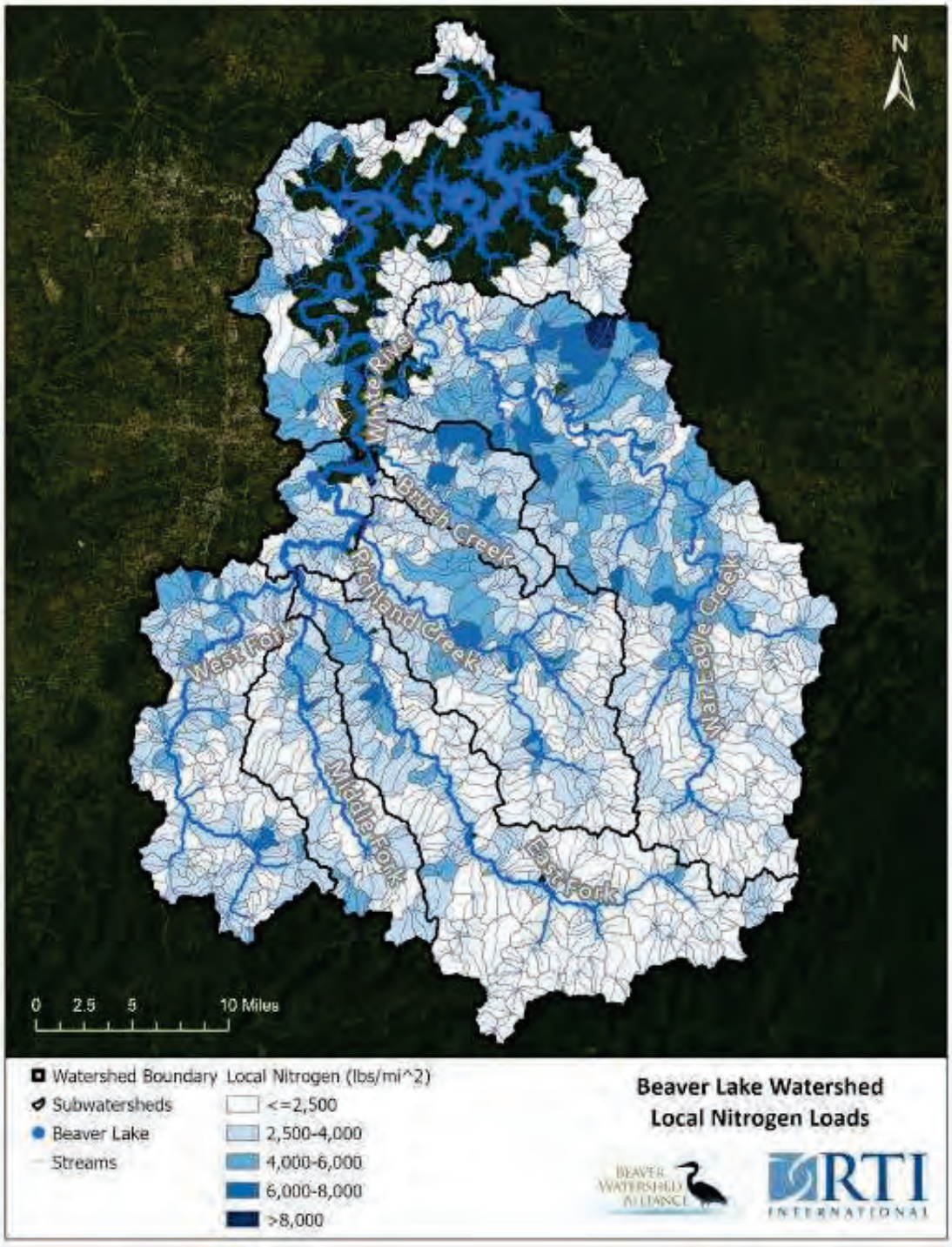


Figure 3.10. Total nitrogen yields for catchments of Beaver Lake estimated using WaterFALL model (from RTI 2023).

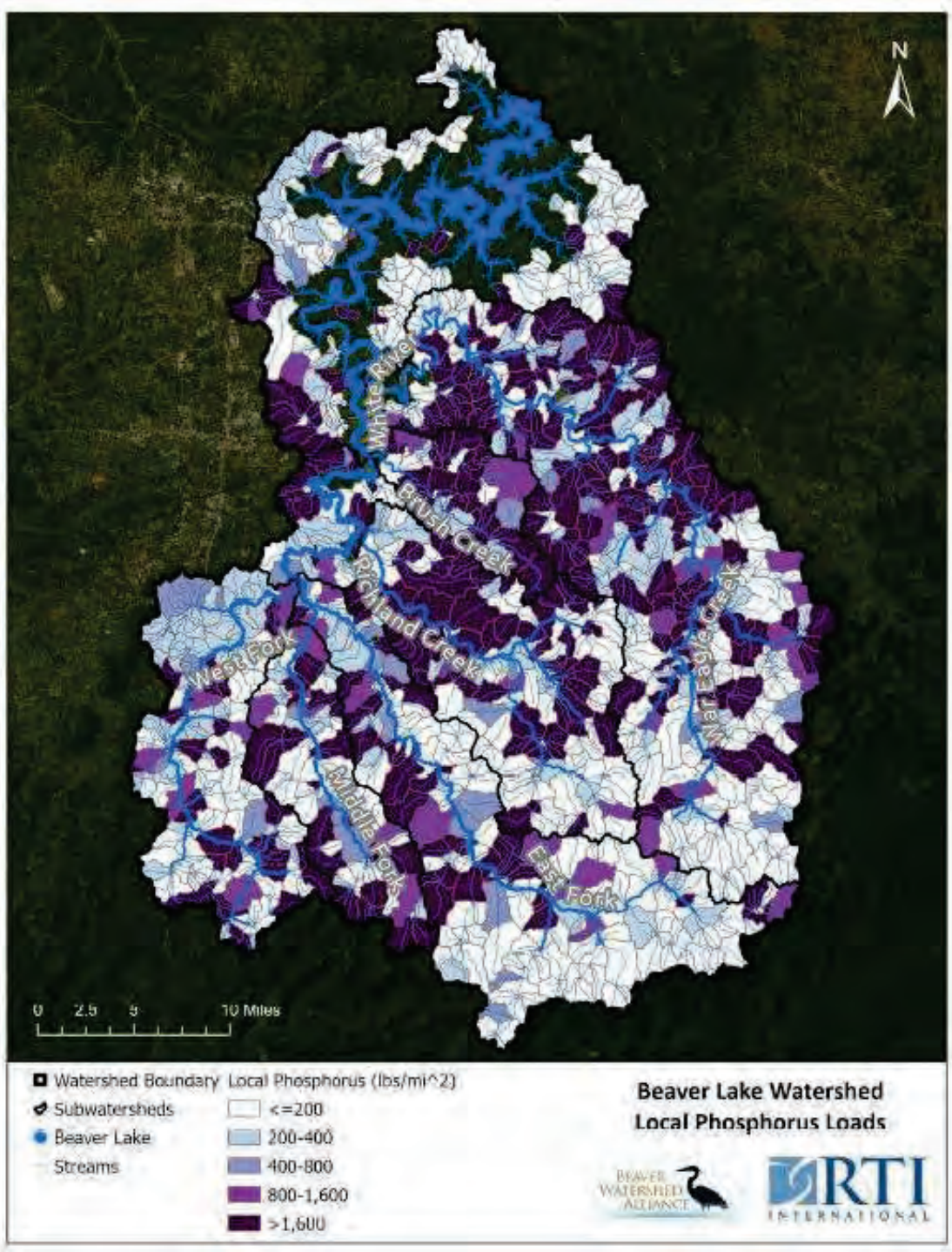


Figure 3.11. Total phosphorus yields for catchments of Beaver Lake estimated using WaterFALL model (from RTI 2023).

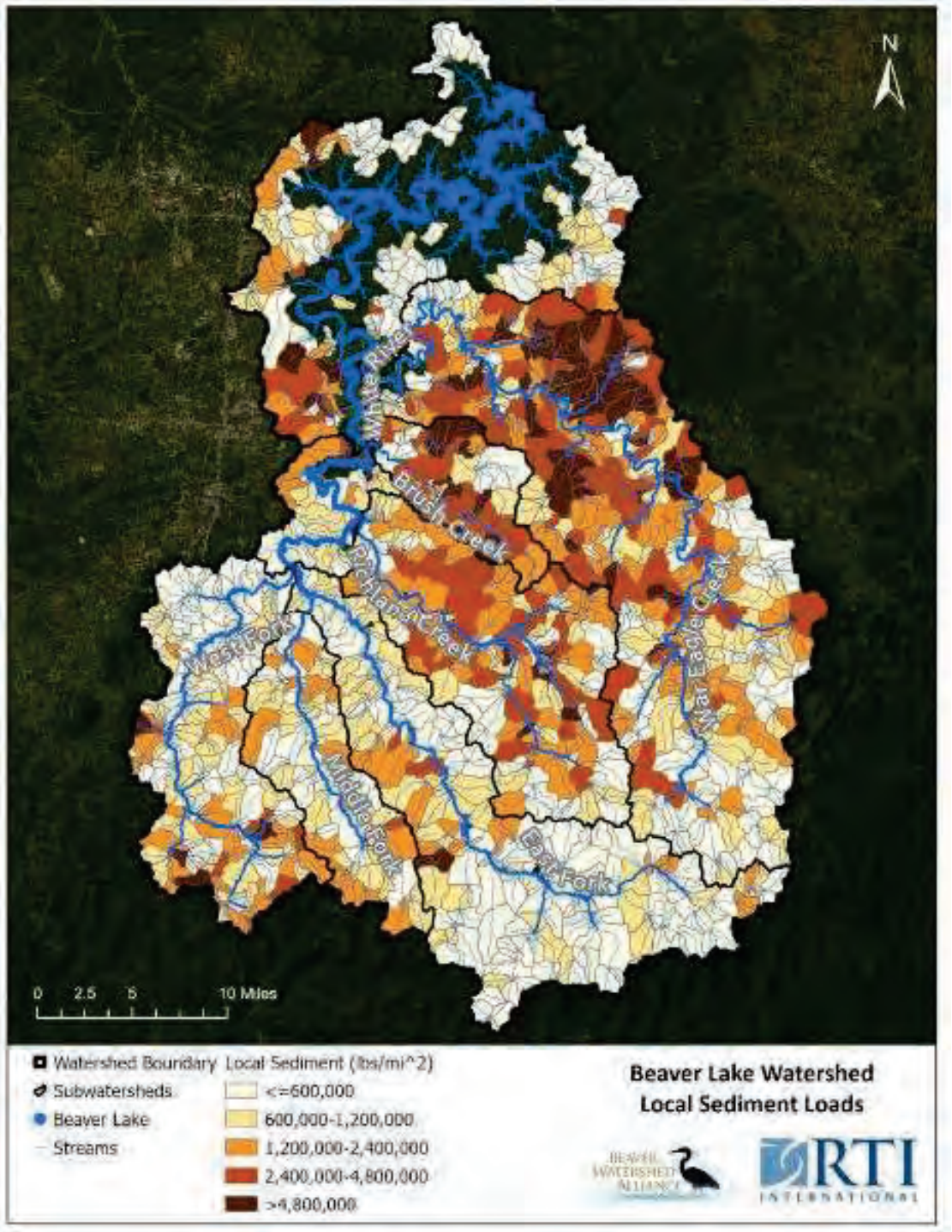


Figure 3.12. Sediment yields for catchments of Beaver Lake estimated using WaterFALL model (from RTI 2023).

3.1.7.4 SWAT Model

FTN used the SWAT (Soil and Water Assessment Tool) model to estimate nonpoint source total nitrogen, total phosphorus, and sediment yields for each of the 69 12-digit hydrologic unit code (HUC12) sub-watersheds of the Upper White River watershed with 50% or more of their area in Arkansas (FTN Associates, Ltd. 2024). SWAT estimated average yields for 1996-2021 from the Upper White River watershed are listed in Table 3.10. Shown in this table are the yields generated from the land in the watershed (upland yield) and yields within the stream, which are affected by instream processes. For nutrients, instream processes include temperature-dependent chemical and biological transformations and settling. For sediment, instream processes include channel and bank erosion and channel deposition. Thus, instream yield includes streambank erosion inputs, which are not included in upland yield.

Table 3.10. SWAT model estimated average yields of nutrients and sediment from the Upper White River watershed (FTN Associates, Ltd. 2024).

Parameter	SWAT model upland yield	SWAT model instream yield
Total nitrogen	3,191 kg/sq km	465 kg/sq km
Total Phosphorus	279 kg /sq km	75 kg /sq km
Suspended sediment	1,960 kg /sq km	142 kg /sq km

Figures 3.13-3.15 show the relative ranking of the SWAT model nonpoint source yields from each 12-digit hydrologic unit code sub-watershed of the Upper White River. The values used to prepare these maps are instream yields. The relatively high sediment yields from the headwater areas of the watershed are a function of the land slope, stream slope and velocity, and the soil types present. Researchers have found that SWAT tends to overestimate land erosion in areas with steep slopes. To match target instream sediment concentrations sedimentation must be increased (Pontes, et al. 2021; Batista, et al. 2019).

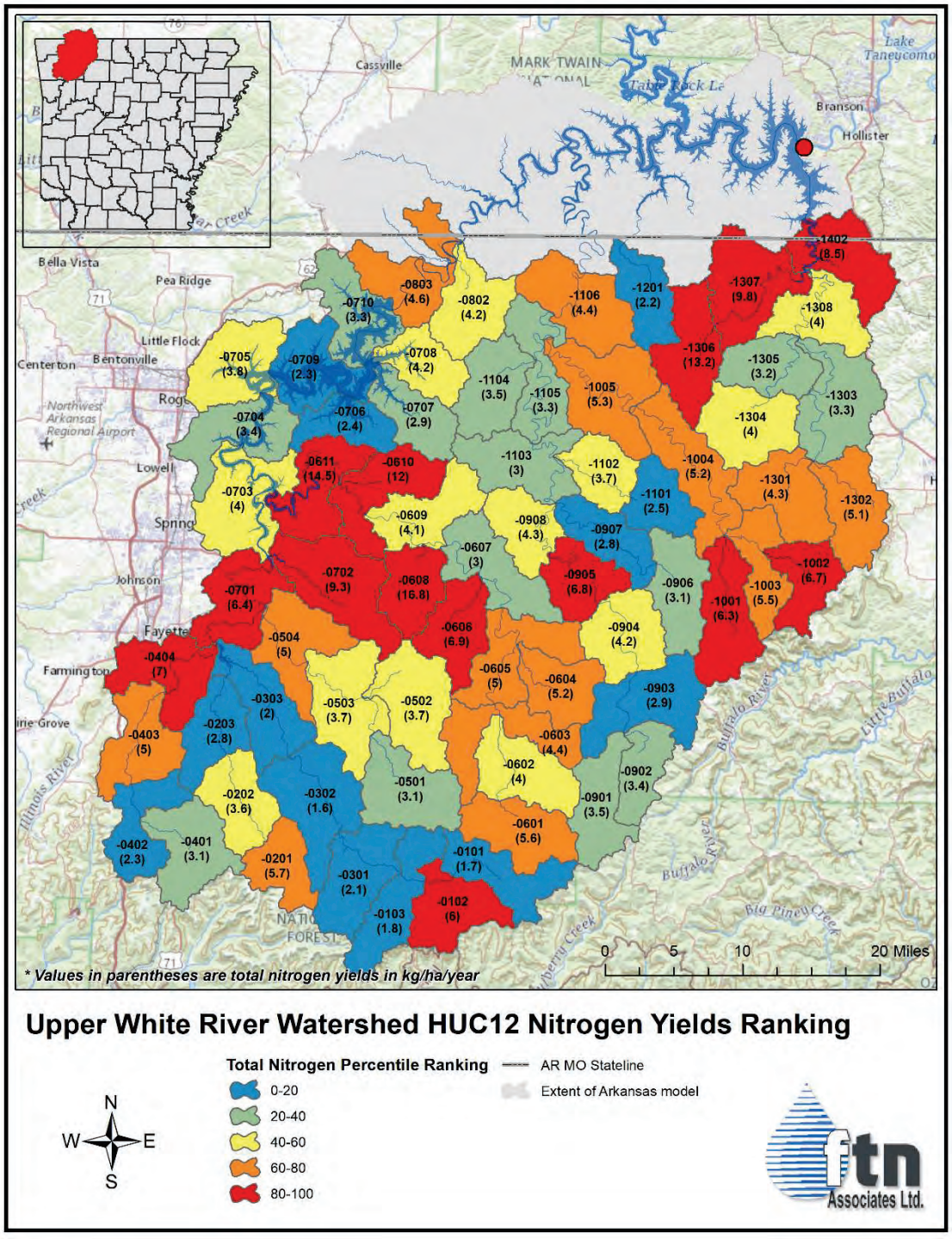


Figure 3.13. Relative ranking of SWAT model nonpoint source total nitrogen yields for HUC12 sub-watersheds of the Upper White River watershed (FTN Associates, Ltd. 2024).

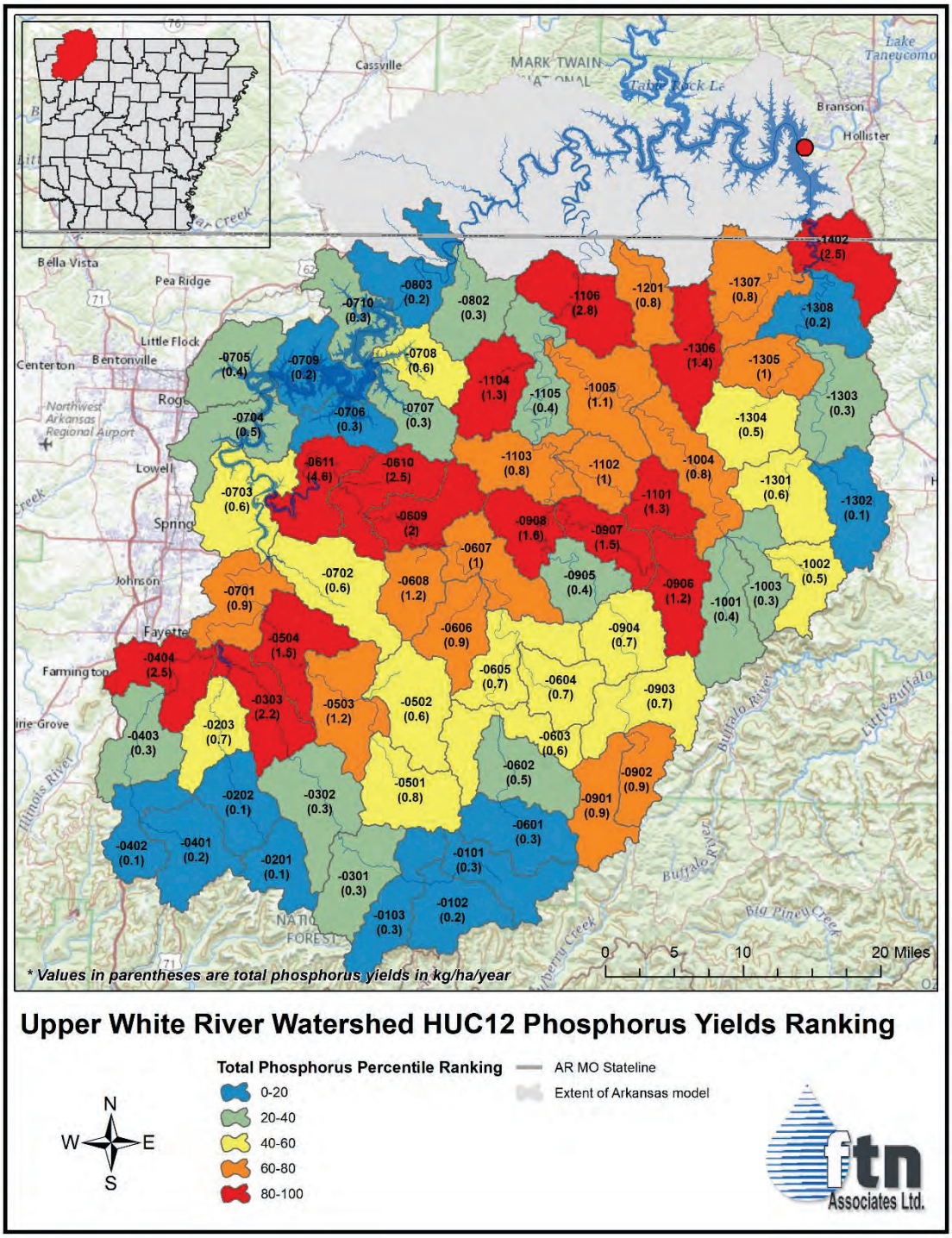


Figure 3.14. Relative ranking of SWAT model nonpoint source total phosphorus yields for HUC12 sub-watersheds of the Upper White River watershed (FTN Associates, Ltd. 2024).

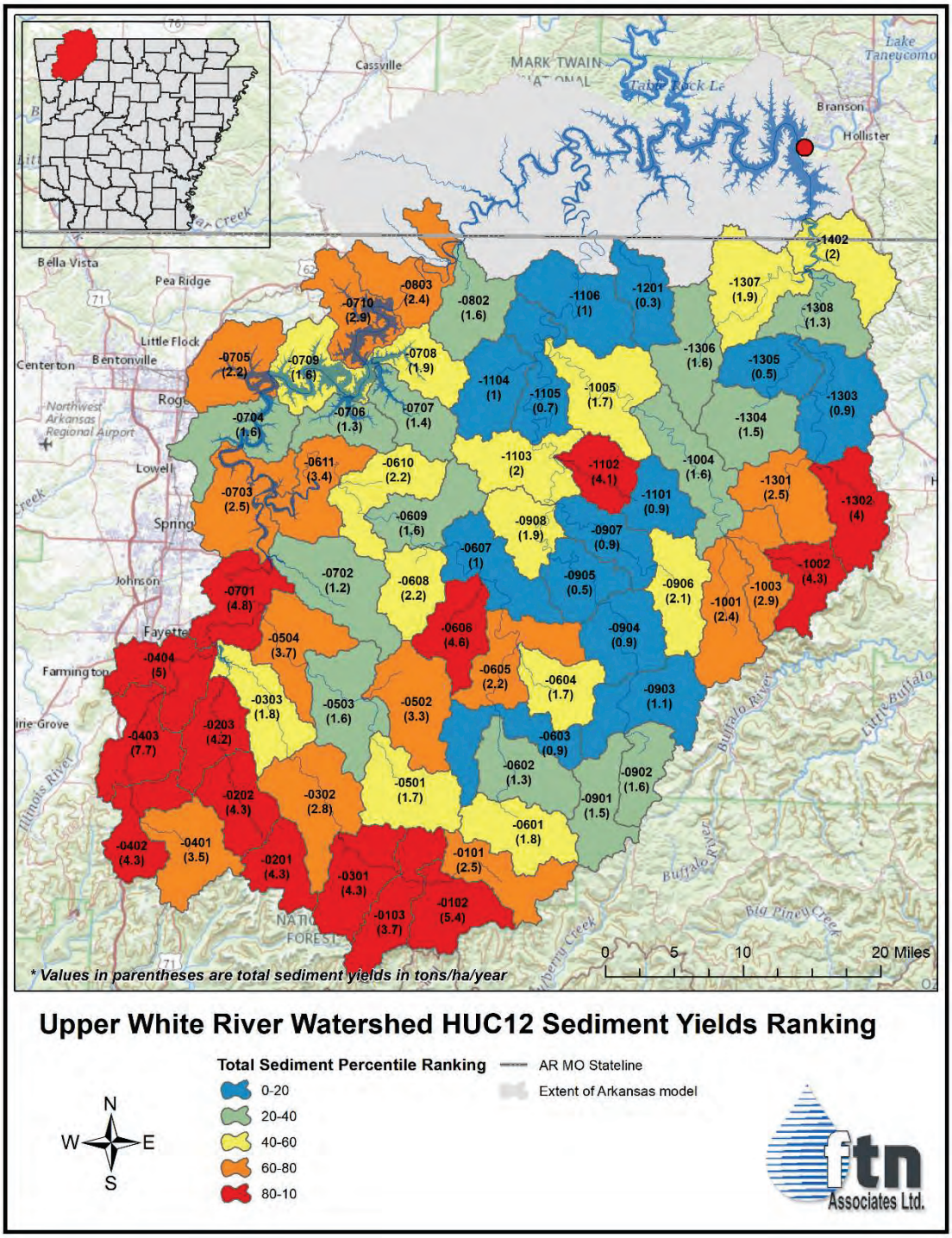


Figure 3.15. Relative ranking of SWAT model nonpoint source sediment yields for HUC12 sub-watersheds of the Upper White River watershed (FTN Associates, Ltd. 2024).

3.1.8 Summary

Surface water quality data are being collected in the Upper White River watershed by at least 10 organizations, including state and federal agencies, interest groups, and universities. Surface water samples were collected from 85 water quality monitoring stations at 71 locations 2018-2022 by AWRC, BWD, DEQ, H2Ozarks, and USGS. In all, these organizations collected over 60,000 water quality measurements in this watershed 2018-2022.

As of this writing, the most recent EPA approved state impaired waters list (i.e., 303(d) list) for Arkansas is from 2018. On the 2018 303(d) list, over 135 miles of streams in the watershed, and over 3,400 acres of Beaver Lake are classified as impaired. Impaired waterbodies in this watershed do not meet water quality criteria for DO, *E. coli*, pH, sulfate, TDS, temperature, or turbidity. Several waterbodies do not meet water quality criteria for more than one pollutant.

Analysis of water quality measurements from 2010-2021 identified primarily statistically significant decreasing trends in nutrients and minerals, and increasing trends in DO, all of which suggest improving water quality. One exception was a possible increasing trend in total phosphorus in the White River at Wyman, based on BWD data (analysis of AWRC data from this location indicated a decreasing trend in total phosphorus). Another exception was an increasing trend in sulfate in lower Long Creek. Trend analyses of parameters exceeding water quality criteria at stations on impaired waterbodies mostly indicated no trends, so there is no indication that water quality in impaired waterbodies is getting better or worse. The exception was a decreasing trend in sulfate in the White River at station WHI0052.

A comparison of flow-normalized yields indicates that, of the locations evaluated, the West Fork White River station exhibits the highest yields of sulfate, TSS, and total phosphorus. Long Creek and Holman Creek stations had the highest yields of chloride, nitrate, and total nitrogen. The higher yields at the Holman Creek station may be a result of the influence of effluent from the Huntsville WWTP on water quality.

The 2012 Midwest SPARROW model ranks the Beaver Reservoir HUC8 in the second highest quintile for phosphorus and nitrogen yields, and in the middle quintile for sediment yields.

USGS estimated annual total nitrogen, total phosphorus, and sediment loads for 2012 at selected USGS water quality and gaging stations. The estimated 2012 total nitrogen load from War Eagle Creek (07049000) is an order of magnitude greater than the loads estimated for other streams. The highest estimated 2012 total phosphorus annual load is from the White River (07048700), but the estimated War Eagle Creek total phosphorus load is not much smaller. The highest estimated 2012 sediment load is also from the White River (07048600), and again the War Eagle Creek load is not that different. A sediment load was not calculated for West Fork White River.

Relative rankings of modeled yields from catchments and HUC12 sub-watersheds of total nitrogen and total phosphorus from USGS SPARROW, RTI WaterFALL, and SWAT (conducted by FTN) models exhibit similar patterns.

3.1.9 Data Gaps

Available *E. coli* data collected 2018-2022 is not suitable for evaluating criteria attainment (DEQ 2021c). *E. coli* has been identified as a concern in the Upper White River watershed, and segments of Beaver Lake are listed as impaired because of high *E. coli* levels.

Town Branch in Huntsville is listed as impaired for minerals (TDS and sulfate), but there has been no data collected from this stream since the site-specific water quality study in 2013 (GBMc, 2013)(DEQ 2021a).

WHI0051 is listed as the station used to identify impairment of West Fork White River, but it hasn’t been sampled since 2013.

A detailed study of the cause of sulfate and TDS impairments in this watershed would be helpful. Also, a study of the proposed pH impairment listing of Kings River Assessment Unit 11010001-442.

3.2 Groundwater Quality

This subsection describes groundwater quality in the Upper White River watershed in terms of measured concentrations of selected parameters. This includes a summary of the water quality standards that apply and the water quality monitoring programs active in the watershed.

Recent (2018-2022) surface water quality data are summarized and discussed, and trends in long-term water quality data are evaluated.

3.2.1 Groundwater Quality Standards

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

3.2.2 Current Groundwater Quality Monitoring

DEQ and USGS have collected groundwater quality data in the Upper White River watershed. Table 3.11 lists wells and springs in the watershed where water quality measurements were taken during 2018-2022. These locations are shown on Figure 3.16. The locations sampled 2018-2022 are located in the Ozark Highlands ecoregion. Table 3.12 summarizes the water quality parameters that were measured in groundwater during 2018-2022.

Table 3.11. Groundwater quality monitoring stations in the Upper White River watershed sampled 2018-2022.

Entity	Station ID	Aquifer*	Description	County	Depth, ft	Start Year	End Year	Number of dates
USGS	362334093444601	Boone	20N26W16DDD1SP Sycamore	Carroll	-	2009	2019	3
USGS	355200093541901	Bloyd shale	14N28W24DBB1 MW-AGL	Madison	45	2019	2019	1
DEQ	WHI0209	Unknown	Withrow Spring at Withrow Springs Cave at Withrow Springs State Park	Madison	0	2016	2018	24
DEQ	WHI0207	Unknown	War Eagle Cave Spring at War Eagle Cave at Withrow Springs State Park	Madison	0	2016	2018	24

Table 3.12. Water quality parameters monitored in groundwater (springs and wells) in the Upper White River watershed 2018-2022.

Parameter	DEQ	USGS
Metals	Quarterly	X
Dissolved oxygen	Monthly	X
Turbidity	Monthly	
Nutrients	Monthly	X
Total suspended solids	Monthly	-
Pathogens	-	X
Alkalinity	Monthly	-
Minerals	Monthly	X
Temperature	Monthly	X
Specific conductance	Monthly	X
pH	Monthly	X
Hardness	Quarterly	-
Total organic carbon	Monthly	-
Organics	-	X

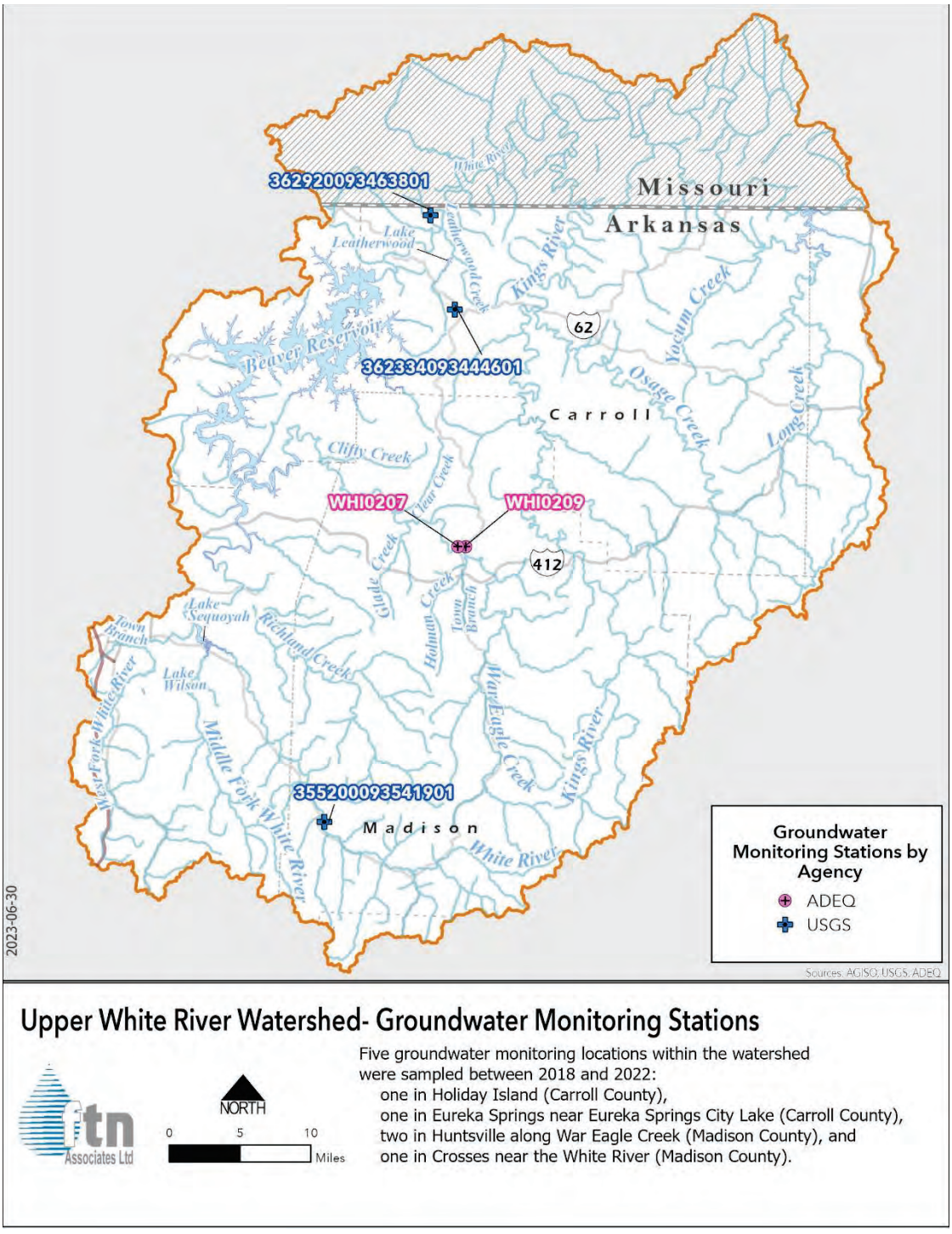


Figure 3.16. Groundwater monitoring locations in the Upper White River watershed sampled 2018-2022.

DEQ monitors groundwater quality in a portion of Boone County in the Upper White River watershed through its Ambient Groundwater Monitoring Program, initiated in 1986. This program consists of 12 areas sampled about every three years. A portion of the Omaha Monitoring Area is in Boone County within the Upper White River watershed. The Omaha Monitoring Area was initiated in 1996 to assess potential impacts to groundwater quality in the Springfield Plateau and Ozark aquifers in karst terrain. The last time this area was sampled was 2013 (J. Martin, DEQ, personal communication, 5/2/2023).

3.2.3 Groundwater Quality Summary

Groundwater quality data from 2018-2022 were reviewed. Parameters examined included nitrate, nitrite, *E. coli*, metals, organic compounds, sulfate, and TDS. A detailed evaluation of these parameters in groundwater is provided in Appendix E. Based on this evaluation, groundwater in the Upper White River watershed meets drinking water standards, except where *E. coli* are present. The frequent presence of pathogens in the Springfield Plateaus aquifer limits its use as a drinking water supply (Kresse, et al. 2014). Groundwater in the Upper White River watershed may contribute loads of *E. coli* and nitrate to surface waters, particularly during rain events. Levels of sulfate and TDS in groundwater are lower than the Ozark Highlands ecoregion reference stream values, suggesting that groundwater does not contribute to surface water minerals impairments.

3.2.4 Summary

We did not find much current groundwater quality data from the Upper White River watershed. What was available indicates that groundwater in this watershed meets drinking water standards for nitrate, metals, and organics; and does not contribute to minerals criterion exceedances in surface waters. However, there have been issues with bacteria in the aquifers of this region (Kresse, et al. 2014). In addition, the reported 2018-2022 nitrate concentrations in groundwater are greater than what is considered natural background nitrate levels. This information suggests that groundwater may contribute to nitrogen and pathogen loads in surface waters of this watershed. Since groundwater pathways often do not follow surface water pathways, activities to protect groundwater from nitrogen and pathogen sources just about

anywhere in the watershed could help improve surface water quality. A DRASTIK model of groundwater vulnerability in the Ozark Highlands suggests that areas where groundwater quality is most vulnerable to land management activities in the Upper White River watershed is along river valleys.

3.2.5 Data Gaps

DEQ has not sampled groundwater in the Omaha monitoring area since 2013. DEQ plans to sample in this area in 2024 (J. Martin, DEQ Planning Branch Manager, personal communication 5/2/2023). More measurements of pathogen indicator bacteria (e.g., *E. coli*) in groundwater may be useful.

3.3 Ecological Condition

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

3.3.1 Hydrology

Timing and amount of stream flows are part of the aquatic habitat. Native aquatic species are adapted to the natural seasonal variation in flow. Some even depend on this variation for reproduction success. Hydrology in the Upper White River watershed has been modified through the actions of humans including, construction of Beaver Lake reservoir, land clearing, development, and construction of farm ponds.

There were eight USGS flow gages active in the Upper White River watershed in 2022 (Figure 3.17). There was also a USGS stage gage active in the watershed in 2022, 07048495- Town Branch at Armstrong St. at Fayetteville, AR. Table 3.13 lists summary statistics for measurements from the flow gages active in 2022. USACE collects hourly flow and stage measurements at three USGS gage locations in the watershed, on the White River at 07048600, War Eagle Creek at 07049000, and Kings River at 07050500. They also collect hourly water surface elevations in the Beaver Lake reservoir and tailwater, and release flows from Beaver Dam (USACE 2023a).

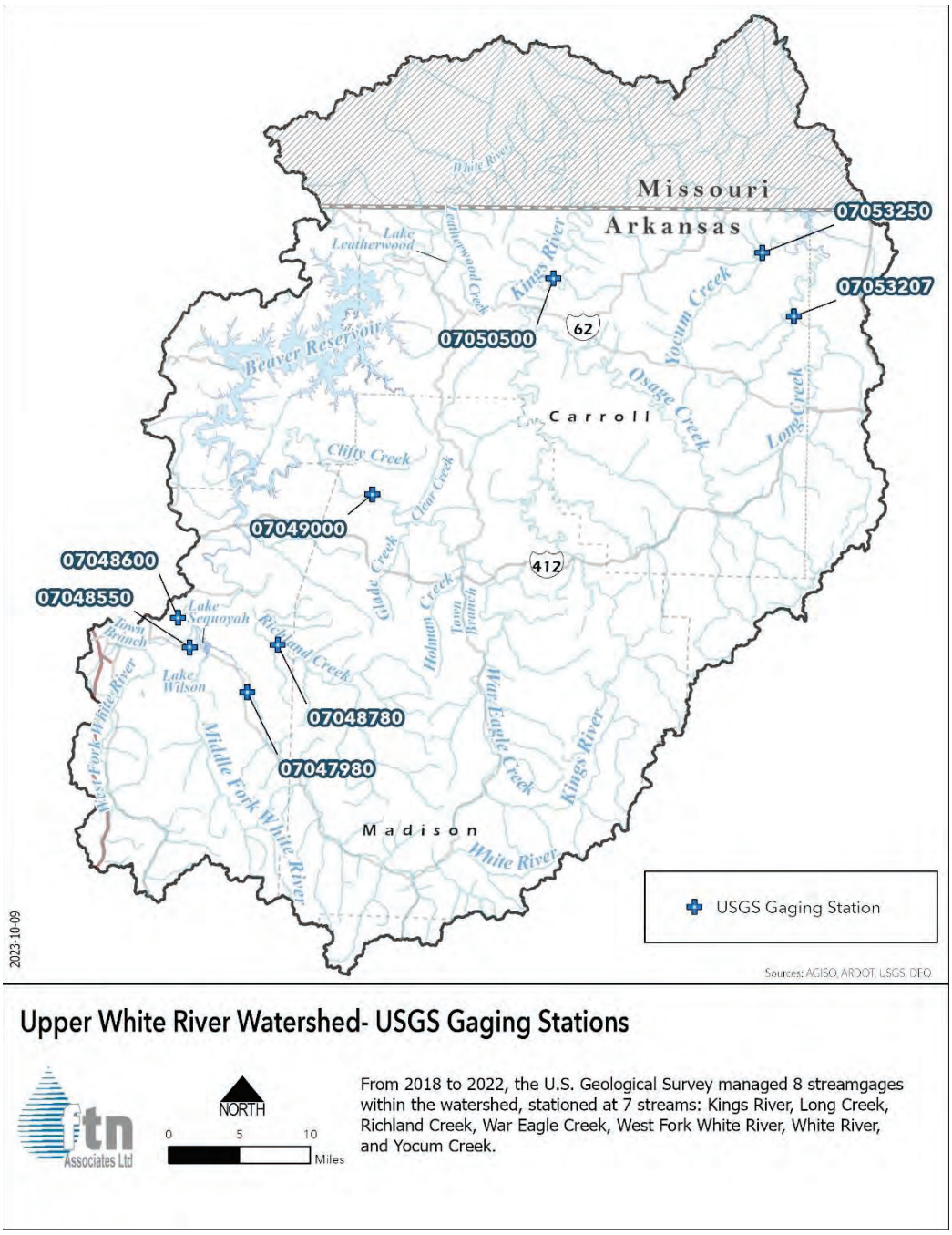


Figure 3.17. USGS flow gages in the Upper White River watershed active in 2022.

Table 3.13. Flow statistics for USGS flow gages in operation in the Upper White River watershed during 2022.

Gage Number	Year Established	Type	Site Name	Annual Average Discharge (cfs)[a]	Lowest Mean Monthly Discharge, (cfs)[a]	Highest Mean Monthly Discharge (cfs)[a]	7Q10 Flow, (cfs)[b]	90% Exceeds Flow, (cfs)[a]	10% Exceeds Flow (cfs)[a]	Peak Flow, (cfs)[a]
07047980[c]	1957	Low-flow until 2018 when daily flows began	White River at Elkins, AR	364.4	47 (July)	761 (May)	0.132	10.8	855.8	18,500, 10/28/2020
07048550[c]	1937	Partial record until 2001 when daily flows began	West Fork White River east of Fayetteville, AR	194.7	35.5 (August)	430.7 (April)	0.40	3.03	460.0	59,900, 4/24/2004
07048600	1964	Continuous	White River near Fayetteville, AR	572.3	66.2 (August)	1,190 (April)	0.795	6.4	1,310	48,000, 11/19/1985
07048780	2015	Continuous	Richland Creek near Goshen, AR	165.8	7.42 (September)	404 (May)	0.206[d]	0.772	407.0	13,000, 12/27/2015
07049000	1952	Continuous	War Eagle Creek near Hindsville, AR	319.2	57.5 (September)	728 (April)	2.217	12.5	676.0	49,000, 11/19/1985
07050500	1939	Continuous	Kings River near Berryville, AR	606.5	122 (August)	1,339 (April)	2.30	23.1	1,390	66,000, 11/19/1985
07053207	1992	Low flow, partial record	Long Creek at Denver, AR	NA	NA	NA	2.92	NA	NA	NA
07053250[c]	1964	Continuous since 1993	Yocum Creek near Oak Grove, AR	56.1	20.9 (August)	119 (April)	3.798	7.60	122.0	20,400, 4/29/2017

a Water Year summaries from National Water Information System (USGS 2022)
b (Funkhouser, Eng and Moix 2008)
c flow statistics, except 7Q10, calculated using continuous flow data only
d calculated using data from partial record low flow gage 07048800 at this location 1998-2015

Graphs of monthly average flows at the USGS continuous data gages are provided in figures 3.16 and 3.17. These graphs show the seasonal flow patterns at these gages. On the graphs the months are in water year order to help make seasonal patterns more apparent. The seasonal pattern of flows at the War Eagle Creek, Kings River, Yocum Creek gages, and the White River gage near Fayetteville are similar, with monthly average flows generally increasing gradually from September to a maximum in April, and then a dramatic decrease in flows between May and June (Figure 3.18). The seasonal patterns at the gages on Richland Creek, West Fork White River, and White River at Elkins are slightly different, with a less gradual increase in flows September through April (Figure 3.19). At the Richland Creek and upper White River gages there is a rather abrupt increase in flow between September and October, and the highest average monthly flow occurs in May instead of April. As at the other flow gages, there is a dramatic drop in flows after May.

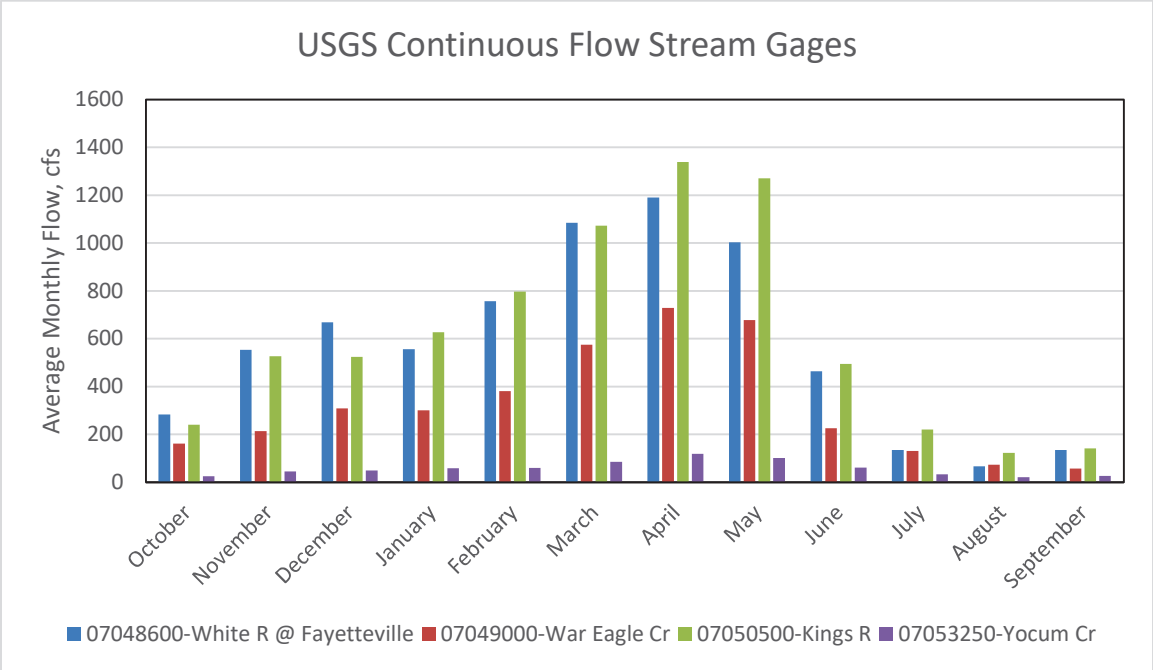


Figure 3.18. Monthly average flows at USGS continuous data gages on Yocum Creek, Kings River, War Eagle Creek, and the White River near Fayetteville.

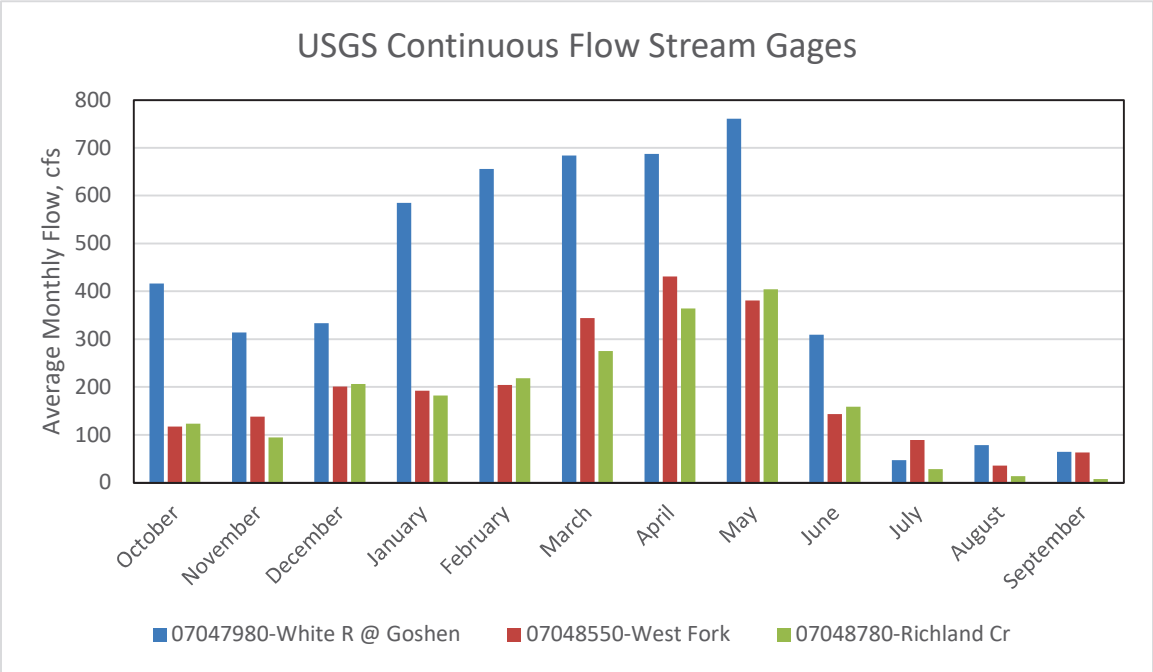


Figure 3.19. Monthly average flows at USGS continuous data gages on Richland Creek, West Fork White River, and White River at Goshen.

Figure 3.20 shows mean monthly releases from Beaver Lake calculated using data from January 2012-December 2021 (G. Knight, USACE, personal communication, 3/28/2022). The lowest releases are typically in October and the greatest releases typically in May. Overall, there is less variation in reservoir releases than in the natural flows at the USGS gages (figures 3.18-3.20).

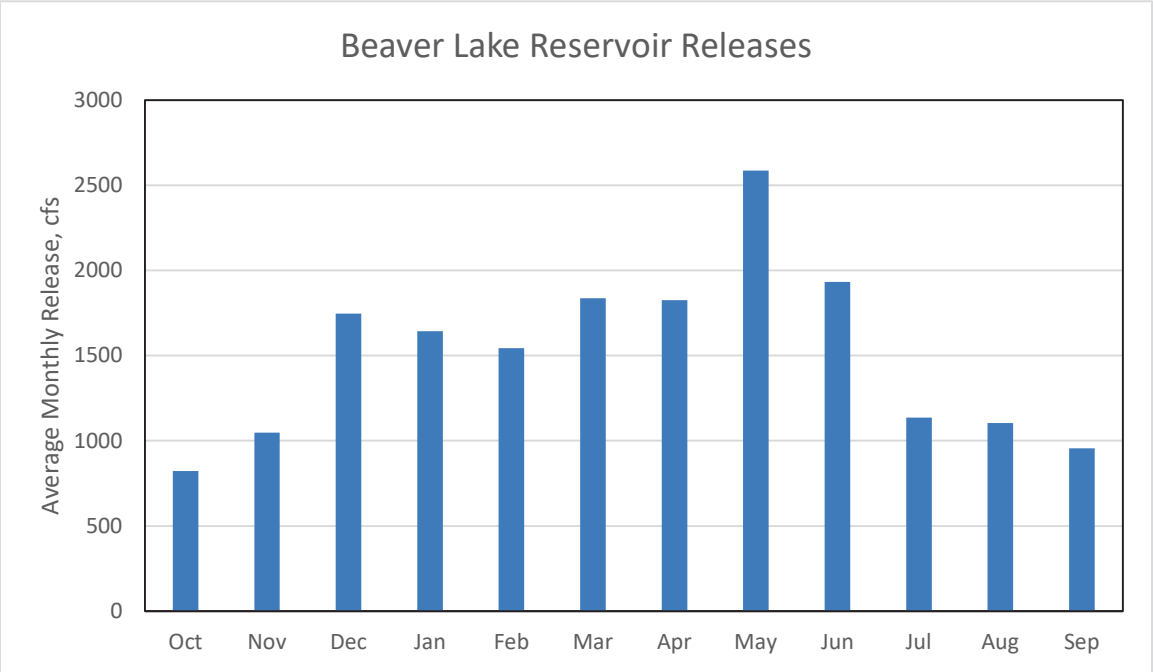


Figure 3.20. Monthly average releases from Beaver Lake reservoir, 2012-2022.

The USGS analyzed reservoir pool elevations and reservoir releases from 16 USACE reservoirs in Arkansas over the period 1951-2011. Beaver Lake was one of the reservoirs analyzed. The analysis showed that annual mean daily pool elevations, annual maximum daily pool elevations, and annual minimum daily pool elevations in Beaver Lake exhibit statistically significant increasing trends 1951-2011. The authors suggest that these trends are the result of changes in the reservoir regulation plan over time. This study also found that annual mean daily releases and annual maximum daily releases from Beaver Lake exhibited statistically significant increasing trends. The authors suggest that flood events in 2008 and 2011 are influencing the trend analysis results. The number of low-flow days downstream of Beaver Dam did not exhibit a statistically significant trend. Modifications to Beaver Lake pool management have occurred since 2011 to reduce time at flood pool (USACE 2023).

Stakeholders often voice concerns that increasing impervious area in the watershed is affecting flow, particularly in tributaries of Beaver Lake. However, we did not find any recent studies analyzing stream flow trends in this watershed. Modeling and analysis by RTI for the Beaver Lake Source Water Protection Plan update concluded that changes in climate would have

a greater impact on future stream flows overall than changes in land cover (RTI 2023). Hydrologic impacts of increased impervious cover will be greater at the local scale.

3.3.2 Geomorphology

Stream geomorphology addresses the relationships between characteristics of a stream watershed (i.e., topography, geology, and land use) and the shape of the stream channel (i.e., width, depth, and slope). A "stable" stream channel experiences only small changes in shape or location over time.

In general, streams in the Ozark Highlands physiographic region of Arkansas are considered to be somewhat unstable. Geologic factors in this region make river systems sensitive to changes in land cover, runoff volume, and inputs of eroded soil and gravel (Pavlowsky and Martin 2009). Ozark streams are responding to the changes in land use and land cover that have occurred in this region since settlement. Specific land use/land cover changes believed to affect stream stability in the Ozark Highlands include large-scale commercial timber harvest that occurred in the region between the 1880s and 1920s, and removal of riparian forest. Symptoms of stream instability in Ozark Highlands streams include large gravel bars and excessive bank erosion (Jacobson and Primm 1997).

Geomorphology in the Upper White River watershed has been influenced by the same historical events as other Ozark streams, including removal of the original forest, modification of riparian areas, construction of Beaver Lake and other reservoirs, and development (i.e., increased impervious area and associated runoff). Streambank erosion is a widespread concern in this watershed. Natural resource conservation organizations active in this watershed report that streambank erosion is the issue about which they are most often contacted (public meeting, Fayetteville Public Library, 2/23/2023). Several streambank erosion studies have been conducted in this watershed. The West Fork White River has been a focus of study and as many as eighteen streambanks are being monitored in the Beaver Lake watershed (DEQ 2004)(RTI 2023). Streambank erosion has also been identified as an issue along the Kings River (https://www.nature.org/en-us/about-us/where-we-work/united-states/arkansas/stories-in-arkansas/ar-2016-annual-report-restoring-rivers/). The Nature Conservancy has identified

priority stream banks for restoration on the Kings River and Rockhouse Creek (C. McCoy, The Nature Conservancy, personal communication 04/24/2025).

3.3.3 Aquatic Habitat

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

3.3.3.1 Habitat Surveys

DEQ collects habitat information during fish surveys and uses this information to develop an index of fish habitat integrity score. The most recent fish surveys conducted by DEQ in the Upper White River watershed were in 2013 and 2011. Fish habitat integrity scores for DEQ 2011 and 2013 fish survey locations in the Upper White River watershed are summarized in Table 3.14. Higher scores indicate better fish habitat.

Table 3.14. DEQ fish habitat integrity scores for the most recently surveyed locations.

Stream	Date	Survey ID	Associated WQ Station ID	Habitat Type	Length (m)	Habitat Score	Index Score
Yocum Creek	8/15/2011	4K039	NR	Pool	98	90	88.2
Kings River	10/24/2013	4K037	WHI0123	Pool	91	89	81.0
Osage Creek	10/25/2013	4K035	WHI069	Pool	114	91	103.7
Kings River	10/25/2013	4K036	NR	Pool	290	102	295.8

EPA also collected habitat metrics at their station on the White River during the 2018 National Aquatic Resources Survey. However, no classification of habitat quality was assigned to the station.

University of Central Arkansas (UCA) collected habitat metrics data during fish surveys conducted for The Nature Conservancy in impaired and unimpaired reaches of the Kings River 2015-2017, and in Rockhouse and Keels creeks 2017-2020 (Adams and Adams 2018, Adams,

Garrett and Adams 2021). They noted that large to moderate flood events changed habitat (pool and riffle lengths and depths) year to year.

3.3.3.2 Stream Barrier Inventory

Dams and road crossings can restrict the movement of fish and mussel species, preventing expansion of populations into new areas, or prevent fish from accessing historical spawning areas. The Southeast Aquatic Resources Partnership (SARP) recently created the online Southeast Aquatic Barrier Prioritization Tool to access their Comprehensive Southeast Aquatic Barrier Inventory (SARP 2023). This inventory indicates that there are over 300 dams present in the Upper White River watershed. Twenty-three of these dams have been assessed for feasibility for removal. Eight were classified as feasible for removal. Most of the dams present in the watershed are for small ponds. The SARP inventory indicates there are over 4,000 road stream crossings in the watershed. About 260 of these crossings have been evaluated and around 40 of these are identified as a moderate to complete barrier that impacts aquatic life. Beaver Dam and Beaver Lake are the most significant stream barrier in the watershed.

3.3.3.3 Cave Aquatic Habitat and Species Vulnerability

The Nature Conservancy has conducted a literature-based survey of the occurrence of state Species of Greatest Conservation Need associated with cave habitats in the Ozarks region of Arkansas (Inlander, Gallipeau and Slay, Mapping the Distribution, Habitat, and Threats for Arkansas' Species of Greatest Conservation Need 2011). In addition, Inlander, Gallipeau and Slay (2011) evaluated threats to these species. This study included around 30 cave habitat sites within the Upper White River watershed where aquatic Species of Greatest Conservation Need have been identified. Around twenty of these sites were classified as having medium or higher overall threat scores for aquatic cave Species of Greatest Conservation Need, with five sites classified as having a high overall threat score (see Figure 2.14).

3.3.4 Aquatic Communities

Aquatic communities respond to changes in habitat, including water quality, and are useful indicators of stream health. The condition of aquatic communities is characterized based

on information such as the abundance of animals, the number of different species present, the water quality and habitat requirements of the species that are present, and how sensitive the species that are present are to changes in water quality or physical habitat. In many cases, selected information about the aquatic communities present is used to develop a score or grade that reflects the health of streams, such as an Index of Biotic Integrity (IBI) or multi-metric index (MMI).

DEQ has surveyed aquatic communities in the Upper White River watershed since the 1980s. EPA has also surveyed aquatic communities in the Upper White River watershed as part of its National Aquatic Resource Surveys. EPA surveyed locations in the watershed in 2004, 2009, 2013, and 2018. Universities, citizen scientists, and state and federal natural resource agencies and interest groups have also conducted surveys of aquatic communities in the Upper White River watershed. U.S. Fish and Wildlife Service (USFWS) has identified several federally listed threatened and endangered aquatic species as being present in the Upper White River watershed. Some populations of these species present in the watershed have been evaluated.

3.3.4.1 Fish Surveys

Fish surveys have been conducted in the Upper White River watershed by DEQ, EPA, and other entities. The most recent survey for which information was identified was conducted by EPA as part of the 2018-2019 National Aquatic Resources Survey (EPA 2020a). The most recent DEQ fish surveys in the watershed were conducted in 2014. Table 3.15 lists the survey dates and condition index scores and ratings from the most recent DEQ, EPA fish surveys. Most of these surveys classify the fisheries as being in poor condition. No discussion of suspected causes behind poor fisheries was associated with these data.

UCA conducted fish surveys for The Nature Conservancy in impaired and unimpaired reaches of the Kings River 2015-2017, and in Rockhouse and Keels creeks 2017-2020 (Adams and Adams 2018, Adams, Garrett and Adams 2021). UCA did not calculate condition index scores or ratings using their fish survey data.

AGFC conducts annual fisheries surveys in Beaver Lake and trout population surveys in Beaver Lake tailwaters. The most recent report of Beaver Lake fishery surveys indicates that Striped Bass are facing increased fishing pressure. The Channel Catfish population does not

appear to be self-sustaining and stocking will be required to maintain this fishery (Stein, Gates and Lindaman 2024). The most recent report on the Beaver Lake tailwater fishery characterizes the trout fishery as stable (Graham, Kaiser and Gary 2024). AGFC conducted a creel survey on the Kings River in 2019 and intends to repeat this survey every five years. The Kings River survey found that the black bass fishery (which consists primarily of Smallmouth Bass) was robust. Walleye and White Bass from Table Rock Lake use the Kings River for spawning (Stein, Gates and Lindaman 2021).

Table 3.15. Results from the most recent fishery surveys conducted in the Upper White River watershed by DEQ.

Agency	Stream	Date	Survey IDs	Associated WQ Station ID	Index Score	Rating
ADEQ	Kings River	8/14/2014	4K040	WHI0203	20	Poor
ADEQ	Kings River	8/1/2014	4K041	BUFET004	28	Poor
ADEQ	War Eagle Creek	8/1/2014	4K042	N/A	33	Poor
ADEQ	Kings River	10/25/2013	4K036	N/A	43	Fair
ADEQ	Osage Creek	10/25/2013	4K035	WHI0069	33	Poor
ADEQ	Kings River	10/24/2013	4K037	WHI0123	39	Poor
ADEQ	Yocum Creek	8/15/2011	4K039	N/A	21	Poor
US EPA	White River	7/22/2018	2012993	NRS18_AR_10027	23	Poor

The threatened Ozark Cavefish is identified as being present in the Upper White River watershed (USFWS 2023). However, no populations in the watershed are routinely surveyed (USFWS Arkansas Ecological Services Field Office 2019).

3.3.4.2 Benthic Macroinvertebrate Surveys

Surveys of benthic macroinvertebrates have been conducted in the Upper White River watershed by DEQ, EPA, AGFC, USFWS, Stream Teams, and universities. The most recent surveys for which information was identified were conducted in 2018-2019 by EPA as part of the 2018-2019 National Aquatic Resources Survey (EPA 2020a), and by Ozark Water Watch (now H2Ozarks) (AGFC 2021). The data from H2Ozarks are part of their citizen science volunteer water quality monitoring, where macroinvertebrate collection and identification were conducted by StreamSmart program volunteers. It should be noted that the level of accuracy and robustness of identification may vary across volunteers. However, Grantz and Haggard (2023b) showed significant relationships between StreamSmart macroinvertebrate community indicators and water quality and land use metrics. Results from the H2Ozarks surveys are summarized in Table 3.16, and the locations surveyed are shown on Figure 3.21. Note that we found no recent surveys in the Kings River. The most recent DEQ macroinvertebrate surveys were in 2001.

Table 3.16. Summary of results from Ozarks Water Watch/H2Ozarks macroinvertebrates surveys conducted 2018-2022.

Stream	Station ID	Date	Survey ID(s)	Index Value	Index Rating
West Fork of the White River (Baptist Ford bridge)	101	6/5/2019	959/1412	13	Fair
		8/12/2019	958/1414	11	Fair
West Fork of the White River (Brentwood Park)	102	6/5/2019	937/1434	22	Excellent
		8/10/2019	933/1438	13	Fair
		5/3/2021	-	9	Poor
		8/9/2021	-	15	Fair
Baldwin Creek	103	5/7/2018	531/1011	2	Poor
		5/13/2019	536/1010	19	Good
		8/14/2019	532/1020	14	Fair
		5/11/2021	-	6	Poor
		8/11/2021	-	19	Good
White River (St. Paul)	104	5/6/2018	981/1455	8	Poor
		8/5/2018	982/1470	13	Fair
		6/3/2019	983/1461	9	Poor
		8/10/2019	985/1463	16	Fair
		8/8/2021	-	10	Poor
War Eagle Creek (near CR6129)	109	6/2/2019	901/1332	16	Fair
		9/9/2019	902/1336	12	Fair
		5/6/2021	-	21	Good
		8/12/2021	-	15	Fair
White River (CR 6578)	110	8/13/2021	-	20	Good
Ward Slough	200	8/3/2018	921/1394	17	Good
		5/16/2019	918/1390	13	Fair
		8/13/2019	919/1393	13	Fair
Middle Fork of the White River	201	8/4/2018	736/1223	19	Good
		5/15/2019	731/1212	12	Fair
		9/11/2019	733/1220	11	Fair
		5/17/2021	-	10	Poor
		8/8/2021	-	13	Fair
Mullins Creek	202	5/4/2018	756/1232	13	Fair
		8/6/2018	757/1235	10	Poor
Hock Creek	205	5/8/2018	675/1146	20	Good
		8/20/2019	673/1152	10	Poor
		5/11/2021	-	8	Poor
		8/11/2021	-	19	Good
Spout Spring Branch	206	8/4/2018	806/1273	2	Poor
		5/4/2019	807/1294	9	Poor
		8/4/2019	809/1293	3	Poor
Town Branch	210	5/13/2018	830/1314	7	Poor

Table 3.16. Summary of results from Ozarks Water Watch/H2Ozarks macroinvertebrates surveys conducted 2018-2022 (continued).

Stream	Station ID	Date	Survey ID(s)	Index Value	Index Rating
		5/6/2019	829/1301	3	Poor
		8/10/2019	832/1305	19	Good
		6/5/2021	-	4	Poor
Brush Creek	300	5/7/2018	558/1026	14	Fair
		5/13/2019	559/1030	20	Good
		8/12/2019	555/1039	14	Fair
		5/3/2021	-	11	Fair
		8/8/2021	-	16	Fair
War Eagle Creek (Huntsville)	301	8/5/2018	880/1355	22	Excellent
		5/15/2019	878/1344	12	Fair
		8/4/2019	877/1353	6	Poor
Glade Creek	302	5/6/2018	649/1120	15	Fair
		8/5/2018	650/1138	12	Fair
		5/12/2019	651/1116	23	Excellent
		8/14/2019	645/1133	8	Poor
		8/8/2021	-	18	Good
Clear Creek	303	5/6/2018	587/1054	13	Fair
		8/8/2018	592/1083	22	Good
		8/12/2019	591/1066	18	Good
		5/1/2021	-	10	Fair
		8/8/2021	-	11	Fair
Clifty Creek	304	5/6/2018	621/1085	10	Poor
		8/8/2018	623/1089	11	Fair
		5/4/2019	616/1088	10	Poor
		8/12/2019	617/1101	9	Poor
		5/1/2021	-	6	Poor
		8/8/2021	-	5	Poor
War Eagle Creek (at the mill)	305	8/5/2018	855/1381	20	Good
		5/16/2019	852/1368	17	Good
		8/14/2019	853/1379	18	Good
Prairie Creek	306	5/13/2019	778/1250	18	Good
		8/15/2019	780/1249	24	Excellent
Holman Creek (Upstream of Huntsville)	307	5/14/2019	710/1184	11	Fair
		8/6/2019	711/1200	12	Fair
		5/13/2021	-	7	Poor
		8/11/2021	-	5	Poor
Holman Creek (Downstream of Huntsville)	308	5/14/2019	689/1161	10	Poor
		8/6/2019	688/1179	9	Poor
		5/13/2021	-	10	Poor
		8/11/2021	-	9	Poor

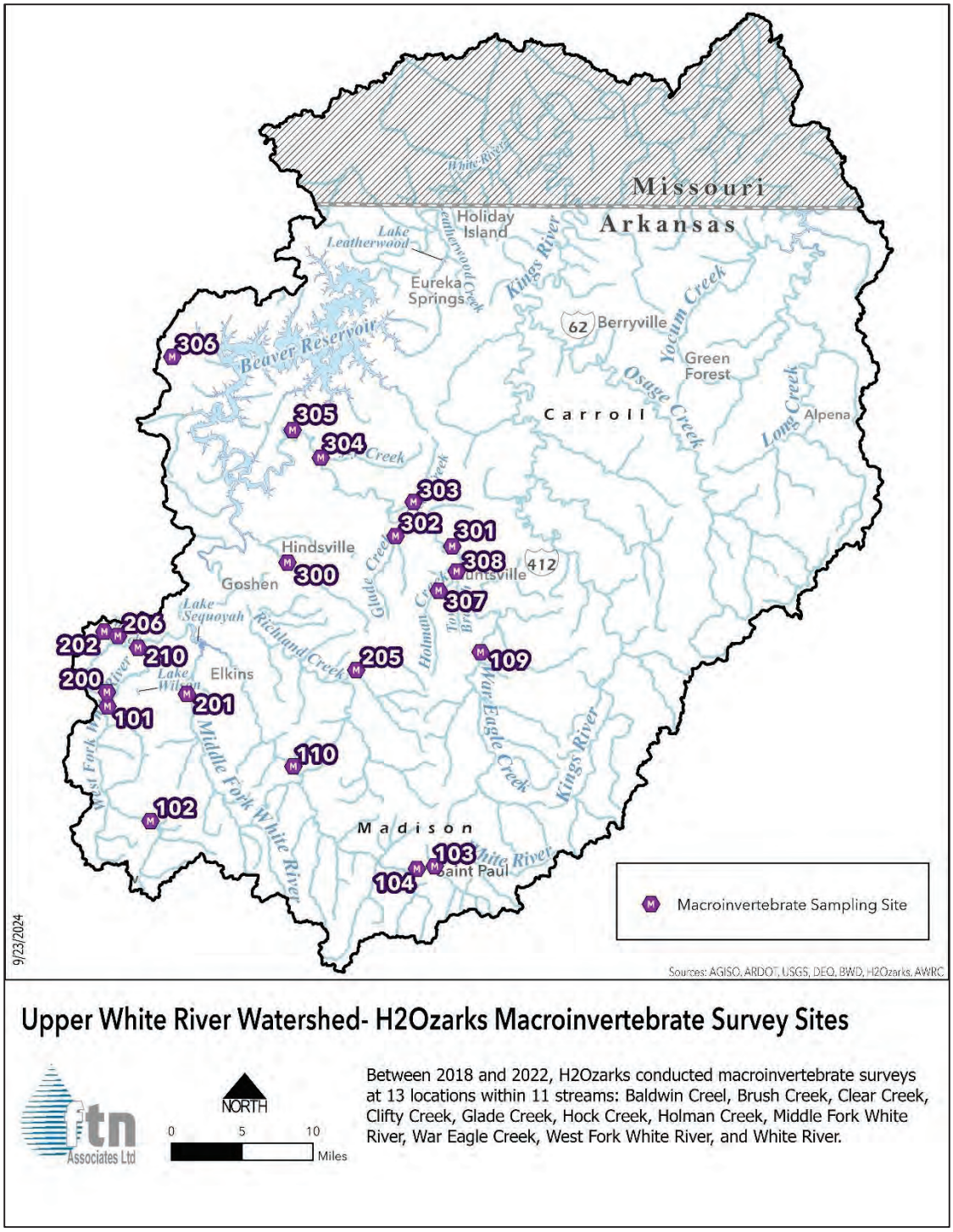


Figure 3.21. Locations of 2018-2022 macroinvertebrate surveys in the Upper White River watershed.

Only four surveys listed in Table 3.16 found macroinvertebrate communities indicative of excellent water quality. At four survey locations all or most surveys found macroinvertebrate communities indicative of poor water quality; Clifty Creek, Holman Creek downstream of the Huntsville WWTP discharge, Town Branch at Fayetteville, and Sprout Spring Branch.

USFWS evaluates some populations of threatened and endangered mussel species present in the Upper White River watershed. USFWS has classified populations of the threatened Rabbitsfoot mussel in War Eagle Creek as improving. The status of Rabbitsfoot mussel populations in the White River is not known (USFWS 2020). USFWS does not appear to have recently evaluated the condition of populations of the endangered Snuffbox mussel in this watershed (USFWS 2018).

3.3.5 Watershed Integrity

EPA researchers have developed a metric of watershed integrity that uses national data sets (Thornburgh, et al. 2018) (Johnson, Leibowitz and Hill 2019). Information used to score this metric includes indicators of hydrologic regulation, water chemistry, sediment, hydrologic connectivity, temperature, habitat condition, and the extent of human activity. Basically, this index is an indicator of the modification of a watershed from its natural state. Index values have been calculated for the catchments associated with every stream segment of the National Hydrologic Dataset (NHDPlusV2). Index values calculated for catchments in the Upper White River watershed are shown in Figure 3.22. Potential index values range from zero to one with lower index values indicating lower integrity and greater modification, and higher index values indicating higher integrity with less modification. This index shows that some of the landscape in the watershed is relatively low integrity (i.e., yellow in Figure 3.22), much of the land area is moderate integrity (i.e., blue in Figure 3.22), and the rest of the landscape is relatively high integrity (i.e., green in Figure 3.22). The range of index values is from 0.38 to 0.94. Index values less than 0.25 indicate poor integrity, so there are no poor integrity catchments in this watershed.

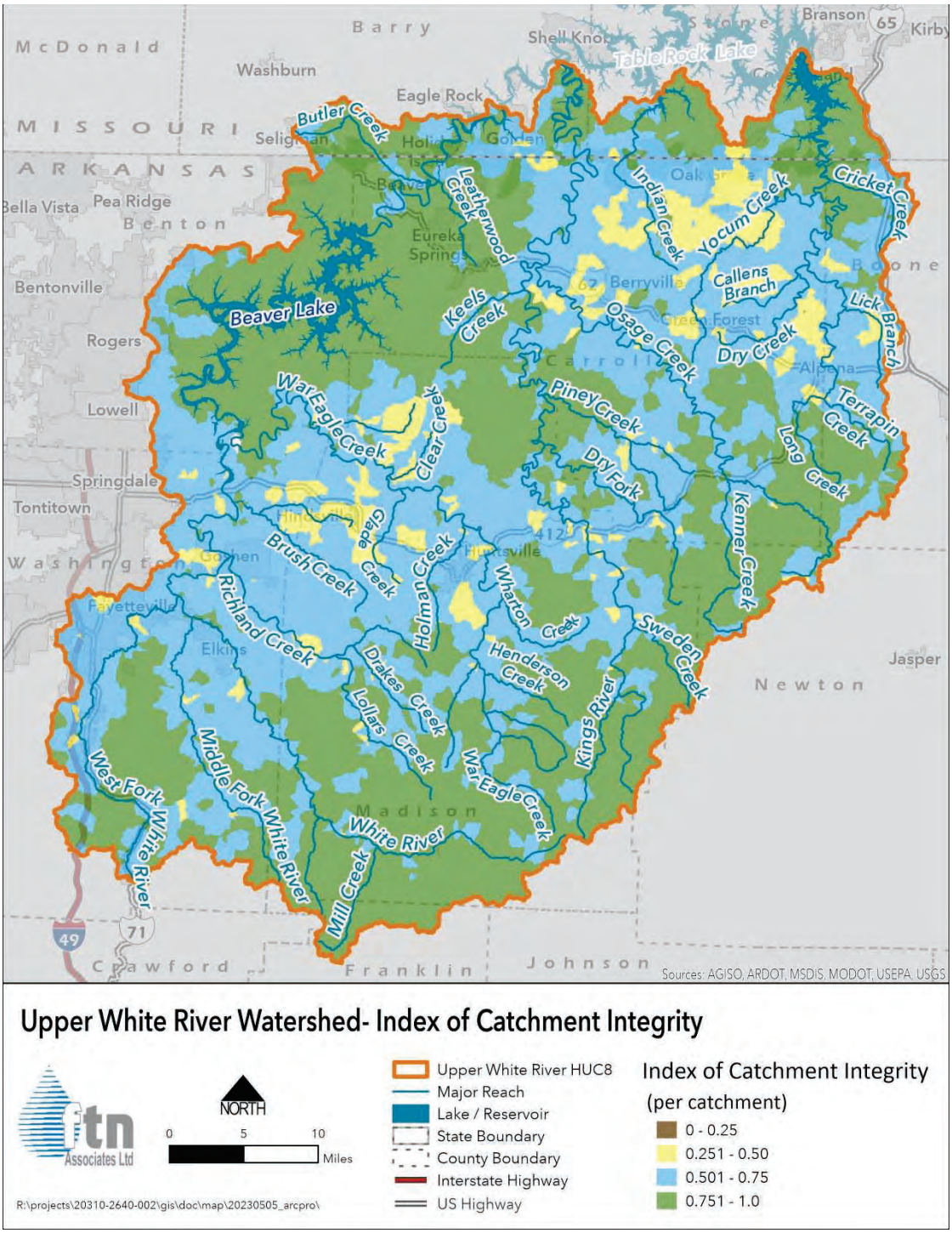


Figure 3.22. Catchment Integrity results from StreamCat (Thornburgh, et al. 2018).

3.3.6 Summary

Hydrology in the Upper White River watershed has been modified as a result of construction and operation of the Beaver Lake reservoir. In addition, around 300 small ponds have been constructed in the watershed. Land clearing and construction in the watershed has also modified the hydrology of the watershed streams. Scores of an EPA index of Watershed Integrity range from 0.38 to 0.94 across the Upper White River watershed (where a score of 1 indicates the highest possible integrity).

Changes in hydrology are impacting stream stability. Excessive streambank erosion is a widespread concern of landowners in this watershed. These changes are also likely affecting stream habitats. Aquatic habitats in five caves in the watershed have been identified as having a high threat of impacts to habitat quality.

Results of fishery surveys we found all indicated poor fishery quality. Benthic macroinvertebrate surveys are more common and more recent in this watershed. Benthic macroinvertebrate communities at most surveyed locations indicate water quality is fair to good. Macroinvertebrate communities at three surveyed locations consistently indicate poor water quality.

3.3.7 Data Gaps

We did not find recent macroinvertebrate surveys in the Kings River or its tributaries. In addition, we found few fishery surveys in the watershed more recent than 2014. We found condition reports for only some of the populations of threatened and endangered aquatic species present in the watershed.

3.4 Nonpoint Sources of Pollutants Causing Impairments

Pollutants causing water quality impairments in the Upper White River watershed include nutrients (low DO in streams and high pH in Beaver Lake), organic matter (low DO in streams), TDS, sulfate, sediment (turbidity), and *E. coli* (pathogens). Nutrients can contribute to low DO in streams and high pH in Beaver Lake by stimulating excessive growth of algae and aquatic plants. In Beaver Lake, respiration by algae and aquatic plant blooms can release enough carbon dioxide

to raise the pH in the upper water column (where pH standards are evaluated). In streams, decomposition of algae and plant blooms uses oxygen and can lower the DO levels. In freshwater waterbodies, growth of algae and other aquatic plants is often controlled more by available phosphorus than by available nitrogen. Research in the Upper White River watershed has shown that in some waterbodies algal growth is most responsive to phosphorus inputs, however in other waterbodies algal growth increases only when both nitrogen and phosphorus inputs increase (Galloway and Green 2007, Ludwig, et al. 2012). In waterbodies, decomposition of any organic matter, including leaves, grass clippings, dead algae and aquatic plants, and manure, can lower DO levels. Eroded soil and sediment carried and stirred up in streams and reservoirs contribute to turbidity.

Nonpoint sources of these pollutants have been identified by stakeholders, researchers, and resource managers working in the Upper White River watershed. These nonpoint sources are listed in Table 3.17 and discussed below. Nitrate and total phosphorus impairments are believed to be caused largely by point source discharges (see Table 3.4). Both point and nonpoint sources of nutrients may contribute to low DO impairments.

Because the Upper White River watershed is a state designated Nutrient Surplus Area, all nutrient applications (fertilizer, poultry litter, waste, etc.) are regulated. Most nutrient applications in this area are required to be conducted by a certified nutrient applicator under the guidance of a nutrient management plan prepared by a certified planner (Arkansas Natural Resources Commission 2010). As a result, applications of commercial fertilizer, poultry litter, and animal manures in the watershed may be somewhat less important as sources of nutrients than they are in watersheds outside of the Nutrient Surplus Area.

Table 3.17. Summary of nonpoint sources of pollutants causing impairments in Upper White River watershed and potential sources (indicated by "X").

Source	Pollutants					
	Nutrients	Organic matter	TDS*	Sulfate*	Turbidity	Pathogens
Runoff from pasture and haylands	X	X	X	X	X	X
Runoff from developed areas	X	X	X	X	X	X
Failing septic systems	X	X	?	?		X
Unpaved roads and trails	X				X	
Streambank and lakeshore erosion	X	X			X	?
Sediments	X				X	X
Livestock in streams	X	X			X	X
Improper disposal of wastewater from boat or marina toilets	X	NA	NA	NA		X
Runoff from animal feeding operations	X	X	?	?	X	X
Wildlife	X	X			X	X
Groundwater	X					X
Geology			X	X		
Soil characteristics					X	

* Potential nonpoint sources of this pollutant indicated in this table based on information in Scott and Haggard 2021.
NA = While this is a potential source of these pollutants, these pollutants are not causing impairment in Beaver Lake
? = Based on available information about potential sources this pollutant in surface waters this may also be a source, but we didn't find information specifically addressing this as a pollutant source.

3.4.1 Runoff from Pasture and Haylands

Runoff from pasture can carry nutrients from livestock manure and fertilizers, including poultry litter, applied to pasture. Pasture runoff can also carry sediment from erosion and organic matter and pathogens from manure and poultry litter. Runoff from haylands can carry nutrients from fertilizers, pathogens and organic matter from poultry litter applied as fertilizer, sediment from erosion of the field, and organic matter from mowing. Studies have shown that agricultural land uses influence mineral concentrations in streams, particularly sulfate and chloride (Scott and Haggard 2021, Zampella, et al. 2007). In 2019 about 642 square miles, or 28%, of the Upper White River watershed was classified as pasture or haylands (Dewitz and USGS 2021). Twenty-six percent of the riparian buffer area (100 m wide) in the watershed was pasture or haylands in 2019 (Hill, et al. 2016). Pasture in riparian areas is more likely to impact water quality.

In the 2015 State Resource Assessment, NRCS identified much of the watershed as having a high risk for erosion, both sheet/rill/wind erosion, and gully erosion. Figures 3.23and 3.24 show erosion risk maps published by NRCS with the Upper White River watershed shown.

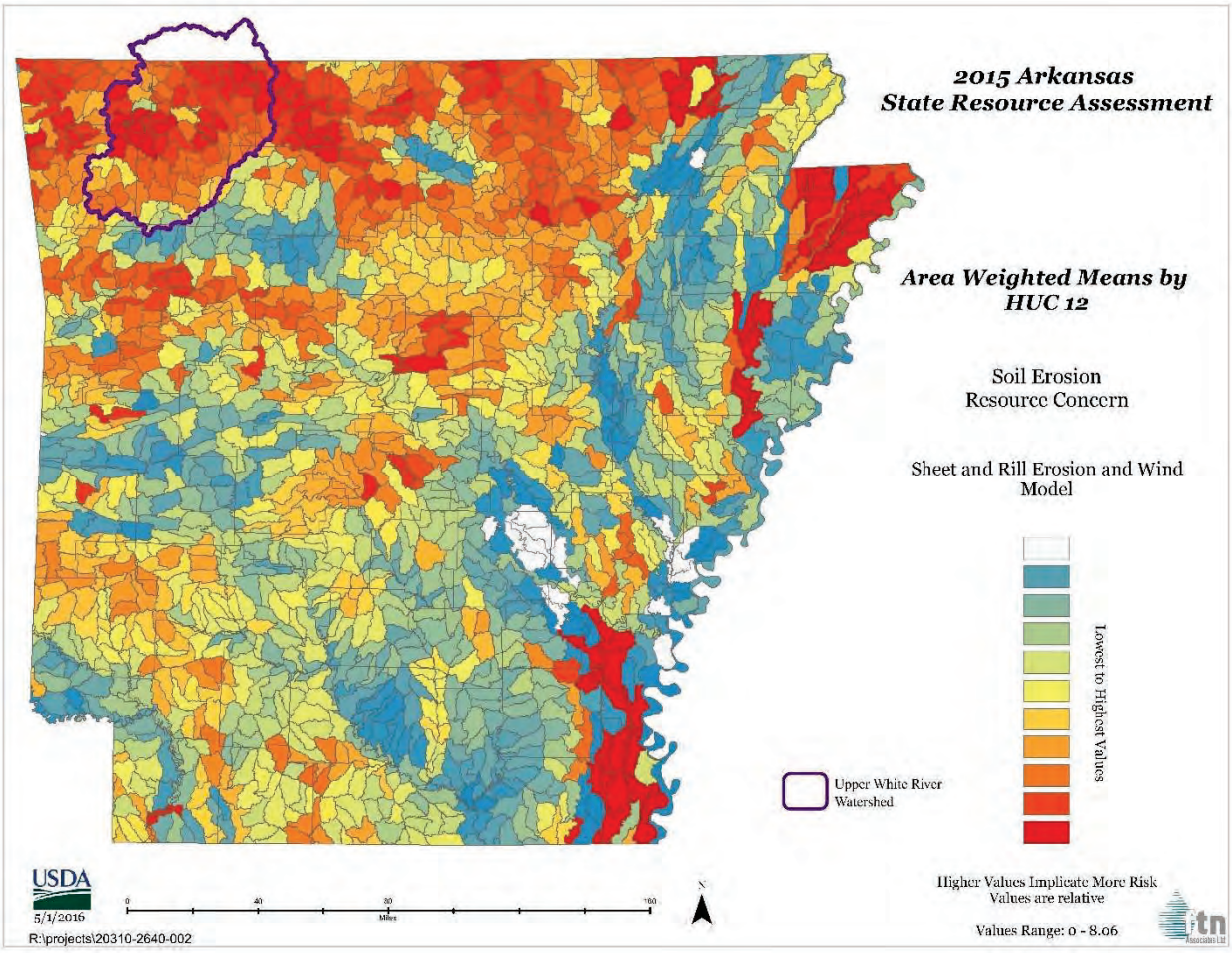


Figure 3.23. 2015 State Resource Assessment map of risk of sheet, rill, and wind erosion in Arkansas (NRCS 2016).

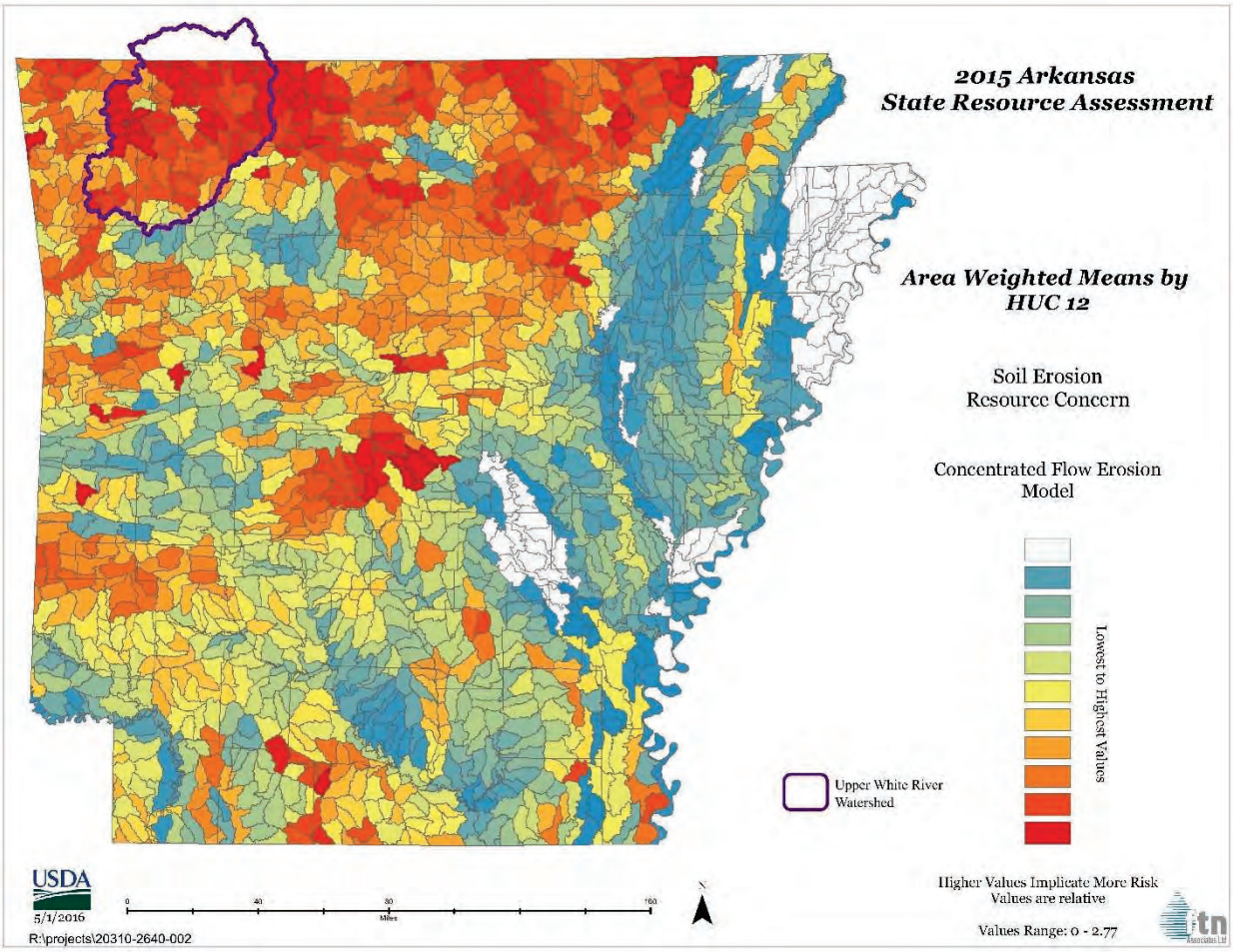


Figure 3.24. 2015 State Resource Assessment map of risk of gully erosion in Arkansas (NRCS 2016).

A 2015 study of *E. coli* sources in the Beaver Lake watershed found that poultry host markers were one of the most prevalent. Samples from White River, War Eagle Creek, and Beaver Lake were analyzed (Gibson, et al. 2017). All poultry feeding operations (2,500 birds or more) within Arkansas are required by state law to register their operation and report poultry litter generation, export, and application (Arkansas Natural Resources Commission 2005). Figure 3.25 shows reported poultry litter application in selected Upper White River counties over time. Although there can be quite a bit of variation from year to year, over all it appears that the amount of poultry litter applied in these counties has tended to decrease over time or remain relatively stable. Total poultry litter application values for 2021 are not available from Benton

and Carroll counties. Table 3.18 lists information about poultry litter generation and application reported to Arkansas Department of Agriculture Natural Resources Division (NRD) for 2020 under the Nutrient Management Planning Program, by county (T. Wentz, NRD, personal communication, 1/3/2022).

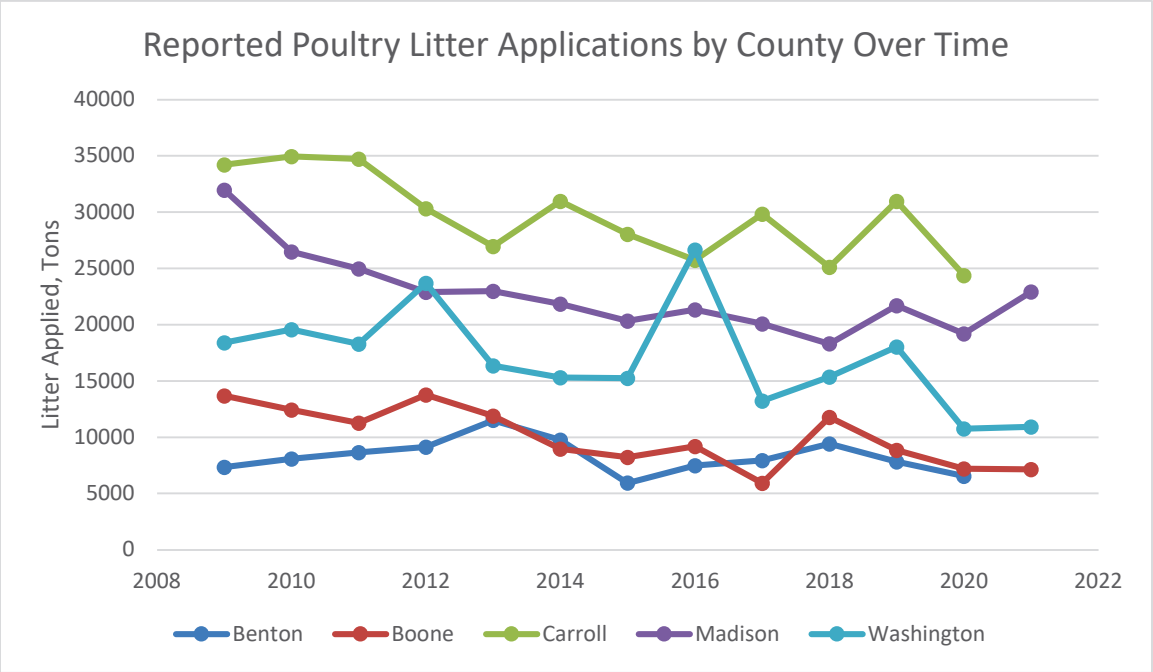


Figure 3.25. Reported poultry litter application amounts by county, 2009-2021.

Table 3.18. 2020 reported poultry litter generation and application for counties in the Upper White River watershed (National Resources Division 2021).

County	Litter generated, tons	Litter applied, tons	Area litter applied, acres[a]	Litter applied, tons/acre[b]
Benton	170,387	6,561	11,462	0.57
Boone	72,175	7,189	22,911	0.31
Carroll	130,546	24,383	45,757	0.53
Madison	66,758	19,187	35,386	0.54
Washington	129,166	10,757	19,937	0.54

a This area does not represent the area where litter was applied, but the area available for litter application. The actual area where litter was applied in 2020 is smaller than this area reported.
b Machinery used to apply poultry litter does not easily apply at rates lower than 1 ton/acre. Rates as low as 0.5 ton/acre are possible, but difficult (T. Wentz, NRD, personal communication, 3/5/24).

There is concern that the application of poultry litter on pastures has caused soil phosphorus levels in the Upper White River watershed to increase. Phosphorus levels in poultry litter are higher than nitrogen levels. Thus, historically, when producers applied poultry litter to the point where desired nitrogen levels were achieved, phosphorus was over-applied. As phosphorus built up in the soil over time, eroded soils became a significant source of phosphorus inputs to surface water and groundwater. The regulations on poultry litter application in state Nutrient Surplus Areas are intended to stop phosphorus build up in soils. To get an idea of whether these regulations are having the desired effect, we compared soil phosphorus concentrations in soils samples from Upper White River watershed counties analyzed during 1996 and 2020.

The Arkansas Agricultural Experiment Station prepares annual soil fertility reports. These reports compile testing results from soil samples submitted to the Extension Service for analysis. Soil samples can be submitted by anyone in the county, so the results include soil samples from cropland, pasture, lawns, and home garden plots. Table 3.19 shows the comparison of soil test phosphorus (STP) data from the 1996 and 2020 Arkansas soil fertility reports (DeLong, Carroll, et al. 1997, DeLong, Slaton, et al. 2021).

In the 1996 soil fertility report, the median STP of samples was not reported, and the phosphorus concentration was in the units of "pounds of the extractable phosphorus per acre (lb P/acre)". The 2020 report includes sample median values and concentration reported in parts per million (ppm). The county-level median STP of 1996 soil samples were calculated and converted to ppm. All the lb/acre to ppm conversions were based on assuming a dry soil bulk density of 1.5 g/cm^3 and a soil depth of 0.5 ft. With these assumptions, 1 lb P/acre is equal to about 0.49 ppm. The median of STP concentration in 2020 soils samples is lower than the median for 1996 in Benton, Crawford, Franklin, Newton, and Washington counties. The median STP concentration in 2020 soils samples is greater than the median for 1996 in Carroll and Madison counties.

Table 3.19. Comparison of STP results from 1996 and 2020 Arkansas soil fertility reports (DeLong, Carroll, et al. 1997, DeLong, Slaton, et al. 2021).

	1996 condition							2020 condition					
Category	<26 lb P/acre	26-44 lb P/acre	45-100 lb P/acre	101-300 lb P/acre	>300 lb P/acre	Calculated median, lb P/acre	Calculated median, ppm	<16 ppm	16-25 ppm	26-35 ppm	36-50 ppm	>50 ppm	Median, ppm
County	% of sampled soil that falls in the category							% of sampled soil that falls in the category					
Benton	2	5	16	41	36	240	118	4	9	9	14	64	70
Boone	8	11	33	37	11	147	72	4	5	8	15	66	73
Carroll	12	8	25	38	17	167	82	2	4	3	8	84	143
Crawford	13	16	34	29	8	122	60	13	17	12	16	42	42
Franklin	30	19	19	17	15	118	58	10	14	12	13	50	51
Madison	8	9	25	33	25	188	92	3	6	7	8	76	123
Newton	10	10	35	38	7	134	66	12	9	9	18	53	51
Washington	4	9	21	38	28	207	101	5	11	7	10	67	86

3.4.2 Runoff from Developed Areas

Runoff from developed areas can carry a wide variety of pollutants, including all of the nonpoint source pollutants of concern for this plan. Pollutants in runoff from developed areas can come from paved areas, vehicles and machinery, landscaping, residences, schools, and commercial and industrial areas. Studies have shown that mineral concentrations in North Arkansas streams increase as the area of pasture and urban land covers within the watershed increase (Scott and Haggard 2021). This suggests that there are nonpoint sources of minerals in developed areas. University of Arkansas Cooperative Extension Service has estimated that nearly 5,000 tons of dog waste is generated each year in Northwest Arkansas (Washington County Cooperative Extension Service, 2023). Pet waste can contribute nutrients, pathogens, and organic matter to runoff. Developed areas produce larger volumes of runoff than undeveloped land. Larger runoff volume can contribute to drainage ditch and stream channel instability resulting in excessive bank erosion. In 2019 about 2.6 square miles, or 8%, of the Upper White River watershed was classified as developed. Development is expected to continue to increase in the Upper White River watershed, increasing this source of pollutants (RTI International 2023).

3.4.3 Failing Septic Systems

Based on data provided by Benton County, Fayetteville, and Springdale, and other local real estate and sewer service information, it is estimated that there are 16,864 septic systems in use in the Upper White River watershed, mapped in Figure 3.26 (see Appendix F for estimation approach). Failing septic systems can allow nutrients, pathogens, sulfates (from detergents), and organic matter from household wastewater to be released, with the potential to find its way to surface waterbodies. A recent study of *E. coli* sources in the Beaver Lake watershed found that human host markers were one of the most prevalent. Samples from White River, War Eagle Creek, and Beaver Lake were analyzed (Gibson, et al. 2017). Septic systems close to streams or Beaver Lake are of greatest concern in the Upper White River watershed. Failing septic systems have been identified as a potential source of *E. coli* in Beaver Lake (Platt 2024).

3.4.4 Unpaved Roads and Trails

Unpaved roads have been identified as a priority concern throughout this watershed (RTI International 2023, The Nature Conservancy 2018). Researchers have estimated sediment loads from unpaved roads in this watershed (Table 3.20). In 2023 there were 4,889 miles of unpaved roads in the Upper White River watershed with 3,057 miles in the White River sub-watershed, 1,084 miles in the Kings River sub-watershed, and 747 miles in the rest of the watershed (Figure 3.27).

Table 3.20. Examples of sediment loads from unpaved roads estimated for locations in the Upper White River watershed.

Location	Sediment yield/export	Annual stream load	Source
West Fork White River watershed (publicly owned roads only)	35.9 ton/mi/year	4,500 ton/year	(DEQ 2004)
Kings River watershed (public roads)	18.9 ton/mi/year	1,089 ton/year	(Inlander, Clingenpeel, et al. 2007)
Beaver Lake watershed	-	76,526 ton/year	(RTI International 2023)

Stream crossings are the locations where unpaved roads usually have the greatest effect on water quality, stream habitat, and aquatic life. The Southeast Aquatic Resources Partnership (SARP) has identified over 4,000 road crossings in the Upper White River watershed (SARP 2023). Though the SARP inventory does not identify how many of these are unpaved roads, it is expected that most are. In this watershed, 265 unpaved road stream crossings have been evaluated for impacts to aquatic organisms (Figure 3.28).

Erosion of trails on public and private lands has also been identified as a concern by stakeholders. The extent of this issue is unknown.

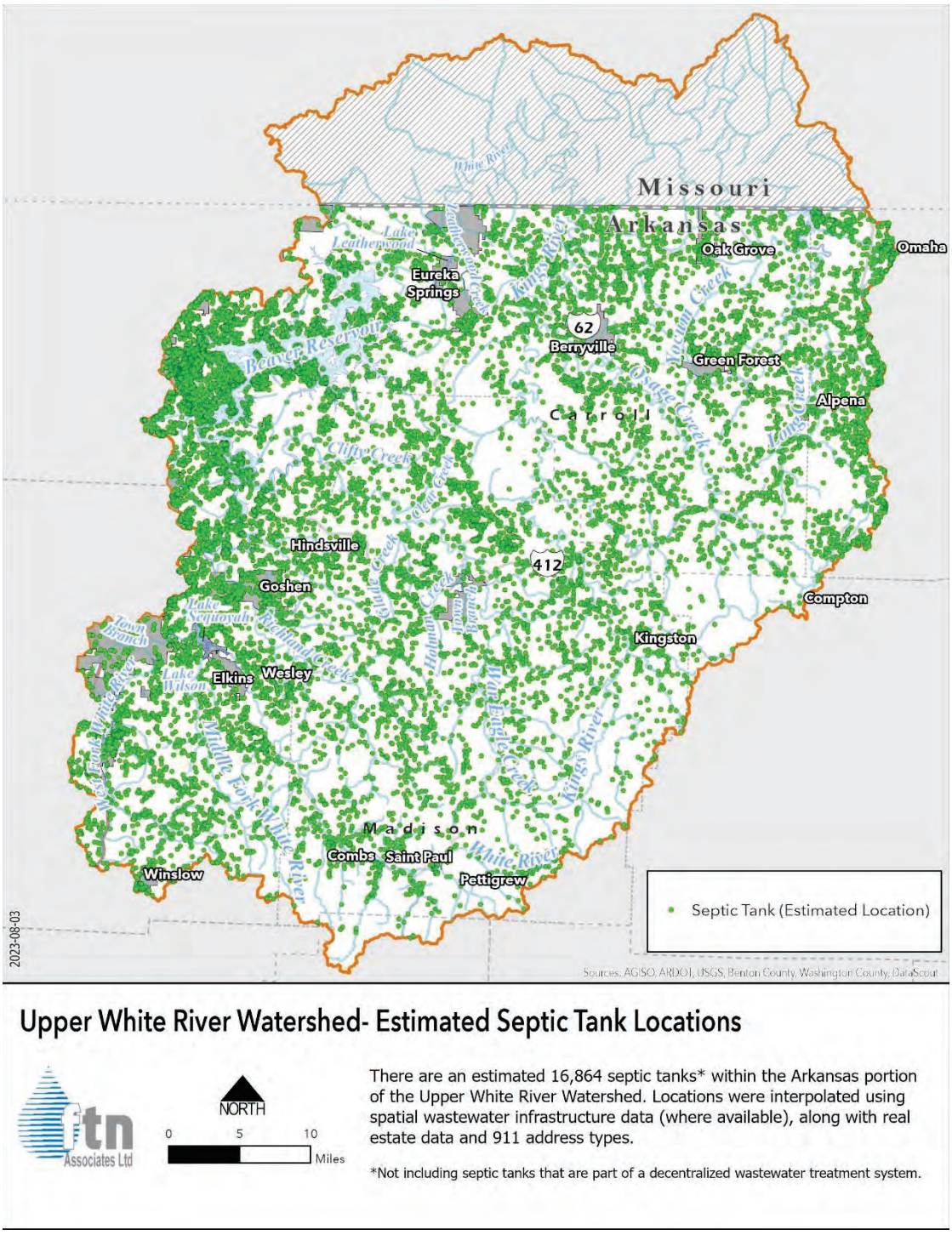


Figure 3.26. Estimated locations of septic systems in use in the Upper White River watershed.

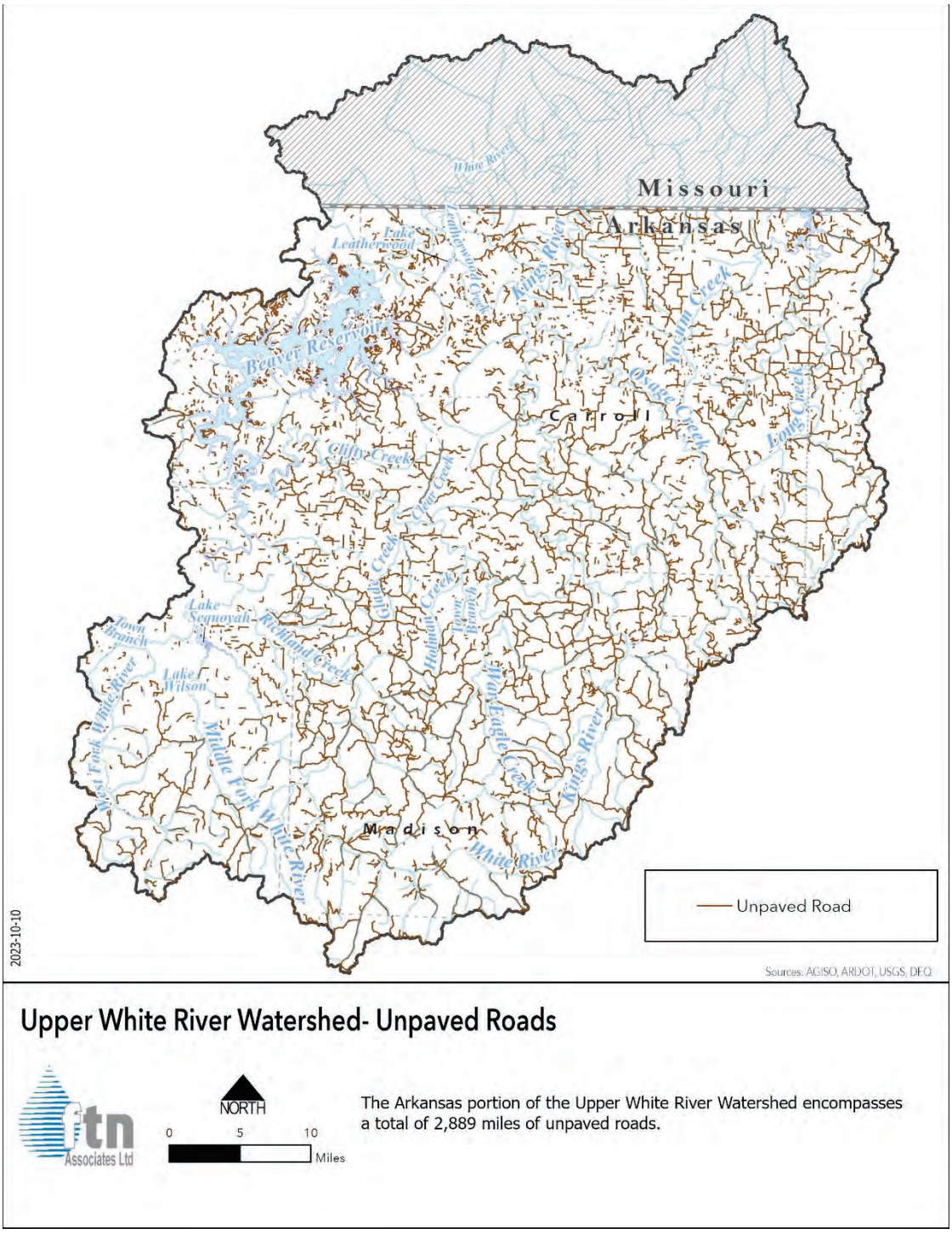
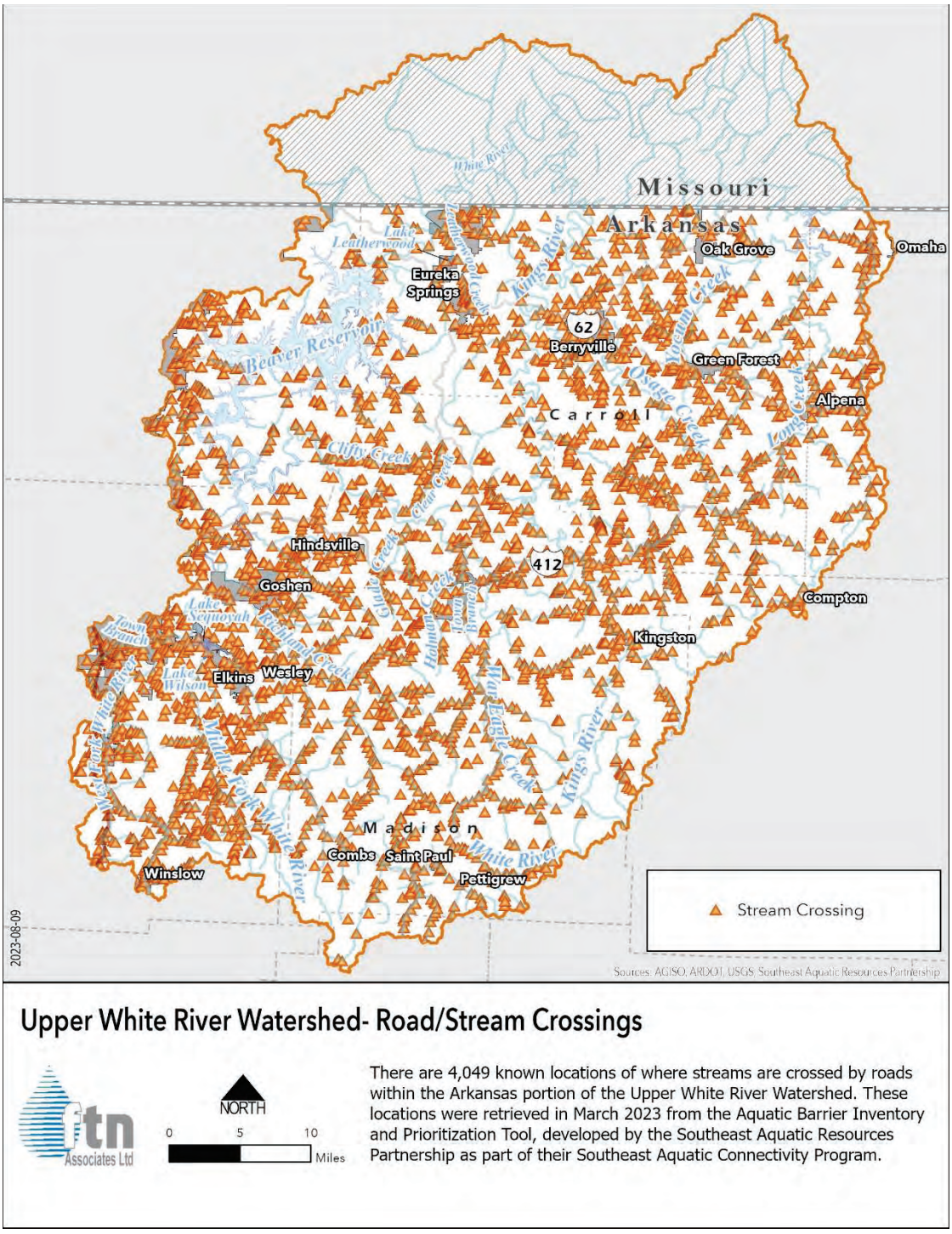


Figure 3.27. Unpaved roads in the Upper White River watershed, 2023 (Arkansas GIS Office 2023).



Upper White River Watershed- Road/Stream Crossings

There are 4,049 known locations of where streams are crossed by roads within the Arkansas portion of the Upper White River Watershed. These locations were retrieved in March 2023 from the Aquatic Barrier Inventory and Prioritization Tool, developed by the Southeast Aquatic Resources Partnership as part of their Southeast Aquatic Connectivity Program.

NORTH

0 5 10 Miles

Figure 3.28. Stream crossings identified by SARP in the Upper White River watershed.

3.4.5 Streambank and Lakeshore Erosion

Streambank erosion has been identified as a priority concern throughout this watershed. Lakeshore erosion has also been identified as a concern. The primary pollutant associated with bank erosion is sediment. However, nutrients, particularly phosphorus, can attach to soil particles and be transported with eroded soil and sediment to surface waters. Figure 3.29 shows areas of the watershed identified by NRCS as having a high risk of streambank erosion in 2015. As mentioned in Section 3.3.2, streambank erosion monitoring and studies have been conducted at several locations in the Upper White River watershed. Table 3.21 lists examples of estimated sediment and nutrient loads from streambanks in the watershed. As a result of this and other research in this watershed, the West Fork White River is often identified as the stream in the Upper White River watershed most affected by streambank erosion. Research in the West Fork White River watershed suggests that streambank erosion is more likely to occur where stream channels pass through soil associations with moderate to high erosivity hazard and runoff potential (Cotton and Haggard 2011).

Local word of mouth suggests that shoreline erosion has become more of a concern recently at Beaver Lake. There is a perception that there has been an increase in the frequency and duration of pool levels at or near flood stage in the reservoir, and this is exposing new areas to wave erosion, potentially increasing sediment input to the reservoir, and reservoir turbidity (personal communication, K. Farmer, FTN, 4/21/21).

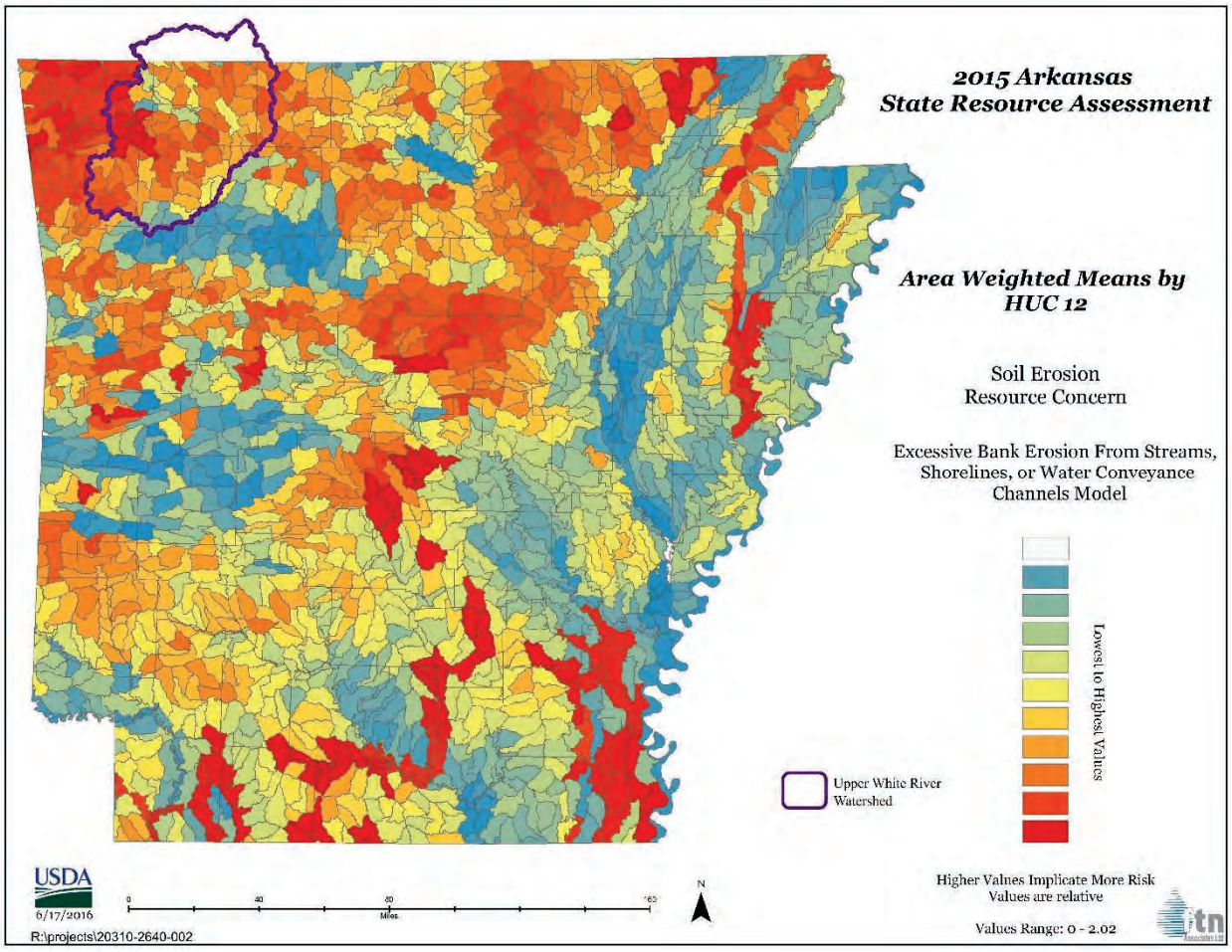


Figure 3.29. Areas in the Upper White River watershed with elevated risk of excessive bank erosion (NRCS 2016).

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

Location	Sediment load	Total Phosphorus load	Total Nitrogen Load	Source
White River at Wyman	3,600 ton/year	Not reported	Not reported	WCRS https://www.watershedconservation.org/projects/white-river-streambank-restoration/
West Fork near Brentwood	1,960 ton/year	Not reported	Not reported	https://www.watershedconservation.org/projects/brentwood-restoration/
West Fork near Drake Field	4,318 ton/year	1,933 lb/year	5,583 lb/year	(M. Van Epps 2013)
West Fork watershed	21,455 metric ton/year	Not reported	Not reported	(Van Epps, et al. 2004)
30 miles of West Fork White River	18,532 ton/year	Not reported	Not reported	(DEQ 2004)
29 miles of West Fork tributaries	5,118 ton/year	Not reported	Not reported	(DEQ 2004)
18 sites in the following watersheds; Beaver Lake, War Eagle Creek, Lake Sequoyah, West Fork, and Middle Fork	38 to 14,700 ton/year	22 to 7,100 ton/year	Not reported	(RTI International 2023)
White R downstream of Noland WWTP	11,250 ton/year	10,500 lb/year	19,500 lb/year	(Watershed Conservation Resource Center 2012)
Kings River watershed (158 miles of streams)	52,048 ton/year	20,819 lb/year	Not reported	(FTN Associates, Ltd. 2005)
Kings River (55 miles of river)	46,971 ton/year	Not reported	Not reported	C. McCoy, The Nature Conservancy, personal communication 04/24/2025

3.4.6 Sediments

Sediments deposited in streams can be resuspended by high flows and contribute to turbidity. Sediments deposited in reservoirs can be resuspended and contribute to turbidity during periods of high inflows, water level changes, or by waves caused by wind or motorboats.

A recent study in a shallow cove of the War Eagle Creek arm of Beaver Lake characterized processes and mechanisms by which sediments in littoral areas of the reservoir can contribute phosphorus to the reservoir epilimnion that can help fuel summer algal blooms in the reservoir that affect pH (McCarty 2020). Another study found significant relationships between total phosphorus and total nitrogen concentrations in sediments and water from streams flowing into Beaver Lake (Giovanetti, et al. 2013).

Research has also shown that pathogens can survive in freshwater sediments and can reenter the water column when sediments are disturbed by events such as high flows, reservoir water level changes, or wave action caused by motor boats (EPA 2017?) (Davis, Hamilton and Brahana 2007) (Baker, et al. 2021) (Pachepsky and Shelton 2011).

3.4.7 Livestock

Cattle and other livestock using streams can make streambanks more susceptible to erosion, or change the shape of the stream channel, which can trigger channel erosion upstream or downstream. Justus et al. (2010) found that indices of algal, aquatic invertebrate, and fishery integrity declined as estimated cattle production in Ozark stream basins increased.

Wastes deposited by cattle in or beside streams can also provide nutrients and coliforms, e.g., as when cows loiter in streams. Studies have shown that, unless access to streams is restricted, cattle generally spend much of the day in the riparian area, no matter the season, or the availability of other water sources (Bagshaw et al. 2008, Zuo and Miller-Goodman 2004). James et al. (2007) found that pastured cattle deposited significantly more manure in and near streams than in other areas of the pasture. Justus et al. (2010) found that in the Ozark region, nutrient concentrations were highest for streams with the highest estimated cattle and poultry production.

Figure 3.30 shows numbers of cattle reported for Upper White River counties in the Census of Agriculture since 1997. Overall, cattle numbers have increased slightly between 1997 and 2017 in Boone, Carroll, and Madison counties. In Benton and Washington counties, cattle

numbers have declined slightly between 1997 and 2017. These counties also experienced loss of pastureland during this period (USDA National Agricultural Statistics Service 2023).

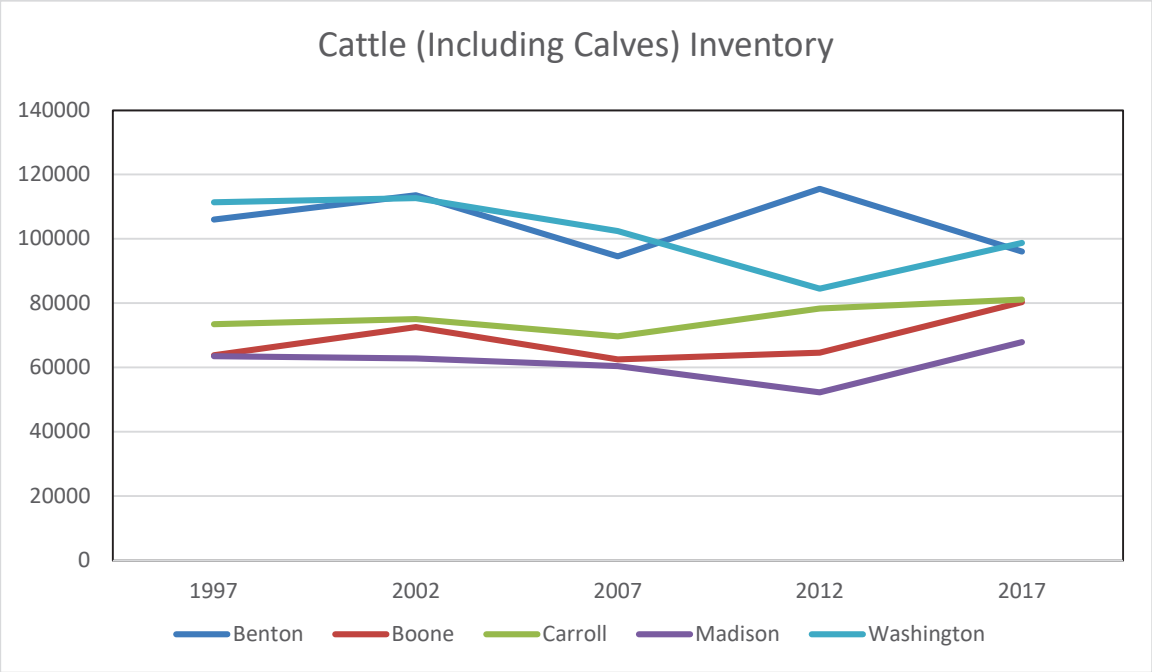


Figure 3.30. Cattle inventories from Census of Agriculture for selected Upper White River watershed counties.

3.4.8 Wastewater from Boats

There is a perception among some stakeholders that improper disposal of wastewater from boats or marinas is a concern in Beaver Lake. Wastewater from boats or marinas would be potential sources of nutrients, pathogens, and oxygen demand in Beaver Lake. It is true that one of the two marinas in the area of Beaver Lake listed as impaired (high pH levels and pathogens) does not have a pump out station for wastewater (Arkansas Department of Health 2018). However, state boating laws and Arkansas Department of Health, and others, have programs in place to encourage safe disposal of wastewater at water recreation areas in the state. As a result, this is not expected to be a significant source of pollutants to Beaver Lake. However, even a single release of untreated wastewater can have a significant local impact on reservoir water quality (Ozarks Water Watch 2009).

3.4.9 Runoff from Animal Feeding Operations

Animal feeding operations have the potential to affect water quality beyond disposal of large amounts of animal waste. Studies have shown that dust from poultry house fans can be a significant source of phosphorus and nitrogen in runoff (Herron 2015). Table 3.22 lists the number of poultry and swine feeding operations reported in the Census of Agriculture for selected Upper White River watershed counties in 2017 with the number of poultry houses reported to Natural Resources Division in 2017 and 2020. Note that information reported to Natural Resources Division suggests that the number of poultry houses in the watershed may be decreasing.

Table 3.22. Reported numbers of poultry and swine farms and poultry houses for selected Upper White River counties in 2017 and 2020.

Source	Benton	Carroll	Madison	Washington
2017 Poultry Operations[a]	382	287	255	449
2017 Swine Operations[a]	58	35	27	43
2017 Poultry Farms Registered with NRD[b]	253	184	153	184
2017 Poultry Houses Reported to NRD[b]	1,070	789	557	903
2020 Poultry Farms Registered with NRD[c]	196	166	150	147
2020 Poultry Houses Reported to NRD[c]	899	769	556	705

a (USDA National Agricultural Statistics Service 2023)
b (National Resources Division 2018)
c (National Resources Division 2021)

3.4.10 Wildlife

Feral hogs are a problem in Carroll, Madison, and Washington counties. In 2023, 739 feral hogs were reported removed from these three counties (Arkansas Department of Agriculture 2024). Feral hogs can contribute nutrients and *E. coli* to surface waters, and their disturbance of the soil and soil cover can contribute to erosion. Feral hogs have been identified as a potential source of *E. coli* in Beaver Lake (Platt 2024).

Canada geese have also been identified as a potential source of *E. coli* in Beaver Lake (Platt 2024).

3.4.11 Groundwater

As noted in Section 3.2 and Appendix E, groundwater has the potential to be a transport pathway for nitrate and *E. coli* to surface waters from sources far away. Most streams in the Upper White River watershed receive flow contributions from groundwater (see Section 2.4.3).

4.0 VOLUNTARY MANAGEMENT PLAN

This section identifies management goals and concerns for the Upper White River watershed, areas to target voluntary management and protection, and voluntary practices to achieve the watershed goals.

4.1 Management Goals

Five management goals to achieve the vision of the Upper White River watershed are listed below:

1. Restore impaired waterbodies where designated uses are not being attained;
2. Protect waterbodies where designated uses are being attained;
3. Encourage land use practices that reduce pollutant transport to surface water and groundwater;
4. Protect stream channels, streambanks, and lakeshores by minimizing activities that disturb and degrade these areas; and
5. Restore eroding streambanks and degraded riparian areas.

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

4.2 Management Concerns

Concerns about the Upper White River watershed were identified from public meetings and online information, in addition to waterbody impairments. Table 4.1 is a list of the water quality related issues identified by stakeholders for this watershed. One or more streams and reservoirs in the watershed do not meet water quality standards for nitrate (a nutrient), turbidity, DO, total dissolved solids, sulfate, pathogens, or pH (see Section 3.1.4). Complaints about streambank and lakeshore erosion are common in the watershed (see Section 3.4.5). Bank erosion results in loss of property (usually land) and can degrade instream habitat and increase stream turbidity and nutrient levels. Several aquatic species of concern in this watershed require rocky stream bottoms. When stream bottoms become sandy instead of rocky, they are no longer suitable habitat for aquatic species of concern. High levels of nutrients in streams or reservoirs can cause algal blooms. In addition to being unsightly and a nuisance to boaters and fishermen, algal blooms can affect water quality by reducing DO levels when the algae die and decompose, raising pH when the algae give off carbon dioxide, and/or increasing turbidity.

Table 4.1. Water quality related issues identified by Upper White River stakeholders.

In-stream	Watershed
Nutrients	Unpaved roads
Sediment, turbidity	Poultry litter application to land
Streambank and lakeshore erosion	Septic systems
Low DO	Road crossings
Total dissolved solids, sulfate	Removal of riparian trees, vegetation
Pathogens (Beaver Lake impairment)	Erosion of trails
pH	Impervious area

Watershed concerns listed in Table 4.1 are primarily sources of the pollutants of concern in the In-stream column of the table. Eroded soil from unpaved roads and trails can enter streams and reservoirs, most frequently at road crossings, contributing to turbidity, sediment on stream bottoms, and adding nutrients (see Section 3.4.4). Road crossings can change stream flow patterns, resulting in streambank erosion, and can be barriers to aquatic species of concern or their food sources (see Section 3.4.4). Failing or poorly maintained septic systems and poultry litter used as fertilizer on pastures are believed by many stakeholders to be contributing nutrients

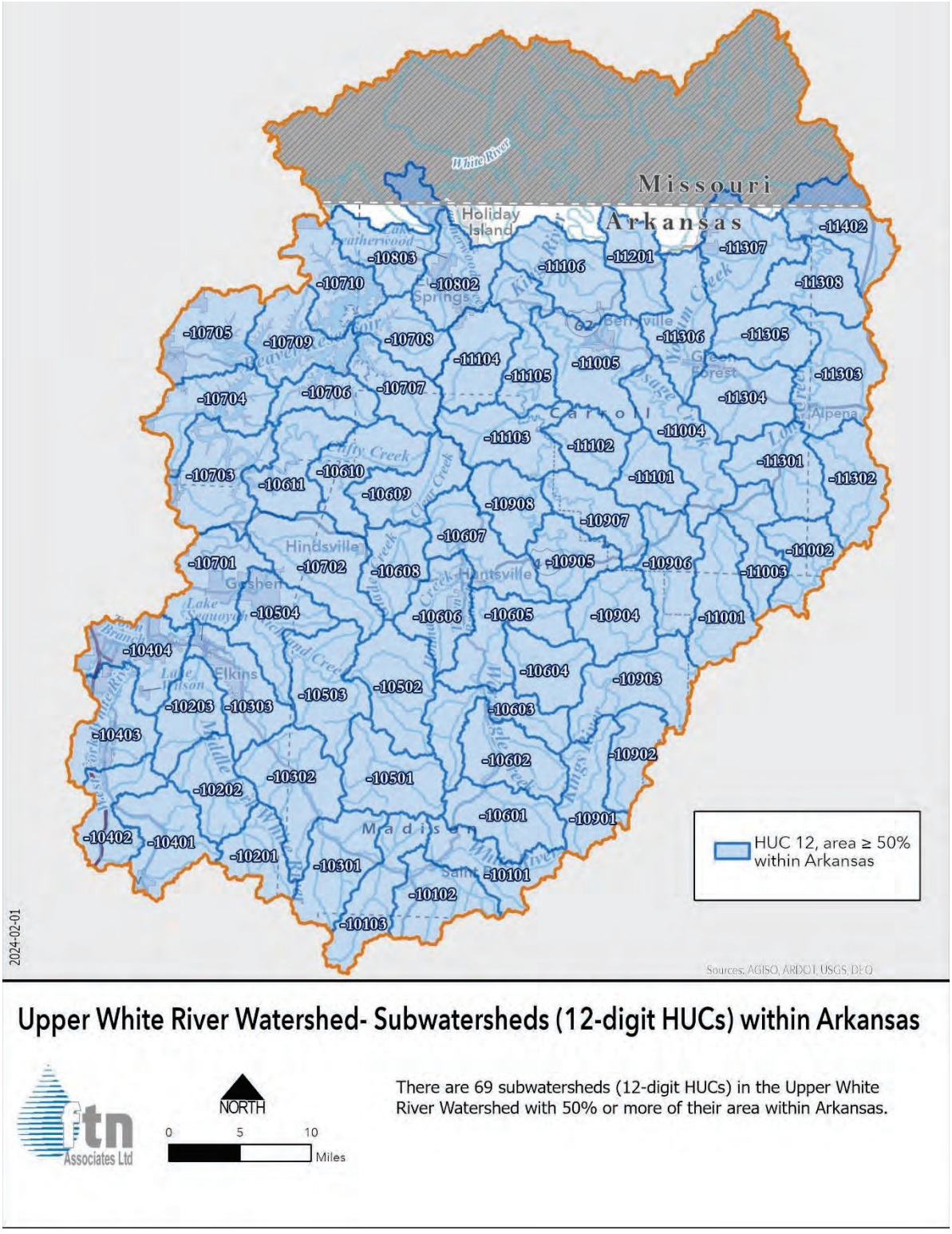
and pathogens to surface waters (see Sections 3.4.1 and 3.4.3). Vegetation in riparian areas helps stabilize streambanks and lakeshores and can filter pollutants such as soil/sediment, nutrients, and pathogens out of runoff before it enters surface waters. Clearing vegetation in riparian areas can increase bank erosion and pollutants carried to surface waters in runoff. Increasing the impervious area in a watershed increases the runoff volume, which can lead to streambank and channel erosion (see Section 3.4.2).

4.3 Sub-watersheds Recommended for Management

For this watershed management plan, HUC12 sub-watersheds delineated by the USGS are used as focus areas for nonpoint source pollution management. The Upper White River watershed has 75 HUC12 sub-watersheds (Figure 4.1). Because resources are limited for nonpoint source pollution management, we identified several HUC12s in the Upper White River watershed where it appears the return on investment of using nonpoint source pollution management activities would have greater benefits than in other HUC12s.

To identify HUC12 sub-watersheds to recommend for additional management of nonpoint source pollution under this plan, available information was used to rank the HUC12 sub-watersheds of the Upper White River watershed with at least 50% of their area in Arkansas, in terms of water quality concerns. Three sets of water quality-related information were used to rank the 69 HUC12 sub-watersheds with at least 50% of their area in Arkansas. The following information was used to rank the HUC12 sub-watersheds:

- Water quality impairment based on DEQ lists of impaired waterbodies for 2018 and 2020 (DEQ 2020, 2021b),
- Modeled loads (FTN Associates, Ltd. 2024), and
- Water quality natural resource concerns from the NRCS State Resources Assessment (NRCS 2016).



Upper White River Watershed- Subwatersheds (12-digit HUCs) within Arkansas

ftn Associates Ltd

NORTH

0 5 10 Miles

There are 69 subwatersheds (12-digit HUCs) in the Upper White River Watershed with 50% or more of their area within Arkansas.

Figure 4.1 Map of HUC12 sub-watersheds in the Upper White River watershed.

A detailed description of the data used and the ranking approach is included as Appendix G. The 11 HUC12 sub-watersheds with the highest total scores (Category 1) were selected for additional nonpoint source pollution management through this watershed management plan. The Category 1 HUC12 sub-watersheds are listed in Table 4.2 and mapped on Figure 4.2. These are not the only Upper White River HUC12 sub-watersheds with existing or potential water quality issues (see Appendix G). This plan is not intended to restrict management activities in areas outside the Category 1 HUC12 sub-watersheds. Water quality management is essential, and is encouraged, anywhere in the Upper White River watershed.

Table 4.3 summarizes issues and concerns in the 11 Category 1 sub-watersheds. The sub-watershed issues are identified based on assessed water quality impairments (sediment/turbidity, minerals, low DO, pathogens, pH, temperature), NRCS State Resource Assessment (excess nutrients, sediment/turbidity, pathogens, streambank erosion), SWAT model results (nutrients, sediment/turbidity, habitat degradation), USFWS threatened and endangered species listings (Threatened/ Endangered aquatic species), Arkansas Rule 2 (Ecologically Sensitive Waterbody, Extraordinary Resource Waters, Natural and Scenic Waterway), and trend analysis of water quality data (Water quality trends).

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

HUC12 ID Number[a]	HUC12 Name	Ranking Score (out of 5 possible)	Rule 2 Ecoregion[b]	County	2019 land cover percentages[c]				
					Developed	Forested	Pasture and hayland	Wetland	Other undeveloped
110100010303	Lake Sequoyah	2.28	OH, BM	Washington	9%	49%	39%	1.5%	1.6%
110100010404	Town Branch-West Fork White River	2.57	OH, BM	Washington	30%	47%	21%	<1%	1.1%
110100010606	Holman Creek	2.41	OH	Madison	12%	45%	39%	<1%	3.6%
110100010608	Glade Creek	2.19	OH	Madison	6%	33%	58%	<1%	2.7%
110100010610	Clifty Creek-War Eagle Creek	2.26	OH	Benton, Madison, Washington	6%	36%	53%	<1%	3.9%
110100010611	Beaver Lake-War Eagle Creek	3.27	OH	Benton, Washington	6%	62%	28%	<1%	2.9%
110100010701	Roberts Creek-Beaver Lake	2.23	OH	Washington	11%	42%	45%	<1%	1.3%
110100010702	Brush Creek-Beaver Lake	2.73	OH	Madison, Washington	7%	38%	51%	<1%	3.5%
110100010904	Spanker Branch-Kings River	2.19	BM, OH	Madison	5%	54%	38%	<1%	1.8%
110100011106	Clabber Creek-Kings River	2.33	OH	Carroll	7%	36%	55%	<1%	1.5%
110100011306	Braswell Branch-Yocum Creek	2.26	OH	Carroll	8%	18%	69%	<1%	5.9%

a (USGS 2021?)

b OH=Ozark Highlands, BM=Boston Mountains, based on Arkansas Pollution Control and Ecology Commission 2022

c Dewitz and USGS 2021

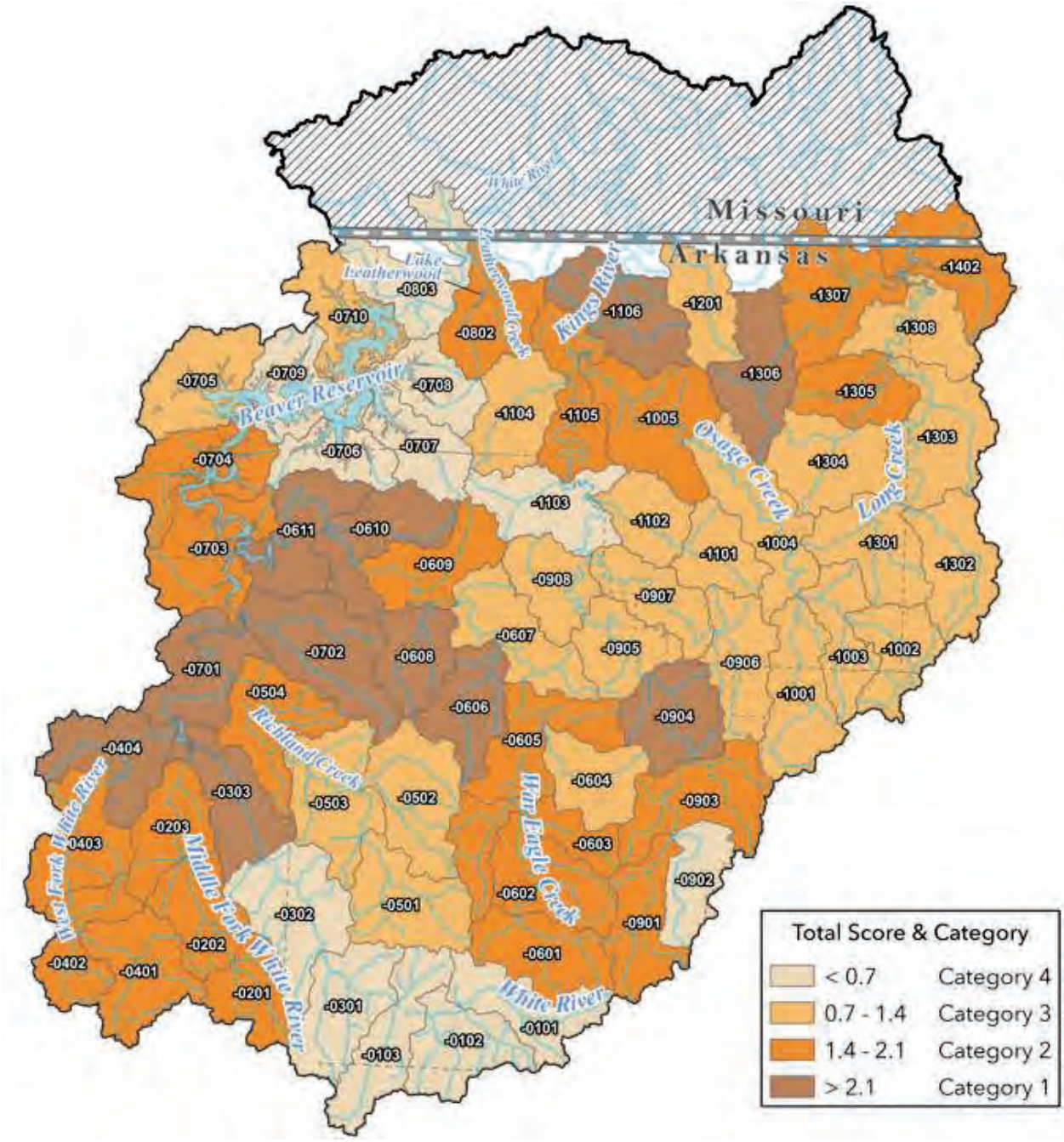


Figure 4.2. Map of HUC12 sub-watersheds of Upper White River recommended for nonpoint source pollution management.

Table 4.3. Upper White River watershed water quality issues of concern in recommended sub-watersheds.

Issue	Lake Sequoyah (0303)	Town Branch-West Fork White River (0404)	Holman Creek (0606)	Glade Creek (0608)	Clifty Creek – War Eagle Creek (0610)	Beaver Lake-War Eagle Creek (0611)	Roberts Creek-Beaver Lake (0701)	Brush Creek-Beaver Lake (0702)	Spanker Branch-Kings River (0904)	Clabber Creek-Kings River (1106)	Braswell Branch-Yocum Creek (1306)
Nutrients	S(phosphorus)	S(nitrogen and phosphorus)	*I*, S(nitrogen), N	N, S(nitrogen)	N, S	S(nitrogen and phosphorus)	N	N, S(nitrogen)	--	S(phosphorus), N	N, S(nitrogen)
Sediment, turbidity	i, S	I, S, TMDL	N	S	S	I, N	I, N, TMDL	I, N	S	N	--
Low DO	--	i	--	--	--	i	i	--	I	--	--
Total dissolved solids	--	I	*I*	--	--	--	--	--	--	I	--
Sulfate	--	I	--	--	--	--	I	--	--	--	--
Pathogens	--	--	N	N	N	I	I, N	I, N	N	N	N
pH	--	--	--	--	--	I	--	--	--	--	--
Temperature	--	i	--	--	--	--	--	--	--	--	--
Threatened/ Endangered aquatic species (IPaC)	1-2	2-3	1-2	1-2	1-2	2-3	2-3	2-3	3-4	3-4	3-4
Ecologically Sensitive Waterbody	Upper White River	--	--	--	--	--	--	--	--	--	--
Extraordinary Resource Waters	--	--	--	--	--	--	--	--	Kings River	Kings River	--
Natural and Scenic Waterway	--	--	--	--	--	--	--	--	Kings River	--	--
WQ trends identified?	Turbidity increasing at White River station WHI0106	No trends indicating declining water quality at station WFWR on West Fork White River	Possible eutrophication at Holman Creek station WHI0070	No analysis	No analysis	No trends indicating declining water quality at station BWD9 on War Eagle Creek	No trends indicating declining water quality in data from White River station Wyman, increasing total phosphorus in data from White River station BWD10	No analysis	No analysis	DO decreasing at Kings River station WHI0009A	No analysis
Habitat degradation	N	N	N	--	--	--	N	N	N	N	--

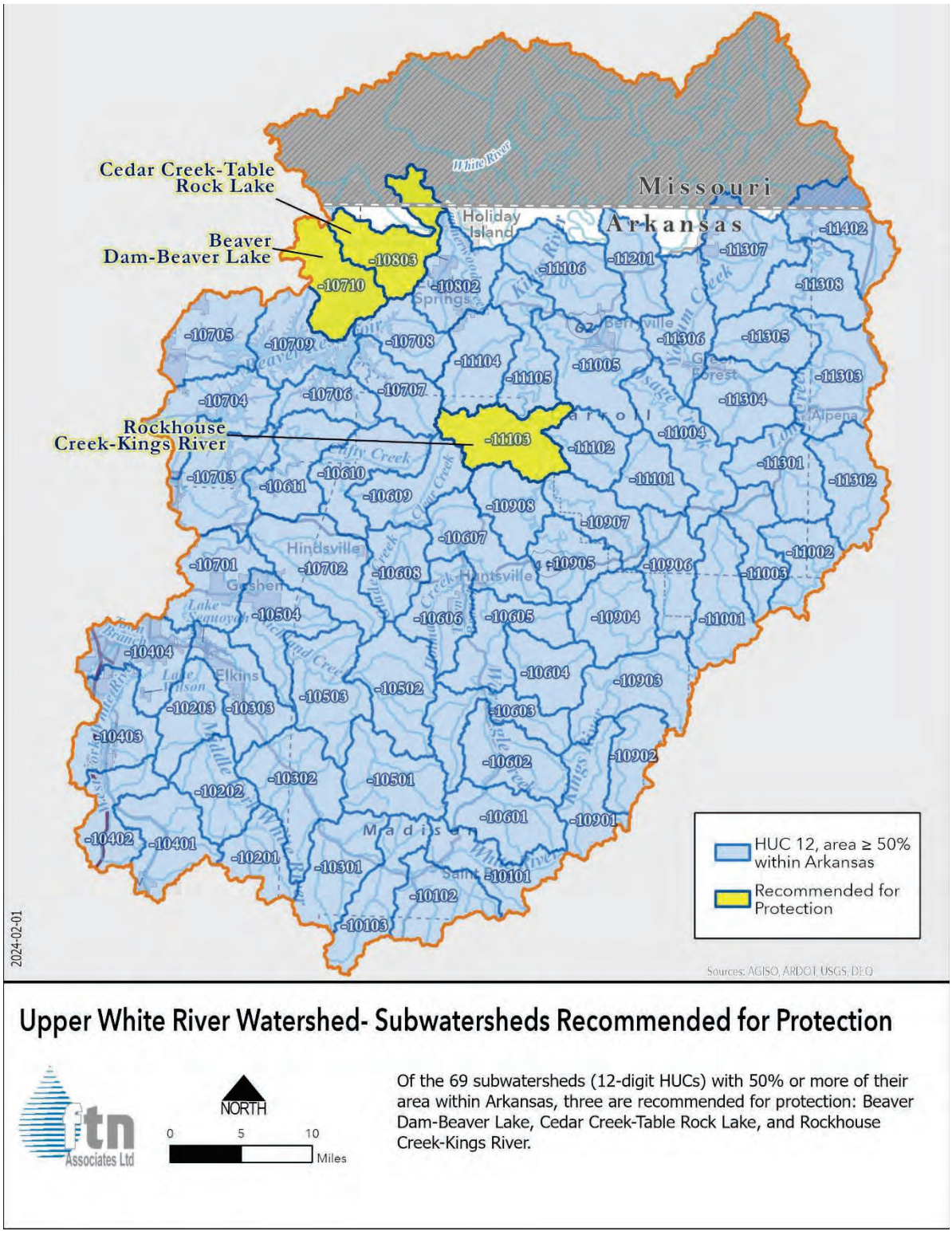
I=2018 impairment, i=2020 impairment only, *I*=2018 impairment because of point source, N=2015 State Resource Assessment risk in top 20%, C=StreamCat 2019 percentage riparian in developed or agriculture > 30%, R=70 or more road crossings from SARP inventory (retrieved 3/29/23), S=SWAT modeled instream yield in the top 20%, NA=no analysis

4.4 Sub-watersheds Recommended for Protection

The mission of this plan includes protection of existing good water quality. To identify HUC12 sub-watersheds to recommend for additional protection from nonpoint source pollution under this plan, available information was used to rank the HUC12 sub-watersheds of the Upper White River watershed with at least 50% of their area in Arkansas, in terms of indicators of good water quality and the presence of species or resources needing protection. Three sets of information were used to rank the 69 HUC12 sub-watersheds with at least 50% of their area in Arkansas. The following information was used to rank the HUC12 sub-watersheds for protection:

- Presence of protected areas, i.e., designated Wildlife Management Areas (WMAs), Natural Areas (NAs), Ecologically Sensitive Waterbodies (ESWs), Natural and Scenic Waterways (NSW), and Extraordinary Resource Waters (ERWs);
- Presence of federally listed threatened or endangered aquatic species;
- Predicted instream flux of sediment and nutrients; and
- Presence of impaired waterbodies.

A detailed description of the data used and the ranking approach is included in Appendix G. The three HUC12 sub-watersheds with the highest total scores were selected as the recommended sub-watersheds for additional protection from nonpoint source pollution through this watershed management plan. The recommended HUC12 sub-watersheds are listed in Table 4.4 and mapped on Figure 4.3. Table 4.4 provides additional information about the sub-watersheds recommended for protection activities. These sub-watersheds are primarily forested. The threatened and endangered aquatic species present in these sub-watersheds are mussels, which can be sensitive to sedimentation. The host fish species for these mussels also need to be protected. In the Beaver Dam-Beaver Lake and Cedar Creek-Table Rock Lake sub-watersheds, identifying recharge areas for ecologically sensitive springs could be important for their protection.



Upper White River Watershed- Subwatersheds Recommended for Protection

tn Associates Ltd

NORTH

0 5 10 Miles

Of the 69 subwatersheds (12-digit HUCs) with 50% or more of their area within Arkansas, three are recommended for protection: Beaver Dam-Beaver Lake, Cedar Creek-Table Rock Lake, and Rockhouse Creek-Kings River.

Figure 4.3. Map of HUC12 sub-watersheds of Upper White River recommended for protection.

Table 4.4. Information about sub-watersheds recommended for protection.

HUC12 ID Number	11010000710	110100010803	110100011103
HUC12 Name	Beaver Dam-Beaver Lake	Cedar Creek-Table Rock Lake	Rockhouse Creek-Kings River
Overall Score	3.83	4.08	5.08
Ecologically Sensitive Waterbody	Springs	Springs	none
Extraordinary Resource Waters	none	none	Kings River
Natural and Scenic Waterway	None	none	Kings River
Natural Areas	Devil's Eyebrow NA	Devil's Eyebrow NA	Bear Hollow NA
Wildlife Management Areas	Beaver Lake WMA	Beaver Lake WMA	McIlroy Madison County WMA
Threatened or Endangered Aquatic Species	3 (Neosho mucket, Rabbitsfoot mussel, and Scaleshell mussel)	3 (Neosho mucket, Rabbitsfoot mussel, and Scaleshell mussel)	3 (Rabbitsfoot mussel, Scaleshell mussel, and Snuffbox mussel)
Rule 2 Ecoregion	Ozark Highlands	Ozark Highlands	Ozark Highlands
County	Benton	Carroll	Madison
Developed	8%	6%	
Forest	57%	84%	85%
Pasture and Hay	3%	5%	10%
Water and Wetlands	31%	4%	<1%
Other Undeveloped	1%	2%	1%

4.5 Management Targets

Based on the water quality concerns listed in Table 4.3, pollutants of concern in the management Category 1 sub-watersheds are nutrients, turbidity/sediment, TDS, sulfate, pathogens (*E. coli*), pH, and temperature. DO levels also need to be managed through management of nutrients and/or organic matter. These pollutants are targets for management under this plan. Management targets for turbidity, TDS, sulfate, *E. coli*, pH, and temperature are the applicable water quality standards, as detailed in the following subsections. Water quality standards from Arkansas Pollution Control and Ecology Commission Rule 2 that are applicable in the Upper White River watershed are listed in Table 3.1 (Arkansas Pollution Control and Ecology Commission 2022). Rule 2 does not include water quality standards for stream nutrients or sediment. So, other approaches are used to set management targets for nutrients and sediment.

4.5.1 Nutrients

The only numeric criteria related to nutrients that apply in the Upper White River watershed are chlorophyll *a* and Secchi transparency criteria for Beaver Lake. These criteria do not apply to the Beaver Lake segments in the Category 1 sub-watersheds (Beaver Lake-War Eagle Creek (110100010611), Roberts Creek-Beaver Lake (110100010701) or Brush Creek-Beaver Lake (110100010702)). So, there are no numeric nutrient criteria that could be used as management targets for the Category 1 sub-watersheds (Arkansas Pollution Control and Ecology Commission 2022).

Often, low-DO conditions in Arkansas waterbodies are a result of excessive algal production caused by nutrient inputs. In such situations, management of nutrient inputs will improve DO conditions. In several Category 1 sub-watersheds nutrients are a concern and waterbodies don't meet the DO criteria. However, a simple linear regression analysis, and comparison of modeled nutrient loads for sub-watersheds with and without DO impairments did not reveal relationships between DO and nutrients that would be useful for establishing nutrient management targets (see Appendix I).

The DEQ method for assessing whether wadable streams are nutrient impaired uses the 75th percentile of total nitrogen and total phosphorus measurements from each of the state

ecoregions, DO and pH measurements, and the condition of biological communities (DEQ 2021c). Table 4.5 shows 75th percentile total nitrogen and total phosphorus concentrations for the Ozark Highlands and Boston Mountain ecoregions calculated using measurements collected 2018-2022 at DEQ stream stations in these two ecoregions.

Table 4.5. Seventy-fifth percentile nutrient concentrations for Upper White River ecoregions calculated from 2018-2022 DEQ stream data, with the Category 1 sub-watersheds associated with each ecoregion.

Rule 2 Ecoregion	Total Nitrogen Target, mg/L	Total Phosphorus Target, mg/L	Category 1 Sub-watersheds	
			HUC12 ID	HUC12 Name
Ozark Highlands	2.28	0.07	110100010303	Lake Sequoyah
			110100010404	Town Branch-West Fork White River
			110100010606	Holman Creek
			110100010608	Glade Creek
			110100010610	Clifty Creek-War Eagle Creek
			110100010611	Beaver Lake-War Eagle Creek
			110100010701	Roberts Creek-Beaver Lake
			110100010702	Brush Creek-Beaver Lake
			110100011106	Clabber Creek-Kings River
			110100011306	Braswell Branch-Yocum Cree
Boston Mountains	0.58	0.03	110100010303	Lake Sequoyah
			110100010404	Town Branch-West Fork White River
			110100010904	Spanker Branch-Kings River

We also evaluated setting nutrient targets based on modeled nutrient yields. We considered using modeled upland yields and instream flux to set the target. Upland yields represent nutrients lost from the landscape. Modeled instream flux is assumed to include nutrients from streambank erosion, as well those from the landscape. Researchers have estimated nitrogen and phosphorus loads associated with streambank erosion (Table 3.21). Streambank erosion was identified as a significant source of phosphorus in the 2012 Beaver Lake Watershed Protection Strategy (Tetra Tech 2012). Other planners in this watershed have not identified streambank erosion as a significant source of nutrients (DEQ 2004, RTI International 2023, Miller 2006). So, we developed the target for nitrogen and phosphorus modeled yield from uplands rather than instream flux. Target values for modeled nitrogen and phosphorus upland

loads are listed in Table 4.6. These target values are based on the 75th percentile modeled upland loads. A detailed description of how these targets were derived is provided in Appendix I.

Table 4.6. Proposed targets for modeled upland nutrient yields.

Target upland yield total nitrogen, kg/ha/yr	Target upland yield total phosphorus, kg/ha/yr
1.10	0.05

4.5.2 Sediment management targets

Sediment has been identified by stakeholders as a concern in all of the Category 1 sub-watersheds. One of the sediment management targets for this watershed management plan are the applicable turbidity water quality criteria. This management target applies to all of the Category 1 sub-watersheds. Table 4.7 lists turbidity criteria that apply to water bodies in the Category 1 sub-watersheds. While sediment has been identified as a pollutant of concern for all of the Category 1 sub-watersheds, there are water bodies classified as impaired by high turbidity in only six of the Category 1 sub-watersheds (Table 4.7).

A TMDL study has been conducted for West Fork White River within 110100010404 and White River within 110100010701. Target nonpoint source loads (Load Allocations) from these TMDLs are listed in Table 4.8. In these TMDLs the target load is assigned entirely to nonpoint sources, no allocation was made to point sources.

Table 4.7. Turbidity criteria that apply to water bodies in the Category 1 sub-watersheds. Water bodies that are classified as impaired by high turbidity are highlighted in yellow (DEQ 2020).

HUC12 ID Number	HUC12 Name	Water Body	Base Flow Criterion, NTU	Storm Flow Criterion, NTU
110100010303	Lake Sequoyah	White River	10	17
110100010404	Town Branch-West Fork White River	Town Branch	10	17
		West Fork White River	10	17
110100010606	Holman Creek	Town Branch	10	17
		Holman Creek	10	17
		War Eagle Creek	10	17
110100010608	Glade Creek	Glade Creek	10	17
110100010610	Clifty Creek-War Eagle Creek	Clifty Creek	10	17
		War Eagle Creek	10	17
110100010611	Beaver Lake-War Eagle Creek	Beaver Lake	25	45
		War Eagle Creek	10	17
110100010701	Roberts Creek-Beaver Lake	Beaver Lake	25	45
		White River	10	17
110100010702	Brush Creek-Beaver Lake	Beaver Lake	25	45
		Brush Creek	10	17
110100010904	Spanker Branch-Kings River	Kings River	10	19
110100011106	Clabber Creek-Kings River	Kings River	10	17
110100011306	Braswell Branch-Yocum Creek	Yocum Creek	10	17

Table 4.8. Target TSS loads from turbidity TMDL (FTN Associates, Ltd. 2006).

Category 1 sub-watershed HUC12 ID	DEQ Reach ID	Stream name	Target Base Flow Concentration, mg/L	TSS Base Flow Load Allocation, tons/day	Target Storm Flow Concentration, mg/L	TSS Storm Flow Load Allocation, tons/day
110100010701	11010001-023	White River	11	0.606	12	19.3
110100010404	11010001-024	West Fork White River	9	0.111	12	4.31

SWAT model output loads were used to set a sediment load target for Category 1 sub-watersheds where sediment TMDLs have not been established. HUC12 sub-watersheds where turbidity was measured 2018-2022 were identified, with the associated SWAT modeled yields of sediment from upland (i.e., soil eroded from the landscape), from streambank erosion, and based on instream flux (representing streambank and channel erosion). Then, the HUC12 sub-watersheds in this group with turbidity impaired water bodies were identified. Finally, HUC12 sub-watersheds in this group where the sum of percentages of land area in developed and pasture or hay uses is 34% or greater were identified. The sum of the percentage of land area in the Category 1 sub-watersheds that is in development and pasture or hay ranges from 34% to 62%. Evaluating loads from sub-watersheds with percentages of pasture/hay, and developed land covers similar to those in the Category 1 sub-watersheds means that the target is more realistic for conditions in the Category 1 sub-watersheds. As opposed to expecting developed and agricultural sub-watersheds to generate sediment loads like those seen in primarily forested sub-watersheds.

Box and whisker graphs were used to compare the SWAT sediment yields from monitored HUC12s where the combined percentage of land area in developed and pasture is 34% or more, with and without turbidity impairments. Of the SWAT outputs evaluated, only the medians of SWAT sediment yield from upland were statistically significantly different for the evaluated HUC12s with and without turbidity impairments (Figure 4.4). The upland sediment load yield target for Category 1 sub-watersheds for this plan is set to the median upland yield from monitored HUC12s without turbidity impairment, and where the combined percentage of land area in developed and pasture uses is 34% or greater, which is 0.07 ton/ha/yr. The data analyzed to develop this target is provided in Appendix H.

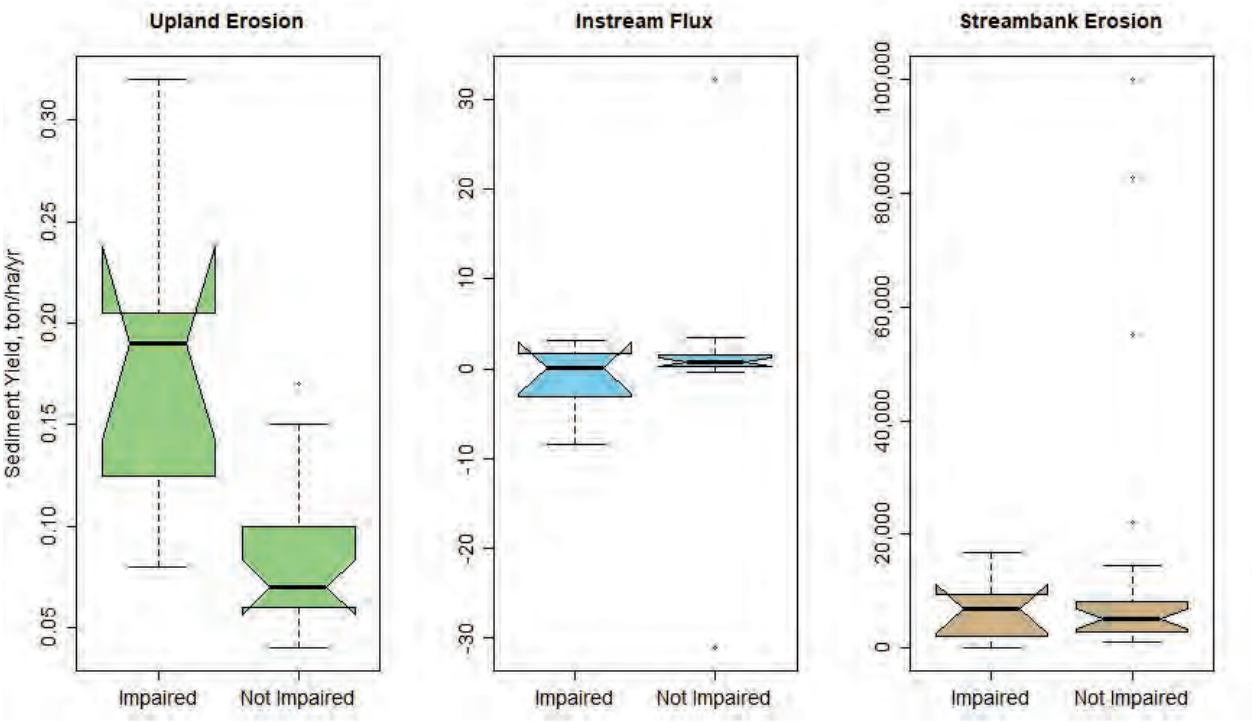


Figure 4.4. Box plot comparison of modeled sediment yields from land, instream flux, and streambanks for monitored HUC12 sub-watersheds with (left) and without (right) waterbodies impaired by high turbidity. The notches represent the median value, with a 95% confidence interval. If notches do not overlap, the median values are statistically significantly different with 95% confidence.

4.5.3 TDS management target

The TDS management target for this watershed management plan is to attain the TDS water quality criteria. This management target applies to the Town Branch-West Fork White River (110100010404) and Clabber Creek (110100011106) Category 1 sub-watersheds. Although Town Branch in the Holman Creek Category 1 sub-watershed is listed as impaired by high TDS levels, the TDS source has been identified as industrial and municipal point sources. So, management of nonpoint TDS sources in this sub-watershed is not required under this plan. To be assessed as meeting the TDS criteria, DEQ requires that at least 90% of at least 10 measurements from the assessment period meet the TDS criteria. The TDS criterion that applies to the impaired reaches of West Fork White River and Kings River is 150 NTU (see Table 3.1).

4.5.4 Sulfate management target

The sulfate management target for this watershed management plan is to attain the sulfate water quality criteria. This management target applies to the Town Branch (110100010404) and Roberts Creek (110100010701) Category 1 sub-watersheds. To be assessed as meeting the sulfate criteria, DEQ requires that at least 90% of at least 10 measurements from the assessment period meet the sulfate criteria. The sulfate criterion for stream reaches in the Category 1 sub-watersheds that are classified as impaired by high sulfate is 20 mg/L (Table 4.9).

Table 4.9. Sulfate criteria management targets for Category 1 sub-watersheds.

HUC12 ID Number	HUC12 Name	Impaired Stream	Sulfate Criterion, mg/L
110100010404	Town Branch-West Fork White River	West Fork White River	20
110100010701	Roberts Creek-Beaver Lake	White River	20
110100011106	Clabber Creek-Kings River	Kings River	20

4.5.5 *E. coli* management target

Bacteria management targets for this watershed management plan are the *E. coli* primary contact individual sample water quality criteria. To be assessed as achieving the *E. coli* criteria, DEQ requires that 75% or more of at least 8 *E. coli* measurements from the assessment period (see Table 3.1 For Primary and Secondary Contact assessment periods) must be lower than the criterion (DEQ 2021c). The applicable Primary Contact *E. coli* criterion in the Category 1 sub-watersheds where pathogens have been identified as a concern by stakeholders (see Table 4.3) are listed in Table 4.10.

Table 4.10. *E. coli* individual sample water quality criteria applicable in Category 1 sub-watersheds where pathogens have been identified by stakeholders as a concern. Yellow highlighted water bodies are classified as impaired because of high *E coli* levels (DEQ 2020).

HUC12 ID Number	HUC12 Name	Monitored Water Body	Primary Contact Criterion, cfu/100mL
110100010606	Holman Creek	Town Branch	410
		War Eagle Creek	410
110100010608	Glade Creek	none	410
110100010610	Clifty Creek-War Eagle Creek	Clifty Creek	410
		War Eagle Creek	410
110100010611	Beaver Lake-War Eagle Creek	Beaver Lake	298
		War Eagle Creek	410
110100010701	Roberts Creek-Beaver Lake	Beaver Lake	298
		White River	410
110100010702	Brush Creek-Beaver Lake	Beaver Lake	298
		Brush Creek	410
110100010904	Spanker Branch-Kings River	Kings River	298
110100011106	Clabber Creek-Kings River	Kings River	298
110100011306	Braswell Branch-Yocum Creek	none	410

4.5.6 pH management target

The pH management target for this watershed management plan is to attain the pH water quality criteria. To be assessed as achieving the pH criteria, DEQ requires that 90% or more of at least 10 measurements from the assessment period be between 6 standard units and 9 standard units (DEQ 2021c). This is the management target for this plan.

4.5.7 Temperature management target

The temperature management target for this watershed management plan is to attain the temperature water quality criteria. To be assessed as meeting the temperature criteria, DEQ requires that 90% or more of at least 10 measurements from the assessment period meet the temperature criteria. The West Fork White River within the Town Branch-West Fork White River Category 1 sub-watershed (110100010404) is classified as impaired because of high temperatures. The temperature criterion that applies to this stream in this sub-watershed is 29°C.

4.5.8 Dissolved Oxygen

DO management targets for this watershed management plan are the critical season DO water quality criteria. The critical season for DO is defined in Rule 2 as the period when water temperatures are greater than 22 deg C, usually mid-May to mid-September. To be assessed as achieving DO criteria, DEQ requires that 90% or more of at least 10 DO measurements from the assessment period must be greater than the criterion (DEQ 2021c). Applicable critical season DO criteria for waterbodies in Category 1 sub-watershed where there are DO impairments are listed in Table 4.11.

Table 4.11. DO management targets for Category 1 sub-watersheds with DO impairments.

HUC12 ID Number	HUC12 Name	Rule 2 Ecoregion	Impaired stream	Critical Season Criterion, mg/L
110100010404	Town Branch-West Fork White River	Ozark Highlands	West Fork White River	6
110100010611	Beaver Lake-War Eagle Creek	Ozark Highlands	War Eagle Creek	6
110100010701	Roberts Creek-Beaver Lake	Ozark Highlands	White River	6
110100010904	Spanker Branch-Kings River	Boston Mountains, Ozark Highlands	Kings River	5

4.6 Pollutant Reduction Targets

Based on the water quality targets identified in Section 4.5 and available water quality information, it should be possible to determine pollutant load reductions needed to achieve the water quality targets. Determination of load reduction targets for this watershed management plan is discussed in the following subsections.

4.6.1 Phosphorus

The average of at least 10 total phosphorus measurements from water quality monitoring stations within the Category 1 sub-watersheds were compared to the ecoregion target concentrations (Table 4.13). This is part of the approach used by DEQ to identify waterbodies impaired by nutrients (DEQ 2021c). Note that in one of the Category 1 sub-watersheds where nutrients have been identified as a concern, phosphorus measurements were not collected 2018-2022; Braswell Branch-Yocum Creek. The comparison shown in Table 4.12 indicates that phosphorus loads may need to be reduced in the Lake Sequoyah (110100010303), Town Branch-West Fork (110100010404), Holman Creek (110100010606), Beaver Lake-War Eagle Creek (110100010611), and Roberts Creek-Beaver Lake (110100010701) sub-watersheds. High phosphorus concentrations in Holman Creek may be the result of the influence of the Huntsville WWTP discharge.

Table 4.12. Comparison of average total phosphorus concentrations from Category 1 HUC12 sub-watersheds to ecoregion target total phosphorus concentration.

HUC12 ID	HUC12 Name	Target Total Phosphorus, mg/L	WQ station (sampled 2018-2022)*	Sampling Organization	Waterbody	2018-2022 average Total Phosphorus, mg/L	Percent reduction to reach target concentration (difference/average)
110100010303	Lake Sequoyah	0.03	WHI0106	DEQ	White River	0.026	--
			5	BWD	White River	0.062	52%
		0.07	22	BWD	Lake Sequoyah outflow	0.086	19%
110100010404	Town Branch-West Fork White River	0.07	202	H2Ozarks	Mullins Creek	<10 measurements	--
			206	H2Ozarks	Sprout Spring Branch	0.031	--
			WHI0223	DEQ	Town Branch	<10 measurements	--
			210[x]	H2Ozarks	Town Branch	0.02	--
			TB[x]	AWRC	Town Branch	0.11	36%
			07048495[x]	USGS	Town Branch	0.12	42%
			WHI0100[y]	DEQ	West Fork	0.03	--
			8[y]	BWD	West Fork	0.08	12%
			WFWR	AWRC	West Fork	0.13	46%
110100010606	Holman Creek	0.07	WHI0070[f]	DEQ	Holman Creek	0.45	84%
			308[f]	H2Ozarks	Holman Creek	0.593	88%
			307	H2Ozarks	Holman Creek	0.017	--
110100010608	Glade Creek	0.07	302	H2Ozarks	Glade Creek	0.023	--
110100010610	Clifty Creek-War Eagle Creek	0.07	304	H2Ozarks	Clifty Creek	0.017	--

Table 4.12. Comparison of average total phosphorus concentrations from Category 1 sub-watersheds where nutrients have been identified as a concern, to ecoregion target total phosphorus concentration.

HUC12 ID	HUC12 Name	Target Total Phosphorus, mg/L	WQ station (sampled 2018-2022)*	Sampling Organization	Waterbody	2018-2022 average Total Phosphorus, mg/L	Percent reduction to reach target concentration (difference/average)
110100010611	Beaver Lake-War Eagle Creek	0.07	9[a]	BWD	War Eagle Creek	0.07	--
			305[a]	H2Ozarks	War Eagle Creek	<10 measurements	--
			07049050[a]	USGS	War Eagle Creek	0.41	83%
110100010701	Roberts Creek-Beaver Lake	0.07	10[b]	BWD	White River	0.09	22%
			Wyman[b]	AWRC	White River	0.11	36%
			07048600[b]	USGS	White River	0.33	79%
			13	BWD	White River	0.11	36%
			23	BWD	White River	0.14	50%
			WHI0052[c]	DEQ	White River	0.04	--
			07048700[c]	USGS	White River	0.05	--
110100010702	Brush Creek-Beaver Lake	0.07	300	H2Ozarks	Brush Creek	0.03	--
110100010904	Spanker Branch-Kings River[+]	0.07	WHI0121	DEQ	Kings River	0.026	--
110100011106	Clabber Creek-Kings River	0.07	WHI0009A[t]	DEQ	Kings River	0.03	--
			Kings[t]	AWRC	Kings River	0.06	--
110100011306	Braswell Branch-Yocum Creek	0.07	No station	--	--	--	--

* Stations with the same superscript letters are at the same location.
[+] Phosphorus was not initially identified as a concern in this HUC12 sub-watershed (see Table 4.3).

Table 4.13 shows a comparison of SWAT modeled total phosphorus yields to the target yield from Table 4.6. Modeled total phosphorus yields for six of the Category 1 sub-watersheds are greater than the management target. Load reduction targets are set to the nearest multiple of five that is less than or equal to the percent reduction to reach the target yield. **Total phosphorus load reduction targets for the Category 1 sub-watersheds range from 15% to 70%**. Note that this comparison does not indicate a need to reduce nonpoint source total phosphorus inputs in the Holman Creek sub-watershed. So, it appears that instream and/or point source phosphorus loads are the primary contributor to the high total phosphorus concentrations in Holman Creek.

Table 4.13. Comparison of modeled total phosphorus loads from Category 1 sub-watersheds to target total phosphorus load of 0.05 kg/ha/year, with load reduction targets.

HUC12 ID Number	HUC12 Name	SWAT modeled phosphorus upland yield, kg/ha/year	Difference from 0.05 kg/ha/year	Percent reduction to reach 0.05 kg/ha/year (difference/modeled)	Load Reduction Target
110100010303	Lake Sequoyah	0.09	0.04	44%	40%
110100010404	Town Branch-West Fork White River	0.10	0.05	50%	50%
110100010606	Holman Creek	0.04	-0.01	--	0
110100010608	Glade Creek	0.05	0	--	0
110100010610	Clifty Creek-War Eagle Creek	0.10	0.05	50%	50%
110100010611	Beaver Lake-War Eagle Creek	0.19	0.14	74%	70%
110100010701	Roberts Creek-Beaver Lake	0.04	-0.01	--	0
110100010702	Brush Creek-Beaver Lake	0.02	-0.03	--	0
110100010904	Spanker Branch-	0.03	-0.02	--	0

Table 4.13. Comparison of modeled total phosphorus loads from Category 1 sub-watersheds to target total phosphorus load of 2,100 kg/ha/year, with load reduction targets (continued).

HUC12 ID Number	HUC12 Name	SWAT modeled phosphorus upland yield, kg/ha/year	Difference from 0.05 kg/ha/year	Percent reduction to reach 0.05 kg/ha/year (difference/modeled)	Load Reduction Target
	Kings River*				
110100011106	Clabber Creek-Kings River	0.12	0.07	58%	55%
110100011306	Braswell Branch-Yocum Creek	0.06	0.01	17%	15%

* Phosphorus was not initially identified as a concern in this HUC12 sub-watershed (see Table 4.3).

4.6.2 Nitrogen

The average of at least 10 total nitrogen measurements from water quality monitoring stations within the Category 1 sub-watersheds were compared to the ecoregion target concentrations (Table 4.14). This is part of the approach used by DEQ to identify waterbodies impaired by nutrients (DEQ 2021c). Note that nutrients have been identified as a concern in the Braswell Branch-Yocum Creek sub-watershed, but total nitrogen measurements were not collected 2018-2022 from that sub-watershed. The results of this comparison indicate that total nitrogen loads may need to be reduced in Holman Creek, Glade Creek, Clifty Creek, and Brush Creek. Percent reductions to meet the target total nitrogen concentrations are shown in Table 4.14. The high total nitrogen concentrations in Holman Creek may be because of the influence of effluent from the Huntsville WWTP, rather than nonpoint sources (see Appendix C).

Table 4.14. Comparison of average of available total nitrogen concentrations from Category 1 sub-watersheds to ecoregion target total nitrogen concentration.

HUC12 ID	HUC12 Name	Target Total Nitrogen, mg/L	WQ station* (sampled 2018-2022)	Sampling Organization	Waterbody	2018-2022 average Total Nitrogen, mg/L	Percent reduction to reach 2.28 mg/L (difference/average)
110100010303	Lake Sequoyah+	0.58	WHI0106	DEQ	White River	0.38	--
			5	BWD	White River	0.42	--
		2.28	22	BWD	Lake Sequoyah outflow	0.52	--
110100010404	Town Branch-West Fork White River	2.28	206	H2Ozarks	Sprout Spring Branch	<10 measurements	--
			WHI0223	DEQ	Town Branch	0.74	--
			210[x]	H2Ozarks	Town Branch	0.92	--
			TB[x]	AWRC	Town Branch	1.09	--
			07048495[x]	USGS	Town Branch	1.33	--
			WHI0100[y]	DEQ	West Fork	0.46	--
			8[y]	BWD	West Fork	0.51	--
			WFWR	AWRC	West Fork	0.73	--
110100010606	Holman Creek	2.28	307	H2Ozarks	Holman Creek	1.04	--
			WHI0070	DEQ	Holman Creek	3.58	36%
			308	H2Ozarks	Holman Creek	3.67	38%
110100010608	Glade Creek	2.28	302	H2Ozarks	Glade Creek	3.97	42%
110100010610	Clifty Creek-War Eagle Creek	2.28	304	H2Ozarks	Clifty Creek	4.03	43%
110100010611		2.28	9[a]	BWD	War Eagle Creek	1.64	--

Table 4.14. Comparison of average of available total nitrogen concentrations from Category 1 sub-watersheds where nutrients have been identified as a concern, to ecoregion target total nitrogen concentration. Red highlighted cells (continued).

HUC12 ID	HUC12 Name	Target Total Nitrogen, mg/L	WQ station* (sampled 2018-2022)	Sampling Organization	Waterbody	2018-2022 average Total Nitrogen, mg/L	Percent reduction to reach 2.28 mg/L (difference/average)
	Beaver Lake-War Eagle Creek		305[a]	H2Ozarks	War Eagle Creek	<10 measurements	--
			07049050[a]	USGS	War Eagle Creek	2.21	--
			07049160	USGS	Beaver Lake	1.01	--
110100010701	Roberts Creek-Beaver Lake	2.28	10[b]	BWD	White River	0.52	--
			Wyman[b]	AWRC	White River	0.68	--
			07048600[b]	USGS	White River	1.25	--
			13	BWD	White River	1.02	--
			23	BWD	White River	1.65	--
			WHI0052[c]	DEQ	White River	0.87	--
			07048700[c]	USGS	White River	0.92	--
110100010702	Brush Creek-Beaver Lake	2.28	300	H2Ozarks	Brush Creek	4.18	45%
110100010904	Spanker Branch-Kings River+	2.28	WHI0121	DEQ	Kings River	0.63	--
110100011106	Clabber Creek-Kings River	2.28	WHI0009A[t]	DEQ	Kings River	0.84	--
			Kings[t]	AWRC	Kings River	0.84	--
110100011306	Braswell Branch-Yocum Creek	2.28	No station	--	--	--	--

* Stations with the same superscript letters are at the same location.
+ Nitrogen was not initially identified as a concern in this HUC12 (see Table 4.3).

Table 4.15 shows a comparison of SWAT modeled total nitrogen loads from upland sources to the target upland load from Table 4.6. Modeled upland loads for six of the Category 1 sub-watersheds are greater than the management target. Load reduction targets are set to the nearest multiple of 5 that is less than or equal to the percent reduction to reach the target load. **Total nitrogen load reduction targets for the Category 1 sub-watersheds range from none to 60%.** Note that this comparison indicates a need to reduce nitrogen loads from uplands in the Holman Creek sub-watershed. So, it appears that both point source and nonpoint source nitrogen loads contribute to the high nitrogen concentrations in Holman Creek.

Table 4.15. Comparison of modeled total nitrogen loads from Category 1 sub-watersheds to target total nitrogen load of 1.10 kg/ha/year, with load reduction targets.

HUC12 ID Number	HUC12 Name	SWAT modeled nitrogen upland yield, kg/ha/year	Difference from 1.10 kg/ha/year	Percent reduction to reach 1.10 ton/ha/year (difference/modeled)	Load reduction target
110100010303	Lake Sequoyah*	0.92	-0.18	--	0
110100010404	Town Branch-West Fork White River	1.47	0.37	25%	25%
110100010606	Holman Creek	1.18	0.08	7%	5%
110100010608	Glade Creek	1.79	0.69	38%	35%
110100010610	Clifty Creek-War Eagle Creek	1.19	0.09	8%	5%
110100010611	Beaver Lake-War Eagle Creek	1.11	0.01	<1%	0
110100010701	Roberts Creek-Beaver Lake	1.57	0.47	30%	30%
110100010702	Brush Creek-Beaver Lake	1.06	-0.04	--	0
110100010904	Spanker Branch-Kings River*	0.80	-0.30	--	0
110100011106	Clabber Creek-Kings River	2.10	1.00	48%	45%
110100011306	Braswell Branch-Yocum Creek	1.92	0.82	43%	40%

* Nitrogen was not initially identified as a concern in this HUC12 (see Table 4.3).

4.6.3 Sediment

TMDL TSS load reductions apply in two of the Category 1 sub-watersheds (Table 4.16). Given that these load reductions are based on conditions in 2005, we compared recent TSS load estimates to the TMDL TSS Load Allocations (Table 4.17). There is no recent data collected from station WHI0051, but there is from WHI0052. Annual flow-normalized loads were calculated using data from this station and daily flow estimated by the SWAT model. Comparing the average estimated flow-normalized annual TSS load at WHI0052 (27.9 ton/day) to the TMDL storm flow TSS load allocation (19.3 ton/day), it appears that TSS loads may still need to be reduced by around one-third in the White River.

Table 4.16. TMDL TSS load reduction targets (FTN Associates, Ltd. 2006).

Category 1 sub-watershed HUC12 ID	Stream name	TMDL WQ Station ID	TSS Base Flow Load Allocation, tons/day	Base Flow Load Percent reduction	TSS Storm Flow Load Allocation, tons/day	Storm Flow Load Percent Reduction
110100010701	White River	WHI0052	0.606	32%	19.3	40%
110100010404	West Fork White River	WHI0051	0.111	53%	4.31	58%

Table 4.17. Comparison of 2017-2021 flow-normalized TSS load for WHI0052 to TMDL TSS Load Allocation.

WQ Station ID	TMDL TSS concentration, mg/L	TMDL TSS load, tons/day	EGRET Flow-normalized annual average concentration 2017-2021, mg/L	Flow-normalized load 2017-2021, 1e6 kg/yr (average)	Flow-normalized load, 1e6 kg/day (1e6 kg/365 days)	Flow-normalized load, ton/day (average)
WHI0052	11 - 12	0.606-19.3	9.21-11.19 (9.9)	9.36-11.03 (10.17)	0.026-0.030 (0.028)	28.6-33.2 (27.9)

Table 4.18 lists the number of base flow turbidity criterion exceedances during 2018-2022 at water quality stations in Category 1 sub-watersheds. Since there is no TMDL for turbidity in the White River upstream of Lake Sequoyah, a reduction target for turbidity in the Lake Sequoyah sub-watershed was calculated by multiplying all turbidity measurements at White River station WHI0106 in the sub-watershed from 2018-2022 by a series of reduction factors until the number of criterion exceedances in the reduced data set was fewer than 20% of the number of measurements (see Appendix J). The resulting reduction factor was 15%, i.e., if base flow turbidity levels were reduced by 15%, it is likely the turbidity base flow criterion would be met in White River upstream of Lake Sequoyah.

Table 4.19 shows a comparison of SWAT modeled sediment loads for Category 1 sub-watersheds to the management target SWAT sediment load (see Appendix H). Modeled upland loads for nine of the Category 1 sub-watersheds are greater than the management target. Load reduction targets are set to the nearest multiple of 5 that is less than or equal to the percent reduction to reach the target load. **Sediment load reduction targets for the Category 1 sub-watersheds range from 5% to 75%.** Note that the load reduction target for sub-watershed 110100010701 is not that different from the TMDL load reduction target for TSS at station WHI0052

Table 4.18. Comparison of 2018-2022 base flow turbidity measurements from Category 1 sub-watersheds to criterion (10 NTU). Yellow cells indicate stations located on turbidity impaired waterbodies. Red cells are stations where 2018-2022 data may indicate impairment.

HUC12 ID	HUC12 Name	Base Flow Turbidity Criterion, NTU	WQ station (sampled 2018-2022)[1]	Sampling Organization	Waterbody	Exceedances /measurements 2018-2022	Number of exceedances for impairment listing[2]
110100010303	Lake Sequoyah	10	5	BWD	White River	6/25	8
			WHI0106[4]	DEQ	White River	9/22	7
			22	BWD	White River	5/15	5
110100010404	Town Branch-West Fork White River	10	WHI0223	DEQ	Town Branch	0/5	--
			TB[a]	AWRC	Town Branch	12/51	14
			210[a]	H2Ozarks	Town Branch	0/2	--
			8[b]	BWD	West Fork White River	21/25	7
			WHI0100[b]	DEQ	West Fork White River	22/22	6
			WFWR	AWRC	West Fork White River	28/50	14
110100010606	Holman Creek	10	307	H2Ozarks	Holman Creek	0/1	--
			WHI0070[f]	DEQ	Holman Creek	3/22	7
			308[f]	H2Ozarks	Holman Creek	0/1	--
110100010608	Glade Creek[3]	10	302	H2Ozarks	Glade Creek	0/1	--
110100010610	Clifty Creek-War Eagle Creek[3]	10	304	H2Ozarks	Clifty Creek	0/1	--
110100010611	Beaver Lake-War Eagle Creek	10	9[h]	BWD	War Eagle Creek	5/25	8
			07049050[h]	USGS	War Eagle Creek	2/4	--
			07049160	USGS	Beaver Lake	0/12	4
110100010701	Roberts Creek-Beaver Lake	10	10[c]	BWD	White River	12/25	8
			Wyman[c]	AWRC	White River	28/51	14
			07048600[c]	USGS	White River	2/4	--
			23	BWD	White River	3/5	--
			13	BWD	White River	11/20	6
			WHI0052[e]	DEQ	White River	18/22	7
			07048700[e]	USGS	White River	7/12	4

Table 4.18. Comparison of 2018-2022 base flow turbidity measurements from Category 1 sub-watersheds to criterion (10 NTU). Yellow cells indicate stations located on turbidity impaired waterbodies. Red cells are stations where 2018-2022 data may indicate impairment (continued).

HUC12 ID	HUC12 Name	Base Flow Turbidity Criterion, NTU	WQ station (sampled 2018-2022)[1]	Sampling Organization	Waterbody	Exceedances /measurements 2018-2022	Number of exceedances for impairment listing[2]
110100010702	Brush Creek-Beaver Lake	10	300	H2Ozarks	Brush Creek	0/1	--
110100010904	Spanker Branch-Kings River	10	WHI0121	DEQ	Kings River	5/22	7
110100011106	Clabber Creek-Kings River	10	Kings[i]	AWRC	Kings River	1/16	5
			WHI0009A[i]	DEQ	Kings River	2/20	6
110100011306	Braswell Branch-Yocum Creek[3]	10	None	--	--	--	--

1 Stations with the same superscript letters are at the same location. Yellow cells are stations on turbidity impaired assessment units.
2 Minimum number of samples for evaluation is 10 (DEQ 2021c). Orange cells are stations where the criterion is exceeded.
3 Sediment/turbidity was not initially identified as a concern in this HUC12 (see Table 4.3).
4 Station WHI0106 is located upstream of the turbidity impaired White River assessment unit.

Table 4.19. Comparison of modeled sediment loads from Category 1 sub-watersheds to target sediment load of 0.07 ton/ha/year, with load reduction targets.

HUC12 ID Number	HUC12 Name	SWAT modeled sediment upland yield, ton/ha/year	Difference from 0.07 ton/ha/year	Percent reduction to reach 0.07 ton/ha/year (difference/modeled)	Load reduction target
110100010303	Lake Sequoyah	0.08	0.01	12%	10%
110100010404	Town Branch-West Fork White River	0.21	0.14	67%	65%
110100010606	Holman Creek	0.19	0.12	63%	60%
110100010608	Glade Creek	0.09	0.02	22%	20%
110100010610	Clifty Creek-War Eagle Creek	0.09	0.02	22%	20%
110100010611	Beaver Lake-War Eagle Creek	0.14	0.07	50%	50%
110100010701	Roberts Creek-Beaver Lake	0.20	0.13	65%	65%
110100010702	Brush Creek-Beaver Lake	0.05	-0.02	--	0
110100010904	Spanker Branch-Kings River	0.04	-0.03	--	0
110100011106	Clabber Creek-Kings River	0.04	-0.03	--	0
110100011306	Braswell Branch-Yocum Creek	0.06	-0.01	--	0

4.6.4 TDS

Table 4.20 lists the number of TDS criterion exceedances 2018-2022 at water quality stations in Category 1 sub-watersheds that are on stream segments identified as impaired by high TDS concentrations in the 2018 303(d) list. Data used to assess Town Branch is not included in any of the public databases used for this plan. Data from both West Fork White River and Kings River have exceedances just under the limit for listing as impaired. The information in Table 4.21 suggests that the TDS criterion is now met in the West Fork White River and the Kings River. No trend analysis was conducted at station WHI0100 and trend analysis at station WHI0009A did not identify a statistically significant trend in TDS (see Section 3.1.6). An examination of historical TDS measurements at these monitoring stations revealed that the frequency of exceedances of the TDS criterion during DEQ five-year water quality evaluation intervals has decreased since 2012-2017 (the evaluation period for the 2018 303(d) list) (Appendix K). The reason for this change in water quality is not known. As a result, while recent water quality data does not allow calculation of specific load reduction targets for TDS for this plan, additional information is needed to confirm the TDS criterion continues to be met. If TDS is from nonpoint sources, management of other nonpoint source pollutants has a good chance of also reducing TDS loads.

Table 4.20. Comparison of 2018-2022 TDS measurements from Category 1 sub-watersheds to criteria.

HUC12 ID	HUC12 Name	TDS Criteria, mg/L	WQ station (sampled 2018-2022)[1]	Sampling Organization	Waterbody	Exceedances /measurements 2018-2022	Number of exceedances for listing[2]
110100010303	Lake Sequoyah[3]	160	WHI0106	DEQ	White River	0/51	17
110100010404	Town Branch-West Fork White River	150	WHI0223	DEQ	Town Branch	0/12	5
			07048495[a]	USGS	Town Branch	0/14	6
			210[a]	H2Ozarks	Town Branch	0/24	9
			WHI0100	DEQ	West Fork White River	15/53	17
110100010606	Holman Creek[4]	621	307	H2Ozarks	Holman Creek	0/14	6
			WHI0070[f]	DEQ	Holman Creek	1/53	17
			308[f]	H2Ozarks	Holman Creek	0/14	6
110100010608	Glade Creek[3]	500	302	H2Ozarks	Glade Creek	0/13	5
110100010610	Clifty Creek-War Eagle Creek[3]	500	304	H2Ozarks	Clifty Creek	0/15	6
110100010611	Beaver Lake-War Eagle Creek[3]	500	9[h]	BWD	War Eagle Creek	0/9	--
			07049050[h]	USGS	War Eagle Creek	0/12	5
		160	07049160	USGS	Beaver Lake	0/21	8
110100010701	Roberts Creek-Beaver Lake[3]	160	07048600	USGS	White River	1/14	6
			WHI0052[e]	DEQ	White River	2/53	17
			07048700[e]	USGS	White River	3/21	8
110100010702	Brush Creek-Beaver Lake[3]	500	300	H2Ozarks	Brush Creek	0/13	5
110100010904	Spanker Branch-Kings River[3]	150	WHI0121	DEQ	Kings River	1/52	17
110100011106	Clabber Creek-Kings River	150	WHI0009A	DEQ	Kings River	15/49	16
110100011306	Braswell Branch-Yocum Creek[3]	500	None	--	--	--	--

1 Stations with the same superscript letters are at the same location. Yellow cells are stations on TDS impaired assessment units, per 2018 and 2020 303(d) lists.
2 (DEQ 2021c), minimum number of samples for evaluation is 10.
3 TDS was not initially identified as a concern in this HUC12 because no TDS impaired assessment units (see Table 4.3).
4 The TDS impaired waterbody in this HUC12 is Town Branch. The data used to identify the Town Branch impairment is not included in any of the public databases used for this plan.

4.6.5 Sulfate

Table 4.21 lists the number of sulfate criterion exceedances during 2018-2022 at water quality stations in Category 1 sub-watersheds that are on stream segments identified as impaired by high sulfate concentrations in the 2018 303(d) list. Sulfate measurements from the White River in sub-watershed 110100010701 2018-2022 do not appear to exceed the criterion enough for the stream to be listed as impaired for sulfate. This segment of the White River is delisted for sulfate on the draft 2020 and 2022 303(d) lists, which matches the results in Table 4.22. As shown in Table 3.6, a statistically significant decreasing trend in sulfate concentration was identified at station WHI0052. No trend in sulfate was identified at Wyman (Grantz and Haggard 2023a). So, the Roberts Creek-Beaver Lake sub-watershed will not be managed for sulfate in this plan.

West Fork White River exceeds the sulfate standard downstream of the confluence with Town Branch and, possibly, upstream of Town Branch (see Appendix C). A reduction target for sulfate in the Town Branch-West Fork White River sub-watershed was calculated by multiplying all sulfate measurements at West Fork White River stations in the sub-watershed from 2018-2022 by a series of reduction factors until the number of criterion exceedances in the reduced data set was fewer than the minimum number of exceedances the triggers an impairment listing (see Appendix J). Based on the results of this analysis the **sulfate target reduction factor for the Town Branch-West Fork White River sub-watershed is set to 40%**, i.e., if sulfate concentrations were reduced by 40%, it is likely the sulfate criterion would be met in West Fork White River. Note that sulfate sources upstream of this sub-watershed may contribute to high West Fork White River sulfate concentrations in the Town Branch-West Fork White River sub-watershed.

Table 4.21. Comparison of 2018-2022 sulfate measurements from Category 1 sub-watersheds to criteria.

HUC12 ID	HUC12 Name	Sulfate Criteria, mg/L	WQ station (sampled 2018-2022)[1]	Sampling Organization	Waterbody	Exceedances /measured 2018-2022	Number of exceedances for listing[2]
110100010303	Lake Sequoyah[3]	20	WHI0106	DEQ	White River	9/22	7
110100010404	Town Branch-West Fork White River	250	WHI0223	DEQ	Town Branch	0/12	5
			TB[a]	AWRC	Town Branch	0/130	31
			07048495[a]	USGS	Town Branch	0/24	9
		20	WHI0100	DEQ	West Fork White River	31/53	17
			WFWR	AWRC	West Fork White River	69/129	32
110100010606	Holman Creek[3]	48	WHI0070	DEQ	Holman Creek	6/53	17
110100010608	Glade Creek[3]	250	None	--	--	--	--
110100010610	Clifty Creek-War Eagle Creek[3]	250	None	--	--	--	--
110100010611	Beaver Lake-War Eagle Creek[3]	250	07049050	USGS	War Eagle Creek	0/12	5
			07049160	USGS	Beaver Lake	0/21	8
110100010701	Roberts Creek-Beaver Lake	20	Wyman[c]	AWRC	White River	14/128	32
			07048600[c]	USGS	White River	1/14	6
			WHI0052[e]	DEQ	White River	10/53	17
			07048700[e]	USGS	White River	6/21	8
110100010702	Brush Creek-Beaver Lake	250	None	--	--	--	--
110100010904	Spanker Branch-Kings River[3]	20	WHI0121	DEQ	Kings River	0/52	17
110100011106	Clabber Creek-Kings River[3]	20	Kings[i]	AWRC	Kings River	0/36	12
			WHI0009A[i]	DEQ	Kings River	0/49	16
110100011306	Braswell Branch-Yocum Creek[3]	250	None	--	--	--	--

1 Stations with the same superscript letters are at the same location. Yellow cells are stations on sulfate impaired assessment units. 2 (DEQ 2021c), minimum number of samples for evaluation is 10. Orange cells are stations that may exceed the criterion. 3 No sulfate impaired assessment units in this HUC12, so sulfate not considered a concern.

4.6.6 *E. coli*

Three of the Category 1 sub-watersheds encompass segments of Beaver Lake listed as impaired because of high levels of *E. coli*. Based on the 2015 NRCS natural resources assessment, pathogens have been identified as a possible issue in four additional Category 1 sub-watersheds (see Table 4.3).

The DEQ approach for evaluating attainment of the *E. coli* Primary Contact criterion uses a data set of at least eight measurements collected between May 1 and September 30 during a single year (DEQ 2021c). None of the *E. coli* data collected from the Category 1 sub-watersheds meet the DEQ data requirements for evaluating attainment of pathogen water quality criteria. So, no load reduction targets can be set for *E. coli* in this plan. More information is needed. However, there is information available for Category 1 sub-watersheds that identify likely sources of *E. coli* and suggest appropriate conservation practices that would reduce *E. coli* inputs to surface and groundwater. So, even though this plan does not set load reduction targets for *E. coli*, recommendations for management of *E. coli* sources and loads are included in this plan, for Category 1 sub-watersheds with *E. coli* impaired waterbodies, and Category 1 sub-watersheds identified by NRCS as having a high risk of pathogen inputs from manure.

4.6.7 pH

The only pH impairment within a Category 1 sub-watershed is for Beaver Lake in Beaver Lake-War Eagle Creek (110100010611). Data from USGS station 07049160 was used to list Beaver Lake as impaired by high pH levels for 2018. However, this impairment is not included in the 2020 303(d) list. Measurements from 2018-2022 range from 6.8 standard units to 9.0 standard units, which is within the water quality standards. So, no load reductions related to pH are required in this plan. However, reductions in upstream nutrient loads may help this area of Beaver Lake continue to meet pH standards.

4.6.8 Temperature

Temperatures at station WHI0100 on West Fork White River in 110100010404 measured 2018-2022 are all lower than 29 deg C. Thus, this impairment has already been addressed.

However, improving riparian cover, i.e., decreasing agriculture and development within 50 m of streams and increasing forest, will help water temperatures in the West Fork White River remain within standards. Much of the work ongoing in the West Fork White River watershed to address streambank erosion involves improving riparian cover and will protect or improve water temperatures in the river.

4.6.9 Dissolved Oxygen

As noted in Section 4.5.8, we were not able to identify a relationship between nutrients and DO. Since the cause of low DO impaired conditions during the critical season is unknown for this watershed (Table 3.4), it is not possible at this time to identify load reductions that will address the critical season DO impairments in Category 1 sub-watersheds. More information is needed. In the meantime, conservation practices that address other pollutants of concern in the Category 1 sub-watersheds with DO impaired waterbodies also have the potential to improve DO conditions in the impaired waterbodies.

4.6.9.1 Summary

Table 4.22 lists the Category 1 sub-watersheds and target pollutants, with the applicable load reduction targets for this plan. Note that not all target pollutants have been identified as a concern in all the Category 1 sub-watersheds.

Table 4.22. Summary of load reduction targets for Upper White River Category 1 sub-watersheds. See notes for explanation of symbols and abbreviations.

Category 1 Sub-watersheds		Load Reduction Targets								
HUC12 ID Number	**HUC12 Name**	**DO**	***E. coli***	**pH**	**Sulfate**	**TDS**	**Temperature**	**Sediment**	**Total Nitrogen**	**Total Phosphorus**
110100010303	Lake Sequoyah	N	N	N	N	N	N	10%	N	40%
110100010404	Town Branch-West Fork White River	D	N	N	40%	*	*	60%[a]	25%	50%
110100010606	Holman Creek	N	D	N	N	N	N	60%	35%[b]	80%[b,d]
110100010608	Glade Creek	N	D	N	N	N	N	20%	35%	0[c]
110100010610	Clifty Creek-War Eagle Creek	N	D	N	N	N	N	20%	40%[b]	50%
110100010611	Beaver Lake-War Eagle Creek	D	D	*	N	N	N	50%	0*	70%
110100010701	Roberts Creek-Beaver Lake	D	D	N	*	N	N	50%[a]	30%	25%[b]
110100010702	Brush Creek-Beaver Lake	N	D	N	N	N	N	D	45%[b]	0[c]
110100010904	Spanker Branch-Kings River	D	D	N	N	N	N	D	N	N
110100011106	Clabber Creek-Kings River	N	D	N	N	*	N	*	45%	55%
110100011306	Braswell Branch-Yocum Creek	N	D	N	N	N	N	N	40%	15%

N = This pollutant has not been identified as a nonpoint source concern in this sub-watershed (see Table 4.3).

D = There is not enough data/information to set load reduction targets for this pollutant, but management recommendations for other pollutants will reduce this pollutant.

* = Data from 2018-2022 indicate that the target may now be met, but management recommendations for other pollutants are expected to also reduce this pollutant.

a = set based on TMDL and SWAT load reductions

b = set based on percent reduction to reach ecoregion nutrient target concentration for wadable streams (Tables 4.13, 4.15)

c = Although NRCS classified this sub-watershed as having a high risk of excess nutrients, phosphorus data from 2018-2022 (Table 4.13) and the SWAT model results (Table 4.14) do not indicate a need to reduce sediment loads in this sub-watershed. Thus, the load reduction target is set to zero.

d = SWAT model results suggest that point sources and non-upland nonpoint sources are the primary source of excess phosphorus. Addressing upland nonpoint sediment and nitrogen will also reduce nonpoint phosphorus.

4.7 Pollutant Source Assessment for Category 1 Sub-watersheds

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

4.7.1 Lake Sequoyah

Erosion, sediment, turbidity, and phosphorus are the primary water quality concerns in this sub-watershed. A portion of the White River in this HUC12 is classified as impaired by high turbidity (DEQ 2020). Trend analysis of data from White River station WHI0106 identified a statistically significant increasing trend in turbidity, though no trend in turbidity was observed in data from BWD station 5 (Appendix D). SWAT model results indicate that estimated instream sediment and phosphorus yields from this HUC12 are in the top 10% for the watershed (FTN Associates, Ltd. 2024), and upland yields of phosphorus are also in the top 10%, while upland yields of sediment and nitrogen are in the midrange for the watershed (Appendix L). A 40% reduction in total phosphorus load is recommended (Table 4.23). The averages of White River total phosphorus concentrations measured at BWD water quality stations in this HUC12 are greater than the ecoregion target concentrations for wadable streams (Table 4.13). A portion of the White River at the upstream end of this HUC12 is classified as an Ecologically Sensitive Waterbody to protect the longnose darter, and streams in this HUC12 may have populations of threatened Rabbitsfoot mussel (Arkansas Pollution Control and Ecology Commission 2022, USFWS 2023). Sedimentation is a threat to both the longnose darter and the Rabbitsfoot mussel. A 10% reduction in sediment load from upland sources is recommended for this HUC12 (see Section 4.6.3).

4.7.1.1 Nonpoint Pollutant Sources Recommended for Management

SWAT model results suggest that pasture is the source of 29% of the upland sediment load in this HUC12, and forest land accounts for two-thirds (Appendix L). In 2019 there were around 7,780 acres of pasture and hayland in this watershed, with around 1,400 acres of pasture within 50 meters of a stream (Dewitz and USGS 2021, Hill et al. 2016). NRCS assessed risk of gully and sheet/rill/wind erosion in this HUC12 is on the low end for the Upper White River

watershed, and in the middle range for the state. Risk of streambank erosion is in the midrange for the watershed and in the upper middle range for the state (Appendix M, NRCS 2016). WCRC has assessed at least one site in this HUC12 for streambank erosion (RTI International 2023). This HUC12 has around 26 miles of unpaved roads and 85 places where roads cross streams, which is the most likely place for eroded material from roads to enter surface waters (Center for Advanced Spatial Techologies 2006, Southeast Aquatic Resources Partnership 2023). Washington County road crew certification in Environmentally Sensitive Maintenance of unpaved roads through the Arkansas Unpaved Roads Program is up to date (K. McGaughey, NRD, personal communication 5/20/2024). A map of priority areas for unpaved road best management practice(s) (BMPs) that includes this sub-watershed is included in Appendix C (Figure C-2) of the 2023 Beaver Lake Watershed Protection Strategy (RTI International 2023).

SWAT model results suggest that pasture is the source of 57% of the upland phosphorus load in this HUC12 (Appendix L). Possible non-upland sources of phosphorus in this HUC12 include streambank erosion, legacy phosphorus in stream and reservoir sediment, cattle in streams, and failing septic systems. Based on reported cattle inventories and acres of pasture reported in Washington County for 2022, we estimate there could be around 5,800 cows pastured in this HUC12, with potentially over 1,000 cows within 50 meters of a stream (USDA National Agricultural Statistics Service 2023).[3] Poultry litter was applied to pasture in this HUC12 in 2019, and there were 20 active poultry houses in this HUC12 that year (T. Wentz, NRD, personal communication, 5/12/2022). Available information suggests that there are 370 septic systems active in this HUC12 (Appendix F). Failing septic systems are a potential source of nutrients to surface water, particularly when the systems are close to streams. Figure 4.5 shows locations of potential nonpoint pollution sources in the Lake Sequoyah sub-watershed.

[3] Cow+calf inventories were divided by the reported acres of permanent pasture. This value of average number of cows+calves per acre of pasture was multiplied by the acreage of pasture and hayland for this HUC12 from the 2019 NLCD to get an estimate of the number of cows and calves in the HUC12. An estimate of cows in riparian areas was calculated by multiplying the average number of cows+calves per acer of pasture, by the acres of pasture within 50 meters of a stream reported in EPA StreamCat.

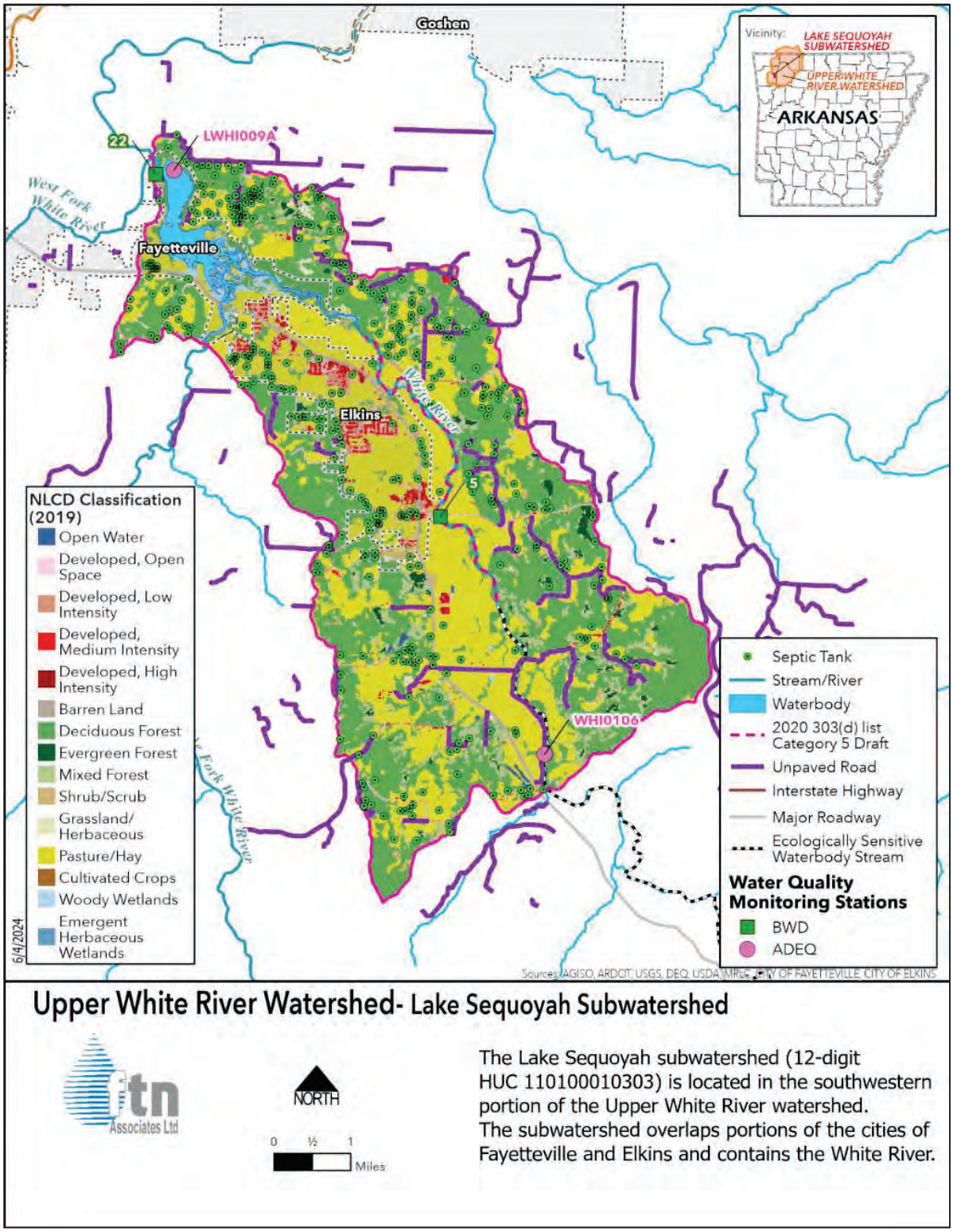


Figure 4.5. Nonpoint pollutant sources in Lake Sequoyah sub-watershed.

4.7.1.2 Plan Management Focus

The proposed focus for this sub-watershed is reduction of sediment from pastures, unpaved roads, and streambank erosion to improve or protect habitat for the longnose darter and Rabbitsfoot mussel, and to protect Lake Sequoyah water quality and storage capacity. Reduction of phosphorus from pastures, streambank erosion, cattle, and septic systems is also a focus. Improved management of riparian areas will contribute to these goals.

4.7.2 Town Branch-West Fork White River

Analysis and data review identified the following water quality issues in the Town Branch-West Fork White River HUC12 that may be addressed through nonpoint source pollution management; turbidity, erosion, sediment load, nitrogen load, phosphorus load, TDS, sulfate, and low DO. Streams in this sub-watershed are potential habitat for Rabbitsfoot mussel and Neosho Mucket (USFWS 2023).

The West Fork White River within this sub-watershed has been classified as water quality impaired by high levels of turbidity, TDS, sulfate, and water temperature; and low DO levels during the critical season (i.e., May-September). The West Fork White River within this sub-watershed is also subject to a TMDL for turbidity and TSS (FTN Associates, Ltd. 2006). Some of the highest median turbidity and TSS values measured in the watershed 2018-2022 were from stations in the West Fork White River (Appendix C). Sedimentation is a threat to Rabbitsfoot mussel and Neosho Mucket.

SWAT model results indicate that nutrient and sediment loads from both upland and instream sources in this HUC12 are in the top 10 for this watershed (FTN Associates, Ltd 2024; Appendix G, L). The averages of total phosphorus concentrations measured by AWRC, BWD, and USGS 2018-2022 are greater than the ecoregion target concentration for wadable streams (Table 4.13). High nutrient loads have the potential to contribute to low DO conditions in West Fork White River. Load reduction targets for upland nitrogen, phosphorus, and sediment loads are established in Section 4.6 and summarized in Table 4.23. Trend analysis identified decreasing trends in nitrate, soluble reactive phosphorus, and total phosphorus concentrations at the WFWR station (sampled by AWRC) (Appendix D).

Median total nitrogen and TDS concentrations in Town Branch from 2018-2022 are significantly higher than concentrations in the West Fork White River in this HUC12. The highest median sulfate concentrations in Town Branch from 2018-2022 are significantly higher than the median concentrations at all other sampled stations (Appendix C). Although *E. coli* have not been identified as a concern for this sub-watershed, and *E. coli* measurements have not been collected recently in this sub-watershed, given the large developed area in this sub-watershed, evaluation of attainment of *E. coli* criteria in Town Branch and West Fork White River seems warranted (USGS 2021, DEQ 2021a).

4.7.2.1 Nonpoint Sources Recommended for Management

No source/cause for the low DO conditions in West Fork White River is identified by DEQ. Surface erosion is identified as the source of turbidity causing impairment of Town Branch (DEQ 2020).

Streambank erosion has been identified by researchers as a significant source of sediment and nutrients in the West Fork White River (Formica et al. 2004, Formica and Van Eps 2010). Legacy phosphorus in sediments of the West Fork White River and Town Branch are another potential nonpoint source in this HUC12. Nine to eleven eroding streambanks of the West Fork White River within this sub-watershed have been identified as priorities for restoration to reduce sediment loads to Beaver Lake. Four streambanks of Town Branch, and two streambanks of Cato Springs Branch have also been identified as priorities for restoration (RTI International 2023). Hydrologic alteration resulting from increased impervious area contributes to stream instability and bank erosion. This HUC12 has the largest impervious area of any HUC12 in the Upper White River watershed; 30% of the HUC12 was classified as impervious in 2019 (Dewitz and USGS 2021).

Erosion associated with unpaved roads has also been identified as a source of sediment in the West Fork White River. A 2004 study of unpaved roads in the West Fork White River watershed estimated that the average sediment export coefficient for unpaved roads in this watershed was 35.9 tons/mile/year (DEQ 2004). The Town Branch-West Fork White River HUC12 has around 14 miles of unpaved roads mapped (Center for Advanced Spatial

Techologies 2006). SARP identified 174 road crossings in this HUC12, the highest number in the Upper White River watershed, one of which is classified as a barrier to aquatic species (Southeast Aquatic Resources Partnership 2023). This number of crossings is not surprising given the amount of development. Washington County road crew certification in Environmentally Sensitive Maintenance of unpaved roads through the Arkansas Unpaved Roads Program is up to date (K. McGaughey, NRD, personal communication 5/20/2024).

SWAT model results indicate that runoff from developed areas in this HUC12 contributes 39% of nitrogen, 35% of phosphorus, and 34% of sediment (Appendix L). A portion of the city of Fayetteville is in this HUC12 and in 2019 there were 6,200 acres of developed land in this sub-watershed, with most classified as medium or lower density (Dewitz and USGS 2021). In 2019 there were around 340 acres of developed land in this HUC12 located within 50 meters of a stream (Hill et al. 2016). Available information suggests that there are over 345 septic systems active in this HUC12 (Appendix F). Failing septic systems are a potential source of nutrients to surface water, particularly when the systems are close to streams. Although we were not able to identify a relationship between nutrients and DO levels in the Upper White River watershed (see Section 4.6.1), excessive nutrients can contribute to low DO conditions.

Developed areas, agricultural land (pasture), and streambed geology are potential nonpoint sources for TDS and sulfate. Town Branch, which runs through Fayetteville, has significantly higher levels of TDS and sulfate than the West Fork White River and most other streams in the Upper White River watershed (Appendix C). Water quality standards allow higher concentrations of these minerals in Town Branch than in the West Fork White River (Arkansas Pollution Control and Ecology Commission 2022). It may be that nonpoint source inputs of sulfate and TDS to the West Fork White River have reduced its capacity to assimilate TDS and sulfate loads from Town Branch. Scott and Haggard (2019) have suggested that underlying geology contributes to high sulfate concentrations in downstream sections of the West Fork White River, and that agricultural land uses may influence mineral concentrations in streams, particularly sulfate and chloride.

SWAT model results indicate that runoff from pasture contributes 50% of the upland sediment, 58% of upland nitrogen, and 60% of upland phosphorus loads in this HUC12

(Appendix L). In 2019 there were around 4,300 acres of pasture in this sub-watershed with around 24 acres within 50 meters of a stream. Records of active poultry houses or poultry litter being applied to pastures in this HUC12 in 2019 were not available (T. Wentz, NRD, personal communication, 5/12/2022). So, nutrient loads from pastures in this HUC12 are more likely to be from livestock and commercial fertilizer applied to pastures. Based on reported cattle inventories and acres of pasture reported in Washington County for 2022, we estimate there could be around 2,800 cows pastured in this HUC12 (USDA National Agricultural Statistics Service 2023).[2]

Figure 4.6 shows locations of nonpoint sources of pollutants of concern in the Town Branch-West Fork White River sub-watershed.

4.7.2.2 Plan Management Focus

The suggested management focus for this sub-watershed includes:

- Improved understanding of causes of low DO conditions and high TDS and sulfate levels in the West Fork White River,
- Evaluation of attainment of *E. coli* criteria,
- Improved management of riparian areas,
- Reduction of sediment inputs from streambanks, unpaved roads, pasture, and developed areas
- Reduction of nutrients from pasture, streambank erosion, developed areas, and failing septic systems, especially for properties located close to streams, and
- Improved understanding of the extent of local populations of Rabbitsfoot mussel and Neosho mucket, and the potential for water quality impacts to these mussels, is suggested.

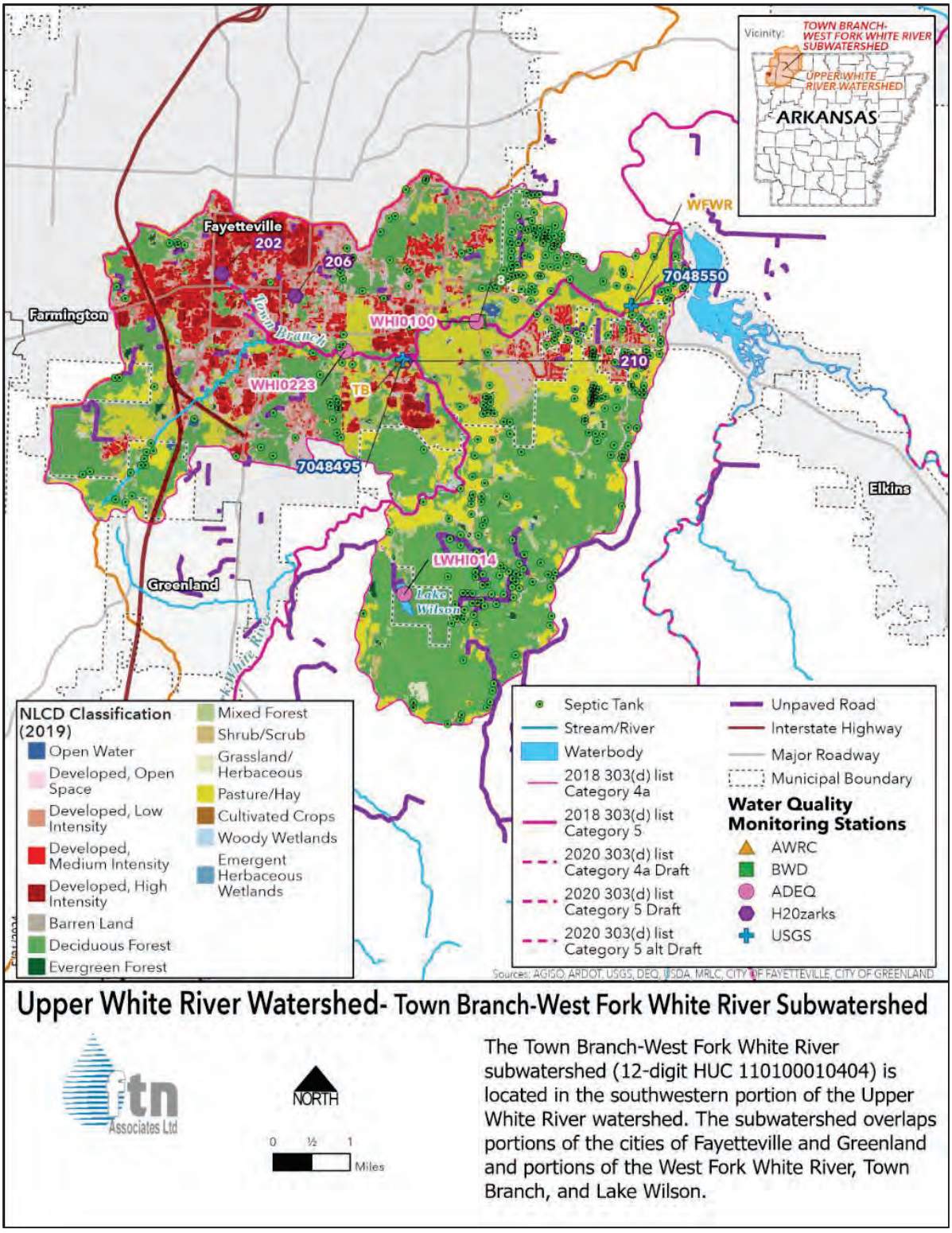


Figure 4.6. Nonpoint pollutant sources in Town Branch-West Fork White River sub-watershed.

4.7.3 Holman Creek

Analysis and data review identified the following water quality issues in the Holman Creek HUC12 that may be addressed through nonpoint source pollution management; turbidity, erosion, sediment load, nitrogen load, phosphorus load, and pathogens. The nitrate and TDS water quality impairments of Town Branch and Holman Creek are attributed to the influence of the Huntsville WWTP so they will not be addressed through nonpoint source management under this plan (DEQ 2021). Streams in this sub-watershed are potential habitat for Rabbitsfoot mussel and the NRCS State Resource Assessment of 2015 identified this HUC12 as having higher than average risk for habitat degradation. So, water quality impacts on listed aquatic species is also a concern (USFWS 2023).

The NRCS State Resource Assessment of 2015 identified this HUC12 as also having higher than average risk for excessive nutrients, sediment, and pathogens (NRCS 2016). Results from the SWAT model indicate that predicted nitrogen, phosphorus, and sediment yields from uplands in this HUC12 are on the high end (Appendix L). In addition, modeled instream nitrogen yields are in the top 20% (FTN Associates, Ltd. 2024). The median total nitrogen concentrations for 2018-2022 at the Holman Creek stations downstream of Town Branch (WHI0070 and 308) are significantly higher than median concentrations at all but the farthest downstream War Eagle Creek stations, but are lower than median concentrations in other War Eagle Creek tributaries; Clear Creek, Clifty Creek, and Glade Creek, which are some of the highest in the watershed (Appendix C). The average Holman Creek total nitrogen concentrations are over 35% higher than the ecoregion target total nitrogen concentration for wadable streams (see Table 4.15). Some of the highest median total phosphorus concentrations for 2018-2022 were measured in Holman Creek downstream of Town Branch. The average Holman Creek total phosphorus concentration is over 80% higher than the ecoregion target total phosphorus concentration for wadable streams (see Table 4.13). Load reduction targets for upland sediment and nitrogen loads are established for this HUC12 in Section 4.6 and summarized in Table 4.23.

The median of DO concentrations from 2018-2022 measured at the DEQ Holman Creek station (WHI0070) is the highest in the Upper White River watershed, and trend analysis identified an increasing trend in DO concentrations at the Holman Creek station (Appendix C,

D). However, given the high nutrient loads and high incidence of DO supersaturation, the high DO concentrations may indicate nutrient-induced high primary productivity, that could eventually lead to detrimental water quality impacts (Appendix C).

4.7.3.1 Nonpoint Sources Recommended for Management

SWAT model results suggest that 73% of sediment is from pasture and 8% is from developed areas. In 2019 there were around 6,900 acres of pasture in the sub-watershed, with around 1,100 acres within 50 meters of a stream. NRCS risks of gully and sheet/rill/wind erosion are in the midrange for the Upper White River watershed.

The risk of excessive streambank erosion assigned to this HUC12 in the NRCS 2015 State Resource Assessment is in the top 20% for the Upper White River watershed and in the upper 30% or so for the state. Streambank erosion can contribute to nutrient loads and sediment load. Risks of gully erosion and sheet/rill/wind erosion are around average for the watershed, but on the high end for the state as a whole (Appendix M, NRCS 2016). SWAT output also suggests that streambank erosion is on the high end for this watershed (FTN Associates, Ltd. 2024). Hydrologic alteration resulting from increased impervious area contributes to stream instability and bank erosion.

Unpaved roads are another source of sediment in this HUC12. This HUC12 has 38 miles of unpaved roads. SARP has identified 76 road crossings in this HUC12 (Center for Advanced Spatial Techologies 2006, Southeast Aquatic Resources Partnership 2023). A map of priority areas for unpaved road BMPs that includes this sub-watershed is included in Appendix C (Figure C-4) of the 2023 Beaver Lake Watershed Protection Strategy (RTI International 2023). Madison County road crew certification in Environmentally Sensitive Maintenance of unpaved roads through the Arkansas Unpaved Roads Program is not up to date (K. McGaughey, NRD, personal communication 5/20/2024).

While the Huntsville WWTP discharge contributes to high nutrient concentrations in Holman Creek downstream of Town Branch, the SWAT modeling and other analyses indicates that nonpoint sources also contribute to high nitrogen concentrations in this stream. The SWAT model results indicate no need to reduce upland phosphorus loads, however non-upland nonpoint

sources, including failing septic systems, stream sediment (e.g., legacy phosphorus), and streambank erosion, may also contribute to high phosphorus (and nitrogen) concentrations in Holman Creek downstream of Town Branch.

Potential nonpoint sources of nitrogen and pathogens in this HUC12 include livestock, runoff from pastures and developed areas, pets and wildlife, and failing septic systems. SWAT model results suggest that 81% of upland nitrogen load in this HUC12 is lost from pasture and 14% is from developed areas (Appendix L). Based on information provided by NRD, in 2019 poultry litter was applied to pasture in this HUC12. The number of active poultry houses in this HUC12 is unknown (T. Wentz, NRD, personal communication, 5/12/2022). Based on reported cattle inventories and acres of pasture reported in Madison County for 2022, we estimate there could be around 4,500 cows pastured in this HUC12 (USDA National Agricultural Statistics Service 2023).[2] Most of the town of Huntsville is in this HUC12, thus in 2019 there were over 2,000 acres of developed land in this HUC12 with 68 acres of developed land within 50 meters of a stream (Dewitz and USGS 2021, Hill et al. 2016). Available information indicates that there are around 160 active septic systems in this watershed (Appendix F). Figure 4.7 shows locations of nonpoint pollution sources in the Holman Creek sub-watershed.

4.7.3.2 Plan Management Focus

The suggested focus for this sub-watershed is control of pathogens and nitrogen in runoff from developed areas and pastures, and remediation of failing septic systems. Controlling sediment from streambank erosion, developed areas, unpaved roads, and pasture is also a focus. Given the NRCS evaluated risk of excess pathogens, evaluation of attainment of *E. coli* criterion in Town Branch and Holman Creek is also recommended.

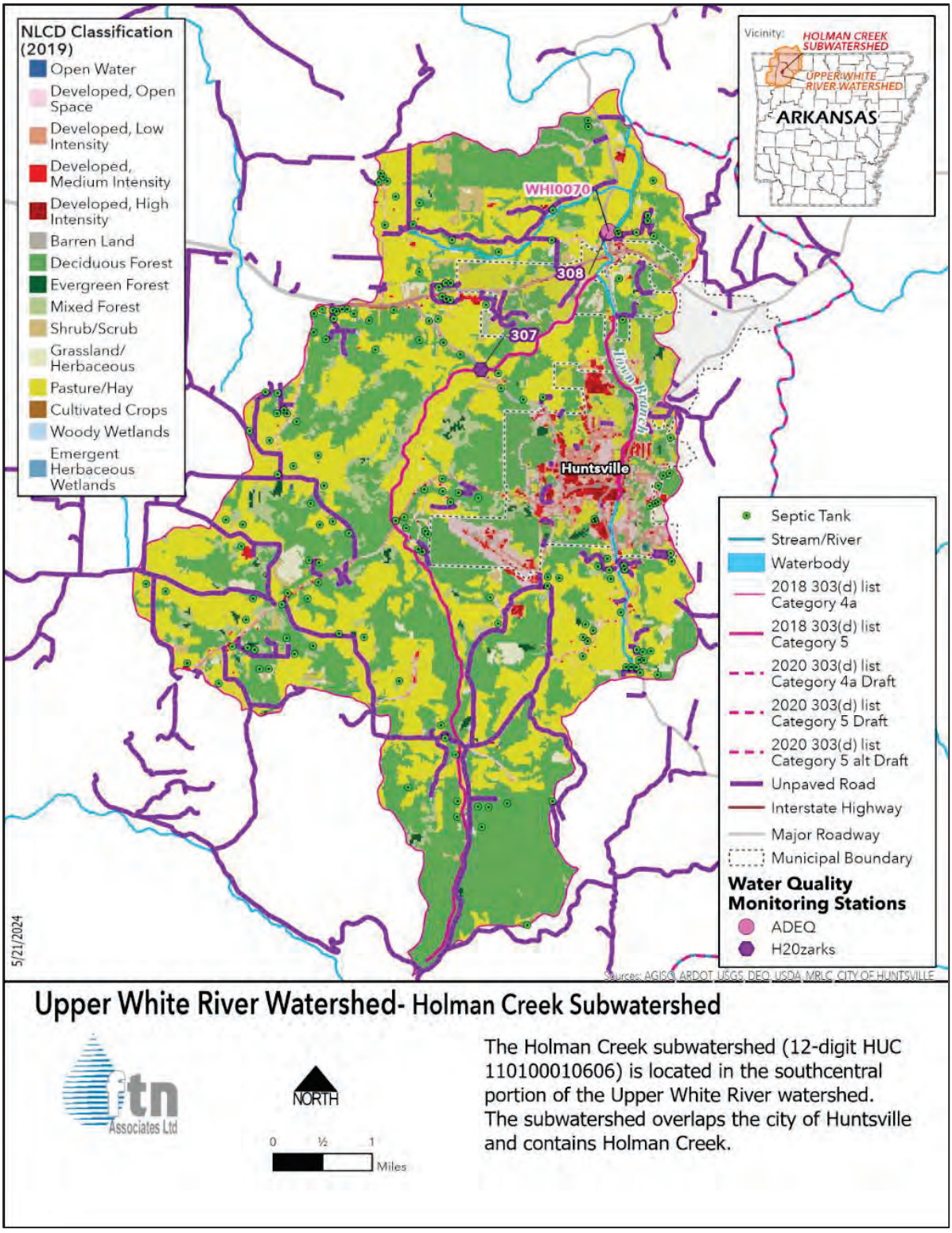


Figure 4.7. Nonpoint pollution sources in the Holman Creek sub-watershed.

4.7.4 Glade Creek

Analysis and data review identified the following water quality issues in the Glade Creek HUC12 that may be addressed through nonpoint source pollution management; nitrogen loads, pathogens, and sediment loads. Water quality issues are of concern in part because of the potential to impact threatened and endangered species that may be present in the HUC12. The endangered species that may be present in this HUC12 are Indiana Bat, Gray Bat, and Ozark Big-eared Bat. The threatened species in this HUC12 are Rabbitsfoot mussel and Northern Long-Eared Bat (USFWS 2023).

The NRCS State Resource Assessment of 2015 identified this HUC12 as having higher than average risk for excessive nutrients and pathogens (NRCS 2016). Results from the SWAT model indicate that predicted instream nitrogen yield in this HUC12 is the highest in the watershed and nitrogen yield from uplands is in the top 10% for the watershed (Appendix G, L; FTN Associates, Ltd. 2024). The average Glade Creek total nitrogen concentration is over 40% higher than the ecoregion target total nitrogen concentration for wadable streams (see Table 4.15). The median total nitrogen concentration for 2018-2022 at the H2Ozarks Glade Creek station (302) is similar to median concentrations in other War Eagle Creek tributaries, e.g., Clear Creek, Clifty Creek, which are some of the highest in the watershed (Appendix C). No statistical trend analysis was performed on the H2Ozarks data from Glade Creek, however, total nitrogen concentrations appear to be increasing at this station (Figure 4.8). Load reduction targets for upland nitrogen and phosphorus loads are established for this HUC12 in Section 4.6 and summarized in Table 4.23. Available water quality data and SWAT model results indicate reductions in phosphorus loads are not needed at this time (see Section 4.6.1).

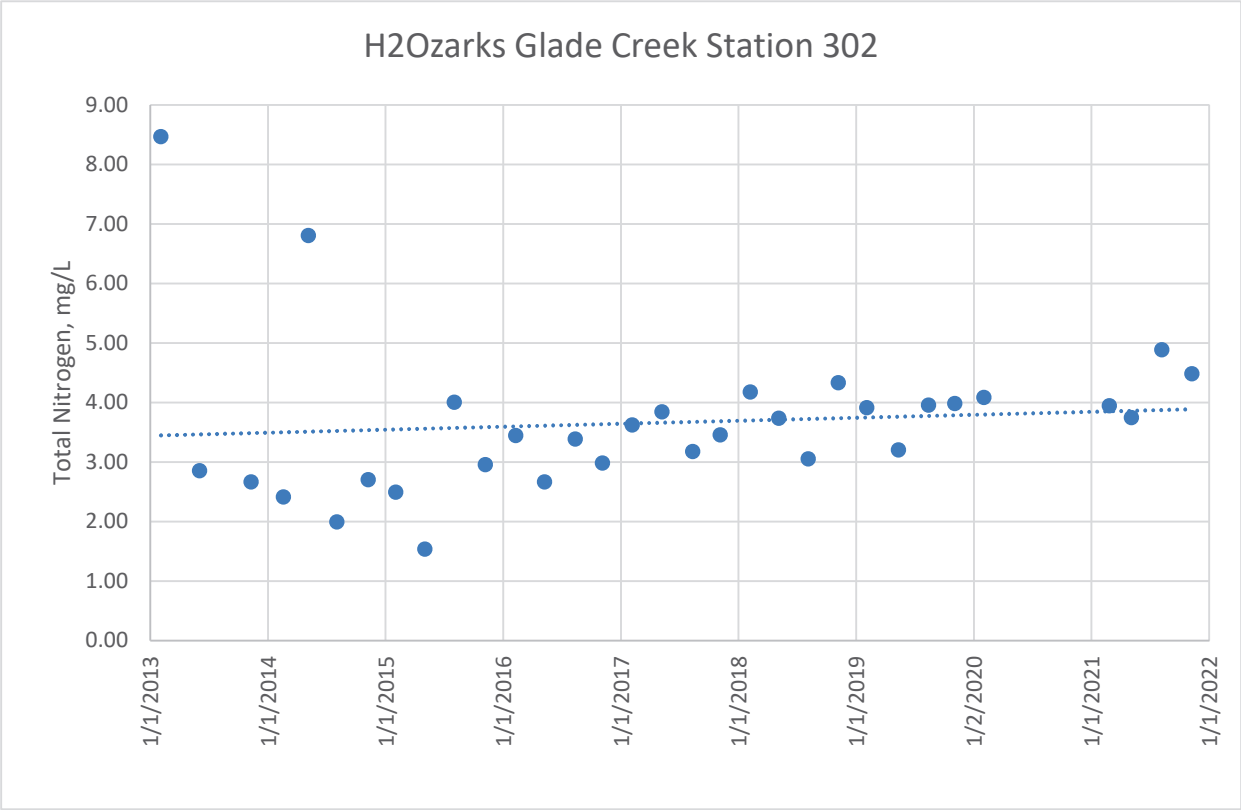


Figure 4.8. H2Ozarks Glade Creek station (302) period of record total nitrogen concentrations.

4.7.4.1 Nonpoint Pollutant Sources Recommended for Management

SWAT model results suggest that pasture is the source of 93% of nitrogen and 90% of sediment loads from uplands in this HUC12 (Appendix L). In 2019 there were around 9,139 acres of pasture and hayland in this watershed, with around 270 acres of pasture within 50 meters of a stream (Dewitz and USGS 2021, Hill et al. 2016). The risks for streambank erosion, and sheet/rill/wind erosion assigned to this HUC12 in the 2015 NRCS Arkansas State Resources Assessment are in the top 20% for the Upper White River watershed, and for the state (NRCS 2016). SWAT model results indicate that sediment yield from streambank erosion is in the top 20% (FTN Associates, Ltd. 2024). This HUC12 has around 40 miles of unpaved roads and 65 stream road crossings where sediment from roads could be carried to surface waters (Center for Advanced Spatial Techologies 2006, Southeast Aquatic Resources Partnership 2023). A map of priority areas for unpaved road BMPs that includes this sub-watershed is included in Appendix C

(Figure C-4) of the 2023 Beaver Lake Watershed Protection Strategy (RTI International 2023). As of May 2024, Madison County road crew certification in Environmentally Sensitive Maintenance of unpaved roads through the Arkansas Unpaved Roads Program is not up to date (K. McGaughey, NRD, personal communication 5/20/2024).

Potential nonpoint sources of pathogens and nitrogen in this HUC12 include livestock, runoff from pastures, wildlife, and failing septic systems. Based on reported cattle inventories and acres of pasture reported in Madison County for 2022, we estimate there could be around 5,000 cows pastured in this HUC12 (USDA National Agricultural Statistics Service 2023).[2] Poultry litter was applied to pastures in this HUC12 in 2019. The number of active poultry houses in this HUC12 is unknown (T. Wentz, NRD, personal communication, 5/12/2022). Available information indicates that there are 167 active septic systems in this watershed (Appendix F).

Figure 4.9 shows locations of nonpoint sources of pollutants of concern in the Glade Creek sub-watershed.

4.7.4.2 Plan Management Focus

The suggested focus for this sub-watershed includes improved management of riparian areas and reduction of hydrologic alteration, and reduction of sediment, nitrogen, and pathogen inputs from streambanks, pastures, animal feeding operations, unpaved roads, and failing septic systems. Given the NRCS evaluated risk of excess pathogens, evaluation of attainment of *E. coli* criteria in Glade Creek is also recommended. Improved understanding of potential water quality threats to local populations of threatened and endangered species is also suggested.

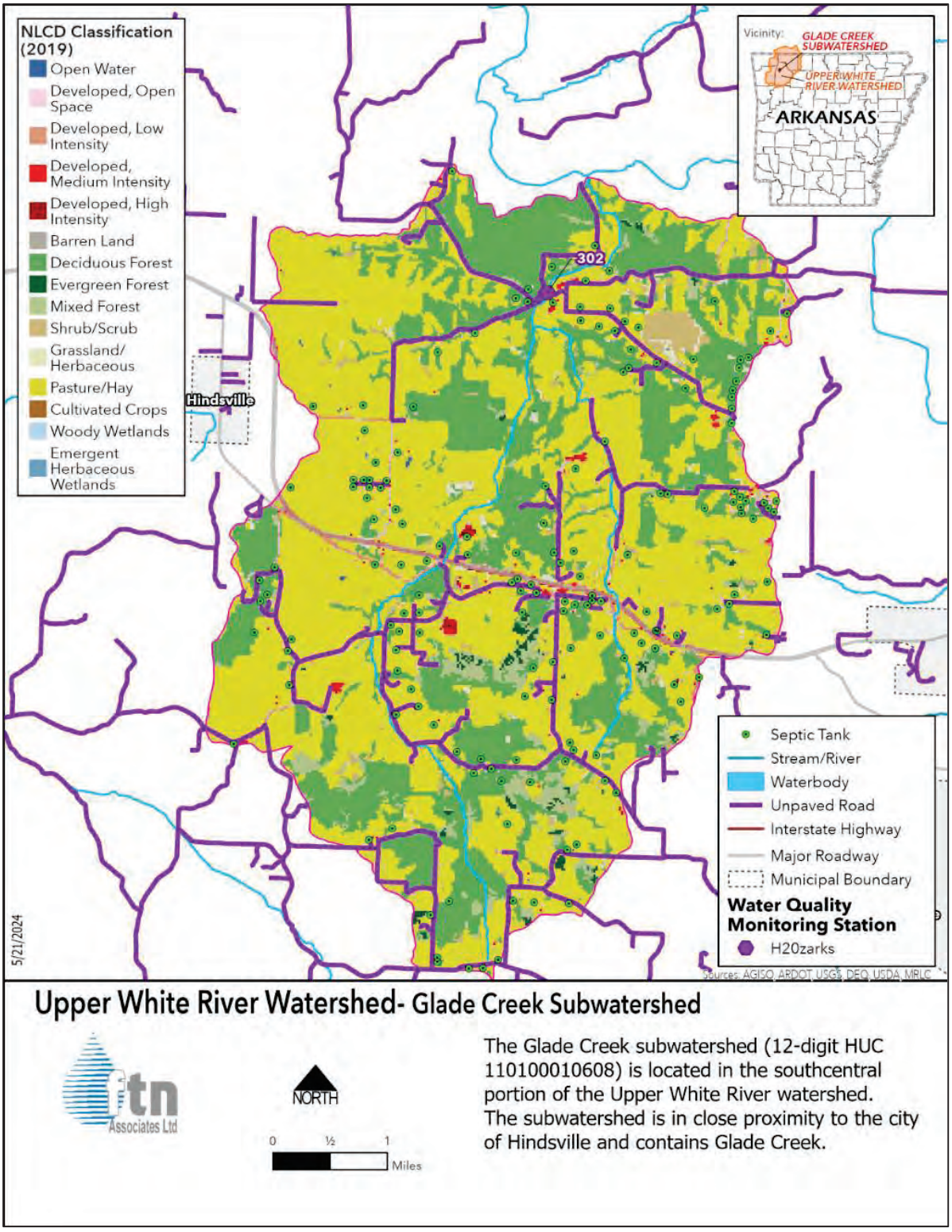


Figure 4.9. Nonpoint pollution sources in the Glade Creek sub-watershed.

4.7.5 Clifty Creek-War Eagle Creek

Analysis and data review identified several water quality issues in the Clifty Creek-War Eagle Creek HUC12 that may be addressed through nonpoint source pollution management; nutrient loads, sediment loads, and pathogens. Water quality issues are of concern in part because of the potential to impact threatened and endangered species that may be present in the HUC12. The endangered species that exist in this HUC12 are Indiana Bat, Gray Bat, and Ozark Big-eared Bat. The threatened species in this HUC12 are Rabbitsfoot mussel, Missouri bladderpod, Piping Plover, and Northern Long-Eared Bat (USFWS 2023).

The NRCS State Resource Assessment of 2015 identified this HUC12 as having higher than average risk for excessive nutrients and pathogens (NRCS 2016). SWAT model results indicate that instream sediment and nutrient yields in this HUC12 are in the top 10% for this watershed (FTN Associates, Ltd. 2024). The average Clifty Creek total nitrogen concentration is over 40% higher than the ecoregion total nitrogen target concentration (see Table 4.15). The median total nitrogen concentration for 2018-2022 at the H2Ozarks Clifty Creek station (304) is similar to median concentrations in other War Eagle Creek tributaries e.g., Clear Creek, Glade Creek, which are some of the highest in the watershed (Appendix C). The average Clifty Creek total phosphorus concentration is lower than the ecoregion total phosphorus target concentration, however the modeled upland total phosphorus yield is in the top 10% (see Table 4.13, Appendix L). Median total phosphorus and TSS concentrations in Clifty Creek do not appear to be unusually high for the watershed (Appendix C). Load reduction targets for upland sediment, nitrogen, and phosphorus loads are established for this HUC12 in Section 4.6 and summarized in Table 4.23.

4.7.5.1 Nonpoint Pollutant Sources Recommended for Management

Potential nonpoint sources of nutrients and pathogens in this HUC12 include livestock, runoff from pastures and animal feeding operations, wildlife, and failing septic systems. Based on reported cattle inventories and acres of pasture reported in Madison County for 2022, we estimate there could be around 5,600 cows pastured in this HUC12 (USDA National Agricultural Statistics Service 2023).[2] SWAT model results indicate that pasture is the source of 84% of

phosphorus and 86% of nitrogen loads from uplands in this HUC12 (Appendix L). In 2019 there were around 11,226 acres of pasture and hayland in this watershed, with around 1,814 acres of pasture within 50 meters of a stream (Dewitz and USGS 2021, Hill et al. 2016). Based on information provided by NRD, poultry litter was applied to pasture in this HUC12 sub-watershed in 2019. The number of active poultry houses in this HUC12 for 2019 is unknown (T. Wentz, NRD, personal communication, 5/12/2022). Available information indicates that there are 177 active septic systems in this watershed (Appendix F). Feral hogs are a problem in Madison and Washington counties. In 2023 246 feral hogs were reported removed from these two counties (Arkansas Department of Agriculture 2024). Feral hogs can contribute nutrients and fecal coliforms to surface waters, and their disturbance of the soil and soil cover can contribute to erosion.

Potential nonpoint sources of sediment in this HUC12 include runoff from pastures, streambank erosion, and unpaved roads. The risk for sheet/rill/wind erosion assigned to this HUC12 in the 2015 NRCS Arkansas State Resources Assessment is in the top 20% for the Upper White River watershed, but risks for gully and streambank erosion were low for this watershed (though moderately high for the state) (Appendix M, NRCS 2016). Thus, streambank erosion may not be a significant source of sediment and nutrients in this HUC12. A map of priority areas for unpaved road BMPs provided in Appendix C (Figure C-4) of the 2023 Beaver Lake Watershed Protection Strategy shows priority areas within this sub-watershed (RTI International 2023). This HUC12 has around 43 miles of unpaved roads and 77 stream road crossings where sediment from roads could be carried to surface waters (Center for Advanced Spatial Techologies 2006, Southeast Aquatic Resources Partnership 2023). As of May 2024, Washington and Benton County road crew certification in Environmentally Sensitive Maintenance of unpaved roads through the Arkansas Unpaved Roads Program is up to date, Madison County is not (K. McGaughey, NRD, personal communication 5/20/2024). Figure 4.10 shows locations of nonpoint sources of pollutants in the Clifty Creek-War Eagle Creek sub-watershed.

4.7.5.1 Plan Management Focus

The suggested focus for this sub-watershed includes improved management of riparian areas and reduction of nutrient, sediment, and pathogen inputs from pastures, animal feeding operations, wildlife (feral hogs), unpaved roads, and failing septic systems. Given the NRCS evaluated risk of excess pathogens, evaluation of attainment of *E. coli* criterion in Clifty Creek and War Eagle Creek in this HUC12 is also recommended. Improved understanding of potential water quality threats to local populations of threatened and endangered species is also suggested.

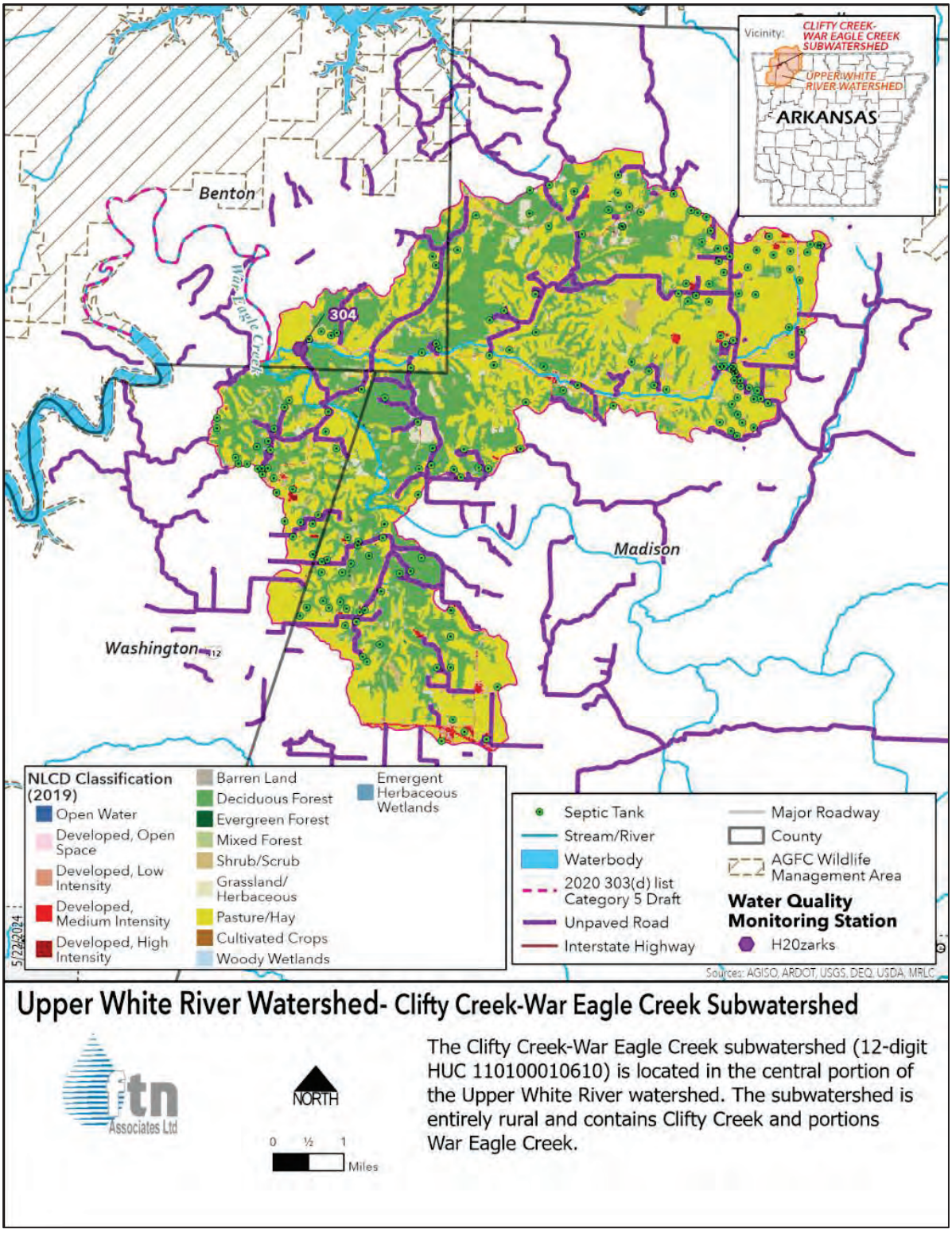


Figure 4.10. Nonpoint pollution sources in the Clifty Creek-War Eagle Creek sub-watershed.

4.7.6 Beaver Lake-War Eagle Creek

Analysis and data review identified several water quality issues in the Beaver Lake-War Eagle Creek HUC12, including sediments, nutrients, and pathogens, that may be addressed through nonpoint source pollution management. These water quality issues are of concern in part because of the potential to impact populations of the threatened Rabbitsfoot mussel and Ozark Cavefish that may be present in the HUC12, and the quality of resources in Hobbs State Park and Wildlife Management Area (USFWS 2023).

The arm of Beaver Lake in this HUC12 has been classified as water quality impaired because of high turbidity, pathogen levels, and pH. War Eagle Creek in this HUC12 is classified as water quality impaired because of low DO levels during the critical season (i.e., May-September). No source/cause for the low DO conditions is identified by DEQ (DEQ 2021). SWAT model results indicate that nutrient loads from both upland and instream sources in this HUC12 are on the high end for this watershed (Appendix G, L; FTN Associates, Ltd. 2024). The NRCS State Resource Assessment of 2015 identified this HUC12 as having higher than average risk for excessive nutrients, sediment, and pathogens, and habitat degradation (NRCS 2016). The average of total phosphorus concentrations measured by USGS in War Eagle Creek is an order of magnitude higher than the ecoregion target total phosphorus concentration for wadable streams. High nutrient loads have the potential to contribute to low DO conditions in War Eagle Creek, and high pH levels in Beaver Lake. Load reduction targets for upland sediment, nitrogen, and phosphorus loads are established in Section 4.6 and summarized in Table 4.23.

4.7.6.1 Nonpoint Pollutant Sources Recommended for Management

DEQ has identified surface erosion as the source of pollutants causing turbidity, pH, and *E. coli* impairments. SWAT model results suggest that pasture is the source of 69% of the sediment load from upland in this HUC12 (Appendix L). In 2019 there were around 5,340 acres of pasture and hayland in this watershed, with around 747 acres of pasture within 50 meters of a stream (Dewitz and USGS 2021, Hill et al. 2016). The risks for streambank erosion, sheet/rill/wind erosion, and gully erosion assigned to this HUC12 in the 2015 NRCS Arkansas State Resources Assessment are in the top four for the Upper White River watershed (Appendix

M). Lake shore erosion has also been identified as a concern by Beaver Lake stakeholders. This HUC12 has around 19 miles of unpaved roads and 36 stream road crossings where sediment from roads could be carried to surface waters (Center for Advanced Spatial Techologies 2006, Southeast Aquatic Resources Partnership 2023). A map of priority areas for unpaved road BMPs that includes this sub-watershed is included in Appendix C (Figure C-4) of the 2023 Beaver Lake Watershed Protection Strategy (RTI International 2023). Benton and Washington County road crew certification in Environmentally Sensitive Maintenance of unpaved roads through the Arkansas Unpaved Roads Program is up to date (K. McGaughey, NRD, personal communication 5/20/2024).

Potential nonpoint sources of pathogens in this HUC12 include livestock, runoff from pastures, wildlife, failing septic systems, boaters, and sediment. As noted in Section 3.4, a recent study of *E. coli* sources in the Beaver Lake watershed found that poultry host markers were present in 33% of samples and human host markers were present in 25% of samples collected at the sampling station in the War Eagle Creek arm of Beaver Lake. Cow host markers were present in only 8% of the samples (Gibson, et al. 2017). Poultry litter was applied to pastures in this HUC12 in 2019 and 18 poultry houses were reported in operation that year (T. Wentz, NRD, personal communication, 5/12/2022). Available information indicates that there are 367 active septic systems in this watershed (Appendix F). Improper disposal of boat wastewater is another potential source of pathogens in Beaver Lake. Based on reported cattle inventories and acres of pasture reported in Benton and Washington counties for 2022, we estimate there could be around 2,500 cows pastured in this HUC12 (USDA National Agricultural Statistics Service 2023).[2] Canada geese and feral hogs have also been identified as possible sources of pathogens in Beaver Lake (Platt 2024).

Pathogen sources are also potential sources of phosphorus loads. In addition, eroded sediment can carry phosphorus to surface waters. SWAT model results indicate that 72% of upland phosphorus load in this HUC12 is from pasture (Appendix L). Figure 4.11 shows locations of nonpoint sources of pollutants in the Beaver Lake-War Eagle Creek sub-watershed.

4.7.6.2 Plan Management Focus

The suggested management focus for this sub-watershed includes:

- Improved understanding of whether *E. coli* criteria are being met in the monitored water bodies,
- Improved understanding of the causes of low DO conditions in War Eagle Creek,
- Improved management of riparian areas, including the lake shore,
- Reduction of sediment and phosphorus inputs from streambanks, unpaved roads, and pastures,
- Reduction of *E. coli* and phosphorus from pastures, nuisance wildlife, and boat wastewater,
- Reduction of *E. coli* and phosphorus from failing septic systems, especially those for properties located along the lake shore and close to War Eagle Creek and other streams, and
- Improved understanding of potential water quality threats to local populations of Ozark Cavefish and Rabbitsfoot mussel.

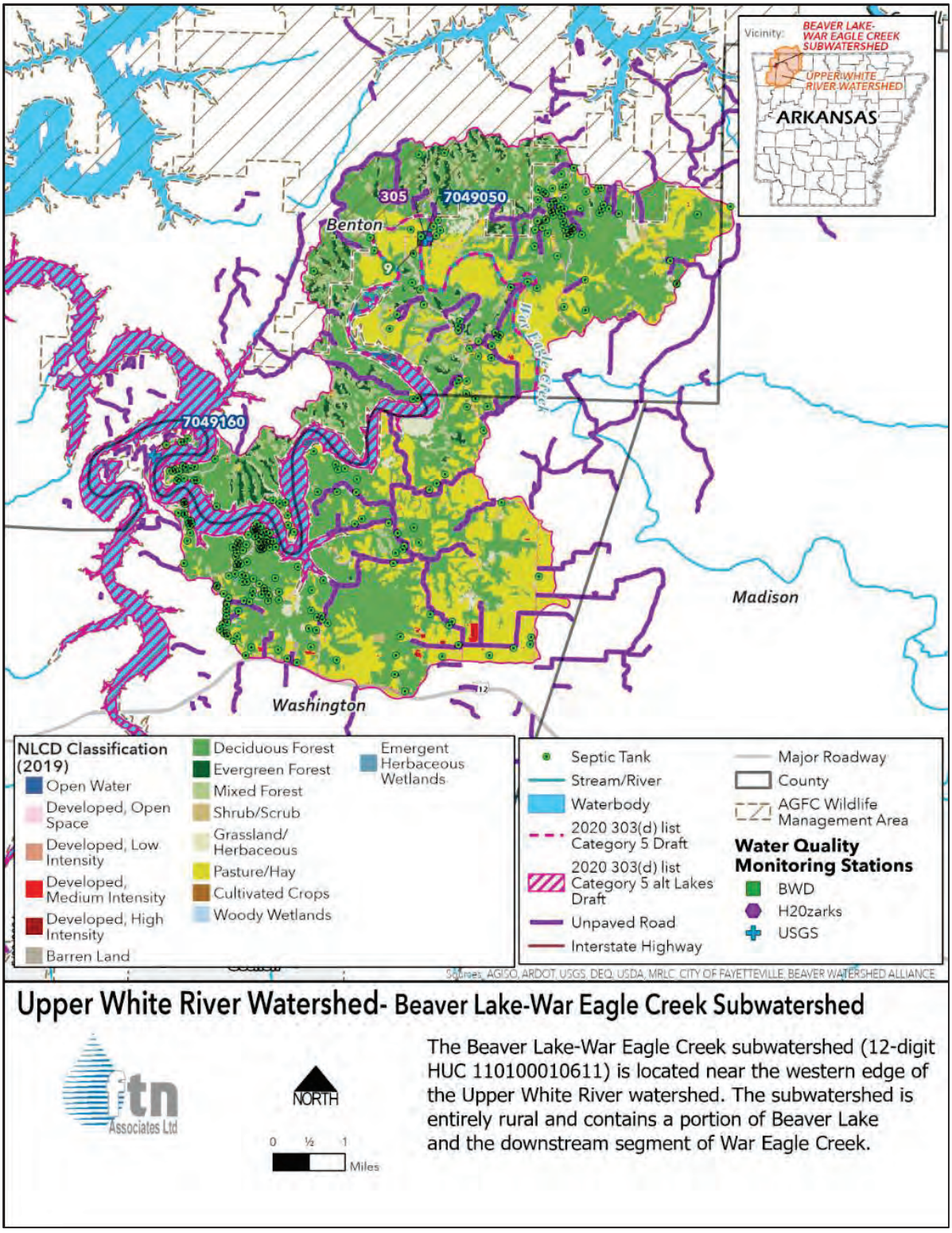


Figure 4.11. Nonpoint pollution sources in the Beaver Lake-War Eagle Creek sub-watershed.

4.7.1 Roberts Creek-Beaver Lake

Analysis and data review identified several water quality issues in the Roberts Creek-Beaver Lake HUC12 that may be addressed through nonpoint source pollution management; nutrients, sediment, turbidity, TSS, low DO, and pathogens. These water quality issues are of concern in part because of the potential to impact populations of Indiana bat, Gray bat, Ozark big-eared bat, and Neosho Musket that may be present in the HUC12, and the quality of resources in Beaver Lake Wildlife Management Area (USFWS 2023).

The arm of Beaver Lake in this HUC12 has been classified as water quality impaired because of high turbidity and pathogen levels. DEQ has identified surface erosion as a possible source of pollutants causing turbidity impairment of Beaver Lake. The White River in this HUC12 is classified as water quality impaired by high levels of turbidity and sulfate, and low DO during the critical season (i.e., May – September) (DEQ 2021). However, since the sulfate impairment is proposed to be removed from the White River in this HUC12, sulfate management is not required for this HUC12 in this plan (DEQ 2021b, 2023). The White River within this sub-watershed is also subject to a TMDL for turbidity and TSS (FTN Associates, Ltd. 2006).

The NRCS State Resource Assessment of 2015 identified this HUC12 as having some of the highest risk for excessive nutrients, sediment, and pathogens in the Upper White River watershed, and risk of habitat degradation in the top 10% (NRCS 2016). SWAT model results indicate that instream nutrient yields are in the midrange for the watershed and instream sediment yield is in the lowest five, and nitrogen and sediment yields from upland sources are in the top 10% (Appendix G, L). Average White River total phosphorus concentrations in this HUC12 are greater than the ecoregion target total phosphorus concentration for wadable streams. High nutrient loads have the potential to contribute to low DO conditions in the White River. Load reduction targets for upland sediment, nitrogen, and phosphorus loads are established in Section 4.6 and summarized in Table 4.23. The only significant water quality trend in this HUC12 was in total phosphorus concentrations collected at White River Station 10 (BWD). Total phosphorus data collected by BWD at this location exhibited a statistically significant increasing trend (Appendix D), however, total phosphorus measurements collected by AWRC at this location exhibited a statistically significant decreasing trend (Grantz and Haggard 2023a).

4.7.1.1 Nonpoint Pollutant Sources Recommended for Management

SWAT model results suggest that pasture is the source of around 74% of the sediment load from uplands in this HUC12 (Appendix L). In 2019 there were around 8,905 acres of pasture and hayland in this watershed, with around 385 acres of pasture within 50 meters of a stream (Dewitz and USGS 2021, Hill et al. 2016). The risks for streambank erosion, sheet/rill/wind erosion, and gully erosion assigned to this HUC12 in the 2015 NRCS Arkansas State Resources Assessment are in the top 3 for the Upper White River watershed and in the top 10% for the state (Appendix M, NRCS 2016). Lake shore erosion has also been identified as a concern by Beaver Lake stakeholders. This HUC12 has around 18 miles of unpaved roads and 50 stream road crossings where sediment from roads could be carried to surface waters (Center for Advanced Spatial Techologies 2006, Southeast Aquatic Resources Partnership 2023). A map of priority areas for unpaved road BMPs that includes this sub-watershed is included in Appendix C (Figure C-2) of the 2023 Beaver Lake Watershed Protection Strategy (RTI International 2023). Washington County road crew certification in Environmentally Sensitive Maintenance of unpaved roads through the Arkansas Unpaved Roads Program is up to date (K. McGaughey, NRD, personal communication 5/20/2024).

Potential nonpoint sources of pathogens in this HUC12 include livestock, runoff from pastures, feeding operation runoff, wildlife, failing septic systems, and boat wastewater. *E. coli* may also be stored in sediment and released when the sediment is disturbed. Water samples were collected from the White River arm of Beaver Lake during a 2015 study of *E. coli* sources in the Beaver Lake watershed. Poultry host markers were present in 30% of these samples, human host markers were present in 22% of the samples, and cow host markers were present in 17% of the samples (Gibson, et al. 2017). This suggests that poultry litter may be a more significant source of pathogens in this part of the reservoir than human sources or cattle. Based on reported cattle inventories and acres of pasture reported in Washington County for 2022, we estimate there could be around 5,900 cows pastured in this HUC12 (USDA National Agricultural Statistics Service 2023).[2] Poultry litter was applied to pastures in this HUC12 in 2019 and 19 poultry houses were reported in operation that year (T. Wentz, NRD, personal communication, 5/12/2022). Available information indicates that there are 911 active septic systems in this

watershed (Appendix F). The Arkansas Department of Health reports that, as of 2018, the public marina located on the White River arm of Beaver Lake within this HUC12 does not have a pump-out for boat wastewater (Arkansas Department of Health 2018). Canada geese and feral hogs have also been identified as possible sources of pathogens in Beaver Lake (Platt 2024).

Pathogen sources are also potential sources of nitrogen and phosphorus loads. In addition, eroded soil can carry nutrients to surface waters, particularly phosphorus, and deposited sediments in lakes can be a source of nutrients (McCarty 2020). The SWAT model results indicate no need to reduce upland phosphorus loads, however non-upland nonpoint sources, including failing septic systems, stream sediment (e.g., legacy phosphorus), and streambank erosion, may contribute to high phosphorus concentrations in the White River. SWAT model results indicate that around 88% of upland nitrogen loads in this HUC12 are from pasture (Appendix L). Figure 4.12 shows locations of nonpoint sources of pollutants in the Roberts Creek-Beaver Lake sub-watershed.

4.7.1.2 Plan Management Focus

The suggested focus for management in this sub-watershed includes:

- Improved understanding of whether *E. coli* criteria are being met in the monitored water bodies,
- Improved understanding of the causes of low DO conditions in White River,
- Improved management of riparian areas, including the lake shore,
- Reduction of erosion and sediment inputs from streambanks, lake shore, and pastures,
- Reduction of *E. coli,* nutrients, and organic matter from pastures, nuisance wildlife, boat wastewater,
- Reduction of *E. coli,* nutrients, and organic matter from failing septic systems, especially those for properties located along the lake shore and close to streams, and
- Improved understanding of potential water quality threats to any local populations of Neosho Mucket.

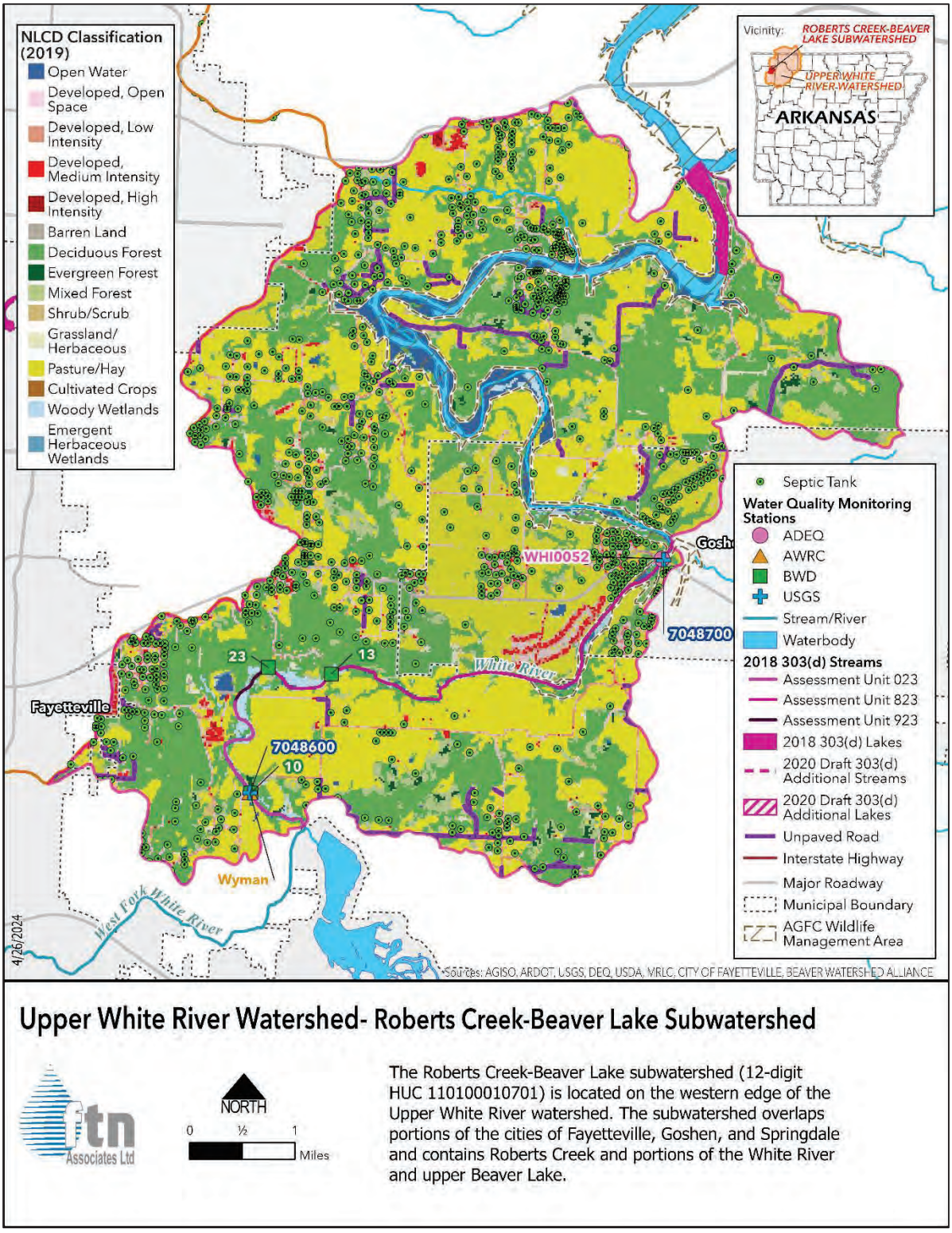


Figure 4.12. Nonpoint pollution sources in the Roberts Creek-Beaver Lake sub-watershed.

4.7.2 Brush Creek-Beaver Lake

Analysis and data review identified several water quality issues in the Beaver Lake-Brush Creek HUC12 that may be addressed through nonpoint source pollution management; nutrients, sediment, turbidity, and pathogens. These water quality issues are of concern in part because of the potential to impact threatened and endangered species that may be present in the HUC12. The endangered species that exist in this HUC12 are Indiana Bat, Gray Bat, and Ozark Big-eared Bat. The threatened species in this HUC12 are Ozark Cavefish, Rabbitsfoot mussel, Missouri Bladderpod, Northern Long-Eared Bat, and Piping Plover (USFWS 2023).

The arm of Beaver Lake in this HUC12 has been classified as water quality impaired by high turbidity and pathogen levels. DEQ has identified surface erosion as the source of pollutants causing these impairments (DEQ 2021). The NRCS State Resource Assessment of 2015 identified this HUC12 as having some of the highest risks for excessive nutrients, sediment, and pathogens in the Upper White River watershed, and risk of habitat degradation on the high end for the watershed (Appendix M, NRCS 2016). SWAT model results indicate that instream nitrogen yield for this HUC12 is in the top 10% (FTN Associates, Ltd. 2024, Appendix G, L). The median total nitrogen concentration at the H2Ozarks station 300 from 2018-2022 is significantly higher than median concentrations reported for other monitoring stations in the watershed during this period (Appendix C), and the average total nitrogen concentration at this station is 45% higher than the ecoregion target concentration for wadable streams (see Table 4.15). A load reduction target for nitrogen is established in Section 4.6 and summarized in Table 4.23. Available data do not indicate a need to reduce phosphorus load in this HUC12 and is not adequate to set a sediment load reduction target.

4.7.2.1 Nonpoint Pollutant Sources Recommended for Management

SWAT model results suggest that upland sediment load may not need to be reduced. The risk of streambank erosion assigned to this HUC12 in the 2015 NRCS Arkansas State Resources Assessment is the second highest for the Upper White River watershed (Appendix M). Lake shore erosion has also been identified as a concern by Beaver Lake stakeholders.

Potential nonpoint sources of pathogens and nitrogen in this HUC12 include failing septic systems, livestock, runoff from pasture and developed areas, wildlife, and boat wastewater. In 2019 there were around 14,603 acres of pasture and hayland in this sub-watershed, with around 384 acres of pasture within 50 meters of a stream. Based on reported cattle inventories and acres of pasture reported in Madison and Washington counties for 2022, we estimate there could be around 7,200 cows pastured in this HUC12 (USDA National Agricultural Statistics Service 2023).[2] Poultry litter was applied to pastures in this HUC12 in 2019 and 32 poultry houses were reported in operation that year in the Washington County portion of the HUC12. Information on the number of active poultry houses in the Madison County portion of this HUC12 in 2019 is not available (T. Wentz, NRD, personal communication, 5/12/2022). In 2019 there were around 2,090 acres of developed land in this sub-watershed, over half of which was classified as open area. Around 57 acres of developed land was within 50 meters of a stream (Dewitz and USGS 2021, Hill et al. 2016). Available information indicates that there are 370 active septic systems in this watershed (Appendix F). Canada geese and feral hogs have also been identified as possible sources of pathogens in Beaver Lake (Platt 2024).

Pathogen sources are also potential sources of nitrogen and phosphorus loads. In addition, eroded sediment can carry nutrients to surface waters, particularly phosphorus. SWAT model results indicate that pasture accounts for about 50% of upland nutrient loads in this HUC12 and developed land accounts for 3% (Appendix L). Figure 4.13 shows locations of nonpoint sources of pollutants in the Brush Creek-Beaver Lake sub-watershed.

4.7.2.2 Plan Management Focus

The suggested focus for management in this sub-watershed includes:

- Improved understanding of whether *E. coli* criteria are being met in the monitored water bodies;
- Improved management of riparian areas, including the lake shore;
- Reduction of sediment, nitrogen, and pathogen inputs from streambanks, lakeshore, failing septic systems, pastures, animal feeding operations, and wildlife; and

- Improved understanding of potential water quality threats to local populations of threatened and endangered species and overall habitat degradation.

4.7.3 Spanker Branch-Kings River

Analysis and data review identified the following water quality issues in the Spanker Branch-Kings River HUC12 that may be addressed through nonpoint source pollution management; low DO and pathogens. Water quality issues are of concern in part because of the potential to impact threatened and endangered species that may be present in the HUC12, and the Kings River, which is designated as Extraordinary Resource Waters, and as a Natural and Scenic Waterway in this HUC12 (Arkansas Pollution Control and Ecology Commission 2022). The endangered species that exist in this HUC12 are Indiana Bat, Gray Bat, and Ozark Big-eared Bat. The threatened species in this HUC12 are Ozark Cavefish, Rabbitsfoot mussel, Missouri Bladderpod, Northern Long-Eared Bat, and Piping Plover (USFWS 2023).

An assessment unit of the Kings River in this HUC12 has been classified as impaired because of low DO. The source of this impairment is not known (DEQ 2020). Nutrient concentrations in the Kings River are relatively low, so it seems unlikely that excessive productivity is causing low DO. SWAT model results indicate that instream sediment yield for this HUC12 is in the top 10, however, no waterbodies in this HUC12 have been classified as turbidity impaired and 2018-2022 turbidity appear to meet the criterion (Table 4.19, FTN Associates, Ltd. 2024, Appendix L). SWAT modeled upland yields of sediment and nutrients in this HUC12 are below the targets for this plan (Table 4.23). The NRCS State Resource Assessment of 2015 identified this HUC12 as having higher than average risk for excessive pathogens (NRCS 2016, Appendix M).

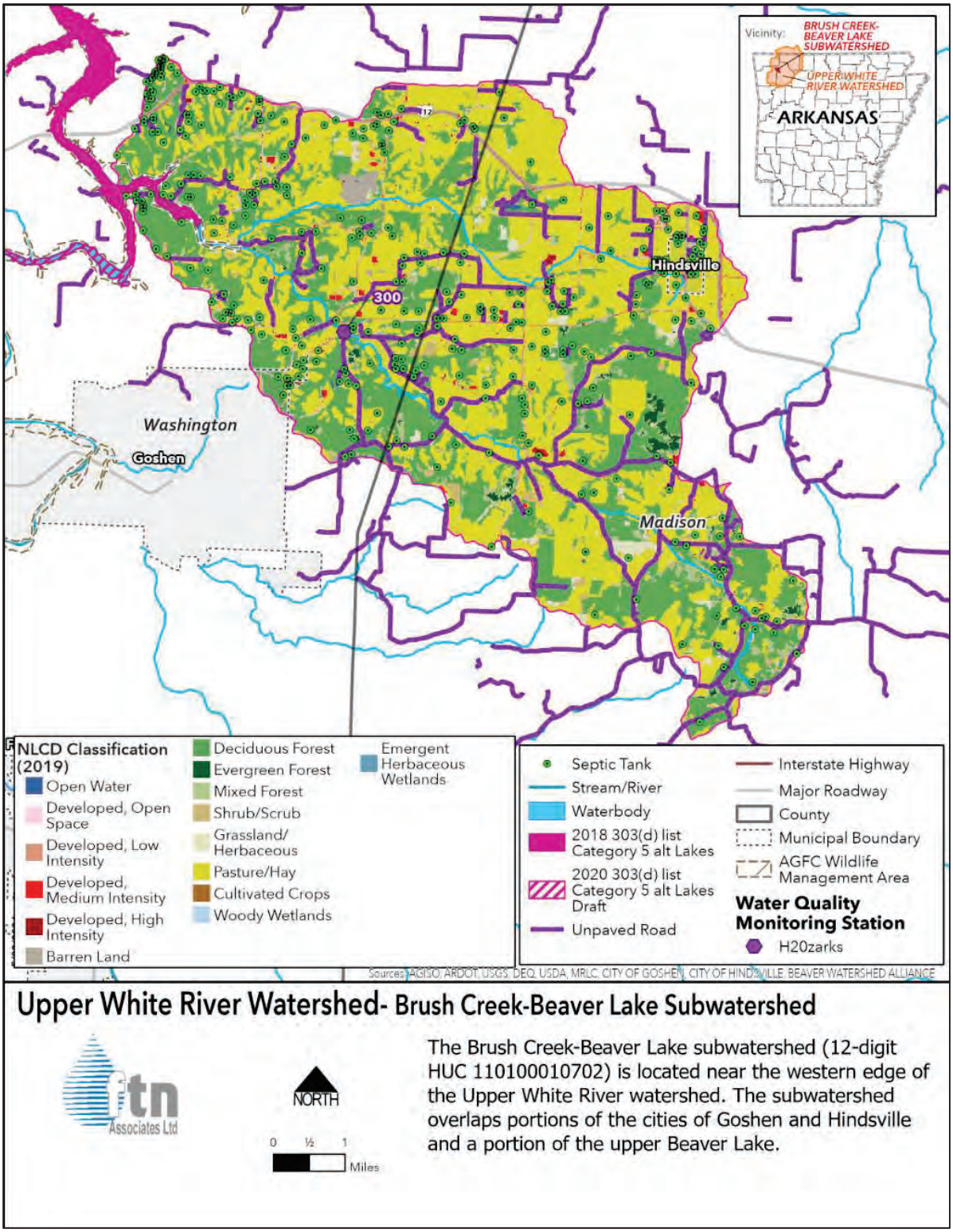


Figure 4.13. Nonpoint pollution sources in the Brush Creek-Beaver Lake sub-watershed.

4.7.3.1 Nonpoint Pollutant Sources Recommended for Management

Potential sources of pathogens and organic matter in this HUC12 include livestock, runoff from pasture, and failing septic systems. This HUC12 has around 7,568 acres of pasture and hayland, with around 240 acres of pasture within 50 meters of a stream (Dewitz and USGS 2021, Hill et al. 2016). Based on reported cattle inventories and acres of pasture reported in Madison County for 2022, we estimate there could be around 3,800 cows pastured in this HUC12.[2] Based on information provided by NRD, poultry litter was applied to pasture in this HUC12 in 2019. The number of active poultry houses in this HUC12 for 2019 is unknown (T. Wentz, NRD, personal communication, 5/12/2022). Available information indicates that there are 199 active septic systems in this watershed (Appendix F). Figure 4.14 shows locations of nonpoint pollution sources in the Spanker Branch-Kings River sub-watershed.

4.7.3.2 Plan Management Focus

The suggested focus for this sub-watershed includes:

- Improved understanding of causes behind low DO in Kings River;
- Determination of whether *E. coli* criteria are being met in the monitored water bodies;
- Improved management of riparian areas;
- Reduction of pathogen and organic matter inputs from pasture, livestock, and failing septic systems; and
- Improved understanding of potential water quality threats to local populations of threatened and endangered species.

4.7.4 Clabber Creek-Kings River

Analysis and data review identified several water quality issues in the Clabber Creek-Kings River HUC12 that may be addressed through nonpoint source pollution management; nutrients, sediment, TDS and pathogens. Water quality issues are of concern in part because of the potential to impact threatened and endangered species that may be present in the HUC12, and the Kings River, which is designated in this HUC12 as Extraordinary Resource Waters (Arkansas Pollution Control and Ecology Commission 2022). The endangered species

that exist in this HUC12 are Indiana Bat, Gray Bat, Ozark Big-eared Bat, Scaleshell mussel, and Snuffbox mussel. The threatened species in this HUC12 are Rabbitsfoot mussel and Northern Long-Eared Bat (USFWS 2023).

The Kings River within this HUC12 has been classified as impaired because of high TDS concentrations (DEQ 2020). However, recent data shows a decline in the frequency of TDS criterion exceedances. This suggests that this impairment is already being addressed and it may be possible to remove the TDS impairment in the future (see Section 4.6.4).

The NRCS State Resource Assessment of 2015 identified this HUC12 as having average risks for excessive pathogens, nutrients, and sediment in the top 20% for the Upper White River watershed (NRCS 2016, Appendix M). SWAT model results indicate that instream and upland phosphorus yields from this HUC12 are the second highest in the watershed (Appendix L), however, 2018-2022 Kings River average total phosphorus concentration is below the ecoregion target (Table 4.13). In addition, most 2018-2022 turbidity measurements appear to be lower than the turbidity criterion (Table 4.19). Instream nitrogen yield from this HUC12 is in the midrange for the Upper White River watershed, and upland yield is the highest in the watershed. However, 2018-2022 Kings River average total nitrogen concentration is below the ecoregion target (Table 4.15). Modeled instream and upland sediment yields from this HUC12 are on the low end for the watershed (Appendix L). Load reduction targets for upland nitrogen and phosphorus loads are established in Section 4.6 and summarized in Table 4.23. A downward trend in DO concentration was identified at station WHI0009A on the Kings River (Appendix D). This could indicate that water quality at this location is getting worse.

Given the information above, reduction of pathogens and nutrients from upland nonpoint sources is the focus for this HUC12 sub-watershed. Although nutrient concentrations in Kings River do not appear to be a concern, reducing upland nutrient loads will help prevent nutrients from becoming a concern.

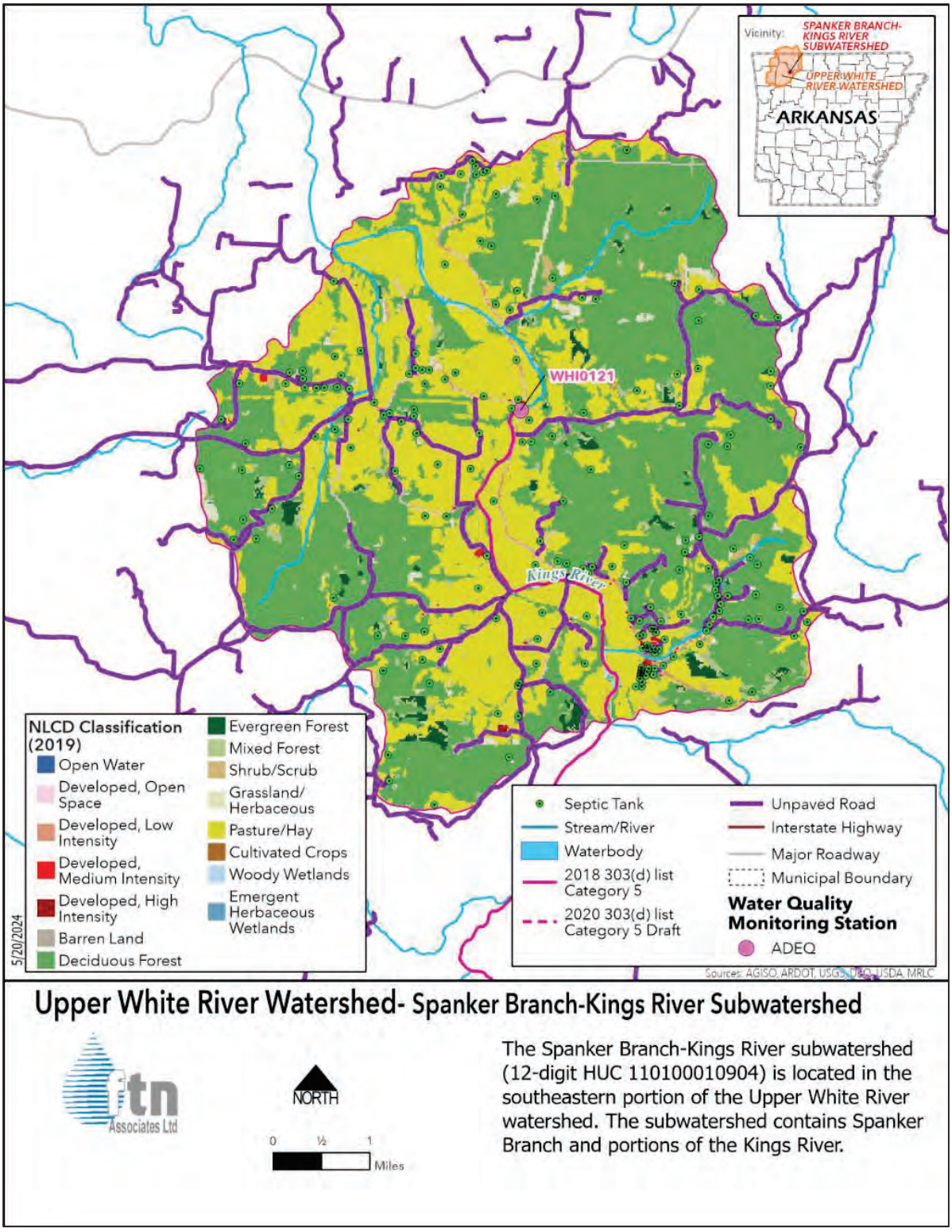


Figure 4.14. Nonpoint pollution sources in the Spanker Branch-Kings River sub-watershed.

4.7.4.1 Nonpoint Pollutant Sources Recommended for Management

Potential sources of pathogens and nutrients in this HUC12 include livestock, runoff from pastures, feral hogs, failing septic systems, and runoff from developed areas. SWAT model results suggest that pasture is the source of 96% of the upland nitrogen load and 89% of the upland phosphorus load in this HUC12 (Appendix L). In 2019 there were around 31,238 acres of pasture and hayland \in this watershed, with around 1,778 acres of pasture within 50 meters of a stream (Dewitz and USGS 2021, Hill et al. 2016). Based on reported cattle inventories and acres of pasture reported in Carroll County for 2022, we estimate there could be around 7,100 cows pastured in this HUC12.[2] Poultry litter was applied to pastures in this HUC12 in 2019 and 79 poultry houses were reported in operation that year (T. Wentz, NRD, personal communication, 5/12/2022). Feral hogs are a problem in Carroll County and can contribute *E. coli* and nutrients to surface waters. Between March 2023 and March 2024, over 500 feral hogs were removed from Carroll County (Arkansas Department of Agriculture 2024). Available information indicates that there are 347 active septic systems in this watershed (Appendix F). A portion of the city of Berryville is in this HUC12 and in 2019 there were 1,717 acres of developed land in this sub-watershed, most of which is classified as low density or open space (Dewitz and USGS 2021). In 2019 there were around 230 acres of developed land in this HUC12 located within 50 meters of a stream (Hill et al. 2016). Figure 4.15 shows locations of nonpoint pollution sources in the Clabber Creek-Kings River sub-watershed.

4.7.4.1 Plan Management Focus

The suggested focus for this sub-watershed includes:

- Improved understanding of whether *E. coli* and TDS criteria are being met in the monitored water bodies in this HUC12
- Improved management of riparian areas
- Reduction of nutrient and pathogen inputs from pasture, developed areas, and failing septic systems
- Improved understanding of potential water quality threats to local populations of threatened and endangered species and overall habitat degradation.

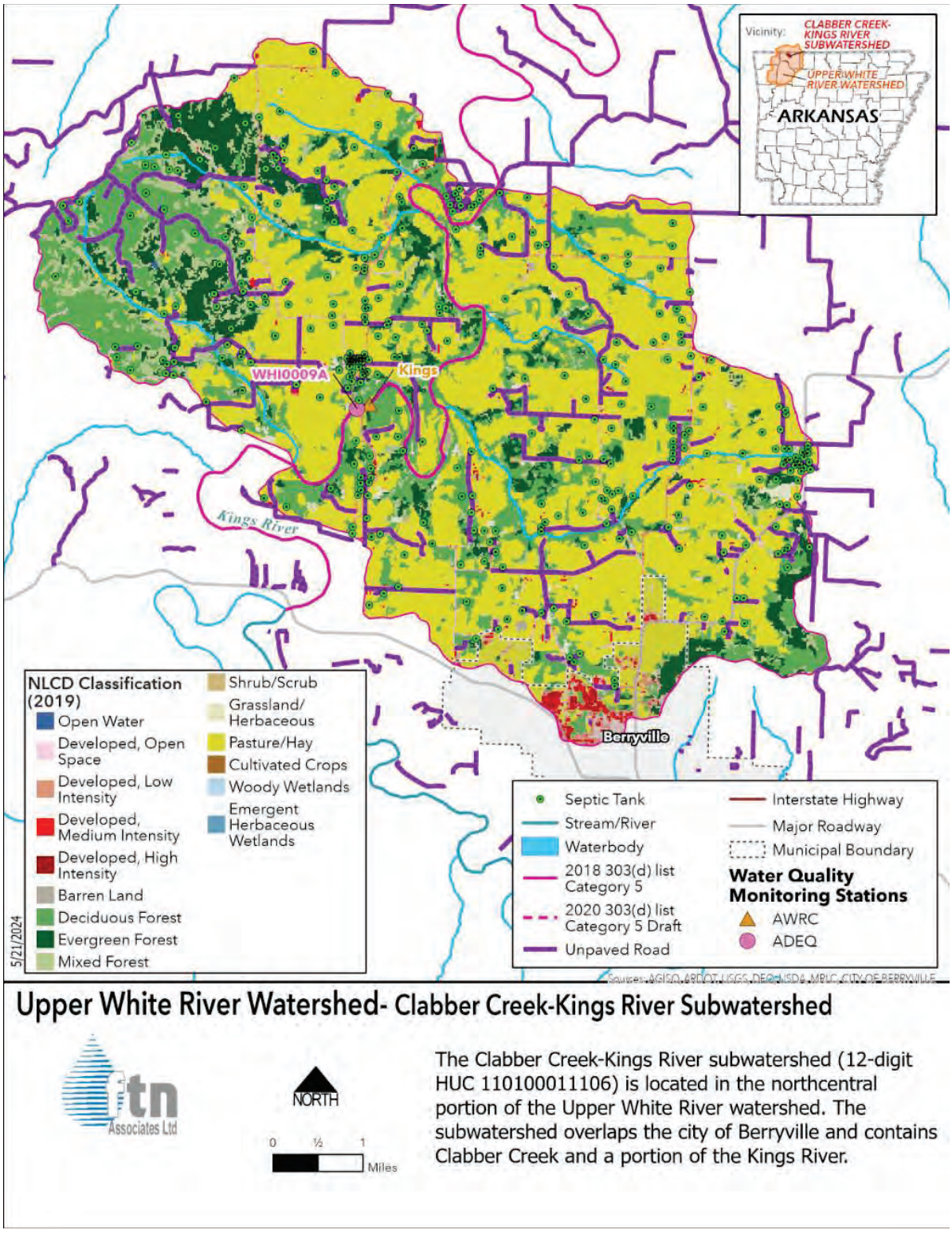


Figure 4.15. Nonpoint pollution sources in the Clabber Creek-Kings River sub-watershed.

4.7.5 Braswell Branch-Yocum Creek

Analysis and data review identified the following water quality issues in the Braswell Branch-Yocum Creek HUC12 that may be addressed through nonpoint source pollution management; nutrients and pathogens. Water quality issues are of concern in part because of the potential to impact threatened and endangered species that may be present in the HUC12. The endangered species that exist in this HUC12 are Indiana Bat, Gray Bat, Ozark Big-eared Bat, Scaleshell mussel, and Snuffbox mussel. The threatened species in this HUC12 are Rabbitsfoot and Northern Long-Eared Bat (USFWS 2023).

The NRCS State Resource Assessment of 2015 identified this HUC12 as having higher than average risk for excessive nutrients and pathogens (NRCS 2016). SWAT model results indicate that instream nitrogen yields are the second highest in the watershed, and instream phosphorus and sediment yields are in the lower two-thirds (Appendix G). Modeled upland nutrient loads are in the top 20 for the watershed (Appendix L). Load reduction targets for upland nitrogen and phosphorus loads are established in Section 4.6 and summarized in Table 4.23.

4.7.5.1 Nonpoint Pollutant Sources Recommended for Management

Potential sources of pathogens and nutrients in this HUC12 include livestock, runoff from pastures, feral hogs, failing septic systems, and runoff from developed areas. SWAT model results suggest that 88% of upland nitrogen load and 96% of upland phosphorus load in this HUC12 are from pasture (Appendix L). This HUC12 has around 14,562 acres of pasture and hayland, with around 2,390 acres of pasture within 50 meters of a stream (Dewitz and USGS 2021, Hill et al. 2016). Based on reported cattle inventories and acres of pasture reported in Carroll County for 2022, we estimate there could be around 7,300 cows pastured in this HUC12.[2] Poultry litter was applied to pastures in this HUC12 in 2019 and 129 poultry houses were reported in operation that year (T. Wentz, NRD, personal communication, 5/12/2022). Between March 2023 and March 2024, over 500 feral hogs were removed from Carroll County (Arkansas Department of Agriculture 2024). Available information indicates that there are 212 active septic systems in this watershed (Appendix F). In 2019 there were 1,599 acres of developed land in this

HUC12, most of which is open space (Dewitz and USGS 2021). Around 220 acres of this developed land was within 50 meters of a stream (Hill, et al. 2016).

Figure 4.16 shows locations of nonpoint pollution sources in the Braswell Branch-Yocum Creek sub-watershed.

4.7.5.1 Plan Management Focus

The suggested management focus for this sub-watershed includes:

- Improved understanding of whether water quality criteria are being met in Yocum Creek, particularly *E. coli* criteria;
- Improved management of riparian areas;
- Reduction of pathogen and nutrient loads from pasture, developed areas, wildlife, and failing septic systems; and
- Improved understanding of potential water quality threats to local populations of threatened and endangered species.

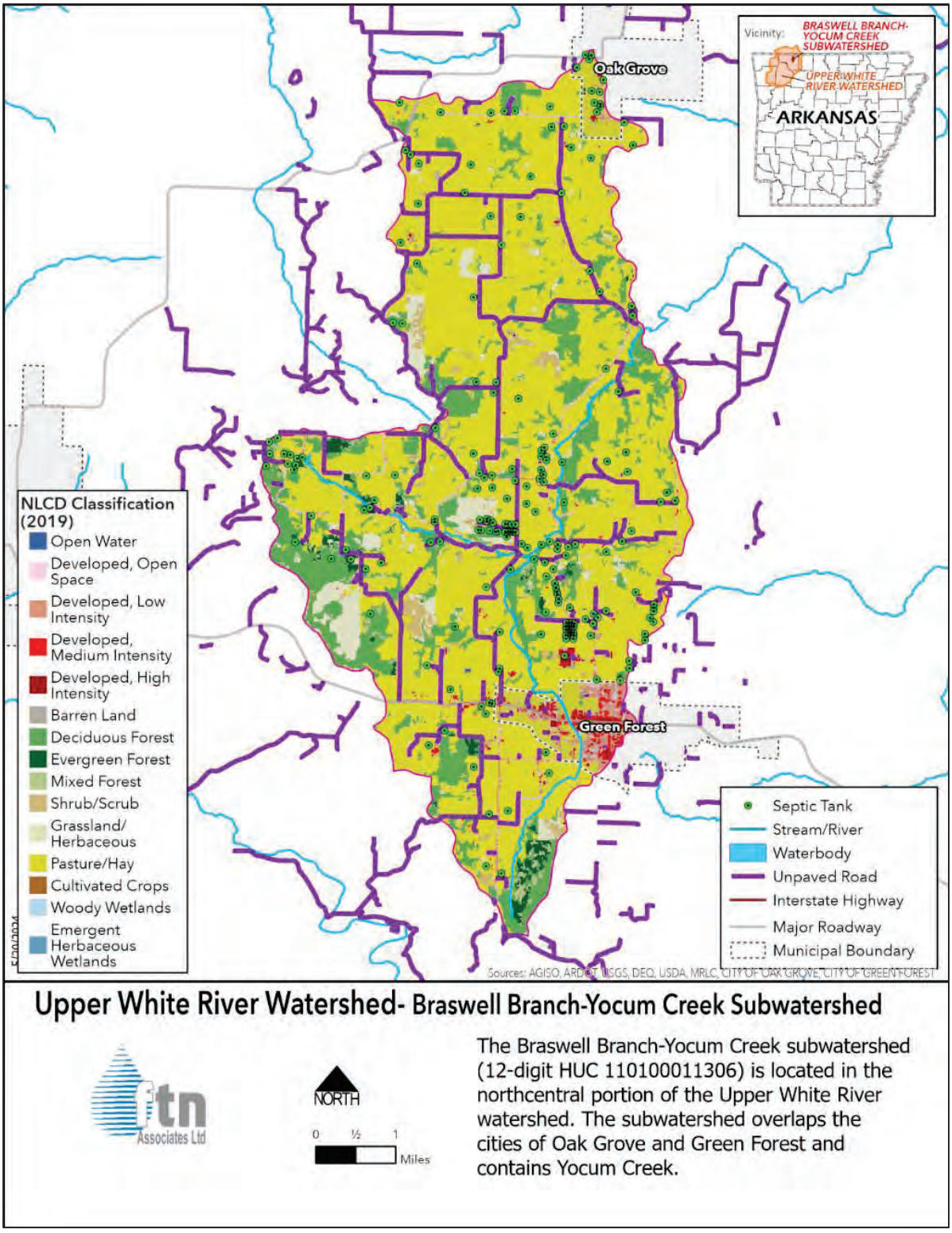


Figure 4.16. Nonpoint pollution sources in the Braswell Branch-Yocum Creek sub-watershed.

4.8 Management Practices

At the fourth public meeting for this watershed management plan, stakeholders were asked to identify management practices to address issues in the Upper White River watershed. Table 4.23 lists the practices discussed at that meeting. These practices identified by stakeholders are applicable to the target pollutant and nonpoint sources in the Category 1 sub-watersheds.

Table 4.23. Management practices for the Upper White River watershed recommended by stakeholders.

Rural	Developed
Rain gardens	Rain gardens
Streambank/stream restoration	Streambank/stream restoration
Streambank stabilization	Smart growth
Environmentally sensitive road maintenance	Low impact development
Septic system remediation	Constructed wetlands
Riparian buffers	Retention, detention basins
Stream clearing (log jams, gravel)	Riparian restoration
	Land conservation

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

4.8.1 Pasture Runoff

Nonpoint sources of pathogens and nutrients associated with pastures that could be reduced include livestock manure and applied fertilizer, including poultry litter or industrial biosolids. The nonpoint source of sediment associated with pasture that could be reduced is field erosion, i.e. gully erosion and sheet/rill/wind erosion. Table 4.24 lists conservation practices that

can reduce nutrient, pathogen, and sediment sources associated with pastures. In this table, the effectiveness of these practices identified through the NRCS Conservation Practice Physical Effects program (CPPE) are shown in parentheses (NRCS, 2024). Note that pasture aeration/restoration has not been evaluated through the CPPE program but has been studied in the Beaver Lake watershed (Popp, et al., 2021). Nutrient management plans help assure that fertilizer is applied appropriately. Because the Upper White River watershed is classified by the State as a Nutrient Surplus Area, all applications of fertilizer to pasture (and hayland), including poultry litter, are required to be guided by a nutrient management plan prepared by a certified nutrient management planner (Arkansas Natural Resources Commission 2010). So, we assume that this practice is already in use for all pasture in the Upper White River watershed.

The first four practices listed in Table 4.24 have been reported as in use in the Upper White River watershed (Popp et al. 2021, R. Christianson, University of Illinois, personal communication 12/7/2021). Critical Area Planting is included because the CPPE program identified this practice as substantially affecting pasture erosion. Prescribed grazing and pasture aeration are identified as recommended pasture management practices in the Beaver Lake Watershed Protection Strategy. Land conservation is also a recommended practice for some pasture areas in that plan (RTI 2023).

Table 4.24. Practices that reduce pasture erosion and sources of pathogens and nutrients. Where available, degree of effectiveness identified from the CPPE program is listed.

Practice	NRCS Practice Code	Effects quantification		
		Pathogen sources	Nutrient sources	Erosion
Prescribed grazing and grazing management	528	Slight	Slight	Moderate to substantial
Nutrient management plans*	102	Moderate to substantial	Substantially	-
Heavy use area protection	561	-	-	Slight to moderate
Pasture and hay planting	512	-	Slight	Moderate to substantial
Pasture aeration	None found	-	X	-
Critical area planting	342	Slight	Slight to moderate	Substantial
Land conservation	None found	X	X	X
Treatment with phosphorus sequestering material	333 or 591	Slight to moderate	Slight to moderate	Slight (333), none (591)

* effectiveness information is for Nutrient Management, practice No. 590

Table 4.25 lists pasture conservation practices that have been identified in the CPPE program as removing substantial amounts of pathogens, sediment, and/or nutrients from runoff (NRCS, 2024). At least some of these practices are in use in the Upper White River watershed (forested riparian buffer, grassed waterway, critical area planting, pond) (R. Christianson, University of Illinois, personal communication 12/7/2021). Restoration and conservation of riparian buffers of pasture streams is recommended in the Beaver Lake Watershed Protection Strategy (RTI 2023). Riparian buffers and constructed wetlands are practices suggested by stakeholders during one of the public meetings (Table 4.23).

Table 4.25. Pasture practices that remove pathogens, sediment, and/or nutrients from runoff (NRCS 2024) and are included in the Arkansas Conservation Practice Catalog (NRCS, 2012).

Practice Name	NRCS Practice Code	Effects quantification		
		Nutrient load	Pathogen load	Sediment load
Filter strip	393	Substantial improvement	Moderate to substantial improvement	Substantial improvement
Riparian forest buffer	391	Substantial improvement	Moderate improvement	Substantial improvement
Riparian herbaceous buffer	390	Substantial improvement	Moderate improvement	Moderate to substantial
Sediment basin	350	Substantial improvement	Minor to moderate improvement	Moderate to substantial
Vegetated treatment area	635	Moderate to substantial improvement	Substantial improvement	Minor to moderate improvement
Constructed wetland	656	Moderate to substantial improvement	Moderate to substantial improvement	Substantial improvement
Grassed waterway	412	Minor to moderate improvement	Minor improvement	Substantial improvement
Critical area planting	342	Minor to moderate improvement	None	Moderate to substantial improvement
Ponds	378	Slight to moderate improvement	Slight worsening	Slight to moderate improvement

4.8.2 Livestock in Streams/Riparian Areas

Practices that reduce the amount of time livestock spend in streams and riparian areas reduce pathogen, nutrient, and sediment loads to streams. Pathogens and nutrients are reduced through reducing deposition of livestock waste in streams and riparian areas. Sediment (and possibly nutrients) are reduced through reduce streambank erosion caused by livestock. Table 4.26 shows practices that are often used to control livestock access to streams. Fencing off riparian areas and providing alternate water supplies can be implemented as part of a prescribed grazing program. Excluding livestock from riparian areas can also be part of riparian restoration or protection. Benefits of prescribed grazing and riparian buffers are listed in previous sections. Exclusion of livestock from streams, providing alternative water sources, and providing stream

crossings are recommended pasture management practices in the Beaver Lake Watershed Protection Strategy (RTI 2023).

Table 4.26. Practices used to control livestock access to streams or riparian areas, with effectiveness from CPPE program (NRCS 2024).

Practice name	NRCS Practice Code	Effects quantification			
		Pathogens	Nutrients	Sediment	Streambank erosion
Watering facility	614	Slight to moderate	Moderate to substantial	Slight to moderate	Moderate to substantial
Access control	472	Slight	Slight	Moderate	Substantial
Fence	382	Slight to moderate	None	Slight	Slight
Stream crossing	578	Slight to moderate	Slight	Slight to moderate	Substantial

4.8.3 Animal Feeding Operations

The primary nonpoint source of nutrients and pathogens at poultry operations that can be reduced is poultry litter stored in the open. Management practices that can reduce this source include storing litter outside for only short periods, transport or transfer of litter off-site, and use of Waste Storage Facilities. The Beaver Lake Watershed Protection Strategy also suggests using litter or manure to produce biogas (RTI 2023). Roof runoff structures can reduce erosion. Practices in the NRCS Arkansas Conservation Practice Catalog that can remove nutrients and pathogens from poultry operation runoff include filter strips, grassed waterways, and vegetated treatment areas (NRCS, 2012). Table 4.27 lists selected practices appropriate for poultry feeding operations and their CPPE effectiveness.

Table 4.27. Selected practices appropriate for poultry feeding operations and their pollutant reduction effectiveness (NRCS, 2024).

Practice name	NRCS Practice Code	Effects quantification	
		Pathogens	Nutrients
Animal mortality facility	316	Slight to moderate	Slight to moderate
Roof runoff structure	558	Slight to moderate	Slight to moderate
Waste storage facility	313	Slight to moderate	Moderate to substantial
Composting facility	317	Slight to moderate	Slight to moderate
Filter strip	393	Moderate to substantial	Substantial
Vegetated treatment area	635	Substantial	Moderate to substantial
Grassed waterway	412	Slight	Slight to moderate
Amendment of waste	591	Slight to moderate	Slight to moderate

4.8.4 Streambank and Lakeshore Erosion

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

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

These practices are in use in the Upper White River watershed and are recommended in the Beaver Lake Watershed Protection Strategy, and by stakeholders. Practices that can reduce hydrologic alteration in both developed and agricultural areas are discussed in Section 4.8.8. As noted in Section 4.7.2, there are stream reaches in the Town Branch-West Fork White River sub-watershed that have been identified as priorities for streambank and channel restoration (RTI 2023). Some of these reaches are associated with developed areas, and others are associated with agricultural areas.

The Beaver Lake Watershed Protection Strategy identifies pasture parcels in the Beaver Lake watershed with riparian area as priorities for riparian restoration. Through the CPPE

program, NRCS has identified practices that substantially reduce streambank erosion. These practices are listed in Table 4.28.

Table 4.28. Practices identified by the CPPE program as effective at reducing streambank erosion (NRCS 2024).

Practice	NRCS Practice Code	CPPE effectiveness for reducing streambank erosion
Access Control	472	Substantial
Stream Crossing	578	Substantial
Stream habitat improvement and management	395	Substantial
Riparian Forest Buffer	391	Moderate to substantial
Riparian Herbaceous Cover	390	Moderate to substantial
Streambank and shoreline protection	580	Moderate to substantial
Watering facility	614	Moderate to substantial

Vegetated buffers or no-mow zones along lake shores, access control, and shoreline protection (e.g., riprap) can reduce lake shore erosion.

4.8.5 Unpaved Roads and Trails and Road Stream Crossings

Erosion and sediment loss from unpaved roads is reduced through the application of practices as part of Environmentally Sensitive Maintenance (ESM) of unpaved roads. These practices have been developed and tested by the U.S. Forest Service and other leaders in the road industry. Examples of ESM practices include appropriate bridge and pipe design at stream crossings, grade breaks and broad dips for drainage control, increasing the number of drainage ditch outlets, and management of roadside and streamside vegetation. ESM is a practice accepted by watershed stakeholders (Table 4.24). As noted in Section 4.7, stretches of unpaved roads in selected Beaver Lake sub-watersheds have been prioritized for application of practices to control erosion and sediment loss, including roads in several Category 1 sub-watersheds (RTI 2023). As of May 2024, Washington and Benton County road crew certification in Environmentally Sensitive Maintenance of unpaved roads through the Arkansas Unpaved Roads Program is up to date, Madison County is not (K. McGaughey, NRD, personal communication 5/20/2024). Thus, we will assume that ESM is in use in Benton and Washington counties, but not in Madison County.

Practices similar to ESM can reduce erosion from unpaved (natural surface) trails. Many erosion reducing features used for unpaved roads can also be used for unpaved trails. Erosion control trail elements can include steps and terraces, edging on the downslope side, water bars, and avoiding steep slopes (The Green Team, 2010).

Stream road crossings can be safety hazards, affect recreation opportunities, and act as barriers to migration of fish and mussel species of concern (Arkansas Water Resources Center, 2019). In addition, they can alter stream geomorphology and contribute to streambank and channel erosion (M. Van Eps, WCRC, personal communication 8/1/2022). These effects can be reduced through thoughtful design of new crossings and modification of existing crossing. Modification of crossings may involve replacing culverts, converting low water crossings to a culvert crossing, or converting a culvert crossing or low water crossing to a bridge (AGFC, 2023).

4.8.6 Failing Septic Systems

The number of failing septic systems acting as sources of nutrients and pathogens can be reduced. Failing septic systems can be in rural areas or developed areas. This can be through either fixing (remediating) or replacing the failing system. Septic system remediation is a practice accepted by watershed stakeholders (Table 4.24). Teaching septic system owners how to properly maintain their systems and supporting owners in proper maintenance prevents septic systems from becoming a source of pathogens and nutrients.

4.8.7 Development Runoff

Several municipalities and Benton and Washington counties in the Upper White River watershed are subject to federal stormwater regulations intended to reduce nonpoint source pollution from development (Municipal Small Separate Storm Sewer Systems (MS4) permits) (Northwest Arkansas Regional Planning Commission, 2024). These regulations require the regulated entities to develop plans to reduce sources of stormwater pollution, including erosion at construction sites, illicit wastewater discharges to storm sewers, pet waste, trash, car washing, vehicle leaks, dumping into storm drains, materials stored outside, and combined sewer overflow

incidents (University of Arkansas Cooperative Extension Service 2024). Thus, one management practice recommended in this plan for addressing nonpoint pollution sources associated with development is to continue to implement the existing stormwater management plans that apply in the Upper White River watershed.

A nonpoint source of sediment in developed areas that can be reduced is erosion of bare or sparsely vegetated soil. An example is areas cleared for construction. Bare soil can be protected from erosion by covering it, either with mulch or adequate planted vegetation.

Nonpoint sources of nutrients in developed areas that can be reduced include pet waste, failing illicit or accidental sewage discharges to storm drains, and improper fertilizer application. Programs or rules that encourage or require pet owners to pick up their pet's waste remove this source of nutrients in developed area runoff. Regular inspection of stormwater and sewer infrastructure can identify sources of sewage contamination of stormwater that can then be fixed. Nutrient management plans and fertilizer application training and certification required in this Nutrient Surplus Area are practices that help reduce improper fertilizer application. Improper fertilizer application may also contribute sulfate to runoff.

Sources of pathogens in developed areas that can be reduced include pet waste, and illicit or accidental sewage discharges to storm drains. These are also sources of organic matter that can affect DO levels. Yard waste is another source of organic matter from developed areas that can be controlled through education and organized collection and management programs.

Reducing the amount of runoff from developed areas, by using Low Impact Development (LID) and Green Infrastructure practices such as rain gardens, green roofs, retention, and detention basins, also reduces pollutant loads to surface waters. However, some LID and Green Infrastructure practices have the potential to increase pollutant inputs to groundwater.

Many LID and Green Infrastructure practices can remove nutrients and other chemicals, pathogens, and sediment from stormwater runoff from developed areas. Examples include filter basins, conservation or restoration of riparian buffers, constructed wetlands, hydrodynamic separators, detention basins, and grassed waterways. Construction site practices that filter sediment from runoff include using silt fence or hay bales.

4.8.8 Hydrologic Alteration

Hydrologic alteration in the Upper White River watershed is believed to be at least partially the result of land use change from forest to pasture and/or development. Pasture, especially poorly managed pasture, and developed areas have different infiltration and runoff characteristics than forest. In general, infiltration is lower for pastures and developed areas, and runoff is higher. However, there are management practices that can improve infiltration and/or reduce runoff from pastures and developed areas.

Pasture management practices that can improve infiltration and reduce runoff include prescribed grazing (EPA, 2003), pasture aeration (Popp, et al., 2021), and conversion of farm ponds to stormwater ponds to reduce peak storm flows (Scott & Haggard, 2015). Prescribed grazing, pasture aeration, and conversion of farm ponds to stormwater ponds are practices recommended in the Beaver Lake Watershed Protection Strategy. Priority catchments for these practices are identified in the strategy, including catchments within the Category 1 HUC12s in the Beaver Lake watershed (IRT 2023).

In developed areas, Low Impact Development and Green Infrastructure practices increase infiltration and reduce stormwater runoff, potentially restoring or maintaining the natural hydrologic function of developed watersheds (EPA, 2023). Examples of these practices include rain gardens, pervious pavement, and stormwater retention and detention basins. These are practices that have already been implemented in the watershed and are accepted by watershed stakeholders (Table 4.24). The Beaver Lake Watershed Protection Strategy has identified developed and developing catchments in several Category 1 sub-watersheds as priority areas for implementation of LID and green infrastructure practices to reduce hydrologic alteration. The Category 1 sub-watersheds of Beaver Lake with identified priority areas are Lake Sequoyah, Town Branch-West Fork White River, Holman Creek, Brush Creek-Beaver Lake, Roberts Creek-Beaver Lake, and Clifty Creek-War Eagle Creek.

4.8.9 Sediments

Phosphorus and pathogens stored in stream and reservoir sediments can be a significant source to aquatic systems, even after land management practices have reduced transport of these

pollutants to waterbodies. Reducing inputs of phosphorus and pathogens to aquatic systems helps reduce their availability from sediment storage. In addition, there are materials that can be added to stream or reservoir sediments to reduce release of phosphorus (Sharpley, et al., 2013). For streams, another option is stream and streambank restoration, which can involve removal of stream sediments that may be a source of phosphorus and/or pathogens. Holistic, integrated practices that work to restore ecological function of watersheds, including stream restoration, have been recommended by some researchers as an approach that is more likely to be effective for reducing sediment pathogens and legacy phosphorus, and/or their effects (Jarvie, et al., 2013) (MacKenzie, Auger, Beitollahpour, & Gharabaghi, 2024).

4.8.10 Boat Wastewater

Safe disposal of wastewater from boats, particularly in the upper end of Beaver Lake, reduces nutrients, pathogens, and organic matter from this source. Proper maintenance and use of pump-out facilities contribute to reducing boat wastewater pollution.

4.8.11 Wildlife

Eradication of feral hogs reduces nutrients, pathogens, organic matter, and erosion from this source. Feral hog control is a difficult endeavor. Trapping and/or killing feral hogs is the approach used in Arkansas.

Canada geese can be encouraged to congregate elsewhere by making the area less attractive to them. This can include not mowing and using harassment techniques that can include noise, predator decoys, dogs, or reflective tape (AGFC 2024).

4.8.12 Groundwater

Groundwater pollutant contributions are reduced by preventing the pollutants from entering the groundwater. However, it should be noted that groundwater trace studies have shown that groundwater can carry pollutants across hydrologic boundaries, i.e., outside of a river basin. The NRCS conservation practice standard for sinkhole treatment recommends using riparian buffers and/or filter strip practices, possibly with fencing, to prevent transfer of

pollutants to groundwater (NRCS, 2021). Table 4.29 lists selected practices that have been identified by CPPE as effective for reducing the transport of nutrients and/or pathogens to groundwater. Table 4.31 lists other agricultural conservation practices identified in Section 4.7.1, 4.7.4, and 4.7.8 with their effect identified by CPPE on transport of nutrients and pathogens to groundwater. Practices in Table 4.31 that are highlighted in yellow have the potential to increase transport of nutrients and/or pathogens to groundwater. Care must be taken to site these practices away from karst features and known spring recharge areas in the Upper White River watershed. Practices that reduce groundwater contamination from developed areas include appropriately designing, installing, and maintaining septic systems; repairing or replacing failing septic systems; fixing vehicle leaks, and detecting and fixing leaks in municipal wastewater collection infrastructure.

Table 4.29. Practices that reduce transport of pathogens and nutrients to groundwater (NRCS, 2024).

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

Table 4.30. Impacts of other agricultural conservation practices on transport of nutrients and pathogens to groundwater (NRCS, 2024). Practices that can increase transport of nutrients or pathogens to groundwater are highlighted in yellow.

Practice Name	NRCS Practice Code	Effects quantification	
		Nutrient load	**Pathogen load**
Constructed wetland	656	Slight improvement	Slight improvement
Critical area planting	342	Slight improvement	Slight improvement
Filter strip	393	Slight improvement	Slight improvement
Heavy use area protection	561	No effect	No effect
Land conservation		--	--
Nutrient management	590	Substantial improvement	Moderate to substantial improvement
Pasture and hay planting	512	No effect	No effect
Pasture aeration		--	--
Ponds	378	Slight worsening	No effect
Prescribed grazing and grazing management	528	Slight improvement	Slight improvement

Table 4.30. Impacts of other agricultural conservation practices on transport of nutrients and pathogens to groundwater (continued).

Practice Name	NRCS Practice Code	Effects quantification	
		Nutrient load	Pathogen load
Sediment basin	350	Slight worsening	Slight worsening
Vegetated treatment area	635	Slight to moderate worsening	No effect
Constructed wetland	656	Slight improvement	Moderate improvement
Grassed waterway	412	No effect	No effect
Watering facility	614	No effect	slight improvement
Access control	472	Slight improvement	Slight improvement
Stream crossing	578	No effect	Slight to moderate improvement
Animal mortality facility	316	Slight to moderate improvement	Slight to moderate improvement
Amendments for treatment of agriculture waste	591	Slight to moderate improvement	Slight to moderate improvement
Roof runoff structure	558	Slight to moderate improvement	No effect
Waste storage facility	313	Slight to moderate improvement	Slight to moderate improvement
Composting facility	317	Slight to moderate improvement	Slight to moderate improvement

4.9 Meeting Load Reduction Goals

Information has been published on the effectiveness of many of the BMPs identified in Section 4.7 for reducing selected pollutants in surface waters, including *E. coli*, sediment, and nutrients. This information was used to estimate potential reductions of these parameters when appropriate BMPs are implemented. Table 4.31 lists ranges of estimated potential load reductions from implementing selected BMPs in the Category 1 sub-watersheds. *E. coli* reductions are included in Table 4.31 for information purposes even though no *E. coli* reduction targets are set in this plan. Potential load reductions were calculated for only some of the many possible BMPs. In general, the results in Table 4.31 suggest that it is not likely that implementing a single type of BMP (e.g., riparian buffers) to address a single pollutant source category (e.g., pasture runoff) will achieve the plan load reduction targets. A variety of BMPs will need to be implemented that address a variety of pollutant sources. The assumptions and calculations used to develop these load reduction estimates are provided in Appendix N. Note that BMPs must be properly installed, operated, and maintained to achieve reported pollutant reduction efficiencies.

Table 4.31. Estimated potential nutrient, sediment, and *E. coli* load reductions from implementing example BMPs in the Category 1 sub-watersheds.

HUC12 sub-watershed name	Total phosphorus (reduction target)	Total nitrogen (reduction target)	Sediment (reduction target)	*E. coli*
Lake Sequoyah	5%-40% (40%)	2%-48%	0-23% (10%)	0-90%
Town Branch-West Fork White River	7%-54% (50%)	1%-51% (25%)	14%-60% (60%)	0-90%
Holman Creek	4%-57% (80%)	<1%-52% (35%)	3%-60% (60%)	0-90%
Glade Creek	1%-49% (0)	<1%-35% (35%)	1%-55% (20%)	0-90%
Clifty Creek-War Eagle Creek	6%-46% (50%)	2%-44% (40%)	<1%-52% (20%)	0-90%
Beaver Lake-War Eagle Creek	11%-51% (70%)	2%-28% (0)	3%-55% (50%)	0-90%
Roberts Creek-Beaver Lake	3%-49% (25%)	<1%-45% (30%)	2%-50% (50%)	0-90%
Brush Creek-Beaver Lake	11%-44% (0)	1%-25% (25%)	17%-35%	0-90%
Spanker Branch-Kings River	2%-20%	1%-14%	13-26%	30%-90%
Clabber Creek-Kings River	1%-47% (55%)	<1%-34% (45%)	1%-45%	25%-90%
Braswell Branch-Yocum Creek	1%-59% (15%)	<1%-40% (40%)	3%-66%	0-90%

We did not find information about the effectiveness of BMPs for reducing sulfate in runoff. So, there are no calculations of the potential for reducing sulfate levels as a result of implementing BMPs. It is expected that practices that filter runoff or reduce the amount of stormwater runoff would also reduce the sulfate load from stormwater runoff. Available information about the effects of urban stormwater BMPs on TDS indicates that these practices either have little to no effect on TDS concentrations or increase TDS concentrations (Clary, Jones, Leisenring, Hobson, & Strecker, 2020).

4.10 Summary

Nonpoint source pollution concerns and management goals have been identified. Eleven Category 1 HUC12 sub-watersheds have been identified in which to focus water quality improvement efforts under this plan. Pollutants targeted for reduction are sediment (turbidity), *E. coli*, nutrients, sulfate, and TDS. Low DO is also a concern in three Category 1 sub-watersheds.

Load reduction targets have been determined for nutrients and/or sediment for nine Category 1 sub-watersheds, and a reduction target has been determined for sulfate for one Category 1 sub-watershed. Recent (2018-2022) *E. coli* data were not available for evaluating attainment of water quality criteria and calculation of reduction targets. We were also not able to determine if nutrient reduction targets could raise DO concentrations in Category 1 sub-watersheds with low DO impairments. Reducing organic matter inputs to surface waters may raise DO concentrations. Many practices that reduce nutrient or sediment inputs to surface waters may also reduce organic matter inputs.

Potential sources of nutrient, *E. coli*, sulfate, TDS, organic matter (low DO), and sediment loads have been identified, and BMPs to reduce nutrient, sediment, and *E. coli* loads from these sources. A variety of practices addressing multiple nonpoint pollution sources will need to be implemented to achieve load reduction targets. Management summaries for each of the Category 1 sub-watersheds are provided below.

- **Lake Sequoyah (HUC 110100010303):** Practices that reduce sediment, phosphorus, and hydrologic alteration are the proposed focus. Streambank and unpaved road erosion, agriculture, and failing septic systems are potential sources of concern. Legacy phosphorus in stream and reservoir sediments may be an issue here. As development increases in this sub-watershed, using low impact development and green infrastructure practices is recommended to reduce water quality and hydrology impacts. Habitat for threatened and endangered aquatic species present in this sub-watershed needs to be protected and/or improved. It should be possible to achieve the sediment load reduction target for this sub-watershed using nonpoint source BMPs, but it may be difficult to meet the phosphorus reduction target.
- **Town Branch-West Fork White River (HUC 110100010404):** Practices that reduce sediment, sulfate, organic matter, nutrients, and hydrologic alteration are the proposed focus. Developed areas, unpaved roads, pasture, and streambank erosion are sources of concern. Legacy phosphorus in stream sediments may be an issue here. Practices that reduce sediment, organic matter, and nutrient inputs from pastures and livestock are also encouraged. Remediation of failing septic systems is also encouraged. As development increases in this sub-watershed, using low impact development and green infrastructure practices is recommended to reduce water quality and hydrology impacts. It could be possible to achieve the nitrogen load reduction target for this sub-watershed using nonpoint source

BMPs, but it may be difficult to meet the phosphorus and sediment load reduction targets.

- **Holman Creek (HUC 110100010606):** Practices that reduce sediment, nutrients, *E. coli*, and hydrologic alteration are the proposed focus. Agriculture, development, streambank erosion, hydrologic alteration, failing septic systems, and unpaved roads are sources of concern. Legacy phosphorus in stream sediments may be an issue here. As development increases in this sub-watershed, using low impact development and green infrastructure practices is recommended to reduce water quality and hydrology impacts. Improvement of Town Branch water quality is suggested as a focus. It may be difficult to achieve sediment and phosphorus load reduction targets by addressing only nonpoint sources.
- **Glade Creek (HUC 110100010608):** Practices that reduce nitrogen and sediment loads, *E. coli*, and hydrologic alteration are the proposed focus. Agriculture, failing septic systems, streambank erosion, and unpaved roads are sources of concern. It appears possible to achieve the nitrogen and sediment load reduction targets for this sub-watershed using nonpoint source BMPs.
- **Clifty Creek-War Eagle Creek (HUC 110100010610):** Practices that reduce nutrients, sediment, and *E. coli* are the proposed focus. Agriculture is the primary source of concern. Practices that reduce sediment inputs from unpaved roads, remediation of failing septic systems, and removal of feral hogs are also encouraged. It could be possible to achieve the nitrogen and sediment load reduction targets for this sub-watershed using nonpoint source BMPs, but it may be difficult to meet the phosphorus load reduction target.
- **Beaver Lake-War Eagle Creek (HUC 110100010611):** Practices that reduce phosphorus, sediment, organic matter, and *E. coli* and improve DO levels in War Eagle Creek are the proposed focus. Sources of concern include agriculture, streambank and lakeshore erosion, unpaved roads, feral hogs, Canada geese, boat wastewater, and failing lakeshore septic systems. It may be difficult to achieve the phosphorus and sediment load reduction targets for this sub-watershed using nonpoint source BMPs.
- **Roberts Creek-Beaver Lake (HUC 110100010701):** Practices that reduce sediment, nutrients, *E. coli*, and organic matter are the proposed focus. Sources of concern include agriculture; development; streambank, lakeshore, and upland erosion; unpaved roads; boat wastewater; feral hogs; Canada geese; and failing lakeshore septic systems. As development increases in this sub-watershed, using low impact development and green infrastructure practices is recommended to reduce water quality and hydrology impacts. It could be possible to achieve the nutrient reduction targets for this sub-watershed using nonpoint source BMPs difficult to achieve the nutrient and sediment load reduction targets.

- **Brush Creek-Beaver Lake (HUC 110100010702):** Practices that reduce nitrogen, sediment, and *E. coli* are the proposed focus. Sources of concern include agriculture, streambank and lakeshore erosion, failing septic systems, feral hogs, and Canada geese. As development increases in this sub-watershed, using low impact development and green infrastructure practices is recommended to reduce water quality and hydrology impacts. It may be difficult to achieve the nitrogen load reduction target for this sub-watershed using nonpoint source BMPs.
- **Spanker Branch-Kings River (HUC 110100010904):** There are not adequate data available to set load reduction targets for this sub-watershed. However, practices that reduce *E. coli* and organic matter are the proposed focus. Agriculture and failing septic systems are sources of concern.
- **Clabber Creek-Kings River (HUC 110100011106):** Practices that reduce *E. coli* and nutrients are the proposed focus. Agriculture, development, failing septic systems, and feral hogs are sources of concern. As development increases in this sub-watershed, using low impact development and green infrastructure practices is recommended to reduce water quality and hydrology impacts. It may be difficult to achieve the nutrient load reduction targets for this sub-watershed.
- **Braswell Branch-Yocum Creek (HUC 110100011306):** Practices that reduce nutrients and *E. coli* are the proposed focus. Agriculture, development, failing septic systems, and feral hogs are sources of concern. As development increases in this sub-watershed, using low impact development and green infrastructure practices is recommended to reduce water quality and hydrology impacts. It appears possible to achieve the phosphorus load reduction target for this sub-watershed using nonpoint source BMPs, but it may be difficult to achieve the nitrogen load reduction target.

5.0 VOLUNTARY IMPLEMENTATION STRATEGY

The voluntary implementation strategy for the Upper White River watershed management plan includes several elements and follows the adaptive management process (Figure 5.1). Beyond voluntary implementation of practices to manage unregulated nonpoint pollution sources, the implementation strategy includes a range of complementary activities. This section describes the following key elements of the implementation strategy in the following subsections:

- Information and education activities for watershed stakeholders,
- An implementation lead to coordinate voluntary activities in Category 1 sub-watersheds,
- Voluntary implementation of BMPs and activities, and influences and barriers to adoption,
- Monitoring water quality and biological indicators to document current conditions and any changes resulting from voluntary nonpoint source pollution management activities,
- Evaluation of the watershed management plan over time,
- Performance measures used to evaluate the progress toward plan goals,
- Update the watershed management plan to accommodate changes in the watershed, and/or in understanding of the watershed, and
- Recommended implementation schedule, with milestones.



Figure 5.1. Illustration of the adaptive management process.

5.1 Information and Education

Watershed management is fundamentally a social activity (Thornton and Laurin 2005). While technical solutions to problems are necessary for effective watershed management, they are not enough. Decisions on how to protect and improve water quality, and implement BMPs, are ultimately based on the socioeconomic perceptions, beliefs, and values of landowners and stakeholders about how these technical solutions will affect them. Researchers have found that watershed residents are not always aware of water quality or other ecosystem issues in their watershed or have misperceptions about ecosystem quality (Lewis, et al. 2017). So, the Information and Education objectives of this watershed plan include the following:

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

5.1.1 Existing Information and Education Activities in the Upper White River Watershed

Several of the organizations active in the Upper White River watershed have outreach and education programs in place that can accomplish the Information and Education objectives of this plan. The BWD and Beaver Watershed Alliance (BWA) are active in the Beaver Lake watershed portion of the Upper White River watershed. The Kings River Watershed Partnership (KRWP) is active in the Kings River watershed. H2Ozarks Arkansas outreach and education programs target the entire Upper White River watershed. Examples of education and outreach programs of these organizations are listed in Table 5.1. Examples of other Upper White River watershed stakeholder groups with active education and outreach programs within this watershed are listed in Table 5.2. Outreach and education activities of some of these organizations are described in Appendix O.

The information and education activities across stakeholder groups in the Upper White River Watershed (Table 5.1) focus on promoting awareness and engagement through workshops, events, and outreach programs tailored to each audience. For agriculture producers, activities include land management practice workshops and assistance programs, with plans for expanded efforts following the completion of this watershed plan. Recreationists and tourists participate in events such as Beaver Lake Volunteer Day, Secchi Day, and cleanup initiatives organized by various groups, complemented by educational signage and online resources. Landowners and residents benefit from diverse programs, including workshops, cleanup events, citizen science opportunities such as StreamSmart, septic system management education, and demonstration projects. Local and county governments are engaged through workshops, speaker series, workforce development efforts, and targeted meeting attendance to share information. Concessioners, vendors, and hospitality businesses are involved in cleanup events and broader lake and watershed initiatives. Finally, teachers and students are reached through lesson plans, classroom presentations, outdoor education events, and teacher training programs, fostering watershed stewardship among youth and educators alike.

5.1.2 Planned Information and Education Activities

In addition to existing, ongoing education and outreach, several organizations have information and education projects planned or in the works. For example, WCRC is developing The River Commons and Institute as a demonstration and training facility showcasing ecological restoration approaches and the benefits of wetlands, prairies, floodplains, natural riparian areas, and rivers. A public access to the West Fork White River is also planned at this facility.

H2Ozarks is planning public meetings and information outreach to local policy makers about septic system maintenance and challenges during 2025. In addition, H2Ozarks has plans to increase outreach to agriculture producers following the completion of this watershed plan, including offering land management practice workshops.

Table 5.1. Examples of active education and outreach activities of selected organizations.

Stakeholder Group	Beaver Water District (BWD)	Beaver Watershed Alliance (BWA)	Kings River Watershed Partnership (KRWP)	H2Ozarks
Agriculture producers		Land management practice workshops, Landowner assistance program		
Recreationists and other tourists	Beaver Lake Volunteer Day, Secchi Day	Workshops, BWA website, clean up events, educational signage	Kings River clean up	Beaver Lake Volunteer Day, H2Ozarks website
Landowners and residents	Beaver Lake Volunteer Day, Secchi Day, War Eagle Appreciation Day, War Eagle Creek Steward Program, Other local events, BWD website	Land management practice workshops, Riparian, Forest, and Source Water Protection Landowner Outreach program, BWA website, Quarterly speaker series, West Fork Watershed Cleanup, other clean up events, invasives removal events, riparian planting events, Demonstration projects, educational signage	Landowner's Guide to Streamside Living, website	Septic system management, StreamSmart citizen science program, Beaver Lake Volunteer Day, Demonstration projects, H2Ozarks website
Local and county governments		Land management practice workshops, Quarterly speaker series, work force development	KRWP website	Attendance at meetings to disseminate information as needed, H2Ozarks website
Concessioners, vendors, hostelers, restaurants	Beaver Lake Volunteer Day, Secchi Day	Clean up events	Kings River clean up	Beaver Lake Volunteer Day
Teachers and students	Lesson plans, tours, local events, classroom presentations	Beaver Lake Watershed Symposium, Outdoor Watershed Education and Recreation	KRWP website	StreamSmart program, "educating the educators" at Arkansas Environmental Education Association meetings

Table 5.2. Additional Upper White River watershed stakeholder groups and organizations with outreach programs.

Stakeholder Groups	Organizations with Information and Education Programs for the Stakeholders
Agriculture producers	NRCS, University of Arkansas Division of Agriculture, County Conservation Districts, Arkansas Grazing Lands Coalition, Arkansas Cattlemen's Association, Arkansas Farm Bureau, Agriculture Council of Arkansas, AGFC, Arkansas Resource Conservation and Development Council (ARCDC), National Center for Appropriate Technology (NCAT), Sustainable Agriculture Research and Education (SARE), Arkansas Land Trust, WCRC
Recreationists and other tourists	USFWS; USACE; AGFC; Audubon Arkansas; The Nature Conservancy; Arkansas Department of Parks, Heritage, and Tourism; Trout Unlimited; Chambers of Commerce, Quail Forever
Landowners and residents	Rural Water Associations, NRCS, University of Arkansas Division of Agriculture, County Conservation Districts, AGFC, Arkansas Natural Heritage Commission, The Nature Conservancy, Arkansas Master Naturalists, ARCDC, Trout Unlimited, USACE, USFWS, Quail Forever, Arkansas Department of Health, Northwest Arkansas Land Trust, WCRC, Northwest Arkansas Regional Planning commission
Local and county governments	Arkansas Economic Development Commission, Natural Resources Division, ARCDC, Arkansas Farm Bureau, WCRC, Northwest Arkansas Regional Planning Commission
Concessioners, vendors, hostelers, restaurants	Arkansas Economic Development Commission; Arkansas Department of Parks, Heritage, and Tourism; Trout Unlimited; AGFC; USACE, Northwest Arkansas Regional Planning Commission
Teachers, students	AGFC, DEQ, Arkansas Farm Bureau, Arkansas Wildlife Federation, Ozark Natural Science Center

5.1.3 Proposed Information and Education Activity

Quantification of the ecosystem services of the Upper White River watershed is proposed as an additional information and education activity. Ecosystem services are the benefits people obtain from ecosystems (Millennium Ecosystem Assessment 2005) and the direct and indirect contributions of ecosystems to human well-being (Kumar 2010).

The Millennium Ecosystem Assessment, categorizes ecosystem services into four types:

- *Provisioning* services such as food, water, timber and fiber;
- *Regulating* services that affect climate, floods, disease, wastes, and water quality;
- *Cultural* services that provide recreational, aesthetic, and spiritual benefits; and
- *Supporting* services such as soil formation, nutrient cycling, pollination, and photosynthesis (Millennium Ecosystem Assessment 2005).

Typically, only provisioning services have market value, with the monetary benefits determined within the marketplace where goods and services are bought and sold. However, there are many more benefits and values provided by ecosystem services than just provisioning services. A set of standard terms about economic values for ecosystem services has been developed based on whether there is a physical relationship between the ecosystem and human use (National Research Council 2004). Value of ecosystem services are categorized as follows:

- Use values: These *values* can be subdivided into consumptive, non-consumptive, or indirect use.
    - Consumptive uses: Market-based provisioning services such as water withdrawals for drinking or irrigation.
    - Non-consumptive uses: These include boating, recreational fishing, or health benefits of clean water.
    - Indirect uses: These encompass services such as providing habitat for birds and birdwatching, hunting areas, or spawning habitat for fish.
- Non-use values: These are not tied directly or indirectly to human use.
    - Option value: The value people place on having the option for future use of an ecosystem where there is no current desire to use the ecosystem.
    - Bequest value: The desire to assure that ecosystem resources are available for future generations.

- Altruistic value: The wish to make sure that ecosystem resources are available for others in the present.

Economists have developed methods for quantifying the value of many of the non-consumptive, indirect, and non-use ecosystem services (Table 5.3). Many of these methods are applicable for estimating the value of services provided by Upper White River and its tributaries. Results of a 2017 study of residents willingness to pay for establishing and maintaining forested riparian buffers in the Clear Creek watershed (tributary of Illinois River in Arkansas) suggest that use of financial costs and benefits would be a useful way to communicate with local stakeholders about protecting and managing ecosystem quality in that watershed (Lewis, et al. 2017). Thus, it is expected that quantifying and presenting the value of services provided by ecosystems in the Upper White River watershed would increase local interest in protecting or improving those ecosystems.

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

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

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

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

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

- Drivers (D): Underlying causes or motivations for changes,
- Pressures (P): Direct effects or stressors imposed on the ecosystem,
- Status (S): The current condition or state of the ecosystem,
- Impacts (I): Consequences of changes in ecosystem status on human well-being, and
- Responses (R): Actions and strategies, including BMPs, implemented to address or mitigate impacts.

Using the DPSIR framework will aid in understanding how changes in ecosystem services affect human well-being in the Upper White River sub-watersheds. This type of analysis is useful for stakeholders wanting to balance ecosystem services in a changing environment (Mansoor Leh, 2013). For instance, ecosystem services provided by agricultural production under various management schemes could mitigate those lost by urbanization. The tools could also quantify changes in ecosystem services under BMP scenarios in both urban and agricultural settings. The set of ecosystem services that could be considered for valuation, and the proposed valuation method, is shown in Table 5.4.

5.2 Implementation Lead

The greatest efficacy in implementing watershed management plans, and protecting and improving water quality, is typically achieved through locally-led watershed groups or teams. There is empirical evidence that nonprofit watershed groups or teams can provide public goods (Grant and Langpap 2018). In economics, a public good is a commodity or service available to all individuals and where one individual cannot reduce the availability to others. Grant and Langpap reviewed information from 2,150 watersheds across the lower U.S. from 1996 to 2008. Watershed groups in these watersheds increased from 500 to 1,500 over this same period. They found the activity of these watershed groups resulted in improved water quality, specifically a decrease in DO deficiency (i.e., increase in DO concentrations in waterbodies), compared to watersheds in which there were no groups. Donations to watershed groups were associated with reduced DO deficiency. Watershed groups can make a significant difference in improved water quality within a watershed through their activities.

H2Ozarks has committed to leading implementation of the Upper White River Watershed Management Plan. H2Ozarks works with several locally led interest groups active in this watershed. This includes BWD, BWA, and KRWP. Table 5.5 lists additional possible partners associated with the Category 1 sub-watersheds for this plan.

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

Ecosystem services	Category[a]	Value type	Valuation method[b]	Examples of economic good provided
Water for Drinking	Provisioning	Direct	MP, CV	Water for domestic uses
Raw (biotic) materials	Provisioning	Direct	MP, RC	Algae as fertilizers
Water for non-drinking purposes	Provisioning	Direct	MP, PF	Water for industrial or agricultural uses
Raw materials for energy	Provisioning	Direct	RC	Wood from riparian zones
Water purification	Regulation	Indirect	RC, CV	Excess nitrogen removal by microorganisms, solids and nutrients removed by vegetation
Erosion prevention	Regulation	Indirect	RC	Vegetation controlling soil erosion
Flood protection	Regulation	Indirect	RC, CV	Vegetation acting as barrier for the water flow, infiltration capacity of soils
Maintaining populations and habitats	Regulation	Indirect	RC	Habitats used as a nursery, host fish for protected mussel species
Pest and disease control	Regulation	Indirect	RC, CV	Natural predation of diseases and parasites
Soil formation	Regulation	Indirect	RC	Rich soil formation in flood plains
Carbon sequestration	Regulation	Indirect	RC, MP	Carbon accumulation in sediments
Location climate regulation	Regulation	Indirect	RC, MP	Maintenance of temperature patterns
Recreation	Cultural	Direct	CV, TC, DC, HP	Swimming, boating, sightseeing
Recreational fishing	Cultural	Direct	TC, CV	Sportfishing for bass, crappie, walleye, catfish, trout
Recreational boating/swimming	Cultural	Direct	MP, TC, CV	Boating, swimming
Intellectual and aesthetic appreciation	Cultural	Non-use	CV, DC	Matter for research, artistic representation
Spiritual and symbolic appreciation	Cultural	Non-use	CV, TC, DC	Sense of being
Raw abiotic materials	Extra abiotic	Direct	PF, MP	Extraction of sand and gravel
Abiotic energy sources	Extra abiotic	Direct	PF, MP	Hydropower generation

a Provisioning, Regulation and maintenance, Cultural, Extra abiotic

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

Table 5.5. Potential stakeholder partners for H2Ozarks in the Upper White River Category 1 sub-watersheds.

Category 1 sub-watershed	Potential stakeholder partners
Lake Sequoyah	BWA, City of Elkins, City of Fayetteville, cattle farmers, poultry producers, Washington County, developers
Town Branch-West Fork White River	BWA, City of Fayetteville, University of Arkansas, Washington County, poultry producers, cattle farmers, pork producers
Holman Creek	BWA, City of Huntsville, cattle farmers, poultry producers, Madison County, developers
Glade Creek	BWA, cattle farmers, town of Hartwell, poultry producers, Madison County
Clifty Creek-War Eagle Creek	BWA, BWD, Benton County, Madison County, Washington County, City of Clifty, cattle producers, poultry producers, developers
Beaver Lake-War Eagle Creek	BWA, USACE, BWD, developers, cattle farmers, poultry producers, Benton County, Washington County
Roberts Creek-Beaver Lake	BWA, City of Goshen, City of Fayetteville, Washington County, USACE, BWD, poultry producers, cattle farmers, pork producers, developers
Brush Creek-Beaver Lake	BWA, City of Hindsville, Washington County, Madison County, cattle farmers, poultry producers, USACE, developers, pork producers
Spanker Branch-Kings River	KRWP, Town of Kingston, Madison County, Kings River Outfitters, cattle farmers, poultry producers
Clabber Creek-Kings River	KRWP, City of Berryville, Town of Grandview, Carroll County, Kings River canoe liveries, developers, cattle farmers, poultry producers
Braswell Branch-Yocum Creek	City of Green Forest, City of Oak Grove, Carroll County, cattle farmers, developers, poultry producers

5.3 Voluntary Implementation of BMPs

Section 4.8 identifies nonpoint source pollution BMPs appropriate for Upper White River watershed and the Category 1 sub-watersheds. Focus areas for management are identified in Sections 4.3 and 4.7. There is no legal requirement that anyone implement any of the practices listed in Section 4.8. These are practices that are suggested for landowners, operators, and other stakeholders interested in improving or protecting water quality in the Upper White River watershed. In addition to protecting water quality, these practices can increase the value and

returns on the property where they are implemented (when they are properly installed, operated, and maintained). These are not the only practices appropriate for the watershed, but rather those that are generally accepted within the watershed and suggested by stakeholders. Other practices not listed could also improve or protect water quality and habitat. Programs that can provide technical and financial assistance to landowners, operators, and other stakeholders for implementing (i.e., installing, operating, and maintaining) these BMPs are listed in Section 6.

5.3.1 Past Implementation of BMPs

Many of the BMPs listed in Section 4.8 are already in use in the Upper White River watershed and in the Category 1 sub-watersheds. Particularly in the Beaver Lake watershed there have been many BMPs implemented. For example:

- Land Easements
    - Northwest Arkansas Land Trust reports that as of the end of 2022 their program protects 6,785 acres on 42 properties in Benton, Carroll, Crawford, Johnson, Madison, Marion, and Washington counties (Northwest Arkansas Land Trust 2022) (Northwest Arkansas Land Trust 2024).
    - FSA reports that in 2022 430 acres in Benton, Boone, Carroll, Madison, and Washington counties were enrolled in their Conservation Reserve Program (FSA 2023).
    - The Nature Conservancy dedicated the Kings River Preserve in May 2010, which spans 10.5 miles of the Kings River (The Nature Conservancy 2024).
- Riparian area improvement
    - FSA reports that through 2020, 200 acres of riparian buffers were restored on CRP lands (FSA 2020).
    - NRCS reports that 2008-2020, 38 acres and 7,128 feet of riparian areas were improved through EQIP and CSP (R. Christianson, University of Illinois, personal communication 12/7/2021).
    - The Nature Conservancy reports restoration of ¾ miles of Kings River riparian corridor (The Nature Conservancy 2023).
    - WCRC reports over 48,000 feet of riparian area protected or restored since 2010 (WCRC, personal communication 11/1/2024).
- Stream restoration:

  - WCRC reports over 26,000 feet of streambank restoration since 2010 (WCRC, personal communication 11/1/2024).
  - The Nature Conservancy reports ¾ miles of Kings River streambank restored (The Nature Conservancy 2023).
- H2Ozarks reports 61 septic tanks remediated or replaced through their septic tank program (E. Scott, H2Ozarks, personal communication 9/23/24).

Figures 5.2 and 5.3 summarize practices implemented in the Upper White River watershed through NRCS EQIP and CSP programs during the period 2008-2020. The 2022 Census of Agriculture reported the number of operations within each county on which prescribed grazing was implemented in 2022 (U.S. Department of Agriculture National Agricultural Statistics Service 2024). These data for the counties associated with the Upper White River watershed are listed in Table 5.6. The U.S. Department of Agriculture (USDA) Farm Services Agency (FSA) reports acres enrolled in the Conservation Reserve Program (CRP) annually by county (FSA 2021a). Acres enrolled in CRP during 2022 in the counties associated with the Upper White River watershed, and the specific practices used on the CRP acreage in 2022, are included in Table 5.7. Table 5.8 lists examples of BMP implementation projects from 2014-2023 funded by sources other than EQIP and CSP.

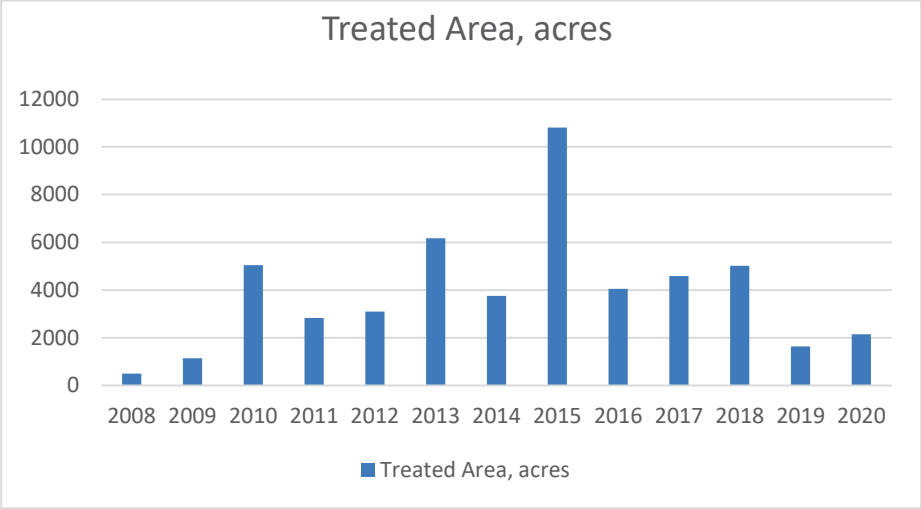


Figure 5.2. Summary of area treated by BMPs implemented through EQIP and CSP programs 2008-2020 in Upper White River watershed (R. Christianson, University of Illinois, personal communication 12/7/2021).

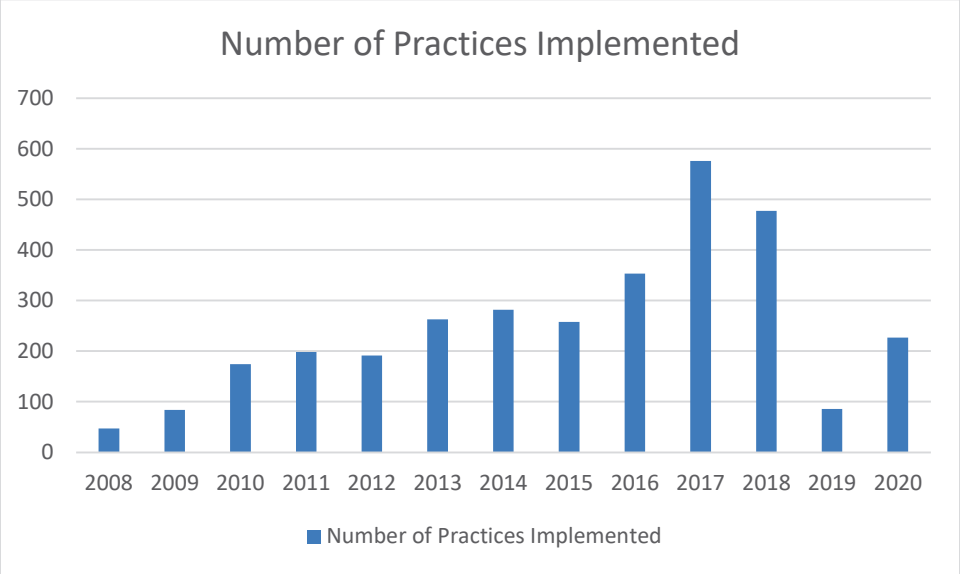


Figure 5.3. Number of BMPs implemented in Upper White River watershed through EQIP and CSP programs 2008-2020 (R. Christianson, University of Illinois, personal communication 12/7/2021).

Table 5.6. Extent of conservation practices by county reported in the 2022 Census of Agriculture (U.S. Department of Agriculture National Agricultural Statistics Service 2024) and by FSA (FSA 2023).

Practices	Reporting year	Extent in:				
		Benton County	Boone County	Carroll County	Madison County	Washington County
Prescribed grazing	2022	269 operations	208 operations	170 operations	173 operations	367 operations

Table 5.7. Acreage enrolled in CRP practices by county reported by FSA cumulative through 2020 (FSA 2020).

CRP Practices	Acreage by County				
	Benton	Boone	Carroll	Madison	Washington
Introduced grass plantings	--	195	--	--	--
Native grass plantings	32	--	--	--	--
Riparian buffers	11	12	71	9	97
Wildlife buffers	--	--	--	3	--
TOTAL	43	207	71	12	97

Table 5.8. Examples of BMPs installed 2014-2023 through projects funded by other sources (Completed Projects - Watershed Conservation Resource Center, Project Directory | Beaver Watershed Alliance, Nonpoint Source Management - Arkansas Department of Agriculture – Annual Reports).

Project Title (Lead Organization)	Start year	End year	BMPs	Type of Project/funding source
Rock Creek Phase II (WCRC)	2019	2021	Streambank restoration	
Cato Springs at Mount Kessler Regional Park (WCRC)	Unknown	2016	2,000 feet of stream restoration	City of Fayetteville, BWD, Natural Resources Division
Devil's Eyebrow Erosion Control Project (Arkansas Natural Heritage Commission)	2014	2015	Planting of native tree seedlings for erosion control	Arkansas Natural Heritage Commission
White River Bank Restoration and Monitoring Project (Natural Resources Division)	2014	2017	Restored 1,200 feet of riverbank Established native riparian area	319 project 13-1100
Beaver Lake Watershed Landowner Assistance (AFGC Stream Team – Region I)	2015	2018	Technical assistance Streambank stabilization	AGFC Stream Habitat Program
Beaver Reservoir Watershed Project (Boone County Conservation District)	2015	2018	Technical and financial assistance for BMP implementation	319 project number 15-600
Beaver Tailwater / Kings River Landowner Assistance (AGFC)	2015	2016	Streambank stabilization	AGFC Trout Habitat Program
Rain Garden Mini Grant Program (BWA)	2015	2017	Rain gardens	BWA
Kings River Mason Bend and Oxbow streambank restoration projects (The Nature Conservancy)	2016	2018	Restored ¾ miles of riverbank Planted over 500 trees in riparian corridor	The Nature Conservancy
Urban Forestry Expansion Program (BWA)	2016	2016	Urban forest improvements	Arkansas Forestry Commission, The Nature Conservancy, Arkansas Natural Heritage Commission
White River and Richland Creek Watershed Opportunity Assessment (BWA)	2016	2019	BMP implementation Education and outreach Water quality monitoring	BWA
Lake Atalanta Sediment Reduction and LID Demonstration Project (H2Ozarks, BWA)	2016	2022	Install series of sediment detention weirs on upper Prairie Creek Install pervious pavement in park parking areas	319 projects 15-500 and 20-500
Five Star and Urban Waters Restoration Program (BWA)	2017	2020	Installed 5 green infrastructure demonstration sites Removed invasive plant species and developed conservation plan for 97 acres of upland urban forest Established 20 acres of riparian forest along 4 miles of tributaries	National Fish and Wildlife Foundation
LID / Green Infrastructure Mini Grant Program (BWA)	2017	2020	Low-water crossing improvement on Mill Creek Riparian improvements along War Eagle Creek and East Fork and West Fork of White River Aerated 295 acres of pastureland Invasive plant eradication on over 90 acres on Mount Sequoyah 7,925 pounds of trash removed from local waterways	BWA
Source Water Protection and Watershed Management Demonstration Project (BWA)	2017	2021	Ponds	Walton Family Foundation
West Fork Stream Restoration at Brentwood Mountain (WCRC)	2017	2022	Stream restoration	319 project 17-900

Table 5.8. Examples of BMPs installed through 2014-2023 projects funded by other sources (continued).

Project Title (Lead Organization)	Start year	End year	BMPs	Type of Project/funding source
West Fork White River Partnership Initiative (NWA Land Trust)	2018	2021	Conservation easements	NRCS
White River RCPP Project (Carroll County Conservation District)	2018	2020	Approved conservation practices: waste storage facility, animal mortality facility, roof and covers, and heavy use area protection	NRCS RCPP
West Fork White River Stream Mitigation Bank Flood Damage Repair (WCRC)	2019	2021	Stream restoration Conservation practices	WCRC
Beaver Lake Cedar Tree Habitat Project (Reservoir Fisheries Habitat Partnership)	2021	2022	600 feet of streambank/channel restoration along Big Clifty Creek Six acres riparian buffer restored to native vegetation 130 new reservoir fish habitat sites, 30 close to public access Removal of invasive red cedar trees from Beaver Lake WMA	Fish America Foundation, Bass Pro Shops
Beaver Lake Watershed – Low Impact Development (BWA)	2021	2021	Permeable pavers and bioretention basin at Hickory Creek Park, Lowell Placed 1,340 square feet of permeable pavement in Huntsville Mitchusson Park Permeable pavers and 1,091 square foot bioretention cell at Kessler Mountain Regional Park, Fayetteville	319 project 17-1000
University of Arkansas Stadium Drive-Bulldog Branch – Fayetteville, Arkansas (WCRC)	2021	2021	550 feet of stream restoration in Bulldog Branch	University of Arkansas
West Fork White River Watershed Project (NRCS)	2022		Stream and streambank restoration Streambank stabilization Establish / restore riparian areas	PL83-566
West Fork White River at Dye Creek Rd. (WCRC)	2023	2023	6,600 ft of streambank restoration 12,000 feet of riparian vegetation protected and/or restored	PL83-566
Ecologically-based Stormwater BMP for the Josh Brown Property, West Fork of the White River Watershed (WCRC)	2022	2024	Prairie and wetland restoration Removal of non-native invasive plants Storm ditch restoration	BWA, BWD, City of Fayetteville, Walton Foundation, Ozark Land Trust
West Fork Public Library (BWA)	2023	2023	Permeable pavers and bioswale	319 project Smart Growth for Source Water Protection

5.3.2 Planned/ongoing implementation

Several BMP implementation projects are underway in the Upper White River watershed. Examples are listed in Table 5.9. The watershed improvement initiatives across Northwest Arkansas continue to focus on implementing best management practices (BMPs) and restoration efforts to enhance water quality, ecological health, and public access. Ongoing projects in the Beaver Lake Watershed, led by the BWA, address agricultural and forestry BMPs, riparian plantings, streambank restoration, erosion control, and unpaved road improvements. Additional efforts include restoration of streams, riparian areas, and wetlands at various sites such as the West Fork White River, Town Branch, and University of Arkansas Fayetteville campus, supported by EPA Climate Pollution Reduction Grants and NRCS PL-566 funding. The Lake Leatherwood watershed assessment aims to rehabilitate reservoir planning while projects such as the River Commons and the River, Riparian, and Wetland Enhancement Initiative focus on floodplain, prairie, and wetland restoration. Conservation easements in the Beaver Lake Watershed, facilitated by the Northwest Arkansas Land Trust, protect up to 500 acres. These collaborative efforts, involving partnerships with local governments, nonprofits, and federal agencies, demonstrate a comprehensive approach to sustaining and restoring critical watershed resources.

Table 5.9. Examples of ongoing BMP projects in the Upper White River watershed.

Project Title (Lead Organization)	Start year	End year	Focus Area	BMPs	Type of Project/funding source
Beaver Lake Watershed – Agricultural BMPs (Beaver Watershed Alliance)	2021	Ongoing	Beaver Lake watershed	Agricultural BMPs (non-EQIP): 6 parcels 12 BMPs 475 acres	Beaver Watershed Alliance
Smart Growth for Source Water Protection (BWA)	2022	2026	Fayetteville, West Fork, TBD	LID practices such as rain gardens, bioswales, permeable pavers at three sites	319 project 22-500
Beaver Lake Watershed – Forestry BMPs (Beaver Watershed Alliance)	2021	Ongoing	Beaver Lake watershed	Forestry BMPs: 11 parcels 41 BMPs 493 acres	Beaver Watershed Alliance
Beaver Lake Watershed – Low Tech Erosion Control (Beaver Watershed Alliance)	2021	Ongoing	Beaver Lake watershed	Low Tech Erosion Control: 5 structures 5 acres	Beaver Watershed Alliance
Beaver Lake Watershed – Low Water Crossing Improvements (Beaver Watershed Alliance)	2021	Ongoing	Beaver Lake watershed	Low water crossing installed at Goshen – Mill Branch Park	Beaver Watershed Alliance
Beaver Lake Watershed – Riparian Plantings (Beaver Watershed Alliance)	2021	Ongoing	Beaver Lake watershed	Riparian Plantings: 8 parcels 9 plantings 37 acres	Beaver Watershed Alliance
Beaver Lake Watershed – Streambank Restoration (Beaver Watershed Alliance)	2021	Ongoing	Beaver Lake watershed	Streambank Restoration: 300 linear feet of Clifty Creek (tributary of War Eagle Creek)	Beaver Watershed Alliance
Beaver Lake Watershed – Unpaved Road Improvements (Beaver Watershed Alliance)	2021	Ongoing	Beaver Lake watershed	Unpaved Road Improvement: 500 linear feet	Beaver Watershed Alliance
Free Tree and Shrub Program (Beaver Watershed Alliance)	2016	Ongoing	Beaver Lake watershed	Native plant distribution for erosion control	Beaver Watershed Alliance
Connecting Community to Urban Streams and Forests in a Low-income Neighborhood at Walker Park, Fayetteville, AR (WCRC)	2023	2028	Walker Park, Fayetteville	Restoration of stream, riparian areas, and native forest Green infrastructure	US Forest Service Urban and Community Forestry Grant
War Eagle Creek Watershed Initiative (BWA, NRCS)	2023	2027	War Eagle Creek watershed	Planning and a wide variety of land management practices for pastures, forests, and streams are eligible, including forest management practices, ponds, streambank stabilization, riparian restoration, and pasture management practices.	NRCS RCPP
War Eagle Creek Stream Barrier Removal (AGFC, BWA, USFWS)	2023	2027	War Eagle Creek	Remove four stream barriers Restore 5,500 to 7,200 feet of streambank Create 4 to 5 acres of wetlands	USFWS Partners for Fish and Wildlife and National Fish Passage Program, SARP, National Fish and Wildlife Federation America the Beautiful Challenge

Table 5.9. Examples of ongoing BMP projects in the Upper White River watershed (continued).

Project Title (Lead Organization)	Start year	End year	Focus Area	BMPs	Type of Project/funding source
West Fork White River at Pump Station Rd (WCRC)	2014	Ongoing	West Fork White River at Pump Station Rd	8,000 feet of stream and riparian restoration Wetland restoration Fish passage Public access	NRCS PL-566
Lake Leatherwood watershed assessment (WCRC)	2022	2026	Lake Leatherwood	Rehabilitation planning reservoir	City of Eureka Springs Parks and Recreation, 319 project 22-700
River Commons Floodplain, Prairie and Riparian Restoration (WCRC)	2024	unknown	Dead Horse Road	Floodplain, prairie, riparian restoration	EPA Climate Pollution Reduction Grant
Town Branch Corridor Stream and Riparian Restoration (WCRC)	2024	2030	Town Branch (Fayetteville)	Stream and riparian restoration	EPA Climate Pollution Reduction Grant
University of Arkansas Oak Knoll Wetland, Prairie, Forest, Stream, and Riparian Restoration (WCRC)	2024	2030	University of Arkansas Fayetteville campus	Wetland, prairie, forest, stream, and riparian restoration	EPA Climate Pollution Reduction Grant
University of Arkansas Oak Ridge Hillside Prairie and Forest Restoration and Trail Construction (WCRC)	2024	2030	University of Arkansas Fayetteville campus	Hillside prairie and forest restoration	EPA Climate Pollution Reduction Grant
University of Arkansas AR Research and Tech Park Floodplain, Prairie, and Forest Restoration (WCRC)	2024	2030	University of Arkansas Fayetteville Campus	Floodplain, prairie, and forest restoration	EPA Climate Pollution Reduction Grant
West Fork White River Wetland, Prairie, Stream, Riparian Restoration (WCRC, City of West Fork)	2024	2030	West Fork White River at City of West Fork	Wetland, prairie, stream, riparian restoration	EPA Climate Pollution Reduction Grant
Enhancement and Establishment of River, Riparian, and Wetland Restoration in Northwest Arkansas (WCRC)	2022	2027	Beaver Lake, Illinois River, Little Sugar River, Elk River watersheds	Enhancement of 5,000 feet of previously restored river and riparian areas and 3 acres of restored wetlands	319 project 22-300
Preserving Water Quality in the Beaver Lake Watershed (Northwest Arkansas Land Trust)	2022	2025	Beaver Lake watershed	Conservation easements – a total of 3 parcels or 500 acres, whichever is greater	319 project 22-400

5.3.3 Influencing Implementation of BMPs and Activities

Over the past decade, there has been considerable work conducted on ways of leading and implementing change within organizations and communities (Grenny, et al. 2013). In general, there are three important domains, and two important subdomains within each domain, that are critical in influencing change. The domains are personal, social, and structural and the sub-domains are motivation and ability. These three domains and two sub-domains form a six-celled matrix (Table 5.10).

Table 5.10. Domain, sub-domain, and elements that can influence behavioral change in implementing BMPs and activities (Grenny, et al. 2013).

	Sub-domain	
Domain	**Motivation**	**Ability**
Personal	Links to Values and Personal Benefits	Training, Skill Building
Social	Peer Pressure	Social Support
Structural	Rewards, Accountability	Change the Environment

In many instances, efforts to encourage implementation of BMPs have addressed only personal motivation and ability, i.e., ensuring that individuals have the motivation to change and are provided with the training and ability to make the change. However, the social elements of motivation such as peer pressure and support groups (e.g., Neighborhood Associations, Grazing Land Coalition, Soil Health Alliance) are critical in supporting the personal domain. Research into adoption of BMPs has identified the importance of social networks in increasing adoption of practices (Froelich 2010, Liu, Bruins and Heberling 2018). In addition, making changes in the social environment (i.e., structural domain) through cost-share and rewards (i.e., motivation), and changing the physical environment in which individuals interact (e.g., native grass pasture vs. fescue or bermudagrass) are also critical in bringing about changes in how land and water are viewed and managed. The key is to simultaneously address all six cells, not just one or two of the cells. In some cases, it might not be possible to address all six, but the emphasis should be on implementing as many of the six cells as possible to encourage and promote change.

Pasture management is a recommended approach for improving water quality within the Upper White River watershed. Examples of factors that might influence change for each of the elements in the matrix for pasture management are shown in Table 5.11. An example matrix for implementation of riparian buffers is shown in Table 5.12. The recommendation is that all six elements of the influence matrix be considered when working with local stakeholders in the Upper White River watershed.

Table 5.11. Elements that might help influence implementation of pasture BMPs.

Domain	Motivation	Ability
Personal	• Better pasture/forage quality • Increased livestock rate of gain • Reduced hay feeding • Sustained water supply • Cost-share programs • Increased profit	• Grazing land conference • Field days • YouTube/other videos • Grazing stick • NRCS technical assistance • University of Arkansas Cooperative Extension
Social	• Leaders implementing practices • Cattleman of the Year Award	• Grazing land coalition • Field days • Rancher to rancher exchanges • Conferences • Workshops
Structural	• NRCS EQIP funding • NRCS RCPP funding • 319 funding	• Grow grass, not algae campaign • Grazing stick • Promote electric fence or invisible fence • AGFC Acres for Wildlife • 4-5 forage paddocks • Stockpile paddock • Alternative water supply

Table 5.12. Elements that could help influence implementation of riparian buffers.

Domain	Motivation	Ability
Personal	• Reduced loss of land/property • Aesthetics	• Field days • YouTube/other videos • NRCS technical assistance • Workshops by interest groups • University of Arkansas Cooperative Extension • Landowner guides
Social	• Implementation by non-government affiliated community leaders • BWA Watershed Champion awards • BWA Conservation Champions • BWA War Eagle Creek Steward award • Northwest Arkansas Land Trust conservation awards	• Field days • Volunteer days • Speaker series • AGFC Stream Habitat Program • Conferences
Structural	• NRCS EQIP funding • NRCS RCPP funding • 319 funding • Riparian zoning in cities/towns • Riparian tax credit program • Land trust funding • Razorback Greenway • Northwest Arkansas Open Space Plan • Strategic Land Protection Plan	• Organizations providing planning and installation services • Trained installers • Availability of materials (plants, fencing options, etc.) • Change how conservation easements affect property value.

5.3.4 Barriers to Implementation

During the last public meeting for the Upper White River watershed management plan, stakeholders discussed practices for reducing nonpoint source pollution applicable for both the rural and the urban areas of the watershed. During this discussion stakeholders identified some conditions or situations that make it difficult to implement BMPs, i.e., barriers to BMP implementation. For example, implementing conservation practices and low-impact development (LID) faces barriers such as high costs, limited funding, regulatory restrictions, and permitting

challenges. These can be addressed by leveraging funding programs, streamlining permits, and seeking guidance from organizations such as AGFC. LID adoption is hindered by a lack of regulations, not enough data, and maintenance concerns, which can be overcome through updated policies, education for city leaders and developers, and training maintenance staff. Concerns about conservation easements affecting property values require further exploration.

Table 5.13 lists barriers discussed during the public meeting and some options for dealing with these barriers that were proposed. One stakeholder commented that partnerships are important for getting through the challenges often associated with conservation or restoration projects. At a previous public meeting an AGFC representative stated that they can help landowners identify funding sources and navigate permitting requirements for projects.

Table 5.13. BMP implementation barriers identified by stakeholders at public meeting.

Barriers	Options
Cost is beyond the means of landowners	Funding programs Leverage funding programs
Assistance programs don't have enough funds for all the proposed projects	Leverage funding programs
Regulations prevent landowners from using some practices they know work, such as removing excess stream gravel	(none mentioned)
Permitting requirements; getting permits takes too long, or costs too much	Contact federal senator for help with federal permitting AGFC can help landowners navigate permit requirements (Stream Habitat Program)
LID is not used by developers because it isn't required by regulations	Change existing regulations or adopt regulations where there are none. Example regulations are available from EPA or on the BWA website.
Developers and city governments don't support LID because they don't have data that quantifies the benefits and/or the cost compared to common approaches/practices.	Provide the data Educate city leaders, developers
Developers and city governments balk at using LID because they think they think maintenance will take more time than traditional, more people than they have, or they don't know how to do the maintenance.	Organize volunteer groups to do maintenance Educate city leaders and maintenance workers about the true maintenance needs associated with LID Train maintenance workers to correctly maintain LID
Conservation easement affects property value	(none mentioned)

5.4 Monitoring

Monitoring is an essential element of adaptive watershed management. The Upper White River watershed is classified as a Teir 2 watershed in the Arkansas Nutrient Reduction Strategy, indicating a need for enhanced water quality monitoring (Natural Resources Division 2022a). The objectives of the ongoing and proposed monitoring programs and special studies in the Upper White River watershed include:

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

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

5.4.1 Existing Monitoring

Existing surface water quality monitoring programs of DEQ, BWD and H2Ozarks in the Upper White River watershed (described in Section 3.1.2) are expected to continue. Table 5.14 provides a summary of these programs. The H2Ozarks monitoring program, StreamSmart, is a voluntary citizen science water quality monitoring program. The BWD annual Secchi Day is another voluntary citizen science monitoring program. AWRC has EPA Section 19 funding to continue water quality monitoring in the Upper White River watershed through 2025 (Project 22-800). See Table 3.3 for a listing of the constituents monitored by these organizations. Available information indicates that USGS is routinely collecting only in situ water quality data in the Upper White River watershed, i.e., temperature, specific conductance, turbidity, dissolved oxygen, and pH. Although only temperature is measured at all four USGS active continuous water quality monitoring stations in the watershed. Quality assurance project plans have been prepared for these water quality monitoring programs and are available from the sampling organization.

Table 5.14. Summary of active surface water quality monitoring programs in the Upper White River watershed.

Organization	Waterbody type	Number of stations	Sampling frequency
DEQ	Stream	27	monthly
	Reservoir	5	Quarterly, every five years
	Springs	2	monthly
BWD	Streams	10	monthly
	Reservoir (Beaver Lake)	25	Daily to weekly
H2Ozarks	Streams	21	Quarterly
USGS	Streams	4	Every 15 minutes

USGS and USACE will continue to monitor flow in the watershed (see Section 3.3.1 for information about active flow monitoring in the Upper White River watershed).

AGFC will continue to conduct annual sportfish population surveys in Beaver Lake and annual trout population surveys in the Beaver Lake tailwaters. In addition, AGFC plans to conduct a sportfish survey in the Kings River every five years (Stein, Gates and Lindaman 2021). H2Ozarks will continue to support macroinvertebrate surveys two times a year as part of the StreamSmart program (E. Scott, H2Ozarks, personal communication 1/24/2025). USFWS is expected to conduct future surveys of threatened and endangered fish and mussels present in the Upper White River watershed. DEQ may also conduct future fishery or macroinvertebrate surveys in the watershed.

5.4.2 Proposed Studies

The Beaver Lake Watershed Protection Strategy recommends development of a program of additional water quality monitoring in the Beaver Lake watershed, which does not include the Kings River subbasin. The recommendations in the strategy include regular, widespread collection of data related to streambank erosion and changes in stream morphology, storm event water quality, water quality sampling in headwater areas with flow measurements to allow load calculation, frequency of algal blooms and beach closings, implementation of BMPS, and other metrics related to the BWA Beaver Lake Watershed Success Metrics (RTI 2023). As appropriate, quality assurance project plans will be prepared for these studies.

Based on existing water quality impairments, water quality patterns, and recent data availability, the following studies are also suggested for the Upper White River watershed:

- Investigation into the causes of low DO impairments in the Upper White River watershed, starting with the following Category 1 sub-watersheds
    - Town Branch-West fork White River (West Fork White River assessment unit 11010001_024 low DO),
    - Beaver Lake-War Eagle Creek (War Eagle Creek assessment unit 11010001_834 low DO),
    - Roberts Creek-Beaver Lake (White River assessment units 11010001_023 and 11010001_823 low DO), and
    - Spanker Branch-Kings River (Kings River assessment unit 11010001_542 low DO).
- Inventory of sulfate sources to impaired waterbodies including contributions from point sources, geology, runoff, septic systems, etc. Start with Category 1 sub-watershed Town Branch-West Fork White River. West Fork White River assessment unit 11010001_024 exceeds sulfate criterion. Also look at sulfate sources to Town Branch, which may be contributing to West Fork White River impairment. Evaluate whether existing Town Branch sulfate criterion is still protective of West Fork White River water quality.
- *E. coli* sampling at active DEQ stream water quality monitoring stations that is adequate for evaluating attainment of *E. coli* criteria. In addition, *E. coli* sampling of impaired Beaver Lake reaches that is adequate for evaluating attainment of criteria. Also, *E. coli* sampling of Withrow Spring and War Eagle Cave Spring that is adequate for evaluating attainment of water quality criteria.
- Investigation into the causes of 2020 and 2022 pH impairment of Kings River (assessment unit 11010001_442 in the headwaters for low pH).
- Assessment of unpaved roads erosion in the Kings River subbasin, perhaps beginning with the Category 1 sub-watersheds.
- Add citizen science water quality sampling and macroinvertebrate survey stations in the Kings River and Yocum Creek subbasins.
- Evaluate the potential impact from the land application of industrial biosolids on water quality.

5.5 Evaluation

It is recommended that an evaluation of plan implementation occur about every seven years. So, the first evaluation of this plan would occur in 2031. This evaluation will be conducted by the plan implementation lead organization(s). Performance measures for this evaluation are

listed in Section 5.6. If the criteria identified in Section 5.6 are not satisfied, the management approaches, scientific knowledge, and stakeholder knowledge and opinions in the Category 1 sub-watersheds will be re-evaluated by the stakeholders involved in managing water quality and nonpoint sources in the Category 1 sub-watershed(s), and management elements will be adjusted. This evaluation will need to take into account the fact that it can take more than five years, or even decades, before in-stream water quality improvements resulting from implementation of management measures become apparent (Meals, Dressing and Davenport 2010). The time required to see significant changes in water quality is, in part, a function of how close water quality measurement locations are to where management activities are implemented.

5.6 Performance Measures

The BWA has developed a Watershed Success Metrics Framework (Framework) for the Beaver Lake watershed that can also be applied to the Upper White River watershed (BWA 2022). This Framework identifies outcomes, activities, and indicators that address the following elements of the Upper White River watershed management plan: information and education, and implementation of BMPs. In the following subsections performance measures are identified for information and education, implementation of BMPs, and monitoring. The performance measures are organized into the three major elements of the implementation of a watershed management plan: program inputs, outputs, and outcomes. As appropriate, outcomes, activities, and indicators of the BWA Framework are included.

5.6.1 Inputs

The inputs for implementation of this plan are the assistance programs available and stakeholder participation. Indicators that measure this component of the plan implementation are listed in Table 5.15. The stakeholders and organizations that participate in implementation of this plan should provide the implementation lead with annual totals for these input indicators for the period 2024 through 2029 by February 2030.

Table 5.15. Indicators of inputs for implementation of this watershed management plan.

Implementation Task	Activity	Indicators
Information and Education	Workshops, training, presentations, and conferences	• Hours and number of people involved in putting on workshops, training, presentations, and conferences • Cost
Information and Education	Events: field days, festivals, lake and river clean-ups	• Hours and number of people involved in putting on events • Cost
Information and Education	Youth programming	• Hours and number of people involved in running youth education programs • Cost
Information and Education	Factsheets and reference materials	• Hours and number of people involved in preparing factsheets and reference materials • Cost
Information and Education	Social media	• Hours and number of people putting content on social media • Cost
Information and Education	Staff continuing education	• Hours and number of people in continuing education • Cost
Implement (install, operate, and maintain) BMPs	Assistance programs in the Upper White River watershed	• Resources distributed to Upper White River watershed • Hours and number of people assisting stakeholders in Upper White River watershed • Number of Upper White River watershed stakeholders requesting assistance
Implement (install, operate, and maintain) BMPs	Implementation projects	• Number of people/organizations partnering • Cost
Monitoring	Agency monitoring programs	• Resources spent on monitoring in Upper White River watershed • Hours and number of personnel involved • Funding
Monitoring	Citizen science monitoring	• Number of inquiries • Hours of training • Number of volunteers • Hours and number of personnel involved
Monitoring	Special studies	• Cost • In-kind resources spent on special studies • Hours and number of personnel involved

5.6.2 Outputs

The outputs for implementation of this plan are formation of partnerships, and implementation of nonpoint source BMPs, information and education, and monitoring and special studies. Indicators that measure this component of the plan implementation are listed in Table 5.16. The stakeholders and organizations that participate in implementation of this plan should provide the implementation lead with annual totals for these indicators for the period 2024 through 2029 by February 2030.

Table 5.16. Indicators of outputs for implementation of this watershed management plan.

Implementation Task	Activity	Indicators
Information and Education	Workshops, training, presentations, and conferences	• Number of workshops, training, presentations, and conferences in watershed • Number of attendees at workshops, training presentations, and conferences in watershed • Number of minority attendees • Number of conferences outside watershed where watershed information was presented
Information and Education	Events: field days, festivals, lake and river clean-ups	• Number of events in watershed • Number of events outside watershed where watershed information presented • Number of attendees • Number of minority attendees
Information and Education	Youth programming	• Number of programs • Number of attendees • Number of minority attendees
Information and Education	Factsheets and reference materials	• Number of factsheets and reference materials prepared • Number distributed/accessed
Information and Education	Social media	Number of posts, Tweets, etc.
Information and Education	Staff continuing education	Hours of continuing education completed
Implement (install, operate, and maintain) BMPs	Assistance programs in the Upper White River watershed	• Number/amount of BMPs implemented • Number of contracts/projects started and finished

Table 5.16. Indicators of outputs for implementation of this watershed management plan (continued).

Implementation Task	Activity	Indicators
Implement (install, operate, and maintain) BMPs	Implementation projects	• Number of partnerships formed • Number of sub-watersheds with implementation projects and/or studies • Number of projects and studies organized through partnerships • Number/amount of BMPs implemented through partnerships
Monitoring	Agency/organization continuing monitoring programs	• Number of active water quality monitoring stations • Number of stations sampled • Number of water quality parameter measurements collected • Number of sampling events • Number of biological surveys
Monitoring	Citizen science monitoring	• Number of active water quality monitoring stations • Number of stations sampled • Number of water quality parameters measured • Number of sampling events • Number of invertebrate surveys
Monitoring	Special studies	• Number of studies completed • Number of sub-watersheds or stream reaches studied • Study results reported

5.6.3 Outcomes

The BWA Watershed Success Metrics identifies three desired outcomes for the Beaver Lake subbasin that could be applied to the entire Upper White River watershed:

- Public and policy-make prioritization of healthy watersheds,
- Resilient human footprint that does not diminish watershed function, and
- Intact and functional ecological systems.

The intended outcomes for this Upper White River watershed management plan are compatible with and support the BWA Watershed Success Metrics:

- Assessment of water quality in all of the Category 1 sub-watersheds;
- Improvement in water quality and aquatic habitat, particularly in the Category 1 sub-watersheds;
- Local and regional policies that support and encourage sustainable management of land and water resources; and
- Increased public and policy-maker awareness of, and interest in, water quality and aquatic habitat concerns of the Upper White River watershed.

The long-term objectives of the Upper White River watershed plan are that waterbodies in the Upper White River watershed meet water quality criteria and attain their designated uses, nutrient loads/loss from this watershed decrease, and populations of threatened and endangered species are stable. Policies that support and encourage sustainable resources management contribute to these long-term objectives, as does increased awareness of and interest in water resources concerns of the watershed.

The primary indicators suggested for the water quality outcomes and long-term objectives of this plan are *E. coli*, DO, sulfate, TDS, temperature, turbidity, total nitrogen, and total phosphorus concentrations; pH levels; and surveys of threatened and endangered species. Additionally, biochemical oxygen demand (BOD) and TSS concentrations; and fish and macroinvertebrate surveys are suggested as secondary indicators. These parameters, which are being monitored in the watershed, are recommended for use in evaluation of the overall effectiveness of nonpoint source pollution management within the Upper White River watershed. Within the next four to six years, the goal of this plan is to support and document incremental progress toward the target *E. coli*, DO, pH, sulfate, TDS, temperature, turbidity, total nitrogen, and total phosphorus levels, stable or increasing populations of threatened and endangered species, and new stakeholder activities contributing to good water quality and quality of life in the Upper White River watershed.

The monitored waterbodies in the Upper White River watershed are assessed by DEQ every two years to develop the Arkansas integrated water quality assessment report, which

includes the 303(d) list of impaired waterbodies. This assessment will be used to evaluate toward the long-term objective of waterbodies meeting water quality criteria and supporting designated uses.

Implementation of this watershed management plan will be considered successful if the following are achieved by 2030:

- At least one BMP implementation project or proposed study has been initiated in a Category 1 sub-watershed;
- At least one waterbody in the watershed is removed from the state impaired waters list;
- Water quality data that meet requirements for the DEQ biennial assessment have been collected from all of the Category 1 sub-watersheds; and
- No new water quality impairments resulting from unregulated nonpoint pollution sources are identified in the Upper White River watershed.

5.7 Update the Watershed Management Plan

A comprehensive update of this watershed management plan will be initiated in 2031 by H2Ozarks. This update will consider and address the following information:

- Results of the evaluation of the implementation of this plan, described in Sections 5.5 and 5.6;
- Relevant information about the Upper White River system and how it works, nonpoint source BMPs, and pollutant sources in the watershed that has been developed since 2023;
- Changes in water quality related issues in the watershed;
- Changes in water quality management assistance programs;
- Changes in local and regional policies that affect water quality management; and
- Changes in land use, industry, population, and/or economy in the watershed.

A summary of changes in the watershed over the period since completion of the previous watershed management plan, will be prepared. This summary will be presented at one or more public stakeholder meetings. At the meeting(s), stakeholders will provide input on adjustments to management of, and/or goals for, the Upper White River watershed. This may include a focus on management in other sub-watersheds for water quality improvement or protection.

An update of this watershed management plan, utilizing the information from the implementation evaluation and the public meeting(s), and any other information deemed appropriate, will be prepared. This update will be presented at one or more public stakeholder meetings to elicit feedback. The final update of the watershed management plan will then be prepared, incorporating stakeholder comments.

5.8 Implementation Schedule

A schedule for implementing the education and outreach, BMPs, and monitoring elements of this watershed management plan described previously is summarized in Table 5.17. Included in Table 5.17 are milestones, indicators, and long-term goals. This schedule incorporates the adaptive management process, where practices are implemented, monitoring is conducted to document results, the results are evaluated relative to the goals and criteria specified in the plan, and the plan is modified based on the results of the evaluation, accommodating any changes in regulations, available assistance programs, understanding of the watershed, or management priorities.

Tale 5.17. Upper White River watershed management plan implementation schedule.

Activity	Action	Lead	Start	Anticipated Completion	2029 Milestones	Indicator	Long-Term Goal
BMP Implementation	Streambank and Stream Restoration	BWA, NRCS, BWD, Other Local Partners, WCRC	Ongoing	Expected to continue indefinitely	Stream and streambank restoration projects active in 2024 completed; At least one streambank or stream reach restored in a Category 1 sub-watershed; At least two projects to restore streambanks or stream reaches initiated after 2024, at least one in a Category 1 sub-watershed	Projects completed; Miles of streambank and stream restored; Sediment load measurements; Habitat quality assessments	Stabilize streambanks in Category 1 sub-watersheds; achieve significant reduction in streambank erosion
BMP Implementation	Nutrient Management Plans	Natural Resources Division	Ongoing	Expected to continue indefinitely	Compliance with nutrient management plans; Total phosphorus monitoring showing decreasing trend; Decreasing soil phosphorus levels	Phosphorus levels in water; land use changes; farmer participation rates; soil phosphorus levels	Reduced algal bloom frequency, waterbodies meet water quality criteria and support designated uses
BMP Implementation	Riparian Buffer Restoration	AGFC, BWA, NRCS, Northwest Arkansas Land Trust, WCRC, Communities	Ongoing	Expected to continue indefinitely	Riparian buffer restoration projects active in 2024 completed; At least one riparian buffer restored in a Category 1 sub-watershed; At least one riparian buffer restoration project initiated in a Category 1 sub-watershed after 2024	Projects completed; Buffer acreage restored; Water quality data; Condition/maintenance of buffer areas	Increased acreage of functional riparian buffer; Improvement in water quality
BMP Implementation	Habitat Restoration Projects	Communities, AGFC, U.S. Forest Service, landowners, WCRC	Ongoing	Expected to continue indefinitely	Habitat restoration projects active in 2024 completed; At least one wetland and one upland area identified for habitat restoration after 2024	Acres restored; species diversity assessments; habitat condition surveys	Significantly increase in biodiversity
BMP Implementation	Agricultural Best Management Practices (BMPs)	BWA, BWD, County Conservation Districts, Extension Service, H2Ozarks, NRCS	Ongoing	Expected to continue indefinitely	Promote and implement sustainable practices on 5 new farms	Soil health indicators; number of farms adopting practices; nutrient levels in runoff; number of practice implemented; acres treated	Increase in sustainable practices in Upper White River watershed (acres of prescribed grazing, etc.); Soil health improvement; Decreased nutrient and soil loss; Waterbodies meet water quality criteria and support designated uses
BMP Implementation	Smart Growth for Source Water Protection	BWA	2022	2025	Project final report submitted At least one group of stakeholders toured each project site	Number of projects funded; Number of BMPs implemented; Number of workshops	GI implemented on all new development projects
BMP Implementation	Preserving Water Quality in the Beaver Lake Watershed (land conservation)	Northwest Arkansas Land Trust	2022	2025	Conserve a total of 3 parcels or 500 acres, whichever is greater Project final report submitted	Acres conserved	Increased riparian buffer acreage; improvement in water quality

Tale 5.17. Upper White River watershed management plan implementation schedule (continued).

Activity	Action	Lead	Start	Anticipated Completion	2029 Milestones	Indicator	Long-Term Goal
BMP Implementation	Land conservation	Northwest Arkansas Land Trust, counties, communities	2012	Expected to continue	10,000 acres in Northwest Arkansas under permanent conservation	Acres conserved Number of properties	10,000 acres of land conserved; Waterbodies meet water quality criteria and support designated uses
BMP Implementation	Forestry BMPs	BWA	2021	Expected to continue	BMPs on at least 10 new parcels Over 100 acres added with BMPs Over 20 new BMPs implemented	Number of parcels Number of acres Number of BMPs	Widespread use of forestry BMPs Waterbodies meet water quality criteria and support designated uses Forestry does not contribute to water quality impairments
BMP Implementation	Septic Tank Remediation Program	H2Ozarks	2021	Expected to continue as long as there is need/ demand	List of remediation/replacement projects identified; Funding committed for identified projects Funding procured for continuation of program beyond 2029	Number of loans/projects	Septic systems do not contribute to water quality impairments
BMP Implementation	Stream Barrier Remediation	AGFC, Stream Heritage Partnership	2021	2027	Four stream barriers removed from War Eagle Creek Over 5,000 feet of War Eagle Creek streambank restored Over 4 acres of wetlands created in War Eagle Creek subbasin At least one new stream barrier removal project identified	Number of stream barriers removed Length of restored streambank Acres of wetlands created/restored Number of new projects identified	Waterbodies meet water quality criteria and support designated uses, especially native fisheries and mussel communities Stable stream channels
BMP Implementation	Unpaved Road Improvements	BWA, Counties	Ongoing	Expected to continue indefinitely	At least 500 linear feet of unpaved roads improved; At least one unpaved road improvement project in a Category 1 sub-watershed; Madison County road crews certified in ESM	Linear feet of unpaved roads improved; Number of improvement projects initiated and completed; ESM certification status of county road crews	Turbidity water quality criteria met in all streams and reservoirs.
Evaluation	State Biennial Water Quality Assessment (DEQ)	DEQ	1980s	Expected to continue indefinitely	EPA approved final impaired waters lists for 2024 and 2026 2028 assessment initiated	Attaining and non-attaining waterbodies in the Upper White River watershed	All water quality criteria met in all monitored waterbodies in the Upper White River watershed
Evaluation	Track implementation of BMPs in Upper White River watershed	H2Ozarks	2025	2028	Information for 2024 – 2028 compiled	Amount of BMPs implemented	All water quality criteria met in monitored waterbodies, reduce pollutant loads to waterbodies
Evaluation	Track education and outreach	H2Ozarks	2024	2028	Information for 2024 – 2028 compiled by partners	Number of events, number of documents, number of people attending or reached	All water quality criteria met in monitored waterbodies, Threatened and endangered species stable, Increased awareness and concern for aquatic ecosystem health and water quality

Tale 5.17. Upper White River watershed management plan implementation schedule (continued).

Activity	Action	Lead	Start	Anticipated Completion	2029 Milestones	Indicator	Long-Term Goal
Evaluation	Track monitoring	H2Ozarks	2024	2028	Information for 2024 – 2028 compiled	Number of organizations sampling, number of sampling locations, number of sampling events, parameters analyzed, species surveyed	All water quality criteria met in monitored waterbodies, threatened and endangered species stable
Evaluation	Evaluation of watershed management plan	H2Ozarks	2028	2028	Data needed for evaluation compiled	Evaluation completed, Evaluation made public	All water quality criteria met in monitored waterbodies, threatened and endangered species stable
Monitoring	Ambient Surface Water Quality Monitoring	DEQ, BWD	Before 1990	Expected to continue indefinitely	Five additional years of water quality data collected at existing stations	Number of sampling events; Number of sampling locations	Identify and track changes in water quality; Assess water quality relative to water quality standards
Monitoring	Citizen Water Quality Sampling and Aquatic Invertebrate Surveys	H2Ozarks, AGFC	2013	Expected to continue indefinitely	Five additional years of water quality and macroinvertebrate data collected at existing stations; One station added on War Eagle Creek; At least two stations added in Kings River subbasin	Number of participants; Number of sampling events per year	Identify and track changes in water quality
Monitoring	DEQ Fish Surveys	DEQ	2012	Expected to continue indefinitely	At least one fish survey	Number of locations surveyed; Number of sampling events	All streams have good biological condition
Monitoring	Water Quality Monitoring in the Upper White River Basin	AWRC	2002	2025	Updated trend analysis report; Funding procured for data collection after 2025; At least three years of water quality data collected at existing stations	Number of monitoring sites; number of sampling events; water quality reports; trend analysis	Identify and track changes in water quality; Assess water quality relative to standards
Special Studies	Bacteria Sampling at active DEQ stations	DEQ, university	To be determined	A minimum of one year	E. coli data adequate to assess criteria collected, at least from waterbodies listed as impaired by E. coli on the 2018 303(d) list.	Data collected meet assessment requirements; Number of impaired assessment units sampled	E. coli criteria met in all streams and reservoirs
Special Studies	Investigate Causes or Sources of Impairments by Sulfate, pH, and Low DO	H2Ozarks	To be determined	A minimum of one year	At least one study initiated in a Category 1 sub-watershed	Study initiated; Study completed; Causes or sources identified	All water quality criteria met in monitored waterbodies
Special Studies	Inventory and/or monitoring of streambank erosion in Kings River Subbasin	H2Ozarks, KRWP, WCRC	To be determined	To be determined	At least one inventory, or, at least two monitoring locations established	Number of inventories; Number of monitoring locations and number of events	Identify and remediate areas of excessive streambank erosion in Kings River subbasin
Special Studies	Assessment of Unpaved Road Erosion in Kings River Subbasin	H2Ozarks, KRWP, WCRC, The Nature Conservancy	To be determined	To be determined	Assessment or inventory project initiated	Project proposal; Project funded; Project initiated; Project progress	Identify and reduce areas of excessive unpaved road erosion in Kings River subbasin

Tale 5.17. Upper White River watershed management plan implementation schedule (continued).

Activity	Action	Lead	Start	Anticipated Completion	2029 Milestones	Indicator	Long-Term Goal
Monitoring	Surveys of Threatened and Endangered Aquatic Species	USFWS, university	Ongoing	Expected to continue until species delisted	Survey of one or more threatened or endangered aquatic species	Surveys in Upper White River watershed; Species surveyed in Upper White River watershed	Stable populations of threatened and endangered aquatic species in the Upper White River watershed
Monitoring	Sportfish Surveys in Kings River, Beaver Lake and Beaver Tailwaters	AGFC	Ongoing	Expected to continue indefinitely	Beaver Lake surveys annually; Kings River survey every five years	Number of surveys; Waterbodies surveyed	Stable sport fisheries
Monitoring	Beaver Lake Secchi Day	BWD	2005	Expected to continue indefinitely	Five more Secchi Days conducted and collected data compiled	Number of events; Number of participants; Number of reports; Secchi depth trends	Identify and track water clarity in Beaver Lake. Beaver Lake provides good quality drinking water and recreation opportunities.
Outreach and Education	Clean Up Events	BWA, BWD, Kings River Watershed Partnership, H2Ozarks	Ongoing	Expected to continue indefinitely	Five years of annual clean up events	Number of events; Number of waterbodies; Number of participants; Amount of trash removed	Stream aesthetics and habitat quality in good condition; Improved stewardship of waterbodies
Outreach and Education	Land Management Practice Workshops	BWA	Ongoing	Expected to continue indefinitely	Regular workshops continue; Workshop in at least one Category 1 sub-watershed	Number of workshops; Number of attendees; Survey of practice use	Sustainable land management practices in widespread use
Outreach and Education	Community Education and Outreach	BWA, BWD, Local Agencies, Cooperative Extension	Ongoing	Expected to continue indefinitely	Education and outreach activities and events continue at 2024 level, or increase; At least two Arkansas Watershed Stewardship workshops in the watershed	Number of events, Attendance at events; Surveys on community awareness	Improved stewardship of water and other natural resources
Outreach and Education	Youth Education	BWD, BWA	Ongoing	Expected to continue indefinitely	Conduct at least one event (class tour, classroom presentation, youth outdoor education or recreation event) monthly; Lesson plans updated at least once	Number of students participating; Number of events	Watershed and ecological education are part of general youth education in NWA
Outreach and Education	Poultry and Livestock Producer Training	BWA, County Conservation Districts, Extension Service, NRCS, Natural Resources Division	Ongoing	Expected to continue indefinitely	At least one training workshop each year	Number of workshops and attendees	All producers following active nutrient management plan; Increased adoption of conservation practices that improve and protect water quality
Outreach and Education	The River Commons Institute	WCRC	2021	To be determined	Phase 1 funding procured; Phase 1 construction initiated	Progress on construction; Progress on raising funds; Number of visitors	Widespread appreciation and understanding of ecosystem services of rivers, wetlands and natural areas, and adoption of sustainable stewardship practices Provide riverine education and advocacy while supporting local ecological restoration
Outreach and Education	Kessler Mountain Outdoor Classroom and Nature Center	Ozark Natural Science Center, NWA Land Trust	2014	Expected to continue indefinitely	At least five youth/school programs (one per year)	Number of events/programs, Number of participants	Watershed and ecological education is part of general youth education in NWA

Tale 5.17. Upper White River watershed management plan implementation schedule (continued).

Activity	Action	Lead	Start	Anticipated Completion	2029 Milestones	Indicator	Long-Term Goal
Outreach and Education	Ozark Natural Science Center	Ozark Natural Science Center	1990	Expected to continue indefinitely	The number of camps provided stays the same or increases; At least five youth/school programs (one per year)	Number of events, Number of participants, children and adults	Watershed and ecological education is part of general youth education in NWA; Improved stewardship of water and other natural resources
Update plan	Public meetings	H2Ozarks	2027	2028	Begin planning public meetings	number of meetings, number of attendees	stakeholder input to water and water quality management
Update plan	Update watershed management plan	H2Ozarks	2028	2030	Initiate preparations for update	updated watershed management plan complete and accepted by EPA, focus sub-watersheds identified, stakeholders involved	Maintain watershed management plan as a living document that reflects stakeholder interest and concerns related to protecting and improving water quality in the Upper Illinois River watershed

6.0 IMPLEMENTATION COSTS, BENEFITS, AND AVAILABLE ASSISTANCE

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

6.1 Implementation Cost Estimates

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

6.1.1 Existing Monitoring

The costs of existing routine water quality and biological monitoring programs of DEQ, BWD, EPA, USGS (including the Stream Team program), and H2Ozarks in the Upper White River watershed are included in their annual budgets. AWRC water quality monitoring in the Upper White River watershed is funded through 2025 by an Arkansas Nonpoint Source Program project using Clean Water Act Section 319 funds.

6.1.2 Proposed Special Studies

The cost of collecting water quality data in Category 1 sub-watersheds without recent data will depend on who conducts the sampling and analysis. AWRC sample analysis charges for DEQ standard parameters would be around $200 per sample (AWRC 2020). For EQIP fiscal year 2024, 75% reimbursements (non-HU) for installing edge of field monitoring systems (practice 201) range from $24,000.00 to $29,000.00, with another $4,000.00 to $30,000.00 a year to collect and analyze data (NRCS 2023).

In October 2024 BWA was awarded just over $700,000 for a project to assess streambank erosion and prioritize restoration locations on Brush Creek, Richland Creek, War Eagle Creek, and East Fork White River; identify and prioritize stream barriers; and remove one barrier in the Beaver Lake watershed (Beaver Lake Watershed Streambank Erosion & Barrier Assessment | Beaver Watershed Alliance).

We did not find information related to the cost of assessing unpaved road erosion or implementing environmentally sensitive road maintenance.

6.1.3 Nonpoint Source Pollution Management

The cost of implementing BMPs to reduce nonpoint source pollution can be variable, depending on materials markets and site conditions (e.g., slope, soil type). Tables 6.1 through 6.11 provide examples of estimated potential relative costs for implementation of selected BMPs in the Category 1 sub-watersheds of Upper White River to achieve load reduction targets. Note that the estimated costs in Table 6.1 through 6.11 have been rounded to two (2) significant digits. Appendix P provides a detailed description of how these cost estimates were calculated, including estimating the extent of practices to implement, and assumptions about practice implementation costs. Estimates of extent of practices to implement are based primarily on land use data and estimated need for practices to meet load reduction targets (see Section 4 and Appendix N).

6.2 Benefits

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

Benefits that humans receive from nature are called ecosystem services. These services have been grouped into four categories: provisioning, regulating, cultural, and supporting (see Section 5.1.3.). Provisioning services refer to the materials used by humans that are provided by nature, including, food, fiber, wood, and minerals. Regulating services refer to the benefits nature provides by regulating or contributing to air quality, soil fertility, flood control, and pollination. Supporting services refer to providing habitat for plants and animals and maintaining genetic diversity. Cultural services refer to non-material benefits from nature including aesthetic enjoyment, inspiration, emotional well-being, spirituality, and cultural identity.

BMPs recommended for the Upper White River watershed are expected to improve the health of ecosystems and their ability to provide services. In some cases, this can result in

economic benefits that can be quantified relatively easily. In other cases, the benefits are more difficult to quantify economically. Examples of economic and non-material benefits of recommended BMPs are provided below.

6.2.1 Economic Benefits

While not all ecosystem services improved by BMPs have directly marketable economic value, there have been assessments of economic benefits of several practices. For example, economic benefits from pasture management BMPs can occur because of improved livestock production; reduced need for inputs such as purchased hay, fertilizer, pesticides, fuel, and labor; and additional opportunities for income-producing activities, such as hunting leases. University of Arkansas Cooperative Extension Service reports that 146 producers implementing the Arkansas 300 Days Grazing System realized total direct savings of over $283,000 (UofA Cooperative Extension Service 2024). Table 6.12 summarizes economic benefits associated with the BMPs recommended for Upper White River watershed. Note that economic benefits have been associated with most, but not all, of the recommended practices. Much of the information in this table is based on NRCS cost-benefit worksheets (NRCS n.d.). Other information sources include studies by NRCS and other researchers (NRCS 2006, Zeckoski, Benham and Lunsford 2012).

Table 6.1. Estimated costs for implementing practices in the Lake Sequoyah sub-watershed.

Practices	Units	Units to implement	Cost per unit	Estimated cost
Access control: Fence	foot	191,592	$4.00	$770,000
Access control: Stream crossing	crossing	58	$3,000.00	$170,000
Filter strip	acre	1.5	$250.00	$380
Headwater ponds	pond	11	$5,000.00	$55,000
Pasture aeration	acre	3,113	$2.00	$6,200
Prescribed grazing	acre	5,445	$40.00	$220,000
Remediate failing septic systems	system	9	$13,000.00	$120,000
Restore forested riparian buffer	acre	493	$800.00	$390,000
Restore herbaceous riparian buffer	acre	493	$280.00	$140,000
Roof runoff structure	house	20	$7,000.00	$140,000
Waste storage	each	5	$19,000.00	$95,000
Watering facility	facility	116	$1,200.00	$140,000

Table 6.2. Estimated costs for implementing practices in the Town Branch-West Fork White River sub-watershed.

Practices	Units	Units to implement	Cost per unit*	Estimated cost
Access control: Fence	foot	127,966	$4.00	$510,000
Access control: Stream crossing	crossing	39	$3,000.00	$120,000
Bank stabilization	foot	15,000	$160.00	$2,400,000
Bioswales	foot	8,015,000	NA	$140,000,000
Green roofs	Square feet	18,164,520	NA	$220,000,000
Headwater ponds	pond	9	$5,000.00	$45,000
Pasture aeration	acre	1,728	$2.00	$3,000
Permeable pavement	square feet	21,800,000	NA	$190,000,000
Prescribed grazing	acre	3,025	$40.00	$120,000
Rain garden	Square feet	5,380,000	NA	$33,000,000
Remediate failing septic systems	system	6	$13,000.00	$78,000
Restore forested riparian buffer	acre	570	$800.00	$460,000
Restore herbaceous riparian buffer	acre	570	$280.00	$160,000
Stream restoration	foot	15,000	$500.00	$7,500,000
Watering facility	facility	78	$1,200.00	$94,000

* Estimated cost for practices with NA (not available) for cost per unit were calculated using the CNT Green Values Stormwater Management Calculator (https://greenvalues.cnt.org/#tabtop).

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

Practices	Units	Units to implement	Cost per unit*	Estimated cost
Access control: Fence	foot	148916	$4.00	$600,000
Access control: Stream crossing	crossing	45	$3,000.00	$140,000
Bioswales	foot	1,963,000	NA	$34,000,000
Green roofs	Square feet	5,805,000	NA	$70,000,000
Headwater ponds	pond	5	$5,000.00	$25,000
Pasture aeration	acre	2,751	$2.00	$5,500
Permeable pavement (parking)	square feet	5,340,000	NA	$46,000,000
Prescribed grazing	acre	5,191	$40.00	$210,000
Rain garden	square feet	1,317,000	NA	$8,000,000
Remediate failing septic systems	system	4	$13,000.00	$52,000
Restore forested riparian buffer	acre	439	$800.00	$350,000
Restore herbaceous riparian buffer	acre	439	$280.00	$120,000
Watering facility	facility	90	$1,200.00	$110,000

* Estimated cost for practices with NA (not available) for cost per unit were calculated using the CNT Green Values Stormwater Management Calculator (https://greenvalues.cnt.org/#tabtop).

Table 6.4. Estimated costs for implementing practices in the Glade Creek sub-watershed.

Practices	Units	Units to implement	Cost per unit	Estimated cost
Access control: Fence	foot	179,620	$4.00	$720,000
Access control: Stream crossing	crossing	55	$3,000.00	$160,000
Headwater ponds	pond	10	$5,000.00	$50,000
Pasture aeration	acre	3,656	$2.00	$7,300
Prescribed grazing	acre	6,802	$40.00	$270,000
Remediate failing septic systems	system	4	$13,000.00	$52,000
Restore forested riparian buffer	acre	459	$800.00	$370,000
Restore herbaceous riparian buffer	acre	459	$280.00	$130,000
Watering facility	facility	110	$1,200.00	$130,000

Table 6.5. Estimated costs for implementing practices in the Clifty Creek-War Eagle Creek sub-watershed.

Practices	Units	Units to implement	Cost per unit	Estimated cost
Access control: Fence	foot	240,863	$4.00	$960,000
Access control: Stream crossing	crossing	73	$3,000.00	$220,000
Headwater ponds	pond	2	$5,000.00	$10,000
Pasture aeration	acre	4,490	$2.00	$9,000
Prescribed grazing	acre	8,413	$40.00	$340,000
Remediate failing septic systems	system	5	$13,000.00	$65,000
Restore forested riparian buffer	acre	628	$800.00	$500,000
Restore herbaceous riparian buffer	acre	628	$280.00	$180,000
Watering facility	facility	146	$1,200.00	$180,000

Table 6.6. Estimated costs for implementing practices in the Beaver Lake-War Eagle Creek sub-watershed.

Practices	Units	Units to implement	Cost per unit	Estimated cost
Access control: Fence	foot	99,135	$4.00	$400,000
Access control: Stream crossing	crossing	30	$3,000.00	$90,000
Pasture aeration	acre	2,136	$2.00	$4,300
Prescribed grazing	acre	3,828	$40.00	$150,000
Remediate failing septic systems	system	7	$13,000.00	$91,000
Restore forested riparian buffer	acre	266	$800.00	$210,000
Restore herbaceous riparian buffer	acre	266	$280.00	$74,000
Roof runoff structure	house	18	$7,000.00	$130,000
Waste storage	each	5	$19,000.00	$95,000
Watering facility	facility	60	$1,200.00	$72,000

Table 6.7. Estimated costs for implementing practices in the Roberts Creek-Beaver Lake sub-watershed.

Practices	Units	Units to implement	Cost per unit*	Estimated cost
Access control: Fence	foot	155,302	$4.00	$620,000
Access control: Stream crossing	crossing	47	$3,000.00	$140,000
Bioswales	foot	1,662,000	NA	$29,000,000
Headwater ponds	pond	7	$5,000.00	$35,000
Pasture aeration	acre	407	$2.00	$810
Permeable pavement (parking)	square feet	4,312,440+	NA	$37,000,000
Prescribed grazing	acre	6,292	$40.00	$250,000
Rain garden	square feet	1,115,000	NA	$6,800,000
Remediate failing septic systems	system	7	$13,000.00	$91,000
Restore forested riparian buffer	acre	407	$800.00	$330,000
Restore herbaceous riparian buffer	acre	407	$280.00	$110,000
Roof runoff structure	house	19	$7,000.00	$130,000
Waste storage	each	5	$19,000.00	$95,000
Watering facility	facility	94	$1,200.00	$110,000

* Estimated cost for practices with NA (not available) for cost per unit were calculated using the CNT Green Values Stormwater Management Calculator (https://greenvalues.cnt.org/#tabtop).
+ This is the total estimated parking area for the sub-watershed

Table 6.8. Estimated costs for implementing practices in the Brush Creek-Beaver Lake sub-watershed.

Practices	Units	Units to implement	Cost per unit	Estimated cost
Access control: Fence	foot	254,899	$4.00	$1,000,000
Access control: Stream crossing	crossing	78	$3,000.00	$230,000
Headwater ponds	pond	1	$5,000.00	$5,000
Pasture aeration	acre	5,842	$2.00	$12,000
Prescribed grazing	acre	10,500	$40.00	$420,000
Remediate failing septic systems	system	11	$13,000.00	$140,000
Restore forested riparian buffer	acre	662	$800.00	$530,000
Restore herbaceous riparian buffer	acre	662	$280.00	$190,000
Roof runoff structure	house	32	$7,000.00	$220,000
Waste storage	each	8	$19,000.00	$150,000
Watering facility	facility	156	$1,200.00	$190,000

Table 6.9. Estimated costs for implementing practices in the Spanker Branch-Kings River sub-watershed.

Practices	Units	Units to implement	Cost per unit	Estimated cost
Access control: Fence	foot	160,197	$4.00	$640,000
Access control: Stream crossing	crossing	49	$3,000.00	$150,000
Prescribed grazing	acre	5,728	$40.00	$230,000
Remediate failing septic systems	system	6	$13,000.00	$78,000
Restore forested riparian buffer	acre	421	$800.00	$340,000
Restore herbaceous riparian buffer	acre	421	$280.00	$120,000
Watering facility	facility	98	$1,200.00	$120,000

Table 6.10. Estimated costs for implementing practices in the Clabber Creek-Kings River sub-watershed.

Practices	Units	Units to implement	Cost per unit	Estimated cost
Access control: Fence	foot	236,056	$4.00	$940,000
Access control: Stream crossing	crossing	72	$3,000.00	$220,000
Prescribed grazing	acre	9,800	$40.00	$390,000
Remediate failing septic systems	system	8	$13,000.00	$100,000
Restore forested riparian buffer	acre	602	$800.00	$480,000
Restore herbaceous riparian buffer	acre	602	$280.00	$170,000
Waste storage	each	20	$19,000.00	$380,000
Watering facility	facility	144	$1,200.00	$170,000

Table 6.11. Estimated costs for implementing practices in the Braswell Branch-Yocum Creek sub-watershed.

Practices	Units	Units to implement	Cost per unit	Estimated cost
Access control: Fence	foot	317,382	$4.00	$1,300,000
Access control: Stream crossing	crossing	97	$3,000.00	$290,000
Pasture aeration	acre	5,825	$2.00	$12,000
Prescribed grazing	acre	10,780	$40.00	$430,000
Remediate failing septic systems	system	4	$13,000.00	$52,000
Restore forested riparian buffer	acre	783	$800.00	$630,000
Restore herbaceous riparian buffer	acre	783	$280.00	$220,000
Waste storage	each	32	$19,000.00	$610,000
Watering facility	facility	194	$1,200.00	$230,000

Table 6.12. Summary of economic benefits associated with recommended BMPs for the Upper White River watershed.

Practices	Increased Cattle Production	Decreased Pesticide Use/Cost	Decreased Damage/Land and/or Soil Loss	Reduced Maintenance Cost	Increased Property Value
Access control	X	X	X	X	X
Amendments for treatment of agriculture waste				X	X
Animal mortality facility				X	X
Composting facility					X
Critical area planting		X	X	X	X
Heavy use area protection			X	X	X
Karst sinkhole treatment	X			X	X
Pasture and hay planting			X		
Pasture aeration			X		X
Prescribed grazing and grazing management	X	X	X	X	X
Roof runoff structure			X	X	X
Livestock stream crossing	X		X	X	X
Waste storage facility				X	X
Watering facility	X		X		X
Constructed wetland		X	X	X	X
Filter strip		X	X	X	X
Grassed waterway			X	X	X
Land conservation		X	X	X	X
Farm ponds to stormwater ponds			X		X
Restore riparian buffer		X	X	X	X
Stream crossing restoration			X	X	

Table 6.12. Summary of economic benefits associated with recommended BMPs for the Upper White River watershed (continued).

Practices	Increased Cattle Production	Decreased Pesticide Use/Cost	Decreased Damage/Land and/or Soil Loss	Reduced Maintenance Cost	Increased Property Value
Stream habitat improvement and management			X	X	X
Stream restoration			X	X	X
Streambank protection			X	X	X
ESM			X	X	
Manure/waste digester			X		X
Trail design/maintenance			X	X	X
Green streets			X	X	X
Low impact development/green infrastructure			X	X	
Septic system maintenance			X		X
Rain gardens			X	X	X
Detention basins			X	X	
Vegetated treatment area			X	X	X
Permeable pavement			X	X	
Bioswale			X	X	X
Green roof			X		X
Retention basin			X	X	
Stormwater wetlands			X		
Rain barrel			X		
Bioretention basin			X	X	X
Feral hog control			X	X	
Canada goose control			X	X	

RTI estimated some economic benefits from pasture aeration. Implementing pasture aeration on land parcels larger than 40 acres where most of the land within 30 meters of streams is pasture was estimated to reduce annual water treatment costs by $78,000, because of reduced turbidity. In addition, lakeshore property values were estimated to increase by $5.2 million because of increased water clarity (RTI 2023).

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

6.2.2 Other Benefits

BMPs also improve ecosystem services in ways that do not translate well into direct economic benefits. Table 6.13 lists examples of ecosystem service provided by BMPs recommended for the Upper White River watershed. Table 6.14 lists specific BMPs proposed for the Upper White River Category 1 sub-watersheds, and the non-material environmental benefits that accrue from the implementation of these practices . Much of the information in this table is based on NRCS cost-benefit worksheets (NRCS n.d.). Other information sources include studies by NRCS and other researchers (NRCS 2006, Zeckoski, Benham and Lunsford 2012).

Table 6.13. Examples of ecosystem service benefits associated with BMPs recommended for Upper White River watershed that don't translate well into direct economic benefits.

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

Table 6.14. Ecosystem service benefits of BMPs proposed for Upper White River watershed.

Practices	Erosion control	Aquatic habitat	Nutrient cycling	Carbon storage	Soil health	Water purification	Wildlife habitat	Flood regulation
Access control	X	X	X	X	X	X	X	X
Amendments for treatment of agriculture waste			X		X			
Animal mortality facility			X					
Composting facility			X	X	X			
Critical area planting	X	X	X	X	X	X	X	X
Heavy use area protection	X				X	X		
Karst sinkhole treatment	X					X		
Pasture and hay planting	X		X	X	X	X	X	X
Pasture aeration			X	X	X	X		
Prescribed grazing and grazing management	X	X	X	X	X	X	X	X
Roof runoff structure					X			
Livestock stream crossing		X						
Waste storage facility					X			

Table 6.14. Ecosystem service benefits of BMPs proposed for Upper White River watershed (continued).

Practices	Erosion control	Aquatic habitat	Nutrient cycling	Carbon storage	Soil health	Water purification	Wildlife habitat	Flood regulation
Watering facility	X	X			X			X
Constructed wetland	X	X	X	X		X	X	X
Filter strip	X		X	X	X	X	X	X
Grassed waterway	X		X	X	X	X	X	
Land conservation	X		X	X	X	X	X	X
Farm ponds to stormwater ponds	X							X
Restore riparian buffer	X	X	X	X	X	X	X	X
Stream crossing restoration	X	X						
Stream habitat improvement and management		X						
Stream restoration		X	X					
Streambank protection	X	X						
ESM	X							
Manure/waste digester			X	X	X			
Trail design/maintenance	X							
Green streets	X		X	X		X		X
Low impact development/green infrastructure	X		X	X		X		X
Septic system maintenance			X					
Rain gardens	X		X	X	X	X	X	X
Detention basins	X		X	X	X	X	X	X
Vegetated treatment area	X		X	X	X	X	X	
Permeable pavement						X		X
Bioswale	X		X	X		X	X	X
Green roof			X	X		X	X	X
Retention basin	X	X	X	X	X	X	X	X
Stormwater wetlands	X	X	X	X	X	X	X	X
Rain barrel	X							
Bioretention basin	X		X	X	X	X	X	X
Feral hog control	X		X					
Canada goose control			X					

6.3 Technical Assistance

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

6.3.1 Monitoring

Agencies and universities conducting water quality monitoring generally have their own technical resources. Technical assistance for volunteer water quality monitoring programs is available through the AGFC Stream Habitat Program (see Stream Habitat Program • Arkansas Game and Fish Commission (agfc.com)). H2Ozarks also offers training for volunteer water quality monitoring through its StreamSmart citizen science program (see Arkansas Streamsmart | H2Ozarks | Arkansas & Missouri).

6.3.2 Information and Education

Information for and assistance with education and outreach activities is available through the Arkansas Environmental Education Association (Project WET), AGFC (Project WILD), BWD (Education and Outreach | Beaver Water District (bwdh2o.org)), Arkansas Cooperative Extension Service, and others. Resources are also available from EPA through the Nonpoint Source Outreach Toolbox (Nonpoint Source Outreach Toolbox | US EPA).

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

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

6.3.3 Implementing BMPs

Several agencies and organizations provide technical assistance for installing, operating, and maintaining BMPs identified for the Category 1 sub-watersheds. Examples are summarized in Table 6.15 and discussed below.

6.3.3.1 County Conservation Districts

Conservation Districts for the counties in the Upper White River watershed are active in nonpoint source management within the watershed. They work with NRCS to provide technical support to landowners, including information and guidance about agricultural BMPs for protecting soil and water resources, including benefits, costs, installation, operation, and maintenance.

6.3.3.2 U of A Division of Agriculture

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

Table 6.15. Examples of organizations active in the Upper White River watershed that provide technical assistance with installing, operating, and maintaining BMPs.

Practices	Arkansas Department of Agriculture Natural Resources Division	Arkansas Game and Fish Commission	Cooperative Extension Service	County Conservation Districts	EPA	Farm Services Agency	NRCS	National Sustainable Agriculture Information Service	Sustainable Agriculture Education Programs	US Fish and Wildlife Service	USDA Wildlife Services	The Nature Conservancy	H2Ozarks	Northwest Arkansas Land Trust	Beaver Watershed Alliance	Watershed Conservation Resource Center
Access control			X	X			X	X					X		X	
Amendments for treatment of agriculture waste			X	X			X									
Animal mortality facility			X	X			X									
Composting facility			X	X			X									
Critical area planting				X			X								X	
Heavy use area protection			X	X			X									
Karst sinkhole treatment				X			X					X				
Pasture and hay planting				X			X								X	
Pasture aeration																
Prescribed grazing and grazing management			X	X			X	X	X				X		X	
Roof runoff structure				X			X								X	
Livestock stream crossing		X		X			X			X						
Waste storage facility				X			X									
Watering facility			X	X			X	X	X							
Constructed wetland		X		X	X		X			X					X	
Filter strip				X	X	X	X								X	
Grassed waterway			X	X	X		X	X								
Land conservation		X				X	X	X		X		X		X	X	X
Farm ponds to stormwater ponds			X				X								X	
Restore riparian buffer		X	X	X		X	X	X		X		X	X	X	X	X
Stream crossing restoration	X	X								X		X				
Stream habitat improvement and management		X	X	X	X		X			X		X	X	X	X	X
Stream restoration		X			X					X		X	X	X	X	X

Table 6.15. Examples of organizations active in the Upper White River watershed that provide technical assistance with installing, operating, and maintaining BMPs (continued).

Practices	Arkansas Department of Agriculture Natural Resources Division	Arkansas Game and Fish Commission	Cooperative Extension Service	County Conservation Districts	EPA	Farm Services Agency	NRCS	National Sustainable Agriculture Information Service	Sustainable Agriculture Education Programs	US Fish and Wildlife Service	USDA Wildlife Services	The Nature Conservancy	H2Ozarks	Northwest Arkansas Land Trust	Beaver Watershed Alliance	Watershed Conservation Resource Center
Streambank protection		X		X			X						X		X	X
ESM	X				X							X				
Manure/waste digester			X		X		X									
Trail design/maintenance			X									X				
Green streets			X		X								X			
Low impact development/green infrastructure			X		X										X	
Septic system maintenance			X		X								X			
Rain gardens			X		X										X	
Detention basins					X										X	
Vegetated treatment area				X			X									
Permeable pavement			X		X										X	
Bioswale			X		X										X	
Green roof					X										X	
Retention basin					X											
Stormwater wetlands															X	X
Rain barrel			X		X										X	
Bioretention basin					X										X	
Feral hog control		X	X				X				X					
Canada goose control		X	X				X			X	X					

6.3.3.3 Arkansas Game and Fish Commission

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

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

6.3.3.4 USDA Natural Resources Conservation Service and Farm Services Agency

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

6.3.3.5 Sustainable Agriculture Education Programs

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

6.3.3.6 US Environmental Protection Agency

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

6.3.3.7 US Fish and Wildlife Service

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

6.3.3.8 Northwest Arkansas Land Trust

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

6.3.3.9 H2Ozarks

H2Ozarks provides technical assistance aimed at improving water quality in the Upper White River watershed through the Landowner Assistance Program and Septic Tank Remediation Program. H2Ozarks Septic Remediation Program personnel can also provide technical assistance with septic system maintenance and advanced treatment systems.

6.3.3.10 Beaver Watershed Alliance

The BWA offers a range of technical assistance programs aimed at improving water quality and promoting sustainable land management practices in the Beaver Lake subbasin. These programs provide support to landowners and agricultural producers through initiatives such as the War Eagle Creek Watershed Initiative, which focuses on reducing sediment and nutrient runoff. BWA assists with the development of Conservation Management Plans, Nutrient Management Plans, and Site Assessment Plans.

6.3.3.11 The Nature Conservancy

The Nature Conservancy is one of the founding partners of the Arkansas Unpaved Roads Program. They also have experience with sustainable trail building and maintenance, streambank and habitat restoration on their preserves and through their Ozark Rivers program. They have also provided guidance on karst, sinkhole, and cave protection and management to communities and organizations in Northwest Arkansas, and have an active Ozark Karst project that involves areas within the Upper White River watershed.

6.3.3.12 Watershed Conservation Resource Center

WCRC provides assistance, guidance, and planning services, for streambank, river, and wetland restoration projects. They work primarily with communities and organizations.

6.3.3.13 USDA Wildlife Services

The state USDA Wildlife Office can provide information to individuals about managing damage caused by a variety of wildlife, including feral swine and Canada geese.

6.4 Financial Assistance

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

6.4.1 Monitoring

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

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

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

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

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

6.4.2 Information and Education

AGFC offers Wildlife Education Grants funded through fines collected from violations of Arkansas game laws (https://www.agfc.com/en/education/classroom/conservation-education-grants/). For the 2023- 2024 school year, a combined amount of almost $35,000.00 was available for Wildlife Education Grants in Benton, Carroll, Madison, and Washington counties (AGFC 2023).

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

SARE offers Research and Education grants. From 2019-2024, SARE funded five education only grants totaling over $200,000 in Arkansas (Sustainable Agriculture Research and Education 2024).

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

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

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

6.4.3 Implementing BMPs

Over the years, funding has been provided for implementation of BMPs in the Upper White River watershed. Several agencies and programs offer financial assistance for implementation of nonpoint source pollution BMPs recommended for the Category 1 sub-watersheds and throughout the Upper White River watershed. Most of these are grant programs, many of which require matching funds from the grant recipient. In addition, there are

low interest loan programs and at least one tax incentive program that address practices that reduce nonpoint source pollution. Table 6.16 lists BMPs for the Category 1 sub-watersheds and examples of state and local funding sources. Table 6.17 lists examples of federal funding sources. It is notable that many federal assistance programs are seeing reductions in available funds. However, it is also notable that use of many of these BMPs can improve the bottom line for producers or communities (see Section 6.2), providing an incentive for implementation even without financial assistance.

6.5 Non-monetary Assistance with Implementing BMPs

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

Table 6.16. Examples of state and local sources of financial assistance available for BMPs recommended in the Upper White River watershed.

Agency/ Organization:	AR Department of Agriculture Natural Resources Division					AR Game and Fish Commission		Beaver Watershed Alliance			Northwest Arkansas Land Trust	H2Ozarks		Beaver Water District
Programs:	**Nonpoint Source Grant Program (Section 319 and Infrastructure funds)**	**State Revolving Loan Fund**	**Agriculture Water Quality Loan Program**	**Arkansas Wetland and Riparian Zones Tax Credit Program**	**Arkansas Unpaved Roads Program**	**Acres for Wildlife**	**Stream Habitat Program**	**Urban Stormwater Management Program**	**War Eagle Creek Watershed Initiative**	**Landowner Assistance Programs: Forestry, Streamside Assistance, Urban/residential lot, Agricultural/pasture, Land Management Mini-Grant Program**	**Northwest Arkansas Land Trust**	**Landowner Assistance Program**	**Septic Tank Remediation Program**	**Source Water Protection Program**
Eligible recipients:	Cities, counties, organizations	Communities, utilities	Individuals	Individuals	Counties	Individuals	Individuals	Counties, communities, companies, organizations, schools, individuals, HOAs	Landowners, Agricultural and Forest Producers	Individuals	Individuals	Landowner	homeowners	Organizations
Focus area within Upper White River watershed:	All	All	Agricultural land	Wetlands and riparian zones	All	Pastures	Streams & rivers & adjacent land	Developed areas	War Eagle Creek watershed	All	undeveloped land	All	All	Beaver Lake watershed
Funding vehicles:	Cost-share	Low-interest loan	Low-interest loan	Tax credit	Cost-share	Grant, materials	Grant, materials	Grant, cost-share	Cost-share	Grant, cost-share	Purchase	Cost-share	Zero-interest loan, grant	Grant, cost-share
Practices:														
Access control	X		X						X	X		X		
Amendments for treatment of agriculture waste	X													
Animal mortality facility	X													
Composting facility	X													

Table 6.16. Examples of sources of financial assistance available for BMPs recommended in the Upper White River watershed (continued)

Agency/ Organization:	AR Department of Agriculture Natural Resources Division					AR Game and Fish Commission		Beaver Watershed Alliance			Northwest Arkansas Land Trust	H2Ozarks		Beaver Water District
Programs:	Nonpoint Source Grant Program (Section 319 and Infrastructure funds)	State Revolving Loan Fund	Agriculture Water Quality Loan Program	Arkansas Wetland and Riparian Zones Tax Credit Program	Arkansas Unpaved Roads Program	Acres for Wildlife	Stream Habitat Program	Urban Stormwater Management Program	War Eagle Creek Watershed Initiative	Landowner Assistance Programs: Forestry, Streamside Assistance, Urban/residential lot, Agricultural/pasture, Land Management Mini-Grant Program	Northwest Arkansas Land Trust	Landowner Assistance Program	Septic Tank Remediation Program	Source Water Protection Program
Critical area planting	X					X			X	X		X		X
Heavy use area protection	X													
Karst sinkhole treatment	X													
Pasture & hay planting	X					X			X	X		X		X
Pasture aeration										X				X
Prescribed grazing and grazing management	X		X						X	X		X		X
Roof runoff structure	X									X				
Livestock stream crossing	X					X			X	X				
Waste storage facility	X		X											
Watering facility	X		X						X	X		X		
Constructed wetland	X			X		X			X	X				
Filter strip	X								X	X				X
Grassed waterway	X									X				X
Vegetated treatment area	X									X				X
Land conservation						X			X	X	X			X

Table 6.16. Examples of sources of financial assistance available for BMPs recommended in the Upper White River watershed (continued)

Agency/ Organization:	AR Department of Agriculture Natural Resources Division					AR Game and Fish Commission		Beaver Watershed Alliance			Northwest Arkansas Land Trust	H2Ozarks		Beaver Water District
Programs:	Nonpoint Source Grant Program (Section 319 and Infrastructure funds)	State Revolving Loan Fund	Agriculture Water Quality Loan Program	Arkansas Wetland and Riparian Zones Tax Credit Program	Arkansas Unpaved Roads Program	Acres for Wildlife	Stream Habitat Program	Urban Stormwater Management Program	War Eagle Creek Watershed Initiative	Landowner Assistance Programs: Forestry, Streamside Assistance, Urban/residential lot, Agricultural/pasture, Land Management Mini-Grant Program	Northwest Arkansas Land Trust	Landowner Assistance Program	Septic Tank Remediation Program	Source Water Protection Program
Restore riparian buffer	X			X		X	X		X	X		X		X
Stream crossing restoration	X					X				X				X
Stream habitat improvement and management	X			X		X			X	X		X		X
Stream restoration	X			X			X		X	X				X
Streambank protection	X			X		X	X		X	X		X		X
ESM					X									
Manure/waste digester			X							X				X
Green streets	X							X						X
Low impact development/green infrastructure	X							X						X
Septic system maintenance										X			X	
Rain gardens	X							X						X
Detention basins	X							X						X
Permeable pavement	X							X						X
Bioswale	X							X						X
Green roof	X							X						X
Retention basin	X							X						X
Stormwater wetlands	X			X				X						X

Table 6.16. Examples of sources of financial assistance available for BMPs recommended in the Upper White River watershed (continued)

Agency/ Organization:	AR Department of Agriculture Natural Resources Division					AR Game and Fish Commission		Beaver Watershed Alliance			Northwest Arkansas Land Trust	H2Ozarks		Beaver Water District
Programs:	Nonpoint Source Grant Program (Section 319 and Infrastructure funds)	State Revolving Loan Fund	Agriculture Water Quality Loan Program	Arkansas Wetland and Riparian Zones Tax Credit Program	Arkansas Unpaved Roads Program	Acres for Wildlife	Stream Habitat Program	Urban Stormwater Management Program	War Eagle Creek Watershed Initiative	Landowner Assistance Programs: Forestry, Streamside Assistance, Urban/residential lot, Agricultural/pasture, Land Management Mini-Grant Program	Northwest Arkansas Land Trust	Landowner Assistance Program	Septic Tank Remediation Program	Source Water Protection Program
Rain barrel								X						X
Bioretention basin	X							X						X
Feral hog control														
Canada goose control														

Table 6.17. Examples of federal sources of financial assistance available for BMPs recommended in the Upper White River watershed.

Agency/ Organization:	Farm Services Agency	NRCS		USDA	US Fish and Wildlife Service	
Program:	Conservation Reserve Programs	Conservation Stewardship Program	Environmental Quality Incentive Program	Regional Conservation Partnership Program	Wildlife Services	Partners for Fish and Wildlife
Eligible recipients:	Individuals	Individuals	Individuals	Individuals, communities, organizations	Individuals	Individuals, organizations
Focus area within Upper White River watershed:	Agricultural land	Agriculture and forest lands	Agriculture and forest lands	Agriculture and forest lands	Agriculture and forest lands	Wetlands, prairies, habitat for species of concern
Funding vehicle:	Rent, 50% cost-share	Cost-share	Cost-share	Cost-share	Cost-share, services	Cost-share
Practices:						
Access control		X	X	X		X
Amendments for treatment of agriculture waste			X	X		
Animal mortality facility			X	X		
Composting facility			X	X		
Critical area planting			X	X		
Heavy use area protection			X	X		
Karst sinkhole treatment			X	X		
Pasture & hay planting			X	X		X
Pasture aeration						
Prescribed grazing and grazing management		X	X	X		
Roof runoff structure			X	X		
Livestock stream crossing			X	X		X
Waste storage facility			X	X		
Watering facility		X	X	X		X
Constructed wetland			X	X		?
Filter strip	X	X	X	X		
Grassed waterway			X	X		
Vegetated treatment area		X	X	X		
Land conservation	X		X	X		X
Restore riparian buffer	X	X	X	X		X
Stream crossing restoration			X	X		
Stream habitat improvement and management			X	X		X
Stream restoration				X		X
Streambank protection		X	X	X		X
ESM						
Manure/waste digester						

Table 6.16. Examples of sources of financial assistance available for BMPs recommended in the Upper White River watershed (continued)

Agency/ Organization:	Farm Services Agency	NRCS		USDA	US Fish and Wildlife Service	
Program:	Conservation Reserve Programs	Conservation Stewardship Program	Environmental Quality Incentive Program	Regional Conservation Partnership Program	Wildlife Services	Partners for Fish and Wildlife
Green streets						
Low impact development/green infrastructure						
Septic system maintenance						
Rain gardens						
Detention basins						
Permeable pavement						
Bioswale						
Green roof						
Retention basin						
Stormwater wetlands						
Rain barrel						
Bioretention basin						
Feral hog control					X	
Canada goose control					X	

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APPENDIX A

Summaries of Public Meeting Attendees

Tables 1 through 4 show the number and type of stakeholders who attended each public stakeholder meeting for the Upper White River watershed management plan. The first stakeholder meeting was held at two locations. The same information was presented at the January and February 2023 meetings. The meeting schedule was as follows:

- First stakeholder meeting:
  - January 23, 2023, at Berryville, AR
  - February 27, 2023, at Fayetteville, AR
- Second stakeholder meeting: June 13, 2023, at Huntsville, AR
- Third stakeholder meeting: October 24, 2023, at Huntsville, AR

Table 5 shows comments provided by the public about the plan with responses. Most of these comments were provided during the plan public review and comment period spring 2025.

Table 1. First stakeholder meeting – January 23, 2023

Organization / Category	Number of attendees
Arkansas Department of Agriculture Forestry Division	1
Arkansas Department of Agriculture Natural Resources Division	2
Arkansas Department of Energy and Environment Division of Environmental Quality	1
Arkansas Department of Parks, Heritage and Tourism	1
Arkansas Game and Fish Commission	2
Arkansas Ozarks Waterkeeper	1
Carroll County government	2
FTN Associates	3
H2Ozarks	4
Kings River Watershed Partnership	1
Tyson	1
University of Arkansas Cooperative Extension Service	1
US Senate	1
USDA Natural Resources Conservation Service	2

Table 2. First stakeholder meeting – February 27, 2023

Organization / Category	Number of attendees
Arkansas Department of Agriculture Natural Resources Division	2
Arkansas Game and Fish Commission	2
Northwest Arkansas Land Trust	2
Arkansas Ozarks Waterkeeper	1
Beaver Watershed Alliance	2
Beaver Water District	1
City of West Fork	1
FTN Associates	3
H2Ozarks	4
Landowner	1
Nelms Foundation	1
University of Arkansas Cooperative Extension Service	1
USDA Natural Resources Conservation Service	1

Table 3. Second stakeholder meeting – June 13, 2023

Organization / Category	Number of attendees
Arkansas Department of Agriculture Natural Resources Division	2
Arkansas Department of Energy and Environment Division of Environmental Quality	1
Arkansas Game and Fish Commission	1
Arkansas Ozarks Waterkeeper	1 (dual representative)
Beaver Water District	2
Beaver Watershed Alliance	2
Benton County	1
Carroll County	1
City of Rogers	1
FTN Associates	3
H2Ozarks	4
Kings River Watershed Partnership	2
Nelms Foundation	1
Northwest Arkansas Democrat Gazette	1
Northwest Arkansas Regional Planning Commission	1
University of Arkansas Cooperative Extension Service	2
US Senate	1
USDA Natural Resources Conservation Service	2

Table 4. Third stakeholder meeting – October 24, 2023

Organization / Category	Number of attendees
Arkansas Department of Agriculture Natural Resources Division	1
Arkansas Department of Health	2
Arkansas Game and Fish Commission	1
Arkansas Farm Bureau	4
Beaver Watershed Alliance	1
County Judge	2
City of Fayetteville	1
Ecological Design Group	1
Farmer/Landowner	8
FTN Associates	3
H2Ozarks	3
Justice of the Peace	1
Kings River Watershed Partnership/Arkansas Ozarks Waterkeeper	2
University of Arkansas Cooperative Extension Service	1
USDA Natural Resources Conservation Service	2
Watershed Conservation Resource Center	2

Table 5. Comments from public review of the draft Upper White River watershed management plan.

Topics	Comment	Date	Response	Plan Edit(s)
waste nutrients, poultry, septic, WWTP	Some of my primary concerns are the management of poultry waste, nutrient excess, septic tank and waste water treatment plants. These beautiful watersheds deserve all the protection we can provide.		Thank you for your comment. Specific management practices to reduce nutrients and other pollutants are discussed in Section 4.8. Wastewater treatment plants are not addressed in this plan because they are regulated by the Arkansas Department of Energy and Environment Division of Environmental Quality (DEQ); this plan focuses on unregulated pollutant sources.	None
rural ponds	I was one of the attendees at your meeting yesterday afternoon in Berryville regarding the WMP. I can't remember your exact wording, but I got to thinking about your final question regarding hopes, goals, and perhaps aspirations, etc, and upon additional thought and consideration, I would like to answer you by saying that it is one of my career goals here in Madison county to encourage landowners to "build a pond at the head of every holler." When I consider our local stream and river systems, I think about how much the watersheds have changed since 1491, about how the 18TH and 19th century explorers described the pools, fish, and lack of gravel in their journals. I think about how many pools have been since been filled in with gravel, these were the same deep holes the old timers say they used to fish and swim in as kids, and that most of those pools are gone now. I think about how the water storing capacity of the local rivers have been much reduced due to these pools being filled with gravel. Imagine how the peak storm flows of the past were buffered by the riffle-run-pool morphology, especially in the headwaters, and like a string of pearls, a rain event would have to fill each successive pool before overflowing to the next. I think that the further up the system money and effort is spent, the cheaper and the better, as the lower in the system you go, the more expensive the projects tend to become. So without the ability to clean the gravel out of those pools to restore headwater systems to that old condition, the best idea I can come up with is to build a pond at the head of every holler, to perform a similar function. I can't always do this, sometimes the soils are not conducive, and not every landowner is interested, but when and where I can promote the building of a livestock pond at the head of a holler, I think it is most appropriate.	1/24/2023	Thank you for this information, and your support of the practice of using farm ponds to reduce storm peak flows in this watershed.	None
send minutes so she can provide input via email	I apologize but I will not be able to attend. If there are any materials you are able to share with me I would be happy to look and give me input.	2/13/2023	Meeting summary was provided.	None
Ranking methodology	Concerned that we eliminated the "Habitat Degradation" metric		The habitat degradation metric was removed based on comments from stakeholders, including: a) the fact that factors used to assign habitat degradation risk are already part of the ranking, e.g., water quality impairment, and we wanted to reduce double counting of factors; b) concern that the metric represents concerns about both upland and aquatic habitat, only two of the factors used to assign habitat degradation risk are related to aquatic habitat, when the plan focus is on aquatic resources ; and c) comments that good/productive aquatic habitat does not necessarily equate to good water quality. Removing habitat degradation risk from the ranking did not significantly change the list of recommended sub-watersheds.	None
changing LULC; loss of pasture for urban	in the WMP, we should acknowledge the historical LULC in comparison of current.		We acknowledged the impact of historic land use changes on geomorphology, and that increasing impervious cover in the watershed is a concern (see Sections 2.3.5 and 4.8.8).	None
Quary and land fill potential		3/12/2025	Thank you.	None

Table 5. Comments from public review of the draft Upper White River watershed management plan (continued).

Topics	Comment	Date	Response	Plan Edit(s)
cattle exclusion	I enjoyed your presentations last night. We live on the Kings between Marble and Marshall Ford. We are probably about 10 river miles below where Spanker Branch comes into the river. I have not read the plan, but have a suggestion. We raised cattle on the river for about 20 years, and the first thing we did was fence them where they could not access the river. We provided water in a stock tank via a well. In the 10 river miles above us, there are hundreds of cows that have direct access to the river and you know what they do in it. I am wondering if it would be possible to provide financial assistance, similar to the septic tank mitigation offered in the plan, for farmers who are willing to install fencing and watering systems to prevent these cattle from accessing the river?? Could this be included in the plan? Voluntary, of course. Besides them pooping directly in the river, they destroy riparian zones at their access points and other places. We appreciate what you and the KRWP are trying to accomplish. I would also be curious to know if you think these cows are a direct issue. We fully understand that chicken litter being spread improperly and excessively on the pasture lands bordering the river can cause excessive phosphorus "nutrient overload" and contribute to the algae blooms, etc. FYI - Elizabeth Watkins (Liz Duffy) is our daughter!	3/26/2025	Both NRCS and US Fish and Wildlife Service offer financial assistance for restricting livestock access to streams and providing alternative water supplies. These practices are recommended in the plan (see Section 4.8.2).	None
general, and terminology of landowner per property rights	Upper White River Watershed Management Plan - Draft February 19,2025 - Future PUBLIC NOTICES TO LOCAL NEWS OUTLETS such as CARROLL COUNTY NEWS , EUREKA INDEPENDENT NEWS and MADISON COUNTY RECORD . RIPARIAN Buffer Zones to reduce soil erosion and sediment and water pollution into the Kings River to the Table Rock Lake is very important. Perhaps , H2OZARKS and / or Kings River Watershed Partnership could collaborate with the AR Game&Fish in being awarded a Grant : Stream Bank Restoration . An area of significance is the ARG&F Kings River Access where the Osage and Kings River intersect , on the west bank is a farm field at extreme episodes of flooding the Kings River in excess goes into that field and a moderate amount of soil is loss . ALSO , partner with AR Game&Fish , Carroll County Solid Waste District in Berryville to reduce pollution of plastic refuse / trash garbage along shoreline of Kings River Access sites by having Solid Waste District maintain a Garbage Bin that could be routinely picked up Bi-monthly . An effort should be made by either / or Kings River Watershed Partnership or H2OZARKS to periodically address the local counties Carroll or Madison Quorum Court jurisdiction to update planned mitigation . The Provisional Draft	4/22/2025	Thank you for this suggestion for H2Ozarks and Kings River Watershed Partnership.	None
general, and terminology of landowner per property rights	Declare and maintain as a VOLUNTARY Program. Change such as in the Introduction Process page 2.	4/22/2025	The plan is delcared voluntary in the first paragraph of the introduction.	Wording of titles and introductions of Sections 4 and 5 modified to highlight the voluntary nature of the plan recommendations.
general, and terminology of landowner per property rights	Stakeholder and INHOLDER throughout the Draft Plan . Glossary / Nomenclature Stakeholder : NGO non- profits such as H2OZARKS or Kings River Watershed Partnership , local businesses or corporation, or Nature Conservancy or State , Federal or global entities as United Nations auspices 2030 AGENDA which should have zero mitigation on sovereign United States lands or Navigable Watersheds or RIPARIAN sites . These are a small example . INHOLDER : LANDOWNER Private Property acreage or Homeowners OR AGRICULTURE PRODUCER within the Watershed Management Plan . Landowner should be identified as Sovereign . Highlight in Bold in plan	4/22/2025	This is not a legal document; all interested parties are referred to as stakeholders, regardless of land ownership. All stakeholders are encouraged to work together towards the watershed vision, which benefits everyone.	None
general, and terminology of landowner per property rights	INTRODUCTION TABLE 1.1 page 1 Kings River Watershed Partnership - Vision, goal, objectives ADDENDUM " to co-exist with / by respecting Various aspects in AGRICULTURE and private land use " ; Carroll County Quorum Court jurisdiction has maintained the outlying unincorporated areas as Zone Free .	4/22/2025	Table 1.1 lists statements of vision, mission, and/or goals published by these entities. It is not the purpose of this plan or its preparers to modify any of these statements. Suggestions for revisions can be submitted to individual entities.	The Table 1.1 caption was modified to clarify that the information provided is taken from organization publications. Citations for the publications were also added to Table 1.1.

Table 5. Comments from public review of the draft Upper White River watershed management plan (continued).

Topics	Comment	Date	Response	Plan Edit(s)
general, and terminology of landowner per property rights	Table 1.2 page 4, Element E: education/outreach, 2 also " identify All INHOLDERS should receive ample notice "	4/22/2025	Public participation the development of this plan included four public meetings at different locations within the watershed, as well as an extended public comment period for the draft plan. This level of public participation is consistent with EPA requirements for Section 319 watershed planning activities. It was not feasible to contact every landowner and tenant throughout this watershed that covers over 2,100 square miles and has a population of over 128,000.	Details about methods used to notify the public about meetings and comment period were added to Section 1.3.
general, and terminology of landowner per property rights	page 5, Element I: monitoring, 2.c. this should address as " need sampling integrity INHOLDERS and AGRICULTURE representatives should be present and involved at monitoring site , if involves their average " .	4/22/2025	Thank you for your suggestion. However, the purpose of this table is to identify where in this document EPA requirements are addressed, not to specify details about how these activities will occur. Our recommendations for monitoring (Section 5.4.2) are from a high level technical perspective only and do not address administrative procedures. Any requests for landowner oversight of monitoring activities should be addressed to the entity conducting the monitoring.	None
general, and terminology of landowner per property rights	Section 3.4 page 62, Non point Sources of Pollutants Causing Impairments, Second paragraph include INHOLDERS, " identified by stakeholders, " "INHOLDERS and AGRICULTURE Representatives need to verify " " , researchers ....., Also , samples should be certified by the participation of INHOLDERS or AGRICULTURE REPRESENTATIVES	4/22/2025	See response to previous comment.	See response to previous comment.
general, and terminology of landowner per property rights	page 63, 3.4.1 Runoff from Pasture and Haylands, change "Studies have shown ..... ", has this been actually proven within the Kings River Watershed ? ? ?	4/22/2025	This statement is not specifically referring to the Kings River watershed, nor is it necessarily applicable there as no streams in the Kings River drainage are listed as impaired due to chloride or sulfate. As noted in Sections 4.6.4 and 4.7.10, although a portion of the Kings River is classified as impaired due to high total dissolved solids (TDS) concentrations, recent data appear to show that TDS concentrations are decreasing at the monitoring station, and continued monitoring to confirm this trend is recommended. The study cited in the referenced sentence (Scott and Haggard 2021) was conducted in the West Fork White River watershed.	Added another reference for this sentence.
general, and terminology of landowner per property rights	5.0 Implementation Strategy 5-1 Monitoring water quality verbage " changes resulting " (NEED Verifiable Witnesses from the INHOLDERS and AGRICULTURE Representatives)	4/22/2025	We assume that entities conducting water quality monitoring will do so under the guidance of a Quality Assurance Project Plan approved by DEQ or EPA and publish or otherwise make the collected data available to the public, upon request. Any suggestions for designing monitoring plans should be directed to the entity conducting the monitoring.	None

Table 5. Comments from public review of the draft Upper White River watershed management plan (continued).

Topics	Comment	Date	Response	Plan Edit(s)
general, and terminology of landowner per property rights	This is a very detailed comprehensive Draft Plan. It should be open for any future deletions or addendums as recognized by All named entities such as INHOLDERS, AGRICULTURE REPRESENTATIVES, Stakeholders etcetera within the fore mentioned Watershed.	4/22/2025	As described in the Section 5 introduction and in Section 5.7, it is expected that this plan will be regularly evaluated for relevance and updated as needed through a public, inclusive, and transparent process. As noted in Section 5.2 and the schedule in Section 5.8, H2Ozarks will be leading evaluation and update of the plan in 2028.	None
public access and community [stakeholder is a landowner in the watershed]	I am concerned about the declining quality of the river. Also I am very concerned about the lack of public access to the upper areas of the White (I read somewhere that indigenous peoples called the river, Unica or clear water). I live in Crosses, Madison County and there existed for over 140 years a community swimming hole at the low water bridge. There are old newspaper stories of community gatherings at that spot on the river, including young folks camping areas, rope swings, large baptisms, community picnics. All gone now due to private development with owners who will not allow anyone access even to the riverbanks. The White belongs to all of us not just the wealthy that buy up the riverfront and have no investment in communities.	2/22/2025	Thank you for your comment. Neither this plan nor its preparers have any authority over public or private landowners.	None

APPENDIX B

Land Cover Changes for Subbasins of the Upper White River Watershed

Land cover change from 2001 to 2019 calculated for subbasins of the Upper White River watershed is presented below. Figure 1 shows the subbasins for which land cover change was calculated.

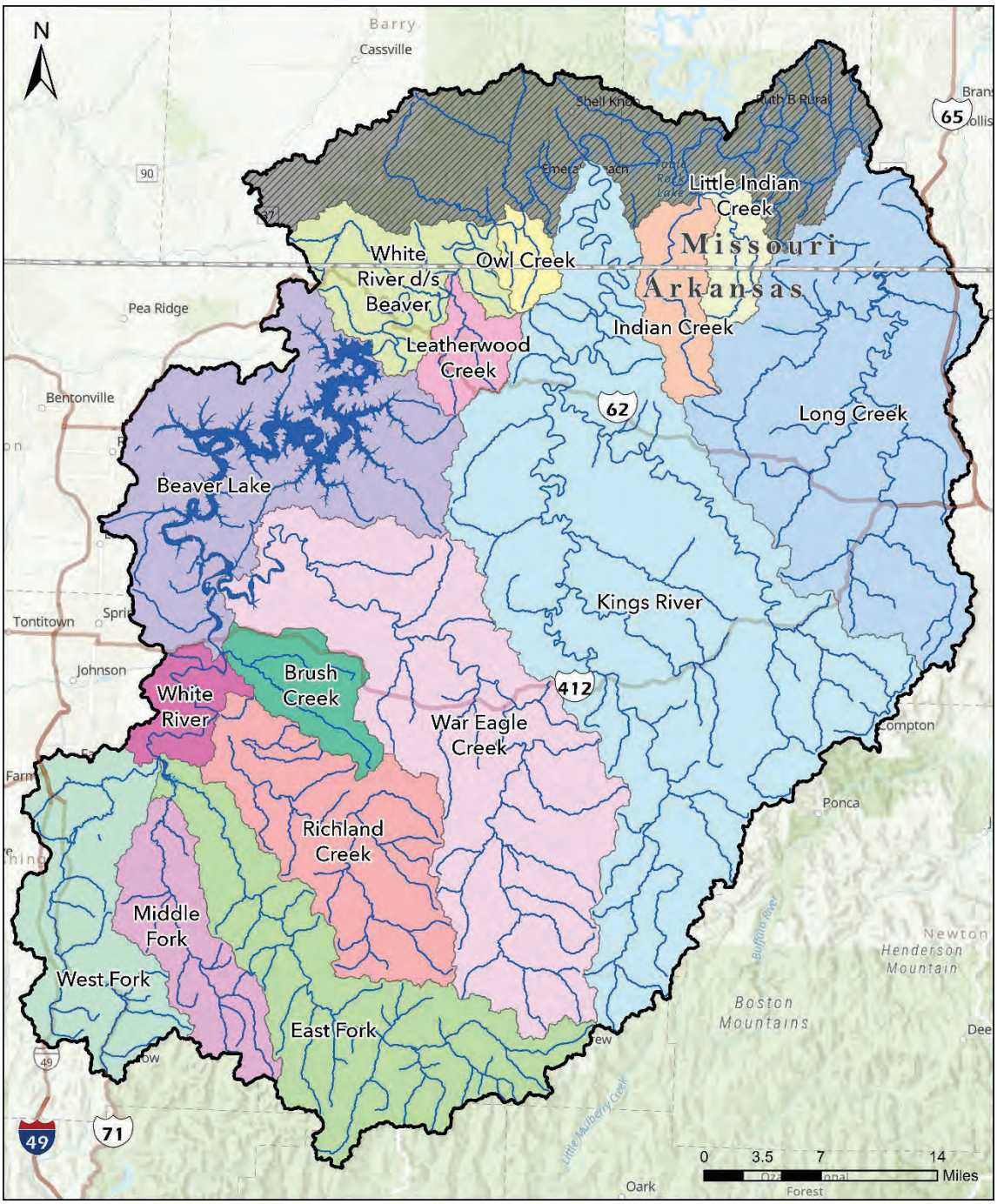


Figure 1. Upper White River watershed subbasins for which land cover change from 2001 to 2019 was calculated.

Land cover change for each subbasin is presented in Tables 1 through 15. In these tables, land cover that had a percent increase in area greater than 100% or has a percent difference greater than 0.9% is highlighted in blue. Land cover that had a percent decrease in area more than -100% or a percent difference more than -0.9% is highlighted in orange.

Table 1. East Fork subbasin land cover change from 2001 to 2019.

Land Cover	2001 Area, acres	2001 % of Subbasin	2019 Area, acres	2019 % of Subbasin	Area change, acres	Area % change (2019-2001)/2001	Percent Difference (2019% - 2001%)
Open Water	520	0.41%	527	0.41%	7	1%	0.01%
Developed, Open Space	4,132	3.25%	4,255	3.35%	124	3%	0.10%
Developed, Low Intensity	911	0.72%	1,018	0.80%	107	12%	0.08%
Developed, Medium Intensity	132	0.10%	319	0.25%	187	142%	0.15%
Developed, High Intensity	13	0.01%	37	0.03%	24	190%	0.02%
Barren Land	43	0.03%	61	0.05%	18	41%	0.01%
Deciduous Forest	98,391	77.37%	97,574	76.72%	-818	-1%	-0.64%
Evergreen Forest	1,081	0.85%	1,037	0.82%	-44	-4%	-0.03%
Mixed Forest	2,790	2.19%	2,821	2.22%	31	1%	0.02%
Shrub/Scrub	236	0.19%	557	0.44%	321	136%	0.25%
Herbaceous	362	0.28%	965	0.76%	603	167%	0.47%
Hay/Pasture	18,233	14.34%	17,659	13.89%	-574	-3%	-0.45%
Cultivated Crops	2	0.00%	0	0.00%	-2	-100%	0.00%
Woody Wetlands	310	0.24%	312	0.25%	2	1%	0.00%
Emergent Herbaceous Wetlands	19	0.01%	32	0.02%	13	68%	0.01%
Total	**127,175**	**100.00%**	**127,176**	**100.00%**			

Table 2. Middle Fork subbasin land cover change 2001 to 2019.

Land Cover	2001 Area, acres	2001 % of Watershed	2019 Area, acres	2019 % of Watershed	Area change, acres	Area % change (2019-2001)/2001	Percent Difference (2019% - 2001%)
Open Water	28	0.06%	42	0.09%	15	53%	0.03%
Developed, Open Space	1,509	3.14%	1,505	3.13%	-4	0%	-0.01%
Developed, Low Intensity	235	0.49%	265	0.55%	30	13%	0.06%
Developed, Medium Intensity	40	0.08%	89	0.18%	49	122%	0.10%
Developed, High Intensity	3	0.01%	12	0.03%	10	363%	0.02%
Barren Land	5	0.01%	13	0.03%	8	151%	0.02%
Deciduous Forest	34,219	71.19%	33,860	70.44%	-358	-1%	-0.74%
Evergreen Forest	180	0.37%	174	0.36%	-6	-3%	-0.01%
Mixed Forest	1,132	2.35%	1,148	2.39%	16	1%	0.03%
Shrub/Scrub	65	0.14%	313	0.65%	247	378%	0.51%
Herbaceous	195	0.41%	318	0.66%	123	63%	0.26%
Hay/Pasture	10,414	21.66%	10,284	21.40%	-130	-1%	-0.27%
Cultivated Crops	0	0.00%	0	0.00%	0	0%	0.00%
Woody Wetlands	45	0.09%	44	0.09%	-0.4	-1%	0.00%
Emergent Herbaceous Wetlands	0	0.00%	0	0.00%	0	0%	0.00%
Total	**48,068**	**100%**	**48,067**	**100%**			

Table 3. West Fork subbasin land cover change 2001 to 2019.

Land Cover	2001 Area, acres	2001 % of Watershed	2019 Area, acres	2019 % of Watershed	Area change, acres	Area % change (2019-2001)/2001	Percent Difference (2019% - 2001%)
Open Water	173	0.22%	195	0.25%	22	12%	0.03%
Developed, Open Space	4,739	5.97%	4,688	5.91%	-52	-1%	-0.06%
Developed, Low Intensity	2,914	3.67%	3,143	3.96%	230	8%	0.29%
Developed, Medium Intensity	1,863	2.35%	2,467	3.11%	603	32%	0.76%
Developed, High Intensity	632	0.80%	818	1.03%	186	29%	0.23%
Barren Land	438	0.55%	255	0.32%	-184	-42%	-0.23%
Deciduous Forest	48,663	61.32%	47,702	60.11%	-962	-2%	-1.21%
Evergreen Forest	259	0.33%	231	0.29%	-28	-11%	-0.04%
Mixed Forest	2,286	2.88%	2,368	2.98%	82	4%	0.10%
Shrub/Scrub	33	0.04%	524	0.66%	491	1488%	0.62%
Herbaceous	231	0.29%	773	0.97%	542	235%	0.68%
Hay/Pasture	16,766	21.13%	15,831	19.95%	-935	-6%	-1.18%
Cultivated Crops	0	0.00%	0	0.00%	0	0%	0.00%
Woody Wetlands	335	0.42%	321	0.40%	-13	-4%	-0.02%
Emergent Herbaceous Wetlands	25	0.03%	42	0.05%	16	65%	0.02%
Total	**79,357**	**100.00%**	**79,356**	**100.00%**			

Table 4. Richland Creek subbasin land cover change 2001 to 2019.

Land Cover	2001 Area, acres	2001 % of Watershed	2019 Area, acres	2019 % of Watershed	Area change, acres	Area % change (2019-2001)/2001	Percent Difference (2019% - 2001%)
Open Water	71	0.08%	74	0.08%	3	5%	0.00%
Developed, Open Space	3,656	3.95%	3,704	4.00%	47	1%	0.05%
Developed, Low Intensity	712	0.77%	784	0.85%	72	10%	0.08%
Developed, Medium Intensity	94	0.10%	193	0.21%	99	105%	0.11%
Developed, High Intensity	9	0.01%	28	0.03%	19	217%	0.02%
Barren Land	21	0.02%	74	0.08%	53	255%	0.06%
Deciduous Forest	54,273	58.60%	53,386	57.64%	-887	-2%	-0.96%
Evergreen Forest	535	0.58%	516	0.56%	-19	-3%	-0.02%
Mixed Forest	3,719	4.02%	3,882	4.19%	163	4%	0.18%
Shrub/Scrub	42	0.05%	650	0.70%	608	1449%	0.66%
Herbaceous	285	0.31%	941	1.02%	656	230%	0.71%
Hay/Pasture	29,155	31.48%	28,341	30.60%	-814	-3%	-0.88%
Cultivated Crops	0	0.00%	0	0.00%	0	0%	0.00%
Woody Wetlands	38	0.04%	37	0.04%	-1	-4%	0.00%
Emergent Herbaceous Wetlands	3	0.00%	4	0.00%	0	14%	0.00%
Total	**92,613**	**100.00%**	**92,612**	**100.00%**			

Table 5. War Eagle Creek subbasin land cover change 2001 to 2019.

Land Cover	2001 Area, acres	2001 % of Watershed	2019 Area, acres	2019 % of Watershed	Area change, acres	Area % change (2019-2001)/2001	Percent Difference (2019% - 2001%)
Open Water	1,256	0.59%	1,626	0.76%	370	29%	0.17%
Developed, Open Space	8,222	3.85%	8,338	3.90%	116	1%	0.05%
Developed, Low Intensity	2,101	0.98%	2,287	1.07%	187	9%	0.09%
Developed, Medium Intensity	464	0.22%	897	0.42%	433	93%	0.20%
Developed, High Intensity	90	0.04%	185	0.09%	95	106%	0.04%
Barren Land	80	0.04%	192	0.09%	112	139%	0.05%
Deciduous Forest	116,324	54.45%	110,386	51.67%	-5,939	-5%	-2.78%
Evergreen Forest	2,328	1.09%	2,138	1.00%	-190	-8%	-0.09%
Mixed Forest	5,803	2.72%	6,066	2.84%	263	5%	0.12%
Shrub/Scrub	198	0.09%	2,512	1.18%	2,314	1166%	1.08%
Herbaceous	786	0.37%	5,022	2.35%	4,237	539%	1.98%
Hay/Pasture	75,686	35.43%	73,758	34.52%	-1,928	-3%	-0.90%
Cultivated Crops	0	0.00%	0	0.00%	0	-100%	0.00%
Woody Wetlands	271	0.13%	207	0.10%	-64	-24%	-0.03%
Emergent Herbaceous Wetlands	29	0.01%	23	0.01%	-6	-20%	0.00%
Total	**213,638**	**100.00%**	**213,638**	**100.00%**			

Table 6. White River subbasin land cover change 2001 to 2019.

Land Cover	2001 Area, acres	2001 % of Watershed	2019 Area, acres	2019 % of Watershed	Area change, acres	Area % change (2019-2001)/2001	Percent Difference (2019% -
Open Water	629	3.03%	985	4.75%	357	57%	1.72%
Developed, Open Space	1,087	5.24%	1,162	5.60%	76	7%	0.37%
Developed, Low Intensity	474	2.28%	635	3.06%	162	34%	0.78%
Developed, Medium Intensity	81	0.39%	227	1.10%	146	181%	0.71%
Developed, High Intensity	6	0.03%	18	0.09%	12	215%	0.06%
Barren Land	9	0.05%	10	0.05%	1	10%	0.00%
Deciduous Forest	7,641	36.84%	7,287	35.14%	-354	-5%	-1.70%
Evergreen Forest	106	0.51%	105	0.50%	-1	-1%	-0.01%
Mixed Forest	950	4.58%	973	4.69%	23	2%	0.11%
Shrub/Scrub	4	0.02%	86	0.42%	82	2149%	0.40%
Herbaceous	24	0.12%	141	0.68%	116	476%	0.56%
Hay/Pasture	9,482	45.72%	8,931	43.07%	-551	-6%	-2.65%
Cultivated Crops	10	0.05%	0	0.00%	-10	-100%	-0.05%
Woody Wetlands	223	1.08%	165	0.80%	-58	-26%	-0.28%
Emergent Herbaceous Wetlands	14	0.07%	10	0.05%	-3	-25%	-0.02%
Total	**20,738**	**100.00%**	**20,737**	**100.00%**			

Table 7. Brush Creek subbasin land cover change 2001 to 2019.

Land Cover	2001 Area, acres	2001 % of Watershed	2019 Area, acres	2019 % of Watershed	Area change, acres	Area % change (2019-2001)/2001	Percent Difference (2019% -
Open Water	89	0.31%	150	0.52%	61	68%	0.21%
Developed, Open Space	1,091	3.81%	1,122	3.92%	31	3%	0.11%
Developed, Low Intensity	527	1.84%	576	2.01%	49	9%	0.17%
Developed, Medium Intensity	131	0.46%	294	1.03%	163	125%	0.57%
Developed, High Intensity	13	0.04%	41	0.14%	28	216%	0.10%
Barren Land	113	0.40%	177	0.62%	64	56%	0.22%
Deciduous Forest	10,441	36.48%	9,713	33.94%	-728	-7%	-2.54%
Evergreen Forest	194	0.68%	187	0.65%	-7	-4%	-0.03%
Mixed Forest	860	3.00%	896	3.13%	37	4%	0.13%
Shrub/Scrub	18	0.06%	313	1.09%	294	1593%	1.03%
Herbaceous	81	0.28%	469	1.64%	387	478%	1.35%
Hay/Pasture	15,053	52.60%	14,678	51.29%	-375	-2%	-1.31%
Cultivated Crops	0	0.00%	0	0.00%	0	0%	0.00%
Woody Wetlands	6	0.02%	3	0.01%	-3	-54%	-0.01%
Emergent Herbaceous Wetlands	1	0.00%	1	0.00%	0	-31%	0.00%
Total	**28,619**	**100.00%**	**28,619**	**100.00%**			

Table 8. Beaver Lake subbasin land cover change 2001 to 2019.

Land Cover	2001 Area, acres	2001 % of Watershed	2019 Area, acres	2019 % of Watershed	Area change, acres	Area % change (2019-2001)/2001	Percent Difference (2019% - 2001%)
Open Water	25,657	16.76%	26,583	17.37%	926	3.6%	0.60%
Developed, Open Space	9,404	6.14%	9,477	6.19%	74	0.8%	0.05%
Developed, Low Intensity	2,922	1.91%	3,254	2.13%	332	11.4%	0.22%
Developed, Medium Intensity	525	0.34%	1,002	0.65%	478	91.1%	0.31%
Developed, High Intensity	82	0.05%	167	0.11%	85	103.6%	0.06%
Barren Land	888	0.58%	867	0.57%	-21	-2.4%	-0.01%
Deciduous Forest	82,563	53.93%	80,708	52.72%	-1,855	-2.2%	-1.21%
Evergreen Forest	2,972	1.94%	2,947	1.93%	-25	-0.8%	-0.02%
Mixed Forest	11,111	7.26%	11,174	7.30%	63	0.6%	0.04%
Shrub/Scrub	121	0.08%	509	0.33%	388	321.0%	0.25%
Herbaceous	406	0.27%	1,045	0.68%	639	157.5%	0.42%
Hay/Pasture	16,380	10.70%	15,319	10.01%	-1,061	-6.5%	-0.69%
Cultivated Crops	3	0.00%	0	0.00%	-3	-100.0%	0.00%
Woody Wetlands	37	0.02%	16	0.01%	-21	-56.2%	-0.01%
Emergent Herbaceous Wetlands	14	0.01%	15	0.01%	1	8.4%	0.00%
Total	**153,085**	**100.00%**	**153,084**	**100.00%**			

Table 9. White River downstream of Beaver Lake subbasin land cover change 2001 to 2019.

Land Cover	2001 Area, acres	2001 % of Watershed	2019 Area, acres	2019 % of Watershed	Area change, acres	Area % change (2019-2001)/2001	Percent Difference (2019% - 2001%)
Open Water	1,824	3.70%	1,849	3.75%	25	1%	0.05%
Developed, Open Space	2,200	4.46%	2,173	4.40%	-27	-1%	-0.05%
Developed, Low Intensity	1,044	2.12%	1,076	2.18%	32	3%	0.07%
Developed, Medium Intensity	152	0.31%	218	0.44%	66	43%	0.13%
Developed, High Intensity	18	0.04%	26	0.05%	8	46%	0.02%
Barren Land	34	0.07%	46	0.09%	12	35%	0.02%
Deciduous Forest	27,673	56.06%	27,389	55.48%	-284	-1%	-0.58%
Evergreen Forest	5,421	10.98%	5,373	10.88%	-48	-1%	-0.10%
Mixed Forest	6,524	13.22%	6,587	13.34%	63	1%	0.13%
Shrub/Scrub	70	0.14%	134	0.27%	64	91%	0.13%
Herbaceous	89	0.18%	341	0.69%	253	285%	0.51%
Hay/Pasture	4,252	8.61%	4,098	8.30%	-154	-4%	-0.31%
Cultivated Crops	0	0.00%	0	0.00%	0	0%	0.00%
Woody Wetlands	62	0.13%	54	0.11%	-7	-12%	-0.02%
Emergent Herbaceous Wetlands	3	0.01%	1	0.00%	-2	-60%	0.00%
Total	**49,365**	**100.00%**	**49,365**	**100.00%**			

Table 10. Leatherwood Creek subbasin land cover change 2001 to 2019.

Land Cover	2001 Area, acres	2001 % of Watershed	2019 Area, acres	2019 % of Watershed	Area change, acres	Area % change (2019-2001)/2001	Percent Difference (2019% - 2001%)
Open Water	170	0.89%	173	0.90%	3	2%	0.02%
Developed, Open Space	1,182	6.19%	1,165	6.10%	-17	-1%	-0.09%
Developed, Low Intensity	565	2.96%	572	3.00%	7	1%	0.04%
Developed, Medium Intensity	184	0.96%	211	1.11%	27	15%	0.14%
Developed, High Intensity	40	0.21%	48	0.25%	8	21%	0.04%
Barren Land	14	0.07%	20	0.10%	6	45%	0.03%
Deciduous Forest	10,999	57.59%	10,864	56.88%	-134	-1%	-0.70%
Evergreen Forest	1,319	6.91%	1,323	6.93%	4	0%	0.02%
Mixed Forest	4,075	21.34%	4,110	21.52%	35	1%	0.18%
Shrub/Scrub	19	0.10%	25	0.13%	6	29%	0.03%
Herbaceous	42	0.22%	134	0.70%	92	221%	0.48%
Hay/Pasture	479	2.51%	446	2.34%	-33	-7%	-0.17%
Cultivated Crops	0	0.00%	0	0.00%	0	0%	0.00%
Woody Wetlands	11	0.06%	8	0.04%	-3	-28%	-0.02%
Emergent Herbaceous Wetlands	0.7	0.00%	0.4	0.00%	-0.3	-39%	0.00%
Total	**19,100**	**100.00%**	**19,100**	**100.00%**			

Table 11. Owl Creek subbasin land cover change 2001 to 2019.

Land Cover	2001 Area, acres	2001 % of Watershed	2019 Area, acres	2019 % of Watershed	Area change, acres	Area % change (2019-2001)/2001	Percent Difference (2019% - 2001%)
Open Water	624	5.59%	632	5.65%	7	1%	0.06%
Developed, Open Space	489	4.38%	507	4.53%	18	4%	0.16%
Developed, Low Intensity	217	1.94%	248	2.22%	31	14%	0.28%
Developed, Medium Intensity	30	0.27%	48	0.43%	18	61%	0.16%
Developed, High Intensity	5	0.04%	8	0.08%	4	75%	0.03%
Barren Land	9	0.08%	10	0.09%	1	7%	0.01%
Deciduous Forest	2,552	22.84%	2,429	21.73%	-123	-5%	-1.10%
Evergreen Forest	1,376	12.31%	1,322	11.83%	-53	-4%	-0.48%
Mixed Forest	1,693	15.15%	1,785	15.97%	92	5%	0.82%
Shrub/Scrub	2	0.01%	105	0.94%	104	6656%	0.93%
Herbaceous	28	0.25%	100	0.89%	71	250%	0.64%
Hay/Pasture	4,134	36.99%	3,970	35.52%	-165	-4%	-1.47%
Cultivated Crops	0	0.00%	0	0.00%	0	0%	0.00%
Woody Wetlands	16	0.15%	12	0.11%	-4	-24%	-0.04%
Emergent Herbaceous Wetlands	0.2	0.00%	0	0.00%	-0.2	-100%	0.00%
Total	**11,176**	**100.00%**	**11,176**	**100.00%**			

Table 12. Kings River subbasin land cover change 2001 to 2019.

Land Cover	2001 Area, acres	2001 % of Watershed	2019 Area, acres	2019 % of Watershed	Area change, acres	Area % change (2019-2001)/2001	Percent Difference (2019% - 2001%)
Open Water	2,462	0.65%	2,509	0.66%	47	2%	0.01%
Developed, Open Space	14,457	3.81%	14,321	3.77%	-136	-1%	-0.04%
Developed, Low Intensity	3,658	0.96%	3,835	1.01%	177	5%	0.05%
Developed, Medium Intensity	726	0.19%	1,145	0.30%	419	58%	0.11%
Developed, High Intensity	170	0.04%	266	0.07%	95	56%	0.03%
Barren Land	283	0.07%	524	0.14%	242	86%	0.06%
Deciduous Forest	212,098	55.90%	207,938	54.81%	-4,160	-2%	-1.10%
Evergreen Forest	14,680	3.87%	14,201	3.74%	-478	-3%	-0.13%
Mixed Forest	17,646	4.65%	18,178	4.79%	532	3%	0.14%
Shrub/Scrub	547	0.14%	2,244	0.59%	1,697	310%	0.45%
Herbaceous	1,361	0.36%	6,233	1.64%	4,872	358%	1.28%
Hay/Pasture	110,907	29.23%	107,610	28.36%	-3,297	-3%	-0.87%
Cultivated Crops	0	0.00%	0	0.00%	0	0%	0.00%
Woody Wetlands	358	0.09%	357	0.09%	-2	0%	0.00%
Emergent Herbaceous Wetlands	56	0.01%	46	0.01%	-10	-17%	0.00%
Total	**379,409**	**100.00%**	**379,408**	**100.00%**			

Table 13. Indian Creek subbasin land cover change 2001 to 2019.

Land Cover	2001 Area, acres	2001 % of Watershed	2019 Area, acres	2019 % of Watershed	Area change, acres	Area % change (2019-2001)/2001	Percent Difference (2019% - 2001%)
Open Water	645	2.29%	659	2.34%	14	2%	0.05%
Developed, Open Space	1,163	4.13%	1,136	4.03%	-27	-2%	-0.10%
Developed, Low Intensity	401	1.42%	422	1.50%	21	5%	0.07%
Developed, Medium Intensity	32	0.12%	72	0.26%	40	123%	0.14%
Developed, High Intensity	4	0.01%	7	0.03%	3	92%	0.01%
Barren Land	23	0.08%	48	0.17%	25	106%	0.09%
Deciduous Forest	7,560	26.83%	6,973	24.75%	-587	-8%	-2.08%
Evergreen Forest	4,970	17.64%	4,854	17.23%	-116	-2%	-0.41%
Mixed Forest	1,160	4.12%	1,184	4.20%	24	2%	0.09%
Shrub/Scrub	48	0.17%	233	0.83%	185	382%	0.66%
Herbaceous	87	0.31%	906	3.22%	819	945%	2.91%
Hay/Pasture	12,074	42.85%	11,678	41.44%	-396	-3%	-1.41%
Cultivated Crops	0	0.00%	0	0.00%	0	0%	0.00%
Woody Wetlands	8	0.03%	4	0.02%	-4	-47%	-0.01%
Emergent Herbaceous Wetlands	1	0.00%	1	0.00%	-1	-50%	0.00%
Total	**28,178**	**100.00%**	**28,178**	**100.00%**			

Table 14. Little Indian Creek subbasin land cover change 2001 to 2019.

Land Cover	2001 Area, acres	2001 % of Watershed	2019 Area, acres	2019 % of Watershed	Area change, acres	Area % change (2019-2001)/2001	Percent Difference (2019% - 2001%)
Open Water	385	2.21%	398	2.28%	13	3%	0.07%
Developed, Open Space	741	4.25%	731	4.20%	-10	-1%	-0.06%
Developed, Low Intensity	253	1.45%	264	1.51%	11	4%	0.06%
Developed, Medium Intensity	32	0.18%	60	0.34%	28	89%	0.16%
Developed, High Intensity	4	0.02%	8	0.05%	4	109%	0.02%
Barren Land	29	0.16%	34	0.19%	5	19%	0.03%
Deciduous Forest	9,954	57.18%	9,892	56.82%	-62	-1%	-0.36%
Evergreen Forest	623	3.58%	625	3.59%	1	0.2%	0.01%
Mixed Forest	372	2.13%	385	2.21%	13	4%	0.08%
Shrub/Scrub	8	0.04%	27	0.16%	19	248%	0.11%
Herbaceous	15	0.09%	155	0.89%	139	904%	0.80%
Hay/Pasture	4,990	28.66%	4,830	27.74%	-160	-3%	-0.92%
Cultivated Crops	0	0.00%	0	0.00%	0	0%	0.00%
Woody Wetlands	5	0.03%	2	0.01%	-3	-59%	-0.02%
Emergent Herbaceous Wetlands	0	0.00%	1	0.00%	0	42%	0.00%
Total	**17,410**	**100.00%**	**17,410**	**100.00%**			

Table 15. Long Creek subbasin land cover change 2001 to 2019.

Land Cover	2001 Area, acres	2001 % of Watershed	2019 Area, acres	2019 % of Watershed	Area change, acres	Area % change (2019-2001)/2001	Percent Difference (2019% - 2001%)
Open Water	6,181	2.90%	6,357	2.99%	176	3%	0.08%
Developed, Open Space	8,557	4.02%	8,458	3.97%	-98	-1%	-0.05%
Developed, Low Intensity	3,142	1.48%	3,337	1.57%	194	6%	0.09%
Developed, Medium Intensity	926	0.43%	1,423	0.67%	497	54%	0.23%
Developed, High Intensity	137	0.06%	234	0.11%	96	70%	0.05%
Barren Land	425	0.20%	592	0.28%	168	39%	0.08%
Deciduous Forest	87,544	41.11%	81,594	38.32%	-5,950	-7%	-2.79%
Evergreen Forest	4,643	2.18%	4,285	2.01%	-358	-8%	-0.17%
Mixed Forest	3,754	1.76%	3,906	1.83%	152	4%	0.07%
Shrub/Scrub	222	0.10%	2,699	1.27%	2,478	1118%	1.16%
Herbaceous	634	0.30%	5,262	2.47%	4,627	730%	2.17%
Hay/Pasture	96,499	45.32%	94,527	44.39%	-1,971	-2%	-0.93%
Cultivated Crops	0	0.00%	0	0.00%	0	0%	0.00%
Woody Wetlands	233	0.11%	226	0.11%	-7	-3%	0.00%
Emergent Herbaceous Wetlands	28	0.01%	25	0.01%	-3	-11%	0.00%
Total	**212,926**	**100.00%**	**212,927**	**100.00%**			

APPENDIX C

Characterization of Current Surface Water Quality in Upper White River Watershed

Measurements of selected parameters of concern collected during the period 2018-2022 by rkansas Department of Environmental uality DE , rkansas Water Resources Center WRC , Beaver Watershed District BWD , H2O arks, and United States eological Survey US S are summari ed below. The data used for this summary was downloaded in March 2023 from the Water uality Portal W P , DE Online Monitoring Database, H2O arks StreamSmart database, and the ational Water Information System WIS . BWD data was provided by BWD to FT ssociates. Parameters examined in this section include those related to current assessed water uality impairments. bacteria, pH, turbidity, total suspended solids TSS , total dissolved solids TDS, sulfate, temperature, dissolved oxygen DO , biochemical oxygen demand BOD , and nutrients. ote that when a measurement is reported as not detected or less than detectable limit, the Kaplan Meier method has been used in analyses through EP s ProUCL tool USEP , 2022 . Eighty-six water uality monitoring stations in the Upper White Watershed were sampled 2018-2022, but only 77 stations had at least ten data points in at least one water uality parameter of concern. The stations were divided into six ma or waterway segments for ease of data analysis and visuali ation Figure 1 .

- White River to Lake Se uoyah,
- West Fork White River,
- White River from Wyman to state line,
- War Eagle Creek,
- Eastern streams Kings River, Osage Creek, and Long Creek , and
- Lake Stations.



Figure 1. Six ma or waterways in the Upper White River Watershed used to display water uality monitoring data.

lso, when multiple results are reported for the same sample date and depth, a single value was derived by averaging the reported values. This average value was used in analyses.

This appendix includes several box and whisker graphs. Box and whisker graphs show the range and distribution of values. They show the minimum and maximum values, the 25th percentile, median or 50th percentile, and 75th percentile. Figure 2 illustrates the elements of the box and whisker graphs in this appendix. ote that the inter uartile range is e ual to the 75th percentile value minus the 25th percentile value. If less than detected values were reported, then the Kaplan Meier method was used for general statistics. Only stations with at least 10 samples were graphed.

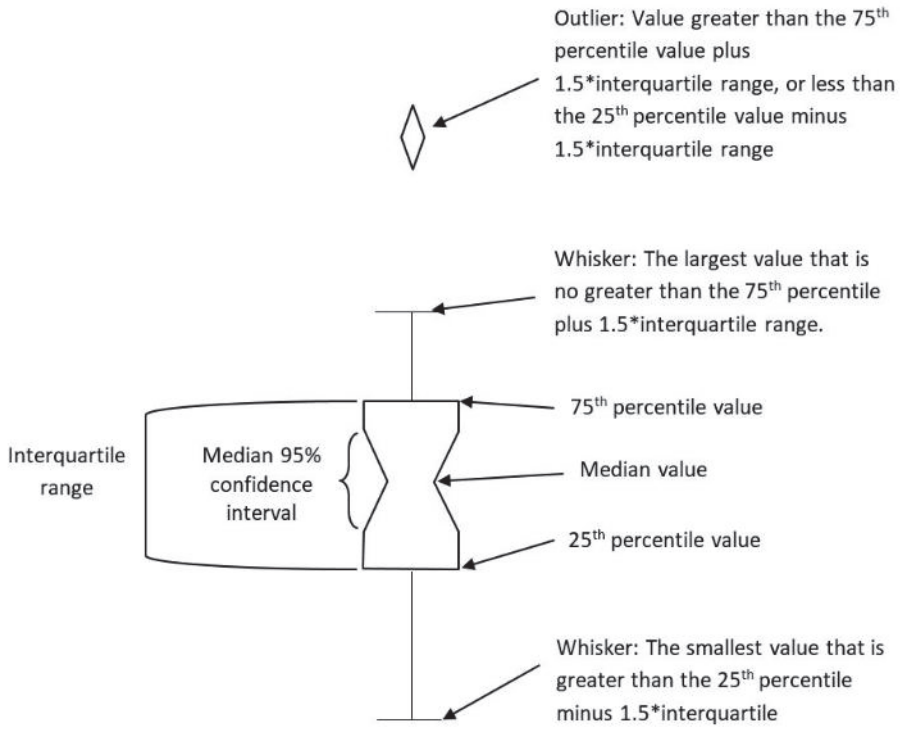


Figure 2. Elements of box and whisker graphs.

1.1 Bacteria Indicator of Pathogens

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

The tables below list summary statistics for *E.Coli* measurements in the watershed during the period 2018-2022. ote that *E.Coli* measurements were only collected at ten 10 stations by US S during 2018-2022. Locations where more than 25% of at least eight 8 individual *E.Coli* measurements exceed the criteria may be classified as impaired PCEC, 2022 . DE Rule 2 specifies separate criteria for primary and secondary contact season for *E.Coli*. Primary contact season is defined as May 1 through September 30 and secondary contact season is year-round.

1.1.1 Primary Contact Season *E.Coli*

Table 1 and Table 2 show the primary contact season May September summary statistics for stream and lake stations, respectively. The stream reaches are not classified as impaired because of high *E.Coli* levels on the final 2018 and draft 2020 303 d Lists. However, Beaver Lake is listed as impaired for not meeting the primary contact season *E.Coli* criterion on these 303 d Lists DE , 2019 DE , 2020 .

Figure 3 shows a box and whisker graph of primary contact season lake *E.Coli* measurements from the Upper White River watershed during the period 2018-2022. Stream primary *E.Coli* measurements were not graphed since only one station had at least ten measurements. The highest median *E.Coli* value occurs at station 07048600 White River near Fayetteville however, only five 5 measurements were collected from this station during the primary contact season from 2018-2022 so there are not enough measurements from this station for attainment assessment. ote that because of the amount of variation in *E.Coli* measurements at all the stations, this high median value is not statistically significantly different from the median values at the rest of the stations. Station 07048600 is located in an agricultural

production area downstream of the Lake Se uoyah dam and upstream of the oland Wastewater Treatment Facility Fayetteville discharge. Both stations 07048600 White River near Fayetteville and 07048780 Richland Creek near oshen had two measurements above 1,000 cfu/100mL each. The lowest median *E.Coli* values occurred at station 07049160 War Eagle Creek near Lowell and lake stations 07049500 Beaver Lake at Hwy 412 bridge and 07049690 Beaver Lake near Eureka Springs near the dam on Beaver Lake. Only one of the lake stations, 07048910 Beaver Lake at Hwy 412 near Sonora had a measurement over the primary contact season criterion.

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

rgani ation	Station D	Strea D	u ber of easures	ini u alue, col/100 L	25th Percentile, cfu/100 L	edian, cfu/100 L	ean, cfu/100 L	75th Percentile, cfu/100 L	a i u alue, cfu/100 L	Criteria, cfu/100 L	u ber of alues Criteria	Percentage of alues Criteria
US S	07048600	WR	5	20	41	310	5,734	3,300	25,000	410	2	-
US S	07048700	WR	11	4	62	140	138	210	270	410	0	0%
US S	07048780	RC	5	16	58	83	5,231	13,000	13,000	410	2	-
US S	07049050	WEC	4	19	39	93	476	93	1,700	410	1	-

WR White River, RC Richland Creek, WEC War Eagle Creek
DE re uires at least 8 samples to evaluate attainment of the Primary Contact *E.Coli* criteria DE , 2018d .

Table 2. Summary statistics for primary contact season *E.Coli* measurements from lake stations Beaver Lake during 2018-2022 stations listed in downstream order . ll samples are taken from depths of 6 ft or less.

rgani ation	Station D	La e D	u ber of easures	ini u alue, col/100 L	25th Percentile, cfu/100 L	edian, cfu/100 L	ean, cfu/100 L	75th Percentile, cfu/100 L	a i u alue, cfu/100 L	Criteria, cfu/100 L	u ber of alues Criteria	Percentage of alues Criteria
US S	07048910	BL	13	1	2	4	95	37	860	298	1	8%
US S	07049160	BL	11	0	0	0	4	3	20	298	0	0%
US S	07049187	BL	5	0	1	1	2	2	7	298	0	-
US S	07049200	BL	10	0	0	1	3	3	21	298	0	0%
US S	07049500	BL	7	0	0	0	0	0	1	298	0	-
US S	07049690	BL	10	0	0	0	1	0	2	298	0	0%

BL Beaver Lake DE re uires at least 8 samples to evaluate attainment of the Secondary Contact *E.Coli* criteria DE 2022 .
Indicates stations are located on assessment units impaired because of high *E.Coli* levels on both the pproved 2018 and Draft 2020 303 d impairment lists.

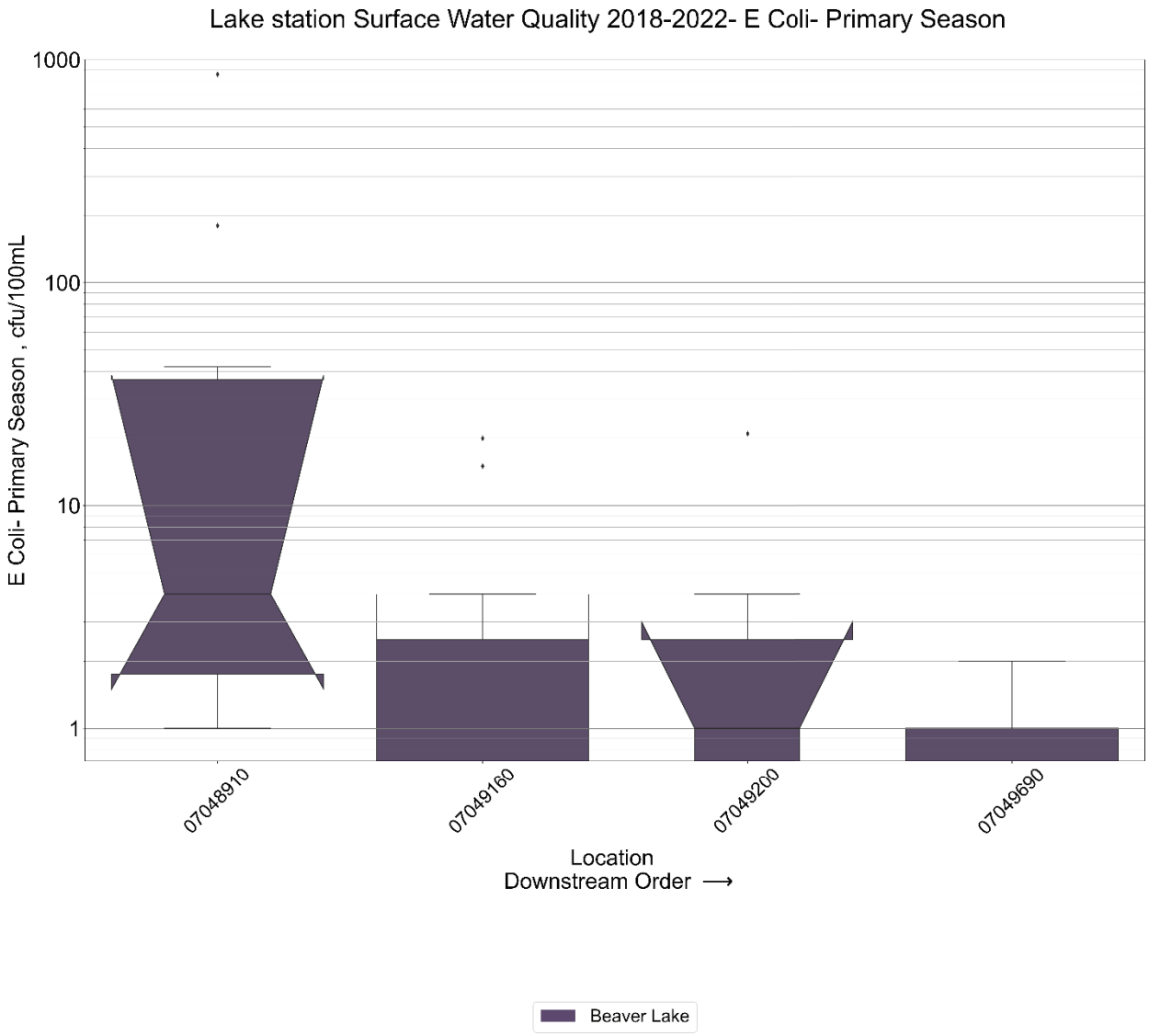


Figure 3. Box and whisker graph of *E.Coli* measurements from lake stations with more than 8 values in primary contact season from 2018-2022.

1.1.1 Secondary Contact Season *E.Coli*

Secondary contact season criteria apply to measurements from October 1- pril 30. Criteria values for secondary contact season are greater than for primary contact 2,050 cfu/100mL for stream stations and 1,490 cfu/100mL for lake stations. s with primary contact season, DE re uires at least eight 8 samples to evaluate attainment for secondary contact *E.Coli* criteria. Table 3 and Table 4 show summary statistics for secondary contact season *E.Coli*

for stream and lake stations, respectively. The box and whisker plots for these tables are shown in Figure 4 and Figure 5.

The stream stations have higher median values than the lake stations overall with station 07048780 Richland Creek near oshen with the highest median value however, two Beaver Lake stations are listed as impaired on the 2018 and Draft 2020 303 d lists. Station 07048600 White River near Fayetteville has the second highest median as well as the highest maximum value. Both stations reported 50% of samples exceeded DE criteria of 2,050 cfu/100mL. The lowest median stream value is at station 07048700 White River near oshen . This station is located ust upstream of the confluence with Richland Creek, approximately 13 miles downstream of station 0748600. s noted previously, no monitored streams in the Upper White River watershed are listed as impaired because of high *E.Coli* levels. This is because our comparison of *E.Coli* measurements to water uality criteria is not how DE evaluates *E.Coli* data to determine if water uality standards are being met. one of the lake stations reported a measurement above the criteria limit. In general, *E.Coli* levels in Beaver Lake decrease from upstream to downstream.

Table 3. Summary statistics for secondary contact season stream *E.Coli* measurements during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, col/100 L	25th Percentile, cfu/100 L	edian, cfu/100 L	ean, cfu/100 L	75th Percentile, cfu/100 L	a i u alue, cfu/100 L	Criteria, cfu/100 L	u ber of alues Criteria	Percentage of alues Criteria
US S	07048600	WR	9	24	620	2,300	3,555	5,500	12,000	2,050	5	56%
US S	07048700	WR	9	4	12	35	82	46	500	2,050	0	0%
US S	07048780	RC	7	18	1,035	4,300	4,884	7,400	13,000	2,050	4	57%
US S	07049050	WEC	5	27	1,500	2,300	6,165	12,000	15,000	2,050	3	60%

WR White River, RC Richland Creek, WEC War Eagle Creek
DE re uires at least 8 samples to evaluate attainment of the Secondary Contact *E.Coli* criteria DE 2022 .

Table 4. Summary statistics for secondary contact season *E.Coli* measurements from Lake Stations Beaver Lake during 2018-2022 stations listed in downstream order . ll samples are taken from depths of 6ft or less.

rgani ation	Station D	La e D	u ber of easures	ini u alue, col/100 L	25th Percentile, cfu/100 L	edian, cfu/100 L	ean, cfu/100 L	75th Percentile, cfu/100 L	a i u alue, cfu/100 L	Criteria, cfu/100 L	u ber of alues Criteria	Percentage of alues Criteria
US S	07048910	BL	8	2	11	20	27	26	98	1490	0	0%
US S	07049160	BL	9	0	2	9	13	13	50	1490	0	0%
US S	07049187	BL	4	0	0	1	5	6	16	1490	0	0%
US S	07049200	BL	7	0	2	6	7	11	17	1490	0	0%
US S	07049500	BL	5	0	0	4	4	7	9	1490	0	0%
US S	07049690	BL	4	0	0	0	0	0	0	1490	0	0%

BL Beaver Lake

DE re uires at least 8 samples to evaluate attainment of the Secondary Contact *E.Coli* criteria DE 2022 .

Indicates stations are located on assessment units impaired because of high *E.Coli* levels on both the pproved 2018 and Draft 2020 303 d impairment lists.

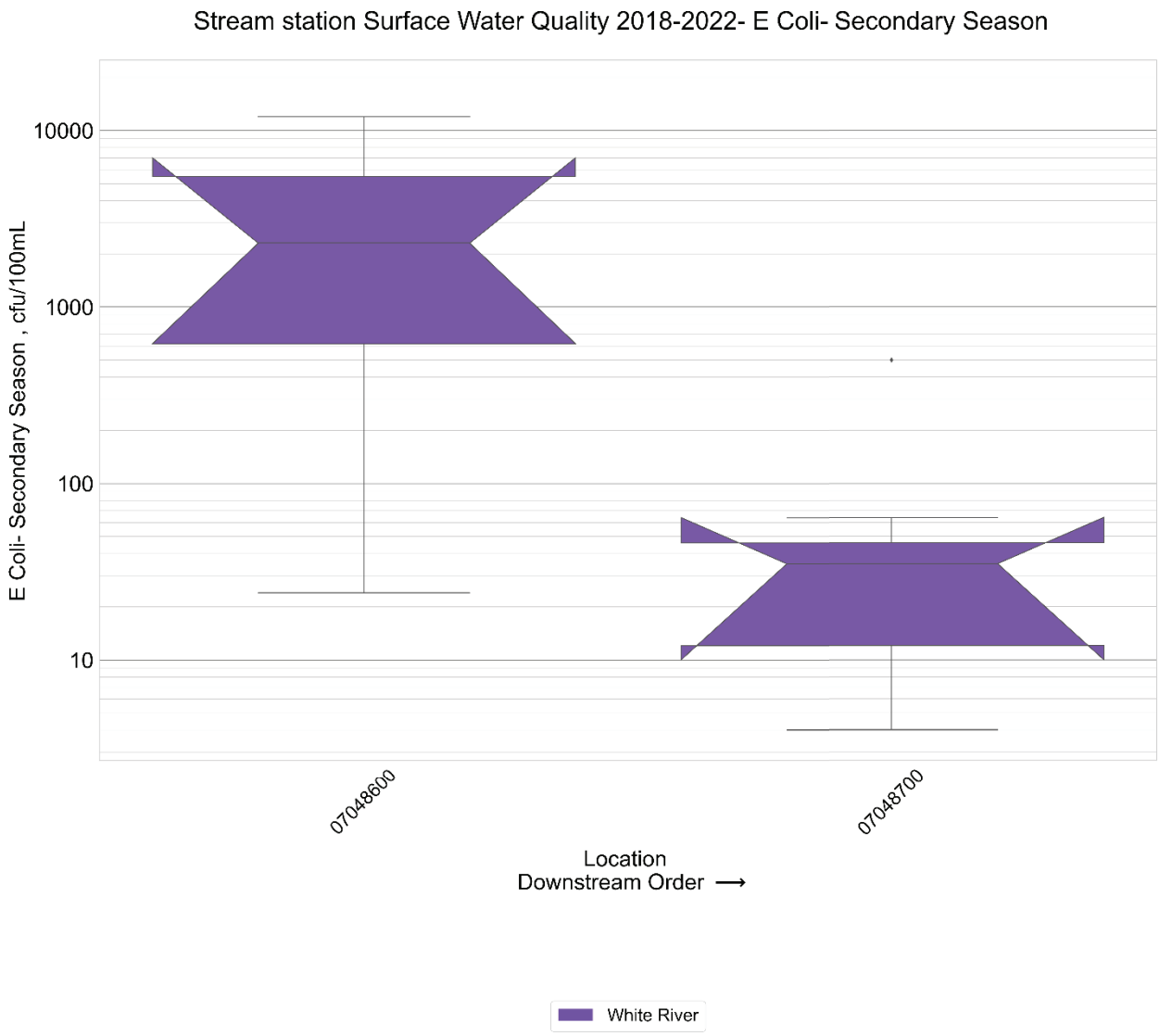


Figure 4. Box and whisker graph of *E.Coli* measurements from stream stations with more than 8 values in secondary contact season from 2018-2022.

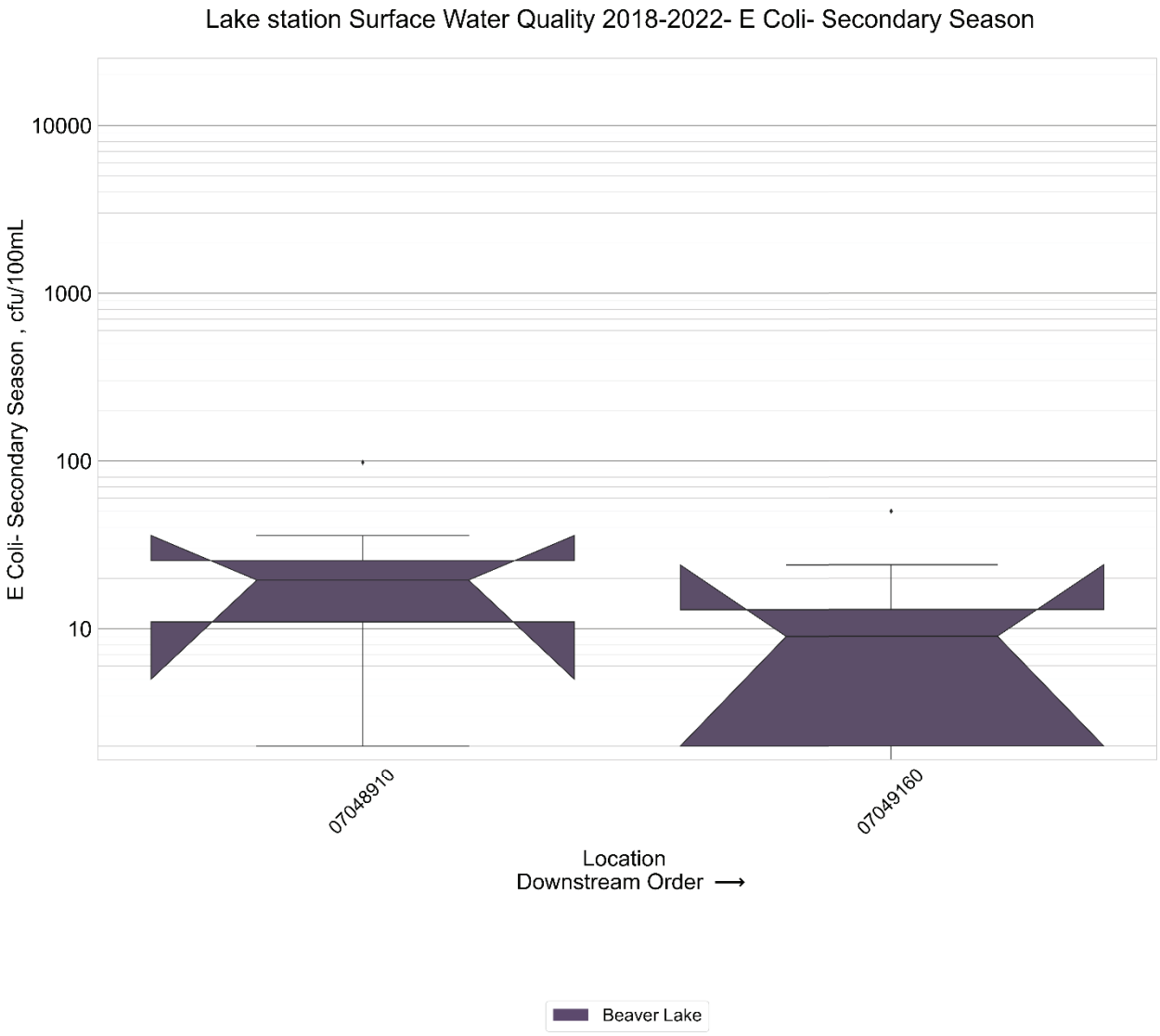


Figure 5. Box and whisker graph of *E.Coli* measurements from lake stations with more than 8 values in secondary contact season from 2018-2022.

1.2 pH

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

Summary statistics for stream and lake pH measurements from the period 2018-2022 are provided in Tables 5-9. The water uality stations were divided into six ma or waterway segments White River to Lake Se uoyah, West Fork White River, White River from Wyman to

state line, War Eagle Creek, Eastern streams, and lake stations for ease of data analysis and visuali ation. US S has five continuous water uality stations in the watershed, two of which measure pH. For these stations, summary statistics were calculated for the continuous data. Three of the stream water uality stations active during 2018-2022 reported pH values below the 6 standard unit su minimum pH criterion.

Summary statistics for lake stations Lake Se uoyah, Lake Wilson, and Beaver Lake are provided in Table 10. Summary statistics of measurements taken from depths of six feet or less i.e., epilimnion are shown in Table 10 and compared to the pH criteria. ote that DE stations LWHI014, LWHI009 and LWHI013 and US S station 07049691 are located near dams. The Lake Wilson station LWHI009 reported a pH value above the maximum 9 su pH criterion.

To determine pH impairment of water uality DE re uires at least 10 measurements. Locations where more than 10% of at least 10 measurements that do not meet pH criteria may be classified as impaired by DE DE 2019 . Only two stream stations with more than 10 pH measurements did not meet criteria, in both cases lower than 6 su. H2O ark Stations 103 and 104 Table 5 near St. Paul both had pH measurements lower than 6 su. ll epilimnion pH measurements from the lake stations with at least ten sampled measurements near the dams at Lake Wilson and Beaver Lake LWHI014, LWHI013 and 07049690 meet the water uality criteria Table 10 . There were insufficient measurements from the lake station near the Lake Se uoyah dam LWHI009 for exceedance assessment although, one of the five recorded measurements was above the maximum criterion of 9 su, pH measurements are higher in Osage Creek and Kings River Figure 10 . nearly five-mile stream segment located on the Kings River head waters is proposed by DE as impaired because of pH levels in the Draft 2020 303 d List DE 2020 . o water uality data was found from this stream segment in 2018-2022. Beaver Lake station 07049160 is proposed to be delisted for pH on the Draft 2020 List.

Table 5. Summary statistics for stream pH measurements from stations in White River to Lake Se uoyah waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, su	25th Percentile, su	edian, su	ean, su	75th Percentile, su	a i u alue, su	u ber of alues do not eet Criteria	Percentage of alues do not eet Criteria
H2O arks	103	BC	15	5.5	5.9	6.1	6.2	6.4	7.6	5	33%
DE	WHI0104	WR	11	6.8	6.9	7.1	7.1	7.3	7.5	0	0%
H2O arks	104	WR	15	5.8	6.1	6.5	6.4	6.7	7.1	2	13%
H2O arks	110	WR	2	6.9			7.0		7.0	0	-
DE	WHI0106	WR	51	6.4	7.3	7.7	7.5	7.8	8.2	0	0%
DE	WHI0219	MFWR	11	6.7	7.6	7.7	7.7	7.9	8.2	0	0%
H2O arks	201	MFWR	14	6.7	7.0	7.3	7.3	7.4	7.9	0	0%
DE	WHI0103	MFWR	53	6.0	7.4	7.7	7.6	7.9	8.2	0	0%

BC Baldwin Creek, WR White River, MFWR Middle Fork of the White River
DE re uires at least 10 samples to evaluate pH criteria attainment DE 2022 .
su standard unit

Table 6. Summary statistics for stream pH measurements from stations in West Fork White River waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, su	25th Percentile, su	edian, su	ean, su	75th Percentile, su	a i u alue, su	u ber of alues do not eet Criteria	Percentage of alues do not eet Criteria
H2O arks	102	WFWR	14	6.4	7.0	7.3	7.3	7.6	8.1	0	0%
H2O arks	101	WFWR	10	6.6	7.3	7.5	7.7	8.3	8.5	0	0%
DE	WHI0229	WFWR	10	7.3	7.5	7.7	7.7	7.8	8.2	0	0%
H2O arks	200	WS	10	7.4	7.5	7.7	7.8	7.9	8.7	0	0%
H2O arks	202	MC	8	7.4	7.5	7.7	7.7	7.8	8.0	0	-
H2O arks	206	SS	9	7.5	7.6	8.0	7.9	8.0	8.4	0	-
DE	WHI0223	TB	11	7.4	7.9	8.0	8.0	8.1	8.6	0	0%
H2O arks	210[a]	TB	14	7.2	7.4	7.6	7.6	7.8	8.0	0	0%
US S	07048495[a]	TB	24	7.2	7.7	7.9	7.8	8.0	8.2	0	0%
DE	WHI0100	WFWR	53	5.9	7.6	7.8	7.7	7.9	8.4	1	2%
US S	07048550	WFWR	5	7.0	7.1	7.5	7.5	7.6	8.4	0	-

Stations in this table with the same superscript letter are at the same location.
WFWR West Fork White River, WS Ward Slough, MC Mullins Creek, SS Sprout Spring Branch, TB Town Branch
DE re uires at least 10 samples to evaluate pH criteria attainment DE 2022 .
su standard unit

Table 7. Summary statistics for stream pH measurements from stations in White River from Wyman to the state line waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, su	25th Percentile, su	edian, su	ean, su	75th Percentile, su	a i u alue, su	u ber of alues do not eet Criteria	Percentage of alues do not eet Criteria
US S	07048600∞	WR	1731	6.0	7.2	7.4	7.3	7.6	8.2	0	0%
DE	WHI0052[b]	WR	53	6.4	7.3	7.5	7.6	7.9	8.8	0	0%
US S	07048700[b]	WR	20	7.2	7.4	7.7	7.7	7.9	8.2	0	0%
H2O arks	205	HoC	14	6.7	6.9	7.0	7.0	7.1	7.5	0	0%
DE	WHI0231	DC	11	6.0	6.7	6.8	6.8	7.1	7.4	0	0%
DE	WHI0221	LlC	11	6.8	7.0	7.1	7.2	7.3	7.5	0	0%
US S	07048780	RC	13	7.2	7.3	7.6	7.6	7.9	8.1	0	0%
DE	WHI0110	RC	11	6.2	7.0	7.7	7.6	8.1	9.0	0	0%
H2O arks	300	BrC	13	6.4	7.4	7.6	7.5	7.6	8.0	0	0%
H2O arks	306	PC	12	7.3	7.5	7.6	7.7	7.8	8.2	0	0%
US S	07049691	WR	8	7.1	7.1	7.2	7.3	7.5	7.8	0	-
DE	WHI0012B	LwC	42	7.3	8.0	8.2	8.1	8.3	8.8	0	0%

Stations in this table with the same superscript letter are at the same location. WR White River, DC Drakes Creek, HoC Hock Creek, LlC Lollars Creek, RC Richland Creek, BrC Brush Creek, PC Prairie Creek, LwC Leatherwood Creek

DE re uires at least 10 samples to evaluate pH criteria attainment DE 2022 . su standard unit ∞ This is a continuous monitoring station. Statistics are calculated using reported daily median pH values.

Table 8. Summary statistics for stream pH measurements from stations in the War Eagle Creek waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani a tion	Station D	Strea D	u ber of easures	ini u alue, su	25th Percentile, su	edian, su	ean, su	75th Percentile, su	a i u alue,	u ber of alues do not eet	Percentage of alues do not eet
DE	WHI0227	WEC	11	6.9	7.0	7.1	7.1	7.2	7.6	0	0%
DE	WHI0233	C	11	6.9	7.2	7.5	7.4	7.6	7.7	0	0%
H2O arks	109	WEC	11	6.3	6.9	7.1	7.0	7.3	7.7	0	0%
DE	WHI0220	WC	11	7.2	7.4	7.6	7.6	7.7	8.0	0	0%
H2O arks	307	HC	14	6.6	7.0	7.2	7.2	7.3	7.9	0	0%
DE	WHI0070[c]	HC	53	7.2	7.8	7.9	8	8.2	8.9	0	0%
H2O arks	308[c]	HC	14	6.8	7.5	7.7	7.6	7.8	8.3	0	0%
H2O arks	301	WEC	9	6.7	7.0	7.1	7.3	7.5	8.1	0	-
H2O arks	302	C	13	7.2	7.5	7.6	7.6	7.7	8.1	0	0%
H2O arks	303	ClC	15	6.9	7.0	7.2	7.2	7.4	7.6	0	0%
DE	WHI0116	WEC	53	6.8	7.6	7.7	7.7	7.9	8.3	0	0%
H2O arks	304	CC	15	6.9	7.1	7.3	7.	7.4	7.7	0	0%
H2O arks	305[d]	WEC	9	7.0	7.2	7.4	7.5	7.6	8.2	0	-
US S	07049050[d ∞]	WEC	1558	7.0	7.6	7.7	7.8	7.9	8.4	0	0%

Stations in this table with the same superscript letter are at the same location. WEC War Eagle Creek, C ackson Creek, WC Wharton Creek, HC Holman Creek, C lade Creek, ClC Clear Creek, CC Clifty Creek DE re uires at least 10 samples to evaluate pH criteria attainment DE 2022 . su standard unit

∞ This is a continuous monitoring station. Statistics are calculated using reported daily median pH values.

Table 9. Summary statistics for stream pH measurements from stations in the Eastern waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, su	25th Percentile, su	edian, su	ean, su	75th Percentile, su	a i u alue, su	u ber of alues do not eet Criteria	Percentage of alues do not eet Criteria
DE	WHI0225	FC	10	7.2	7.5	7.6	7.6	7.7	7.8	0	0%
DE	WHI0121	KR	53	6.9	7.7	7.9	7.8	8.0	8.5	0	0%
DE	WHI0123	KR	53	7.0	7.8	8.0	7.9	8.1	8.9	0	0%
DE	WHI0230	KC	11	7.1	7.3	7.3	7.3	7.5	7.5	0	0%
DE	WHI0129	OC	11	7.1	7.3	7.7	7.6	7.7	8.1	0	0%
DE	WHI0068	OC	44	7.3	8.0	8.2	8.2	8.3	8.8	0	0%
DE	WHI0069	OC	47	7.3	8.0	8.3	8.2	8.5	9.0	0	0%
DE	WHI0009	KR	48	7.2	8.1	8.3	8.2	8.4	8.8	0	0%
US S	07053250	C	2	7.9			8.1		8.2	0	-
DE	WHI0232	TC	9	6.9	7.5	7.6	7.6	7.8	8.0	0	-
DE	WHI0071	LC	47	7.1	8.0	8.2	8.1	8.3	8.6	0	0%

FC Felkins Creek, KR Kings River, OC Osage Creek, C ocum Creek, TC Terrapin Creek, LC Long Creek
DE re uires at least 10 samples to evaluate pH criteria attainment DE 2022 .
su standard unit
Indicates station is located on assessment unit listed as impaired because of low pH on the Draft 2020 and Draft 2022 303 d Lists.

Table 10. Summary statistics for lake pH measurements from Lake Stations Lake Se uoyah, Lake Wilson, and Beaver Lake during 2018-2022 stations listed in downstream order .

rgani ation	Station D	La e D	Sa le Location	u ber of easures	ini u alue, su	25th Percentile, su	edian, su	ean, su	75th Percentile, su	a i u alue, su	u ber of alues do not eet Criteria	Percentage of alues do not eet Criteria
DE	LWHI009	LS	Epilimnion	5	7.8	7.9	8.2	8.3	8.3	9.1	1	-
DE	LWHI014	LW	Epilimnion	12	7.3	7.6	7.9	8.0	8.3	8.8	0	0%
US S	07048910	BL	Epilimnion	22	7.3	7.6	7.9	7.9	8.1	8.8	0	0%
DE	LWHI013B	BL	Epilimnion	5	6.7	7.1	7.4	7.7	8.7	8.9	0	-
US S	07049160	BL	Epilimnion	22	6.7	7.2	7.2	7.3	7.4	7.8	0	0%
US S	07049187	BL	Epilimnion	9	6.5	7.2	7.2	7.2	7.3	7.8	0	-
US S	07049200	BL	Epilimnion	22	7.1	7.6	8.0	8.1	8.6	9.1	1	5%
DE	LWHI013C[e]	BL	Epilimnion	4	6.8	7.1	7.9	7.8	8.6	8.7	0	-
US S	07049500[e]	BL	Epilimnion	22	7.0	7.8	8.4	8.2	8.8	9.0	0	0%
DE	LWHI013	BL	Epilimnion	4	6.4	6.9	7.7	7.6	8.4	8.6	0	-
US S	07049690	BL	Epilimnion	31	7.5	7.8	8.2	8.1	8.4	8.7	0	0%

Stations in this table with the same superscript letter are at the same location.
LS Lake Se uoyah, LW Lake Wilson, BL Beaver Lake
DE re uires at least 10 samples to evaluate pH criteria attainment DE 2022 . su standard unit
Indicates this station is located on an assessment unit listed as impaired because of high pH on the 2018 pproved 303 d List

Figure 6 though Figure 11 below show box and whisker graphs of pH measurements from monitoring locations in the Upper White River watershed with more than 10 measurements during the period 2018-2022. The graphed station with the lowest median pH is H2O arks station 103 Baldwin Creek in Figure 6. The median pH value at this station is lower than the median pH values at the nearest stream stations with more than 10 measurements 104, WHI0104 . It appears that median pH values at H2O arks stations tend to be lower than pH values measured by other organi ations. This is evident in Figure 7 and Figure 9 where H2O arks collects data at the same location as another organi ation.

The station with the highest median pH value is WHI0069 Osage Creek on R-103 bridge upstream of the confluence with Kings River in Figure 10. The median pH value at this station is not significantly higher than the median pH values at all the other stream stations with more than 10 measurements in Osage Creek or Kings River. In Kings River, Osage Creek, War Eagle Creek, and West Fork White River median pH values appear to increase from upstream to downstream, with upstream stations having lower median pH values than the downstream stations. This may be because of differences in ecoregion from upstream to downstream stations.

The median pH value at lake station 07049160 is statistically significantly lower than the median pH values at the rest of the lake stations Figure 11 . Station 07049160 is located in a transitional area of the War Eagle arm of Beaver Lake where flow and water uality are sometimes more similar to a river than a lake.

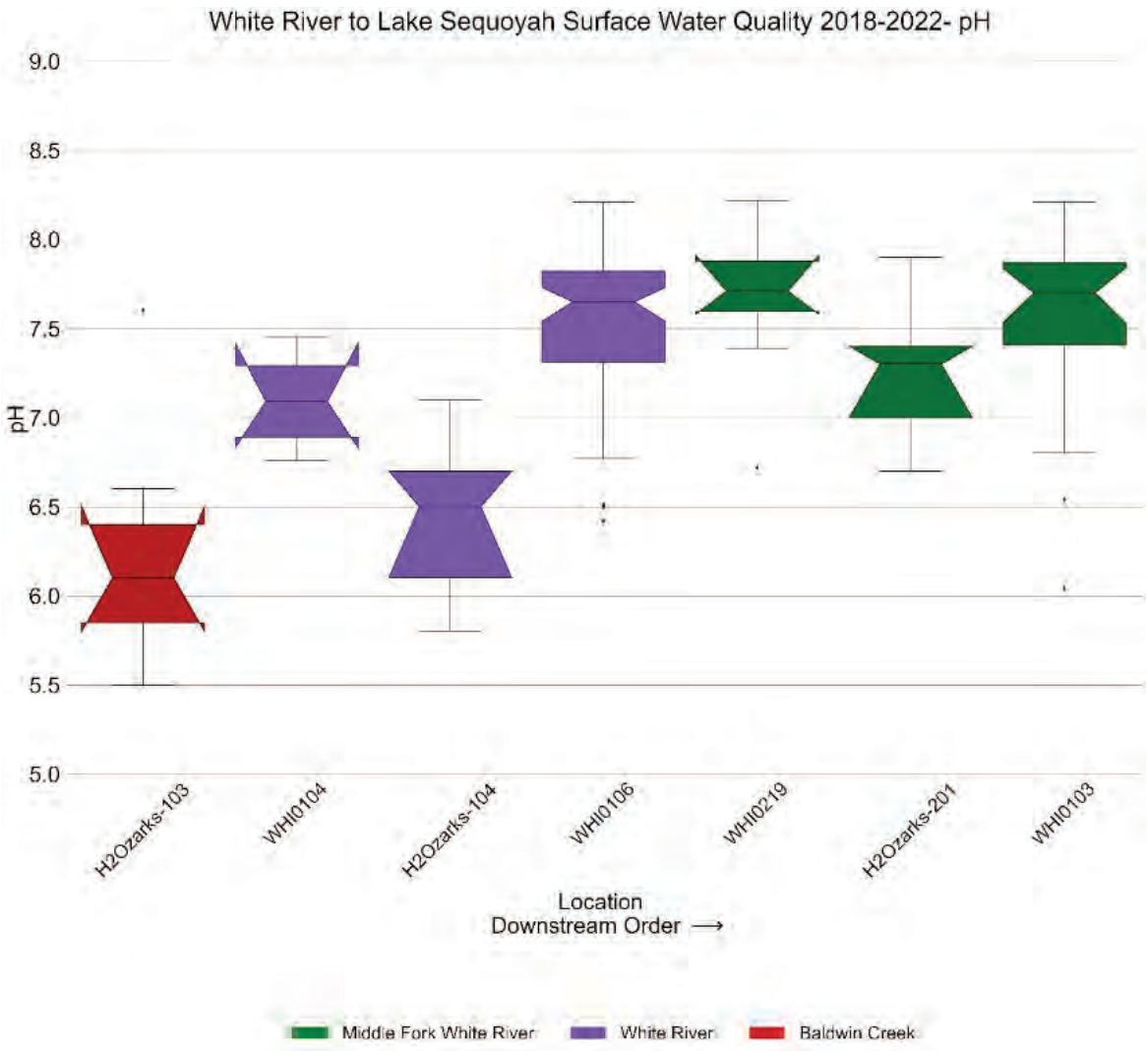


Figure 6. Box and whisker graph of pH measurements from stations in the White River to Lake Se uoyah waterway segment with more than 10 values from 2018-2022.

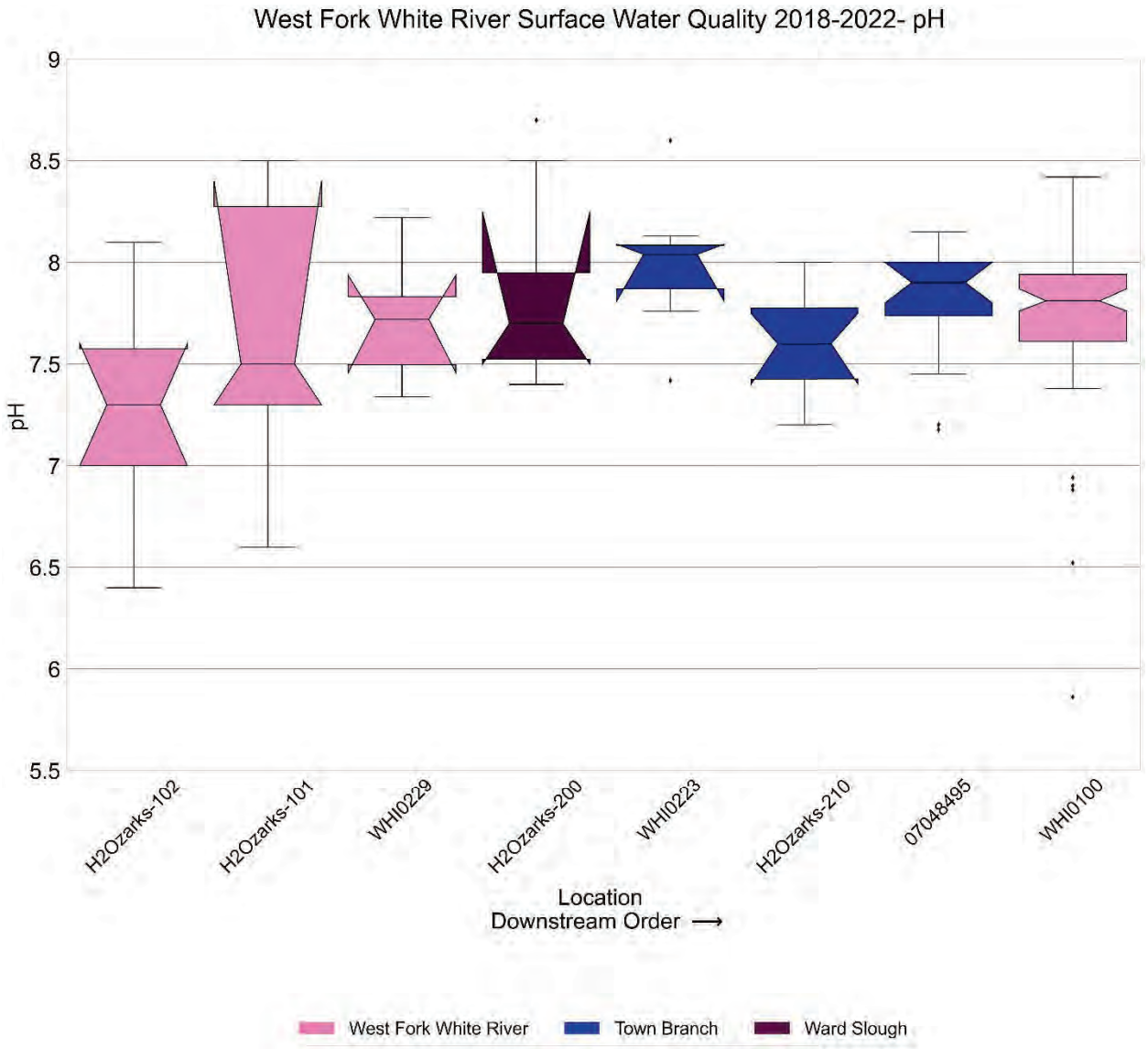


Figure 7. Box and whisker graph of pH measurements from stations in the West Fork White River waterway segment with more than 10 values from 2018-2022. ote that stations H2O arks-210 and 07048495 are at the same location on Town Branch.

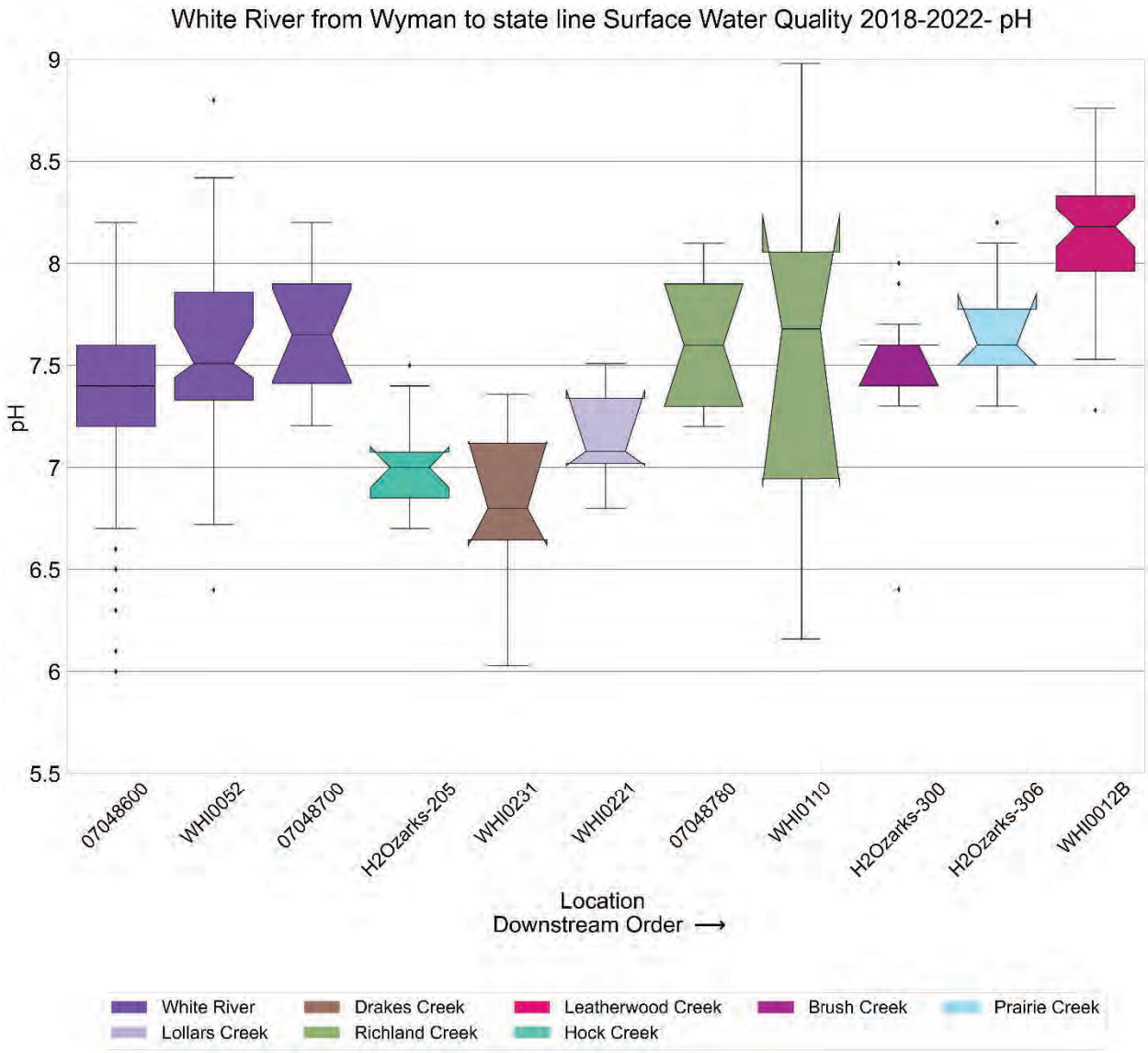


Figure 8. Box and whisker graph of pH measurements from stations in the White River from Wyman to the State Line waterway segment with more than 10 values from 2018-2022. ote that stations WHI0052 and 07048700 are at the same location on the White River.

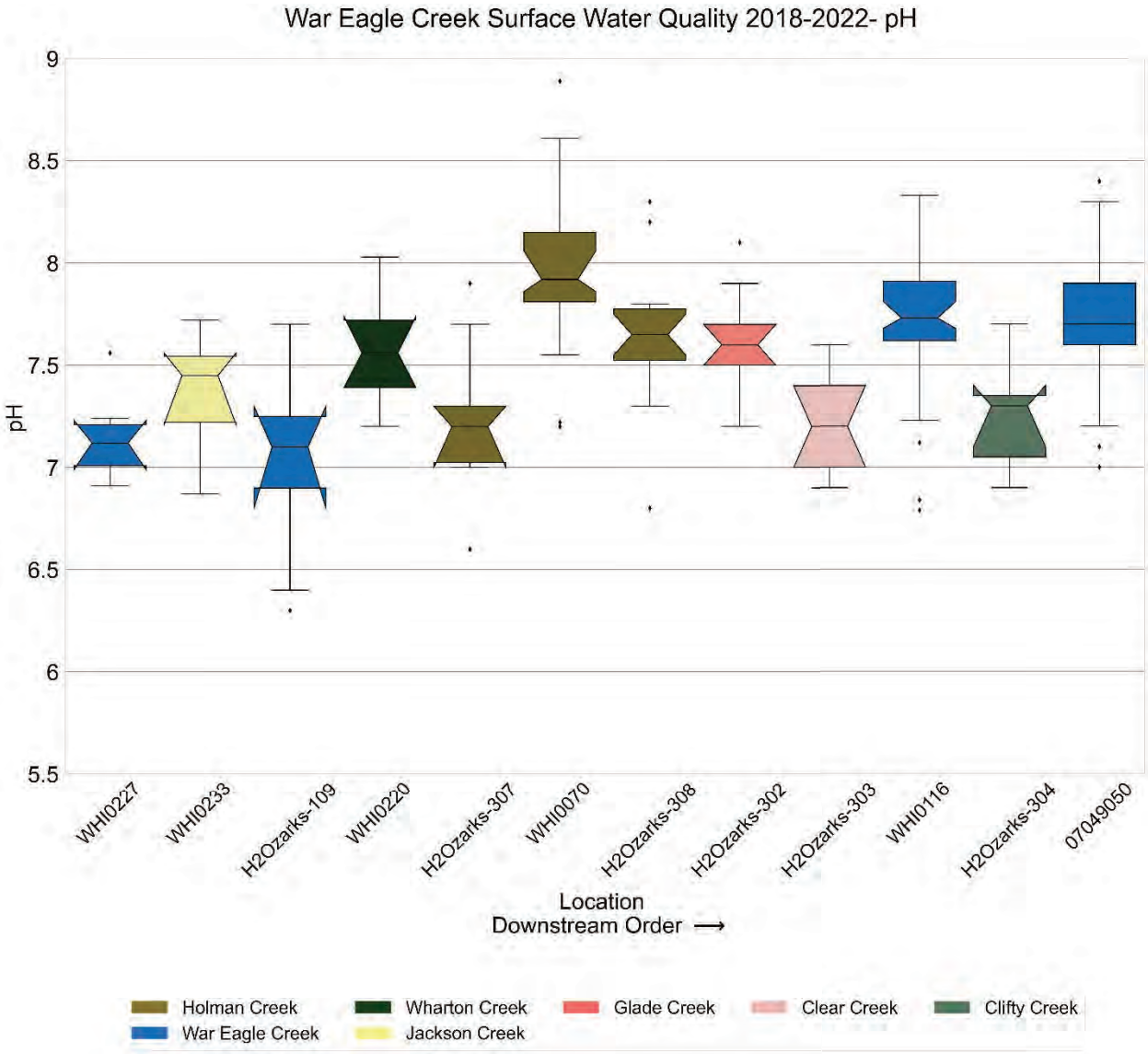


Figure 9. Box and whisker graph of pH measurements from stations in the War Eagle Creek waterway segment with more than 10 values from 2018-2022. ote that stations WHI0070 and H2O arks-308 are at the same location on Holman Creek.

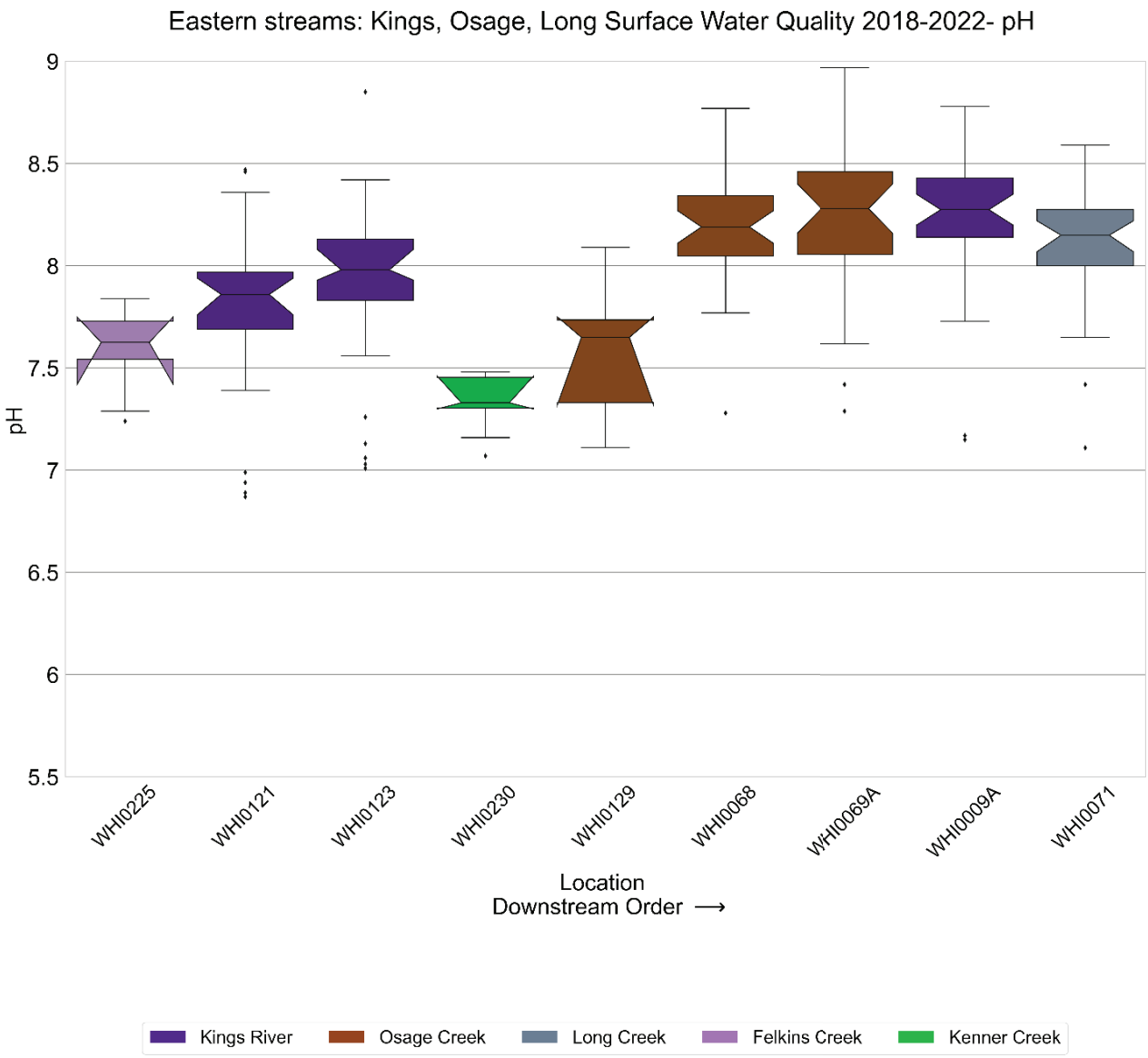


Figure 10. Box and whisker graph of pH measurements from stations in the Eastern Streams waterway segment with more than 10 values from 2018-2022.

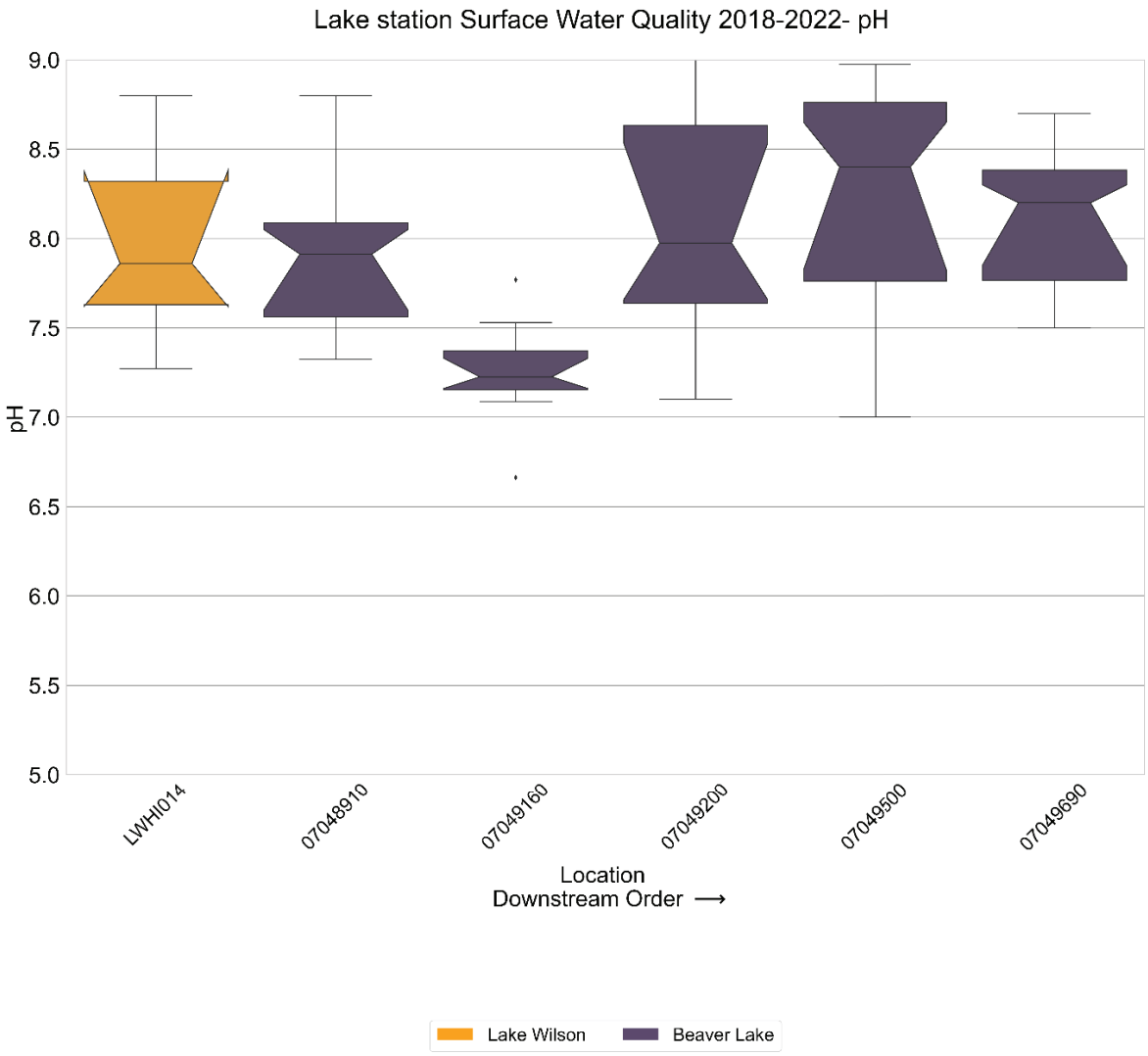


Figure 11. Box and whisker graph of pH measurements from Lake stations with more than 10 values in the epilimnion from 2018-2022.

1.3 Alkalinity

lkalinity is a measure of the ability of water to neutrali e acids, also called buffering capacity. Because pH is an issue in the Upper White River watershed, alkalinity is also characteri ed. ote that rkansas water uality standards do not include numeric criteria for alkalinity PCEC, 2022 . In rkansas, alkalinity in surface water is typically greater than 100 mg/L as CaCO3. However, in the Boston Mountains, average alkalinity in surface water is typically lower than 100 mg/L as CaCO3 because of the low incidence of carbonate rock in the geology damski, et al. 1995 . Surface waters with low alkalinity may also have lower pH values.

The tables below show summary statistics for stream alkalinity measurements from the period 2018-2022. Table 11 through Table 15 list summary statistics for stream alkalinity in the White River to Lake Se uoyah, West Fork White River, White River from Wyman to the state line, War Eagle Creek, and Eastern streams. Table 16 lists reservoir alkalinity measurements from the period 2018-2022. Mean alkalinity ranges from 8.4 White River at St. Paul to 151.5 Leatherwood Creek at Eureka Springs mg/L as CaCO3. ll reservoir alkalinity measurements were below 100 mg/L as CaCO3.

Table 11. Summary statistics mg/L as CaCO3 for stream alkalinity measurements in the White River to Lake Se uoyah during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ati on	Station D	Strea D	u ber of easur es	ini u alue, g/L	25th Percentil e, g/L	edia n, g/L	ea n, g/L	75th Percentil e, g/L	a i u alue, g/L	coregio n
H2O arks	103	BC	25	2.0	6.0	6.0	13.6	8.0	164.0	BM
DE	WHI0104	WR	10	6.1	6.9	8.1	8.4	9.3	11.1	BM
H2O arks	104	WR	24	6.0	7.8	10.0	10.4	12.5	20.0	BM
DE	WHI0106	WR	51	6.1	11.5	15.1	18.5	25.2	42.8	BM
DE	WHI0219	MFWR	12	20.7	32.3	39.4	42.2	55.5	64.2	BM
H2O arks	201	MFWR	28	4.0	38.0	44.0	43.4	49.5	60.0	BM
DE	WHI0103	MFWR	53	22.0	35.4	41.0	43.8	55.1	62.0	OH

BC Baldwin Creek, WR White River, MFWR Middle Fork White River
DE has proposed updating the ecoregion boundaries. If approved, this station would change ecoregions.

Table 12. Summary statistics mg/L as CaCO3 for stream alkalinity measurements in the West Fork White River during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	coregion
H2O arks	102	WFWR	29	14.0	22.0	32.0	35.6	46.0	74.0	BM
H2O arks	101	WFWR	22	20.0	49.0	66.0	65.3	76.0	146.0	BM
DE	WHI0229	WFWR	13	13.2	40.2	53.9	55.4	74.3	84.5	BM
H2O arks	200	WS	14	94.0	126.0	138.0	133.8	143.5	172.0	BM
H2O arks	202	MC	10	116.0	130.0	143.0	144.0	156.5	174.0	OH
H2O arks	206	SS	25	114.0	136.0	150.0	149.3	154.0	200.0	OH
DE	WHI0223	TB	12	85.8	118.8	123.5	120.0	128.0	140.0	OH
H2O arks	210	TB	26	102.0	119.0	133.0	131.7	142.0	160.0	OH
DE	WHI0100	WFWR	53	39.9	56.0	65.4	70.7	85.9	117.0	OH

WFWR West Fork White River, WS Ward Slough, MC Mullins Creek, SS Spout Spring Branch, TB Town Branch

DE has proposed updating the ecoregion boundaries. If approved, this station would change ecoregions.

Table 13. Summary statistics mg/L as CaCO3 for stream alkalinity measurements in White River from Wyman to State Line during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	coregion
DE	WHI0052	WR	53	18.8	32.3	40.9	48.4	63.0	115.0	OH
H2O arks	205	HoC	18	22.0	28.5	32.0	36.1	39.5	66.0	OH
DE	WHI0231	DC	12	9.4	13.9	17.6	17.2	19.0	24.3	OH
DE	WHI0221	LlC	11	6.7	11.4	14.9	17.1	21.7	30.1	BM
DE	WHI0110	RC	12	33.6	43.7	55.0	63.9	90.1	101.0	OH
H2O arks	300	BrC	32	12.0	122.0	137.0	138.4	160.5	178.0	OH
H2O arks	306	PC	30	104.0	127.0	140.0	138.7	149.5	198.0	OH
DE	WHI0012B	LwC	44	115.0	140.0	152.5	151.5	164.0	187.0	OH

DC Drakes Creek, HoC Hock Creek, LlC Lollars Creek, RC Richland Creek, WR White River, BrC Brush Creek, PC Prairie Creek, LwC Leatherwood Creek

DE has proposed updating the ecoregion boundaries. If approved, this station would change ecoregions.

Table 14. Summary statistics mg/L as CaCO3 for stream alkalinity measurements in War Eagle Creek during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	coregion
DE	WHI0227	WEC	12	12.3	15.4	23.6	25.4	36.8	43.6	BM
DE	WHI0233	C	12	12.4	15.4	25.6	32.4	50.8	71.6	BM
H2O arks	109	WEC	11	18.0	26.0	34.0	39.5	50.0	78.0	OH
DE	WHI0220	WC	12	34.1	49.0	65.0	68.5	87.7	103.0	BM
H2O arks	307	HC	26	44.0	65.0	76.0	83.8	104.5	132.0	OH
DE	WHI0070[a]	HC	53	57.9	78.0	91.8	94.3	108.0	143.0	OH
H2O arks	308[a]	HC	26	60.0	86.8	100.0	98.7	111.0	132.0	OH
H2O arks	301	WEC	24	44.0	50.0	64.0	70.2	88.5	114.0	OH
H2O arks	302	C	32	94.0	104.8	134.0	132.7	154.5	192.0	OH
H2O arks	303	ClC	35	52.0	86.0	100.0	96.7	112.0	150.0	OH
DE	WHI0116	WEC	53	40.0	57.8	69.4	75.9	96.2	115.0	OH
H2O arks	304	CC	34	104.0	114.0	139.0	135.8	152.0	168.0	OH
H2O arks	305	WEC	28	44.0	74.0	84.0	86.0	98.5	120.0	OH

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

DE has proposed updating the ecoregion boundaries. If approved, this station would change ecoregions.

WEC War Eagle Creek, C ackson Creek, WC Wharton Creek, HC Holman Creek, C lade Creek, ClC Clear Creek, CC Clifty Creek

Table 15. Summary statistics mg/L as CaCO3 for stream alkalinity measurements in the Eastern Streams during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	coregion
DE	WHI0225	FC	10	11.0	14.2	21.2	24.1	32.3	43.3	BM
DE	WHI0121	KR	52	25.5	39.0	51.0	60.6	84.3	122.0	OH
DE	WHI0123	KR	52	40.7	61.2	75.6	80.1	100.5	120.0	OH
DE	WHI0230	KC	11	16.8	48.2	54.1	63.0	83.3	110.0	OH
DE	WHI0129	OC	11	16.3	47.7	54.5	62.5	86.7	101.0	OH
DE	WHI0068	OC	45	60.3	96.3	112.0	110.8	128.0	145.0	OH
DE	WHI0069	OC	49	64.9	103.0	122.0	121.7	144.0	172.0	OH
DE	WHI0009	KR	50	58.8	93.6	111.0	106.3	119.5	135.0	OH
DE	WHI0232	TC	10	11.4	14.1	23.9	30.2	47.2	61.8	OH
DE	WHI0071	LC	49	76.4	114.0	132.0	132.0	149.0	166.0	OH

FC Felkins Creek, KR Kings River, KC Kenner Creek, OC Osage Creek, TC Terrapin Creek, LC Long Creek

DE has proposed updating the ecoregion boundaries. If approved, this station would change ecoregions.

Table 16. Summary statistics mg/L as CaCO3 for reservoir alkalinity measurements from stations in Lake Se uoyah, Lake Wilson, and Beaver Lake during 2018-2022 stations listed in downstream order .

rgani ation	Station D	La e D	Sa le Location	o. of easures	in alue, g/L	25th Percentile g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a alue, g/L
DE	LWHI009	LS	Epilimnion	8	15.7	18.9	25.4	28.7	37.4	48.9
DE	LWHI014	LW	Epilimnion	12	44.5	66.1	71.8	69.7	76.4	80.4
DE	LWHI013B	BL	Epilimnion	5	11.3	38.1	55.5	45.7	56.1	67.5
DE	LWHI013C	BL	Epilimnion	4	46.6	46.8	51.4	52.9	57.4	62.0
DE	LWHI013	BL	Epilimnion	4	58.5	59.0	61.0	60.5	61.6	61.6

LS Lake Se uoyah, LW Lake Wilson, BL Beaver Lake

Figure 12 through Figure 16 show box and whisker graphs of alkalinity measurements from surface water stream monitoring locations in the Upper White River watershed with more than 10 measurements during the period 2018-2022. The stations with the lowest median alkalinity are Baldwin Creek H2O arks station 103 and White River at St. Paul WHI0104 near the confluence of Baldwin Creek and the White River. These stations are located in the Boston Mountain ecoregion, where alkalinity is typically lower than 100 mg/L as CaCO3. H2O arks station 103 also reports the lowest median pH in the Upper White Watershed. Low alkalinity levels in these streams may contribute to the low pH level although they are not significantly different from other stations in the Boston Mountain Ecoregion. The station with the highest median alkalinity is on Leatherwood Creek, WHI0012B. The median alkalinity at this station is not significantly greater than the median values at the other stations on Beaver Lake tributary streams.

In the White River, War Eagle Creek, Homan Creek, Kings River, and Osage Creek, median alkalinity values at downstream stations located in the O ark Highlands OH ecoregion are higher than median alkalinity values at upstream stations located in the Boston Mountains BM . Median alkalinity values in tributaries tend to be higher than median alkalinity values in main streams. For example, median alkalinity values in Middle Fork White River are higher than in the White River in Figure 12, median alkalinity values in West Fork White River tributaries are higher than in the West Fork White River in Figure 13, etc.

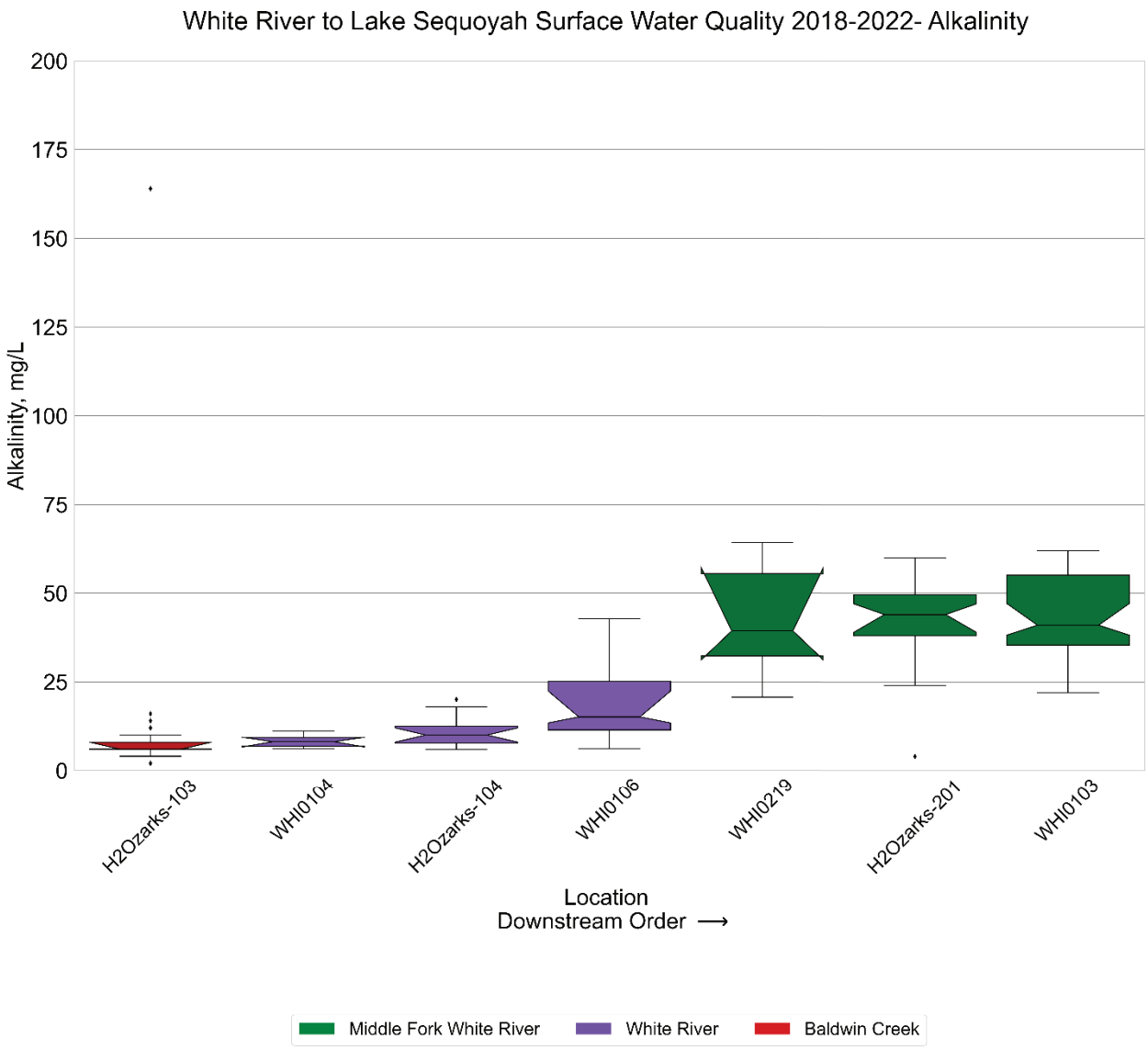


Figure 12. Box and whisker graph of alkalinity measurements from stations in the White River to Lake Se uoyah waterway segment with more than 10 values from 2018-2022. ote that all of these stations are in the Boston Mountains ecoregion if proposed ecoregion changes are approved and exhibit characteristically low alkalinity levels.

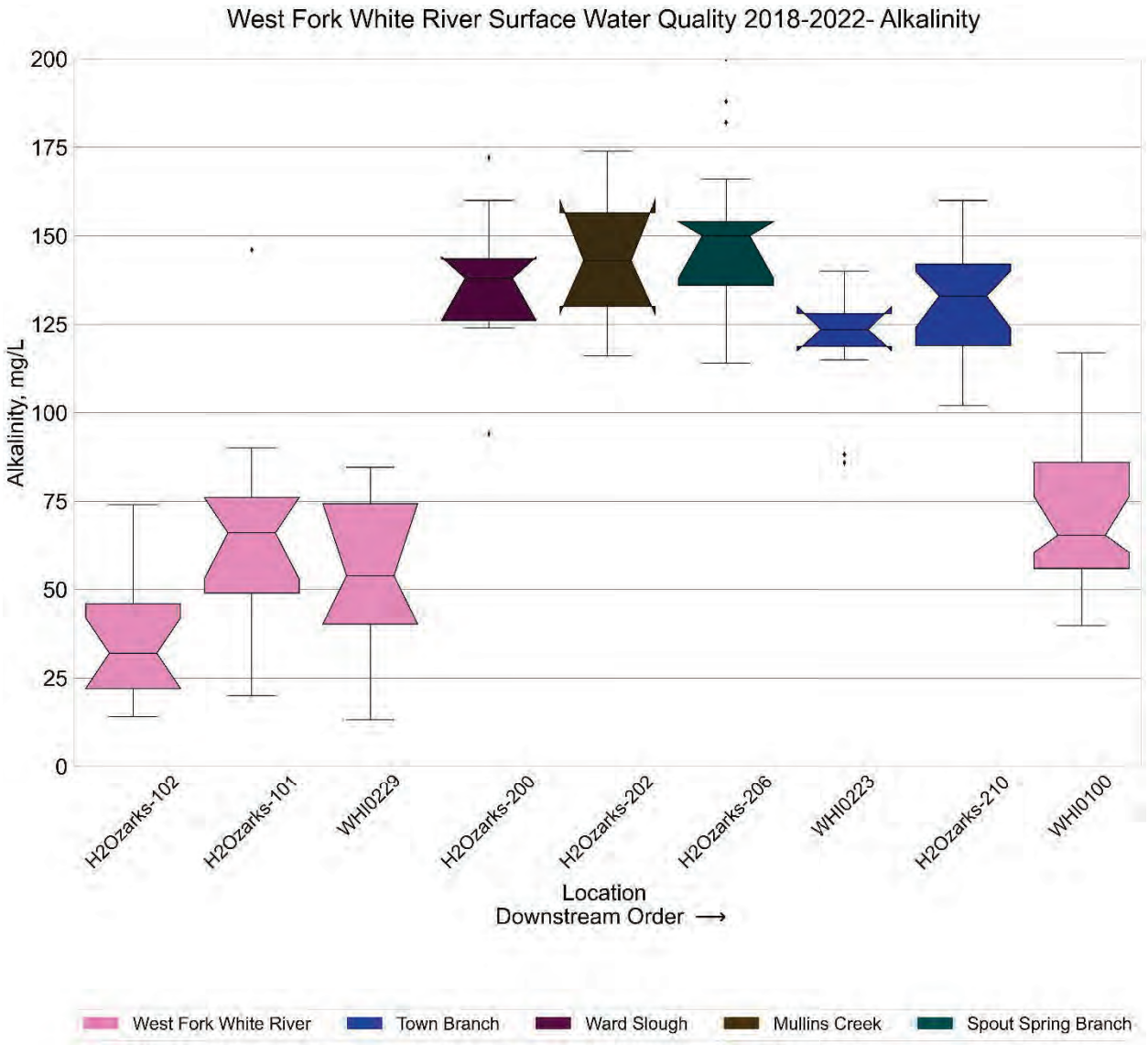


Figure 13. Box and whisker graph of alkalinity measurements from stations in the West Fork White River waterway segment with more than 10 values from 2018-2022. The West Fork White River is located in the Boston Mountain ecoregion and exhibits characteristically low alkalinity. The tributary streams are also located in the Boston Mountain ecoregion if proposed ecoregion changes are approved however, these segments are exhibiting higher alkalinity more typical of the O ark Highlands ecoregion.

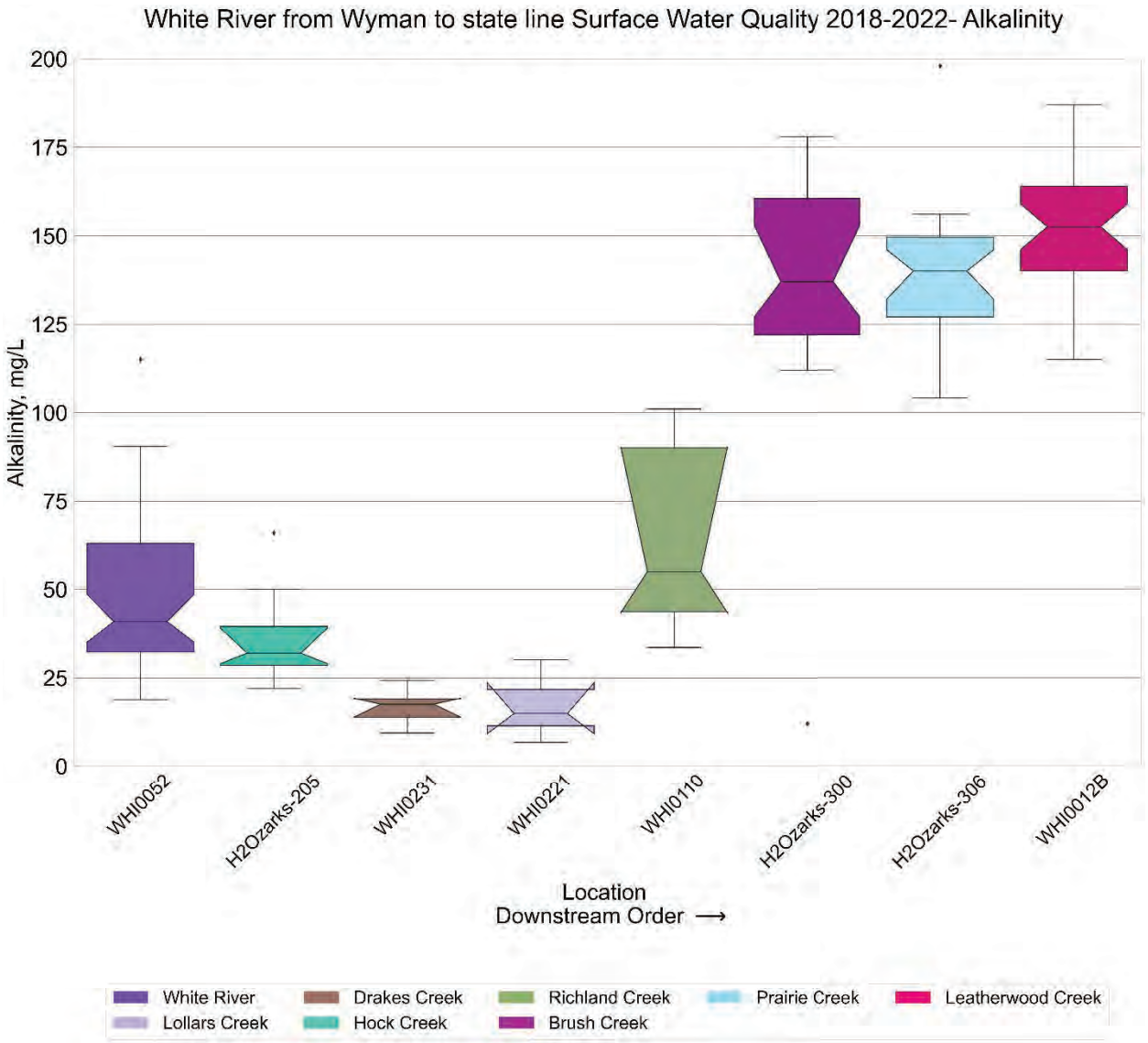


Figure 14. Box and whisker graph of alkalinity measurements from stations in the White River from to state line waterway segment with more than 10 values from 2018-2022. ote that stations WHI0231 through WHI0052 are located in the Boston Mountains ecoregion if proposed ecoregion changes are approved , while stations H2O arks-300 through WHI0012B are located in the O ark Highlands. The statistically significant difference in alkalinity levels is characteristic of streams in these two ecoregions.

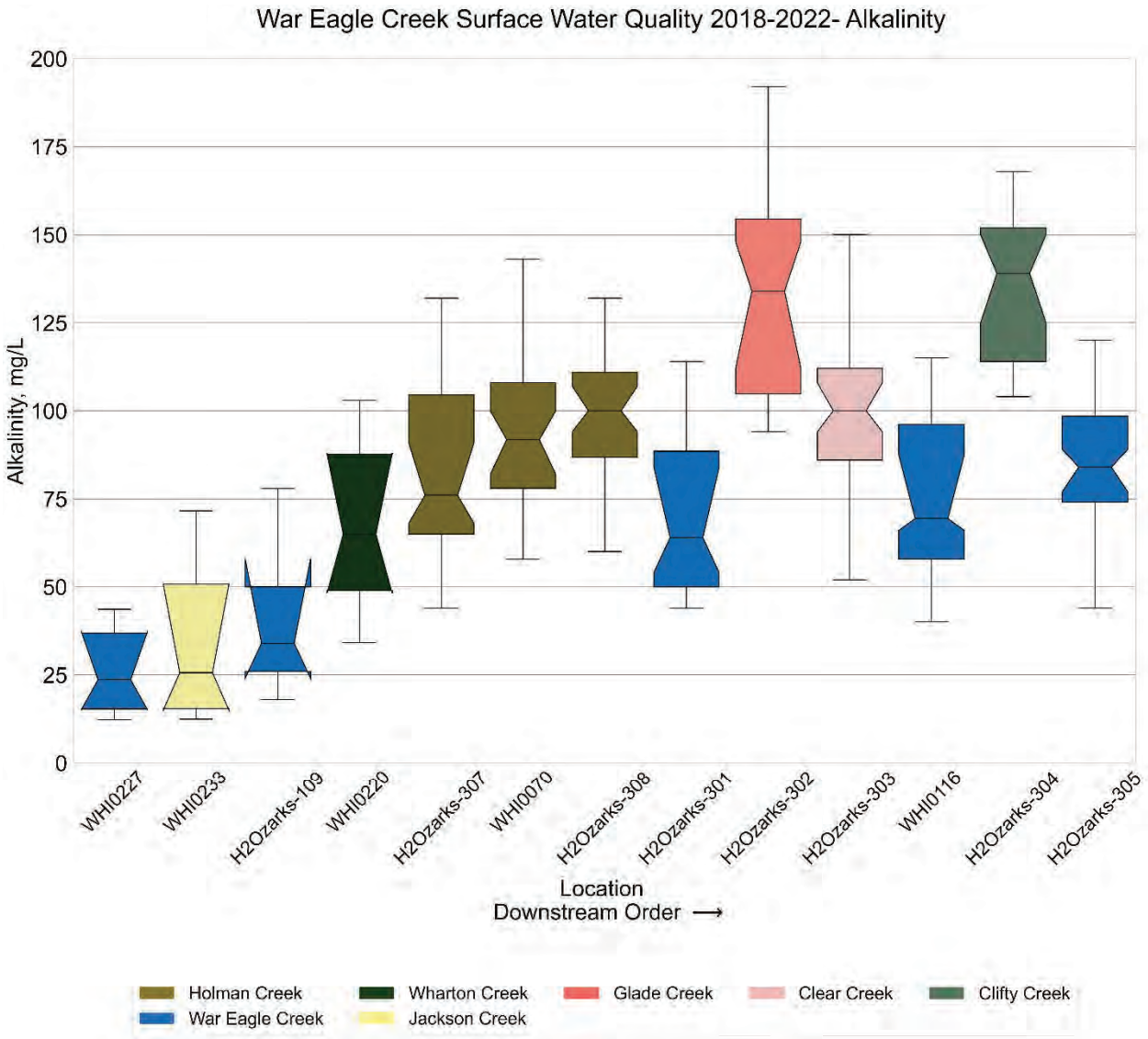


Figure 15. Box and whisker graph of alkalinity measurements from stations in the War Eagle Creek waterway segment with more than 10 values from 2018-2022. ote that stations WHI0070 and H2O arks-308 are at the same location on Holman Creek. Stations WHI0227 through H2O arks-109 exhibit statistically significantly lower alkalinity levels, characteristic of Boston Mountain streams. lkalinity levels in War Eagle Creek tend to be statistically significantly lower than alkalinity levels in tributary streams.

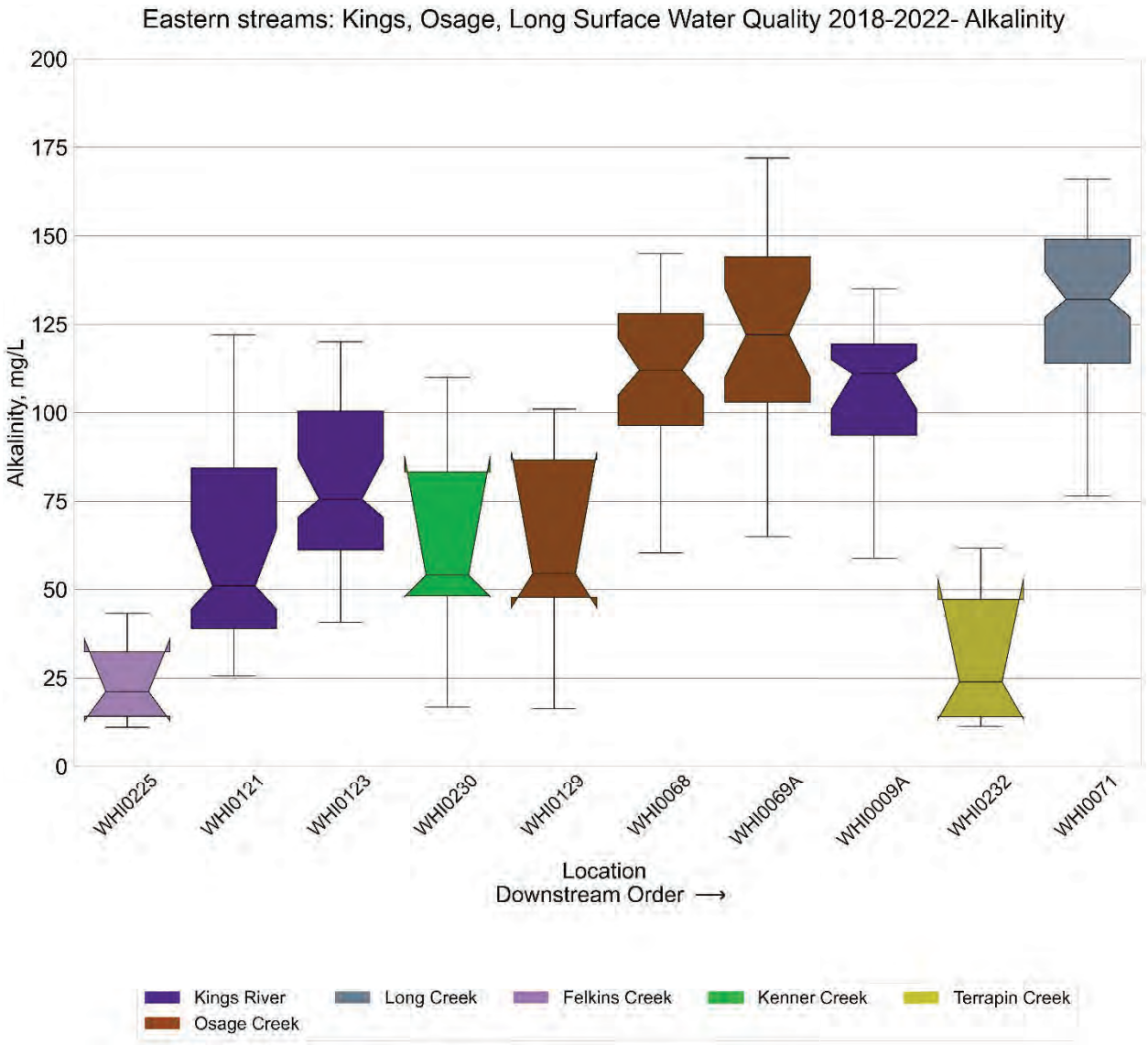


Figure 16. Box and whisker graph of alkalinity measurements from stations in the Eastern streams waterway segment with more than 10 values from 2018-2022. ote that stations WHI0225, WHI0230, WHI0129, and WHI0232 are located in the Boston Mountains ecoregion if proposed ecoregion changes are approved . Unlike the other waterway segments, there is no significant difference in tributary alkalinity versus the main stem of the Kings River.

1.4 Sediment Parameters

WRC, BWD, DE , H2O arks, and US S all measure indicators of sediment water uality issues. The three indicators that are monitored in the Upper White River watershed are turbidity, total suspended solids TSS , and suspended sediment concentration SSC . Only turbidity is measured by every organi ation. Table 17 shows which organi ation measured and reported each sediment parameter from 2018-2022.

Table 17. Matrix of organi ations and monitored sediment parameters.

rgani ation	Turbidit	TSS	SSC
WRC			
BWD			
DE			
H2O arks			
US S			

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

1.4.1 Turbidity

Turbidity is measured by how much light can pass through a water sample. higher turbidity value means less light can pass through the water. Both suspended and dissolved material in water can contribute to turbidity. Turbidity was measured by all five organi ations during 2018-2022. WRC measured turbidity weekly, while DE and BWD measured turbidity monthly. H2O arks measured turbidity uarterly, and US S measured turbidity periodically.

Summary statistics for stream and lake turbidity measurements from the period 2018-2022 are provided in the tables and figures below. The stations were divided into six ma or waterway segments White River to Lake Se uoyah, West Fork White River, White River from Wyman to state line, War Eagle Creek, Eastern Streams, and Lake Stations for ease of data

analysis and visuali ation. To determine stream turbidity impairment, DE re uires at least 24 measurements. Locations where more than 25% of at least 24 measurements do not meet turbidity criteria may be classified as impaired PCEC, 2022 . rkansas water uality regulations include separate numeric criteria for Storm Flow year round and Base Flow conditions une - October .

1.4.1.1 Storm Flow Turbidity Summary Statistics

Table 18 through Table 23 list summary statistics for turbidity measurements from streams in the Upper White River watershed during the period 2018-2022. Included in these tables is a listing of the applicable DE Storm Flow year round turbidity numeric water uality criteria based on the ecoregion the station is located within. For O ark Highlands OH ecoregion, the criteria for storm flows is 17 TU. In the Boston Mountains BM ecoregion, the criteria for storm flows is 19 TU. The number and percentage of measurements that exceed the applicable criteria are also shown in these tables. The criteria listed below are from the Regulation 2 ecoregion boundaries however, some stations are sub ect to criteria change if the proposed ecoregion boundaries are approved.

Twenty-nine stream stations have more than 24 Storm Flow measurements between 2018 and 2022. Thirty-four percent of the measurements at these stations exceed the Storm Flow turbidity criteria. Stations on stream segments impaired by high turbidity are highlighted in the tables below.

Median turbidity is highest in West Fork White River stations and on War Eagle Creek. Station 07049050 and BWD 8 are located at the same location however, they show a significant difference in median turbidity. BWD has 58 monthly measurements whereas US S station only has 12 measurements from 2018-2022. The largest storm values are consistent from both organi ations on the same day. This could mean the streambank at War Eagle Creek is unstable during high flow.

Table 18. Summary statistics for Storm Flow stream turbidity measurements from stations in White River to Lake Se uoyah waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station . The criteria is based on ecoregion. 17 for OH and 19 for BM.

rgani ation	Station D	Strea D	u ber of easures	ini u alue, T	25th Percentile, T	edian, T	ean, T	75th Percentile, T	a i u alue, T	Criteria, T	u ber of alues Criteria	Percentage of alues Criteria
H2O arks	103	BC	5	8.70	8.90	8.90	9.48	10.20	10.70	19	0	-
DE	WHI0104	WR	12	3.40	4.13	7.57	8.24	9.67	19.40	19	1	-
H2O arks	104	WR	5	3.00	5.50	8.30	7.32	8.60	11.20	19	0	-
H2O arks	110	WR	2	3.00			3.05		3.10	19	0	-
DE	WHI0106	WR	49	2.58	5.38	8.91	10.33	11.60	45.70	17	7	14%
BWD	5	WR	58	2.20	5.18	8.35	20.38	14.20	209	19	9	16%
DE	WHI0219	MFWR	12	1.27	1.81	2.68	5.90	4.72	36.10	19	1	-
BWD	7	MFWR	58	0.60	2.43	3.70	9.37	6.88	122	19	6	10%
H2O arks	201	MFWR	5	0.80	1.00	1.90	2.00	2.00	4.30	19	0	-
DE	WHI0103	MFWR	51	0.52	2.19	3.34	5.45	5.57	57.40	17	2	4%

BC Baldwin Creek, WR White River, MFWR Middle Fork of the White River
DE re uires at least 24 samples to evaluate attainment of the Storm Flows turbidity criteria DE 2022 .
Indicates stations are located on assessment units listed as impaired because of high turbidity on the Draft 2020 303 d List.

Table 19. Summary statistics for Storm Flow stream turbidity measurements from stations in West Fork White River waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, T	25th Percentile, T	edian, T	ean, T	75th Percentile, T	a i u alue, T	Criteria, T	u ber of alues Criteria	Percentage of alues Criteria
H2O arks	102	WFWR	5	0.80	1.20	1.30	4.86	6.60	14.40	19	0	-
DE	WHI0229	WFWR	13	0.68	3.03	5.14	7.90	13.15	49	19	1	-
DE	WHI0223	TB	12	1.58	4.23	9.58	11.86	12.30	40.20	19	2	-
WRC	TB[a]	TB	130	0.80	2.90	5.60	74.73	77.81	567	19	47	36%
H2O arks	210[a]	TB	5	1.20	2.00	3.30	2.80	3.40	4.10	19	0	-
BWD	8[b]	WFWR	58	2.60	9.93	13.25	30.14	21.43	328	19	17	29%
DE	WHI0100[b]	WFWR	51	3.03	9.58	13.70	17.28	18.50	96.10	19	17	33%
DE	WFWR	WFWR	129	2.50	8.90	13.10	101.9	123	1494	19	51	40%

Stations in this table with the same superscript letter are at the same location.
WFWR West Fork White River, TB Town Branch
DE re uires at least 24 samples to evaluate attainment of the Storm Flows turbidity criteria DE 2022 .
Indicates stations are located on assessment units listed as impaired because of high turbidity on both the pproved 2018 and Draft 2020 303 d Lists.

Table 20. Summary statistics for Storm Flow stream turbidity measurements from stations in White River from Wyman to state line waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, T	25th Percentile, T	edian, T	ean, T	75th Percentile, T	a i u alue, T	Criteria, T	u ber of alues Criteria	Percentage of alues Criteria
BWD	22	LSO	35	2.30	7.75	13.50	16.12	19.60	108.00	19	10	29%
BWD	10[c]	WR	58	3.2	3.20	9.03	13.65	29.87	26.43	19	22	38%
WRC	Wyman[c]	WR	128	4.5	4.50	8.70	12.10	31.40	21.00	19	51	40%
US S	07048600[c]	WR	14	7.7	7.70	10.30	15.20	23.18	23.25	19	10	-
BWD	23	WR	11	5.9	5.90	17.50	89.00	196.50	362.50	19	4	-
BWD	13	WR	45	5.0	5.00	8.05	11.50	18.99	18.25	19	14	31%
DE	WHI0052[e]	WR	51	1.5	1.48	4.05	7.13	7.42	7.88	19	22	43%
US S	07048700[e]	WR	22	3.2	3.15	9.63	15.40	76.82	98.90	19	5	-
H2O arks	205	HoC	5	0.50	0.60	0.60	1.54	3.00	3.00	19	0	-
DE	WHI0231	DC	12	2.4	2.40	33.25	61.50	156.40	117.50	19	1	-
DE	WHI0221	LlC	12	0.5	0.50	2.30	5.50	58.97	31.93	19	2	-
WRC	Richland[d]	RC	131	6.0	5.98	11.95	16.40	17.58	19.80	19	36	27%
US S	07048780[d]	RC	10	1.8	1.75	3.77	9.16	9.75	13.40	19	9	-
DE	WHI0110	RC	12	1.6	1.60	3.58	5.85	8.55	9.60	19	1	-
H2O arks	300	BrC	5	0.50	0.80	0.90	2.40	4.60	5.20	17	0	-
BWD	12	PL	50	1.00	2.20	3.10	6.14	5.28	53.30	17	3	6%
DE	WHI0012B	LwC	43	0.37	1.03	1.60	2.84	2.36	24.10	17	1	2%

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

LSO Lake Se uoyah outflow, WR White River, DC Drake s Creek, HoC Hock Creek, LlC Lollars Creek, RC Richland Creek, BrC Brush Creek, PL unnamed tributary near Parson s Landfill, LwC Leatherwood Creek

DE re uires at least 24 samples to evaluate attainment of the Storm Flows turbidity criteria DE 2022 .

Indicates stations are located on assessment units on both the pproved 2018 and Draft 2020 303 d impairment lists.

Table 21. Summary statistics for Storm Flow stream turbidity measurements from stations in War Eagle Creek waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, T	25th Percentile, T	edian, T	ean, T	75th Percentile, T	a i u alue, T	Criteria, T	u ber of alues Criteria	Percentage of alues Criteria
DE	WHI0227	WEC	12	0.83	1.91	3.71	5.86	7.05	19.90	19	1	-
DE	WHI0233	C	12	0.93	1.43	2.73	4.80	6.13	16.30	19	0	-
H2O arks	109	WEC	4	1.20	2.03	4.45	5.40	7.83	11.50	19	0	-
DE	WHI0220	WC	12	0.54	0.96	1.42	2.63	2.59	12.40	19	0	-
BWD	15	WEC	58	2.20	5.18	8.40	17.63	14.48	151.00	17	13	22%
H2O arks	307	HC	5	1.30	1.40	1.80	3.38	3.10	9.30	19	0	-
DE	WHI0070[f]	HC	51	0.65	1.83	2.75	4.50	4.47	23.80	17	3	6%
H2O arks	308[f]	HC	5	0.50	0.80	1.10	2.30	2.30	6.80	17	0	-
BWD	21	WEC	57	1.60	3.90	7.10	16.76	11.90	169.00	17	9	16%
H2O arks	302	C	4	0.50	1.48	2.00	1.98	2.50	3.40	17	0	-
H2O arks	303	ClC	5	0.30	0.40	0.40	1.40	1.00	4.90	17	0	-
WRC	WEC	WEC	131	0.95	3.95	6.50	58.22	50.50	898.00	17	42	32%
DE	WHI0116	WEC	51	1.70	4.23	6.33	9.94	11.15	36.00	17	8	16%
H2O arks	304	CC	5	0.30	0.40	0.50	0.94	0.60	2.90	17	0	-
BWD	9[g]	WEC	58	1.00	4.10	6.30	41.70	12.20	769.00	17	12	21%
US S	07049050[g]	WEC	12	2.10	6.78	170.00	207.80	335.00	720.00	17	8	-

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

WEC War Eagle Creek, C ackson Creek, WC Wharton Creek, HC Holman Creek, C lade Creek, ClC Clear Creek, CC Clifty Creek

DE re uires at least 24 samples to evaluate attainment of the Storm Flows turbidity criteria DE 2022 .

Table 22. Summary statistics for Storm Flow stream turbidity measurements from stations in Eastern portion Kings River, Osage Creek, and Long Creek waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, T	25th Percentile, T	edian, T	ean, T	75th Percentile, T	a i u alue, T	Criteria, T	u ber of alues Criteria	Percentage of alues Criteria
DE	WHI0225	FC	10	0.65	1.85	4.75	6.36	8.90	17.20	19	0	-
DE	WHI0121	KR	49	1.35	3.34	4.49	6.64	6.98	31.60	17	3	6%
DE	WHI0123	KR	51	1.64	3.21	4.39	7.03	6.98	32.20	17	5	10%
DE	WHI0230	KC	11	2.51	5.62	7.68	14.38	13.15	66.00	19	2	-
DE	WHI0129	OC	11	1.89	2.97	4.57	11.80	9.75	68.00	19	1	-
DE	WHI0068	OC	44	0.92	2.70	4.08	8.01	7.64	43.70	17	4	9%
DE	WHI0069	OC	49	0.86	1.89	3.13	6.67	8.41	38.70	17	4	8%
WRC	Kings[h]	KR	36	0.30	2.23	3.00	39.38	4.43	499.50	17	7	19%
DE	WHI0009 [h]	KR	49	0.81	2.32	3.60	6.75	6.64	42.60	17	5	10%
DE	WHI0232	TC	10	1.33	2.40	5.21	9.40	7.85	37.00	19	2	-
DE	WHI0071	LC	47	1.22	2.65	4.05	7.20	7.91	34.10	17	5	11%

Stations with the same superscript letter in this table are at the same location.
FC Felkins Creek, KR Kings River, KC Kenner Creek, OC Osage Creek, TC Terrapin Creek, LC Long Creek
DE re uires at least 24 samples to evaluate attainment of the Storm Flows turbidity criteria DE 2022 .

Table 23. Summary statistics for Storm Flow turbidity measurements from Lake Stations at during 2018-2022 stations listed in downstream order, first row is farthest upstream station . ll lake stations are from epilimnion.

rgani ation	Station D	La e D	u ber of easures	ini u alue, T	25th Percentile, T	edian, T	ean, T	75th Percentile, T	a i u alue, T	Criteria, T	u ber of alues Criteria	Percentage of alues Criteria
DE	LWHI009	LS	8	10.60	12.38	13.05	14.10	13.78	14.75	45	0	-
DE	LWHI014	LW	12	1.93	3.79	7.73	9.94	7.24	12.83	45	0	-
US S	07048910	BL	22	3.30	4.45	7.55	10.31	17.00	31.00	45	0	-
DE	LWHI013B	BL	4	2.41	4.83	7.78	9.37	12.32	19.50	45	0	-
US S	07049160	BL	22	3.25	5.10	7.35	10.78	14.43	38.00	45	2	-
US S	07049187	BL	6	2.20	3.03	8.05	13.22	16.75	40.00	45	0	-
US S	07049200	BL	18	2.00	2.40	3.55	10.89	16.75	44.00	45	0	-
DE	LWHI013C[i]	BL	3	1.19	2.81	4.43	6.87	9.72	15.00	45	0	-
US S	07049500[i]	BL	9	2.00	2.50	3.40	5.80	7.10	19.00	45	0	-
DE	LWHI013	BL	5	0.71	1.22	1.41	3.14	2.72	9.65	45	0	-
US S	07049690	BL	6	2.00	2.13	2.65	2.82	3.25	4.20	45	0	-

Stations with the same superscript letter in this table are at the same location.
LS Lake Se uoyah, LW Lake Wilson, BL Beaver Lake lake station
DE re uires at least 24 samples to evaluate attainment of the Storm Flows turbidity criteria DE 2022 .
Indicates stations are located on assessment units on both the pproved 2018 and Draft 2020 303 d impairment Lists.
Indicates stations are located on assessment units on the pproved 2018 and Draft 2020 and 2022 303 d Lists.

Figure 17 through Figure 22 show box and whisker graphs of Storm Flow turbidity measurements from stations in each waterway segment with more than 10 measurements for the period 2018-2022. The lowest median turbidity measurements are in Leatherwood Creek WHI0012B and Wharton Creek WHI0220 . The highest median turbidity measurement occurs at the US S War Eagle Creek station 07049050 followed by White River near Fayetteville 0748600 station. ote that both stations have fewer than the re uired 24 measurements for attainment analysis. There does not appear to be significant change in turbidity in the large streams from upstream to downstream. Only in West Fork White River is the median turbidity at the farthest upstream station significantly lower than median turbidity values at the downstream stations. Median turbidity values at the Beaver Lake stations are not significantly different than the stream median turbidity values. Settling that occurs in the reservoir is expected to result in lower turbidity levels. However, during Storm Flow conditions, it appears that turbidity levels in the upper end of Beaver Lake are not that different from turbidity levels in streams.

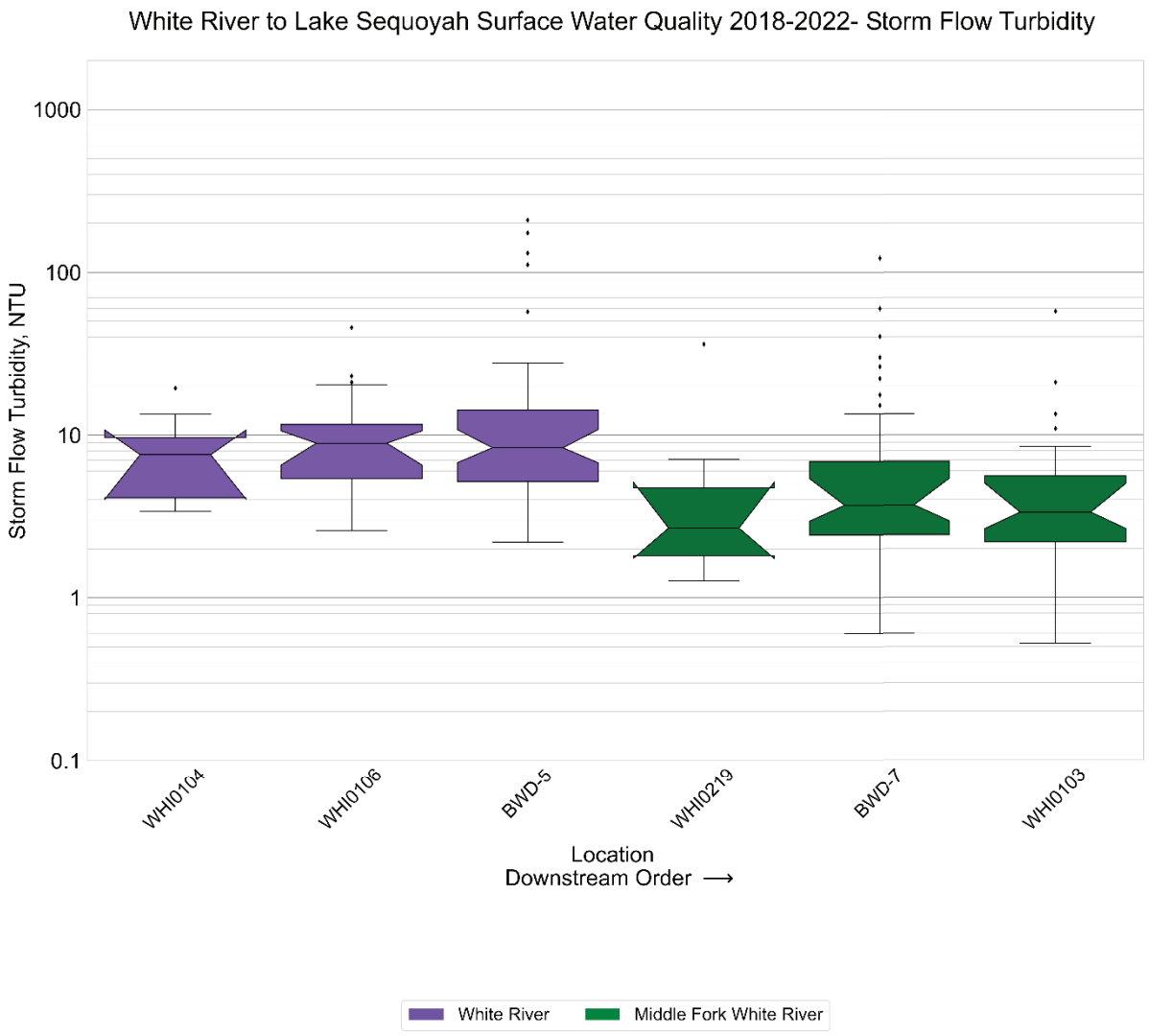


Figure 17. Box and whisker graph of storm flow turbidity measurements from stations in the White River to Lake Se uoyah segment with more than 10 values from 2018-2022.

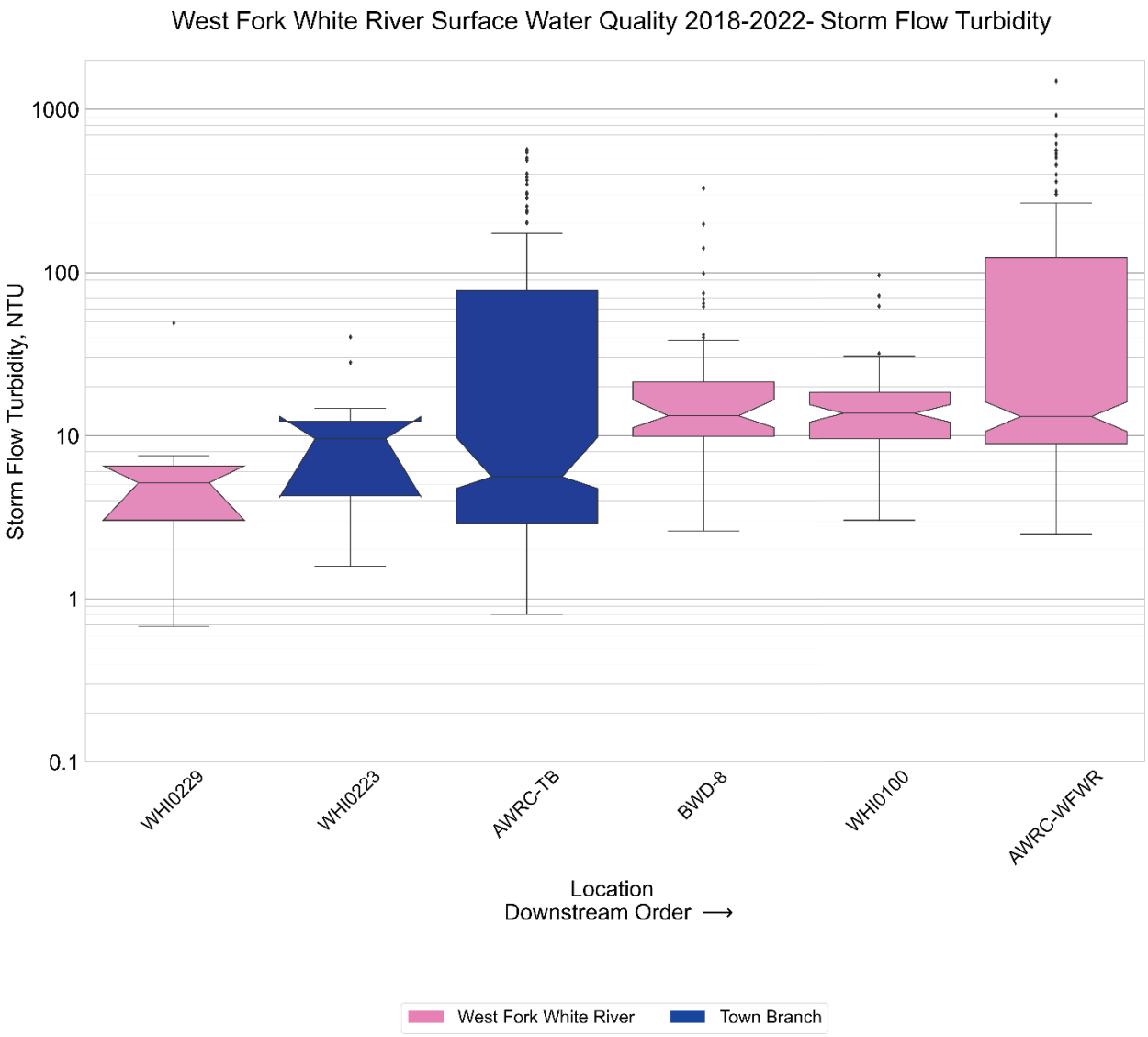


Figure 18. Box and whisker graph of Storm Flow turbidity measurements from stations in the West Fork White River segment with more than 10 values from 2018-2022. ote that stations BWC-8 and WHI0100 are at the same location on the West Fork White River.

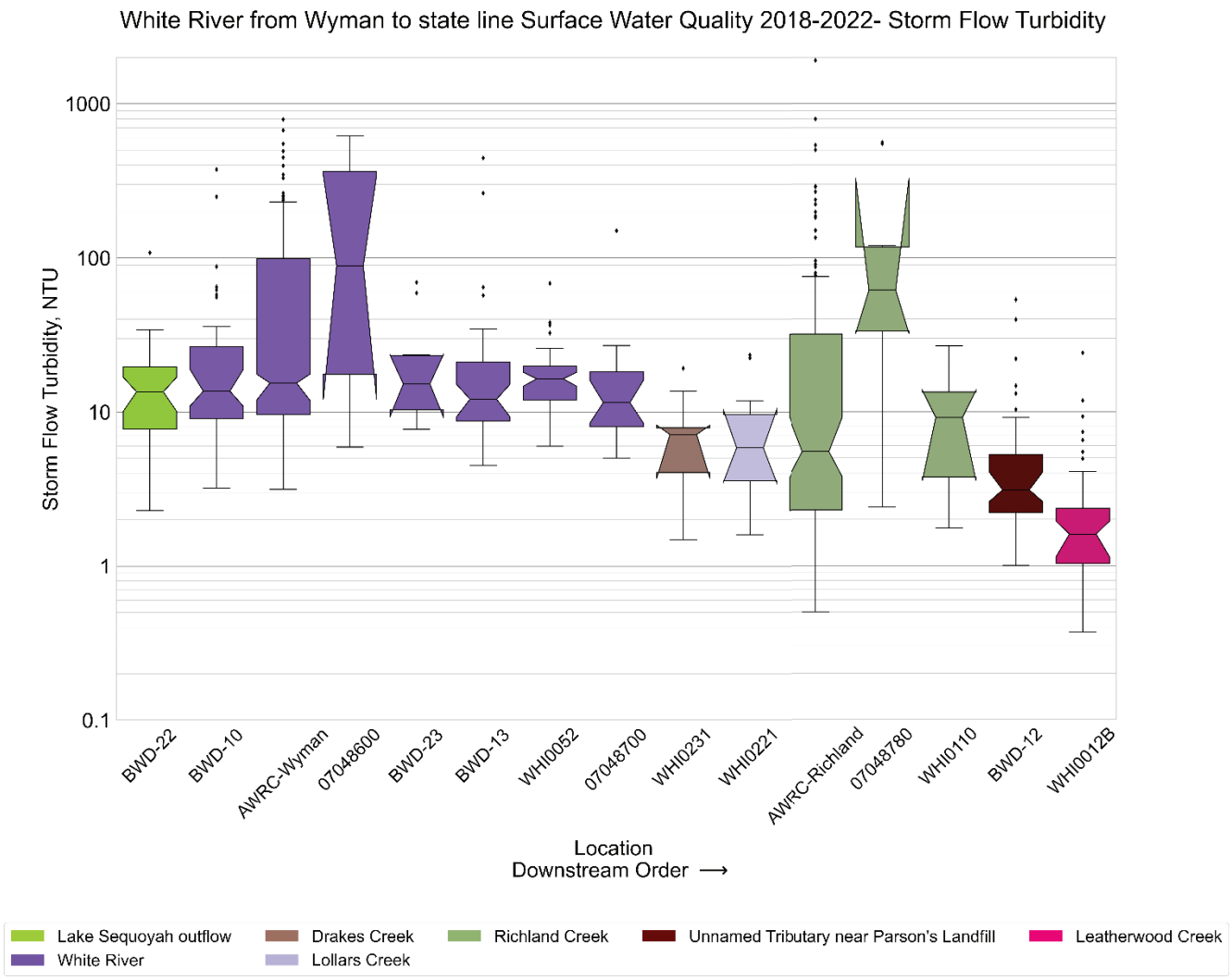


Figure 19. Box and whisker graph of Storm Flow turbidity measurements from stations in the White River from Wyman to state line segment with more than 10 values from 2018-2022. ote that stations BWC-10, Wyman, and 07048600 are at the same location on the White River stations Richland and 07048780 are at the same location on Richland Creek and stations WHI0052 and 07048700 are at the same location on the White River downstream of Richland Creek.

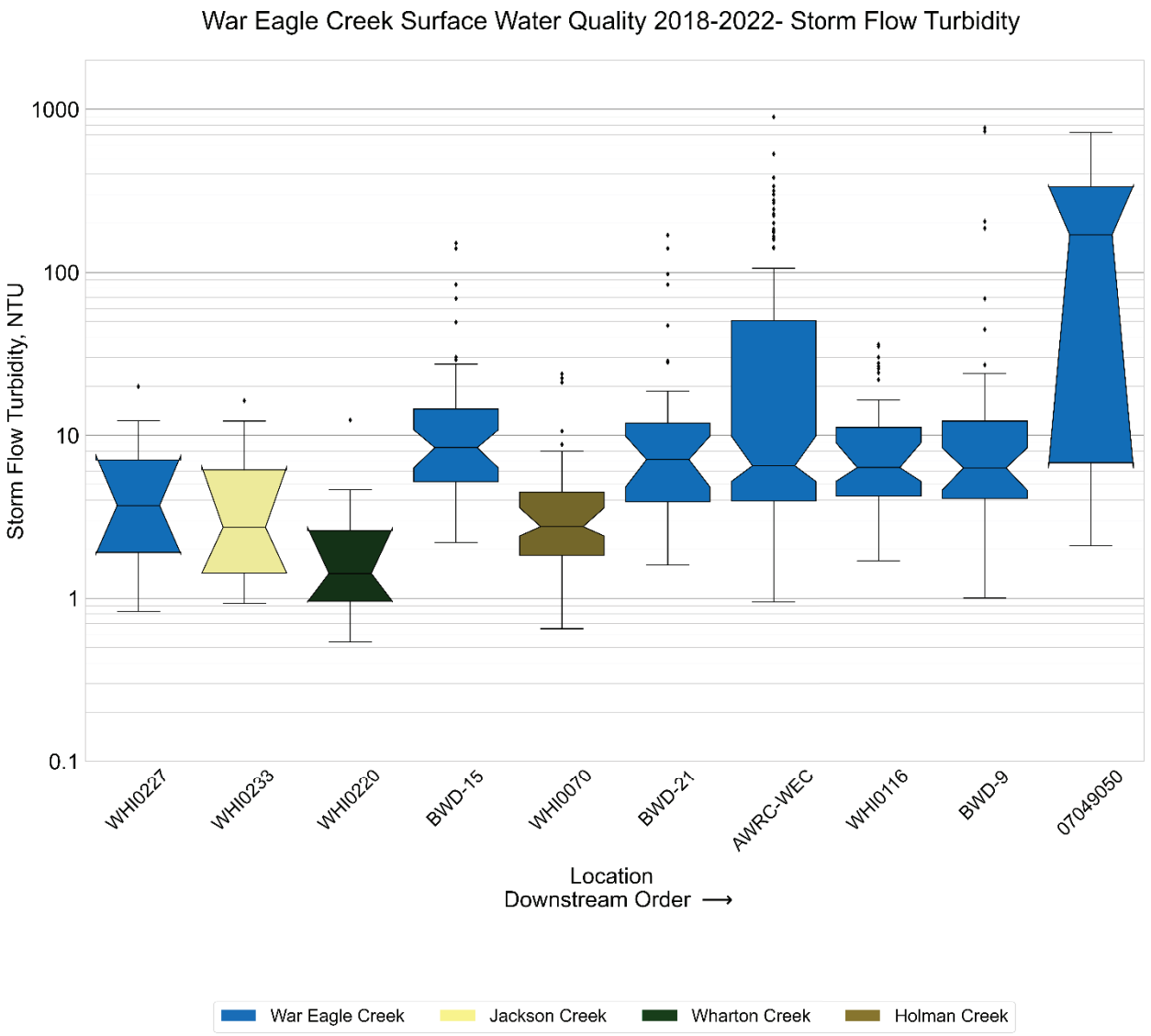


Figure 20. Box and whisker graph of storm flow turbidity measurements from stations in the War Eagle Creek segment with more than 10 values from 2018-2022. ote that stations 9 and 07049050 are at the same location on War Eagle Creek.

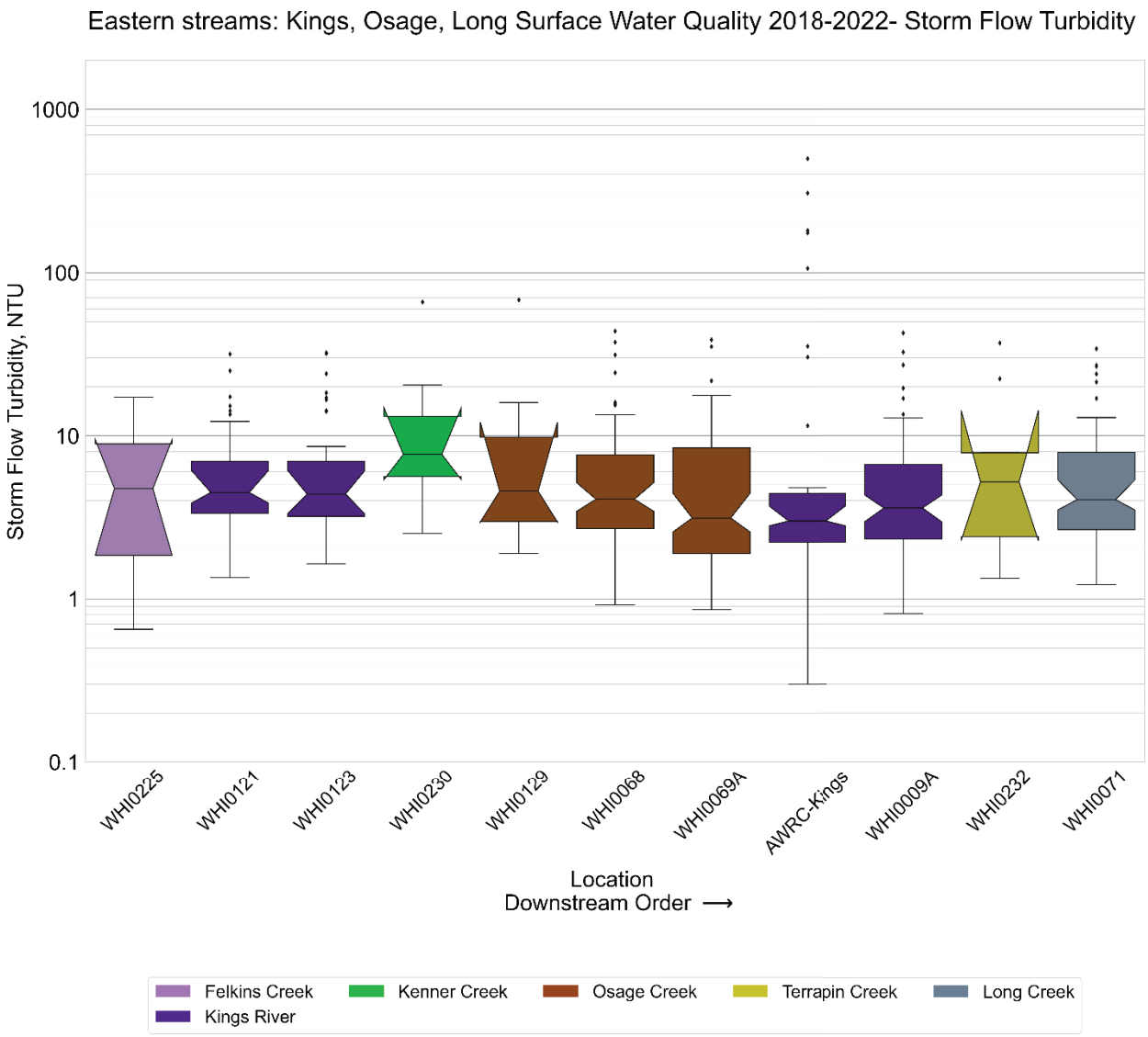


Figure 21. Box and whisker graph of Storm Flow turbidity measurements from stations in the Eastern streams segment with more than 10 values from 2018-2022. ote that stations Kings and WHI009 are at the same location on the Kings River.

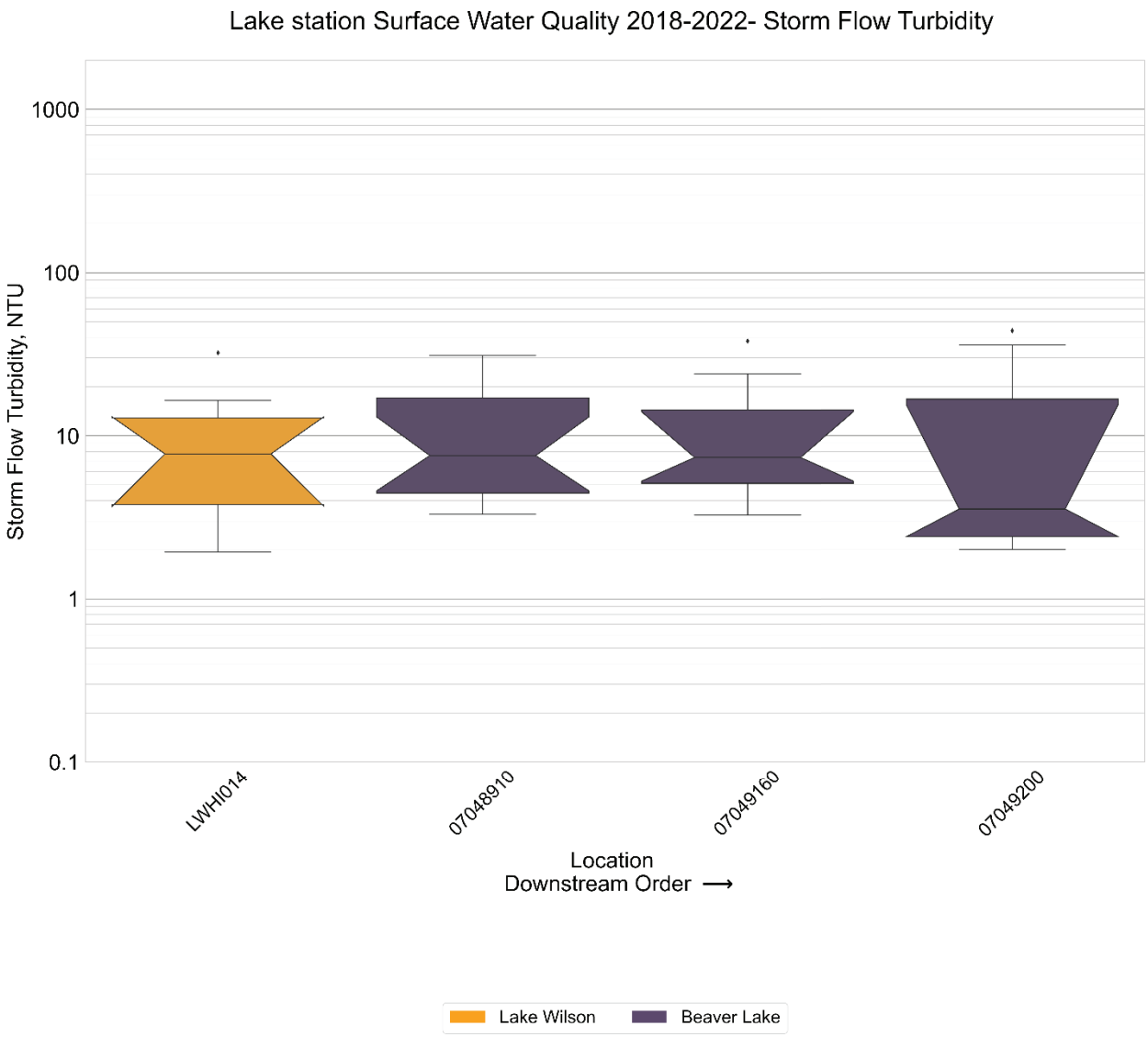


Figure 22. Box and whisker graph of Storm Flow turbidity measurements from Lake Stations with more than 10 values from 2018-2022.

1.4.1.2 Base Flow Turbidity Summary Statistics

Separate numeric criteria are used to evaluate surface water turbidity levels during Base Flow conditions une 1- October 31 . In natural systems, Base Flow conditions are usually characteri ed by reduced runoff and slower flows, which results in lower turbidity levels. Thus, Base Flow turbidity criteria are lower than the Storm Flow criteria PCEC, 2022 . Figure 23 shows a comparison of median Storm Flow and Base Flow turbidity values where at least 10 measurements were taken during the Base Flow season. lthough median Base Flow turbidity is lower for most stations, the stations listed below had higher median Base Flow turbidity than Storm Flow turbidity. However, only station WHI0100 has significantly different median turbidity values during Base Flow and Storm Flow seasons. It is interesting to note that stations WHI0100 and BWC-8 are at the same location, and there is not a significant difference between Base Flow and Storm Flow median turbidity at BWC-8.

- WHI0103 Middle Fork White River bridge south of Black Oak
- BWD 8 West Fork White River at Stone Bridge
- WHI0100 West Fork White River on Dead Horse Mountain Rd.
- WHI0052 White River on SR45 near oshen
- 07048700 White River near oshen
- BWD 12 Unnamed tributary near Parson s Landfill
- WHI0070 Holman Creek on SR23 Huntsville

Table 24 through Table 29 list summary statistics for Base Flow turbidity measurements from streams in the Upper White River watershed during the period 2018-2022. Included in these tables are the applicable Base Flow turbidity numeric water uality criteria based on the ecoregion the station is in. The number and percentage of measurements that exceed the applicable criteria are also shown in these tables. The values should not exceed the Base Flow criteria in more than 20% of samples during Base Flow period DE 2022 . The numeric criterion for Boston Mountain ecoregion and for O ark Highlands ecoregion is 10 TU, and 25 TU for lake stations. o exceedances of the lake Base Flow turbidity criterion were reported for 2018-2022. reater percentages of stream turbidity values exceed the Base Flow numeric criteria than the Storm Flow criteria. In most cases, this is because there is a smaller total number of Base Flow samples, rather than a higher number of exceedances.

ll the stations that were sampled during Base Flow in the West Fork White River and its tributaries have greater than 20% of samples above the exceedance criteria Table 25 . Stations 8 and WHI0100 are sampled in the same location. Restoration pro ects have been done in the West Fork White River over the last several years, and Base Flow turbidity is expected to be reduced by 53% in this stream reach as a result EP , 2022 .

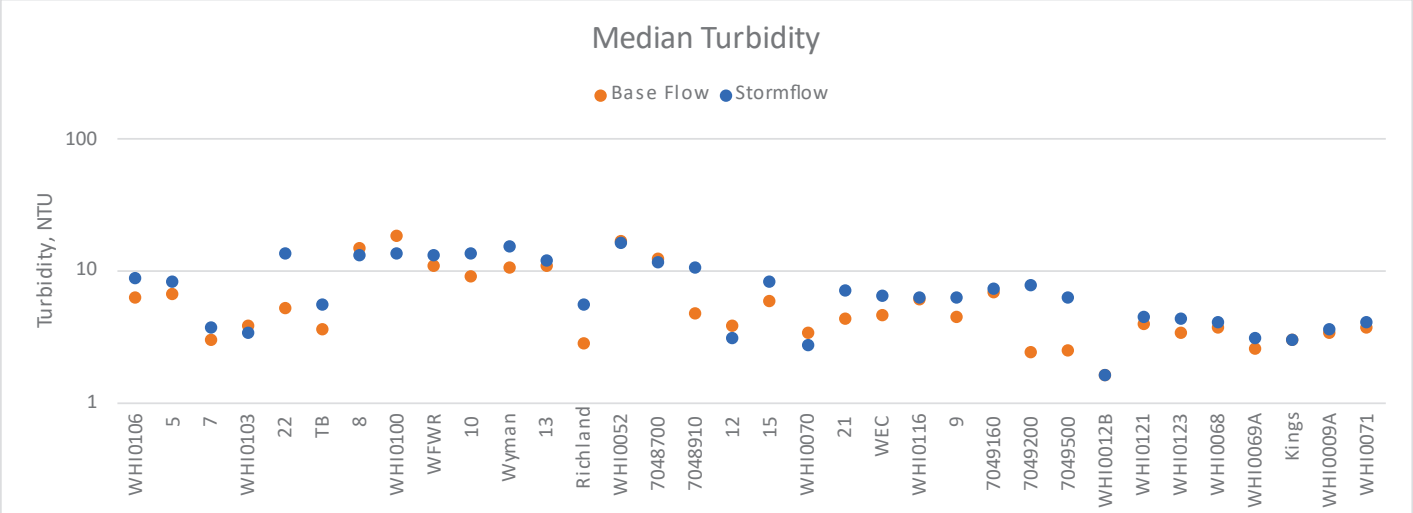


Figure 23. Median base-flow turbidity vs median storm flow turbidity of stations with at least ten measurements from 2018-2022.

Table 24. Summary statistics for Base Flow stream turbidity measurements from stations in White River to Lake Se uoyah waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, T	25th Percentile, T	edian, T	ean, T	75th Percentile, T	a i u alue, T	Criteria, T	u ber of alues Criteria	Percentage of alues Criteria
H2O arks	103	BC	1	8.90	8.90	8.90	/	8.90	8.90	10	0	-
DE	WHI0104	WR	5	3.88	4.21	6.13	7.02	8.09	12.80	10	1	-
H2O arks	104	WR	1	3.00	3.00	3.00	/	3.00	3.00	10	0	-
H2O arks	110	WR	1	3.10	3.10	3.10	/	3.10	3.10	10	0	-
DE	WHI0106	WR	22	2.58	4.18	6.29	10.46	11.75	45.70	10	9	41%
BWD	5	WR	25	2.20	4.00	6.70	8.41	8.50	27.60	10	6	24%
DE	WHI0219	MFWR	5	1.50	1.88	2.42	2.30	2.46	3.23	10	0	-
BWD	7	MFWR	25	1.20	2.20	3.00	5.16	4.40	22.20	10	4	16%
H2O arks	201	MFWR	1	1.90	1.90	1.90	/	1.90	1.90	10	0	-
DE	WHI0103	MFWR	22	1.54	2.32	3.81	7.16	5.97	57.40	10	2	9%

BC Baldwin Creek, WR White River, MFWR Middle Fork of the White River
DE re uires at least 10 samples to evaluate attainment of the Base Flow turbidity criteria DE 2022 .
Indicates stations are located on assessment units listed as impaired because of high turbidity on the Draft 2020 303 d List.

Table 25. Summary statistics for Base Flow stream turbidity measurements from stations in West Fork White River waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, T	25th Percentile, T	edian, T	ean, T	75th Percentile, T	a i u alue, T	Criteria, T	u ber of alues Criteria	Percentage of alues Criteria
H2O arks	102	WFWR	1	1.20	1.20	1.20	/	1.20	1.20	10	0	-
DE	WHI0229	WFWR	5	3.03	4.66	5.22	5.14	5.24	7.53	10	0	-
DE	WHI0223	TB	5	4.35	8.25	10.90	9.24	11.20	11.50	10	0	-
WRC	TB[a]	TB	51	1.10	2.20	3.60	46.76	6.75	551.00	10	12	24%
H2O arks	210[a]	TB	2	3.40	3.58	3.75	3.75	3.93	4.10	10	0	-
BWD	8[b]	WFWR	25	8.50	11.20	14.80	35.13	21.70	328.00	10	21	84%
DE	WHI0100[b]	WFWR	22	11.40	14.38	18.50	26.37	23.05	96.10	10	22	100%
DE	WFWR	WFWR	50	4.40	8.60	10.98	67.78	25.13	921.00	10	28	56%

Stations with the same superscript letter are at the same location
TB Town Branch, WFWR West Fork White River
DE re uires at least 10 samples to evaluate attainment of the Base Flow turbidity criteria DE 2022 .
Indicates stations are located on assessment units on the pproved 2018 303 d impairment list.
Indicates stations are located on assessment units on both the pproved 2018 and Draft 2020 303 d impairment lists.

Table 26. Summary statistics for Base Flow stream turbidity measurements from stations in White River from Wyman to state line waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, T	25th Percentile, T	edian, T	ean, T	75th Percentile, T	a i u alue, T	Criteria, T	u ber of alues Criteria	Percentage of alues Criteria
BWD	22	LSO	15	2.30	3.50	5.20	10.10	14.80	33.60	10	5	33%
BWD	10[c]	WR	25	3.20	7.50	9.20	19.26	28.90	62.00	10	12	48%
WRC	Wyman[c]	WR	51	3.15	6.75	10.70	59.72	31.75	791.00	10	28	55%
US S	07048600[c]	WR	4	5.90	7.10	83.75	155.90	232.50	450.00	10	2	-
BWD	23	WR	5	7.70	9.00	11.30	11.06	12.10	15.20	10	3	-
BWD	13	WR	20	6.10	7.53	10.80	18.24	25.73	64.40	10	11	55%
DE	WHI0052[e]	WR	22	6.68	11.88	17.10	19.77	21.70	68.30	10	18	82%
US S	07048700[e]	WR	12	5.00	8.83	12.50	13.56	16.75	27.00	10	7	58%
H2O arks	205	HoC	1	0.50	0.50	0.50	/	0.50	0.50	10	0	-
DE	WHI0231	DC	5	4.41	6.85	7.41	7.01	7.50	8.88	10	0	-
DE	WHI0221	LlC	5	2.98	3.30	3.67	4.33	4.75	6.95	10	0	-
WRC	Richland[d]	RC	52	0.50	2.05	2.85	22.00	8.10	538.00	10	13	25%
US S	07048780[d]	RC	2	70.00	80.00	90.00	90.00	100.00	110.00	10	2	-
DE	WHI0110	RC	5	3.09	7.82	10.50	9.76	13.10	14.30	10	3	-
H2O arks	300	BrC	1	0.90	0.90	0.90	/	0.90	0.90	10	0	-
BWD	12	PL	20	1.20	2.75	3.80	4.94	4.83	22.00	10	1	5%
DE	WHI0012B	LwC	17	0.37	1.02	1.60	4.13	4.07	24.10	10	2	12%

Stations with the same superscript letter are at the same location

LSO Lake Se uoyah outflow, WR White River, DC Drakes Creek, HoC Hock Creek, LlC Lollars Creek, RC Richland Creek BrC Brush Creek, PL unnamed tributary near Parson s Landfill, LwC Leatherwood Creek

DE re uires at least 10 samples to evaluate attainment of the Base Flow turbidity criteria DE 2022 .

c..d same sampling location

Indicates these stations are located on assessment units on both the pproved 2018 and the 2020 Draft 303 d impairment list.

Table 27. Summary statistics for Base Flow stream turbidity measurements from stations in War Eagle Creek waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, T	25th Percentile, T	edian, T	ean, T	75th Percentile, T	a i u alue, T	Criteria, T	u ber of alues Criteria	Percentage of alues Criteria
DE	WHI0227	WEC	5	0.83	1.56	1.81	2.19	3.10	3.67	10	0	-
DE	WHI0233	C	5	0.93	1.30	1.43	1.69	1.62	3.18	10	0	-
H2O arks	109	WEC	1	2.30	2.30	2.30	/	2.30	2.30	10	0	-
DE	WHI0220	WC	5	0.95	0.96	1.18	1.19	1.27	1.57	10	0	-
BWD	15	WEC	25	2.20	3.60	6.00	8.89	10.60	26.50	10	7	28%
H2O arks	307	HC	1	1.80	1.80	1.80	/	1.80	1.80	10	0	-
DE	WHI0070[f]	HC	22	1.46	2.52	3.40	5.62	5.26	23.80	10	3	14%
H2O arks	308[f]	HC	1	1.10	1.10	1.10	/	1.10	1.10	10	0	-
BWD	21	WEC	25	2.20	3.30	4.40	7.37	10.10	28.60	10	7	28%
H2O arks	302[g]	C	1	1.80	1.80	1.80	/	1.80	1.80	10	0	-
H2O arks	303	ClC	1	0.40	0.40	0.40	/	0.40	0.40	10	0	-
WRC	WEC	WEC	51	1.55	3.65	4.60	27.44	7.25	316.00	10	10	20%
DE	WHI0116	WEC	22	2.87	4.63	6.13	12.12	19.23	36.00	10	8	36%
H2O arks	304	CC	1	0.60	0.60	0.60	/	0.60	0.60	10	0	-
BWD	9[h]	WEC	25	3.00	3.50	4.50	7.63	8.20	27.00	10	5	20%
US S	7049050[h]	WEC	4	2.10	2.63	49.40	120.20	167.00	380.00	10	2	-

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

WEC War Eagle Creek, C ackson Creek, WC Wharton Creek, HC Holman Creek, C lade Creek, ClC Clear Creek, CC Clifty Creek

DE re uires at least 10 samples to evaluate attainment of the Base Flow turbidity criteria DE 2022 .

Table 28. Summary statistics for Base Flow stream turbidity measurements from stations in Eastern streams Kings River, Osage Creek, and Long Creek waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, T	25th Percentile, T	edian, T	ean, T	75th Percentile, T	a i u alue, T	Criteria, T	u ber of alues Criteria	Percentage of alues Criteria
DE	WHI0225	FC	4	0.65	1.06	1.52	1.39	1.85	1.86	10	0	-
DE	WHI0121	KR	22	1.86	2.65	3.91	7.46	8.49	31.60	10	5	23%
DE	WHI0123	KR	22	1.96	2.93	3.38	7.45	6.59	31.90	10	5	23%
DE	WHI0230	KR	5	2.51	5.39	5.84	5.78	7.46	7.68	10	0	-
DE	WHI0129	OC	5	1.89	2.96	2.98	3.96	4.57	7.40	10	0	-
DE	WHI0068	OC	19	1.17	3.17	3.72	6.84	4.64	37.40	10	2	11%
DE	WHI0069	OC	21	1.22	1.78	2.57	5.86	3.77	38.70	10	2	10%
WRC	Kings[i]	KR	16	2.30	2.80	3.00	4.85	3.55	30.30	10	1	6%
DE	WHI0009 [i]	KR	20	1.48	2.64	3.41	6.44	3.86	42.60	10	2	10%
DE	WHI0232	TC	4	1.33	1.99	3.12	3.84	4.97	7.77	10	0	-
DE	WHI0071	LC	19	1.87	2.91	3.75	6.34	5.53	27.00	10	2	11%

Stations in this table with the same superscript letter are at the same location.
FC Felkins Creek, KR Kings River, OC Osage Creek, TC Terrapin Creek, LC Long Creek

Table 29. Summary statistics for lake turbidity measurements and two stream turbidity measurement from stations at Beaver Lake during 2018-2022 stations listed in downstream order, first row is farthest upstream station . ll lake stations are from epilimnion.

rgani ation	Station D	La e D	u ber of easures	ini u alue, T	25th Percentile, T	edian, T	ean, T	75th Percentile, T	a i u alue, T	Criteria, T	u ber of alues Criteria	Percentage of alues Criteria
DE	LWHI009	LS	5	10.60	11.70	12.60	12.20	13.00	13.10	25	0	-
DE	LWHI014	LW	5	1.93	3.48	4.37	7.08	12.10	13.50	25	0	-
US S	07048910	BL	12	5.95	7.98	9.60	9.87	10.79	15.80	25	0	0%
DE	LWHI013B	BL	2	2.41	4.29	6.17	6.17	8.05	9.93	25	0	-
US S	07049160	BL	12	3.25	5.21	6.79	7.28	7.48	15.15	25	0	0%
US S	07049187	BL	2	2.20	-	2.60	2.60	-	3.00	25	0	-
US S	07049200	BL	8	2.00	2.18	2.40	2.71	3.45	3.60	25	0	-
DE	LWHI013C	BL	1	1.19	1.19	-	1.19	1.19	1.19	25	0	-
US S	07049500	BL	3	2.00	2.00	2.50	2.33	2.50	2.50	25	0	-
DE	LWHI013	BL	3	0.71	0.97	1.22	3.86	5.44	9.65	25	0	-
US S	07049690	BL	5	2.10	2.20	3.10	2.98	3.30	4.20	25	0	-

Stations in this table with the same superscript letter are at the same location.
LS Lake Se uoyah, LW Lake Wilson, BL Beaver Lake lake station ,
DE re uires at least 10 samples to evaluate attainment of the stream Base Flow turbidity criteria DE 2022 .
Indicates stations are located on assessment units on the pproved 2018 303 d impairment lists.
Indicates stations are located on assessment units on both the pproved 2018 and Draft 2020 303 d impairment lists.

Figure 24 through Figure 28 show box and whisker graphs of Base Flow turbidity measurements from stream stations in each waterway segment with more than 10 measurements for the period 2018-2022, in downstream order. Turbidity is less variable over the length of long streams and among streams under Base Flow conditions. Stations with the lowest median turbidity are WHI0012B Leatherwood Creek, which makes sense because it is downstream of a reservoir and WHI0069 Osage Creek . Stations with the highest median turbidity values are WHI0100 West Fork White River and WHI0052 White River . Figure 29 shows a box and whisker graph of Base Flow turbidity measurements from reservoir stations with more than 10 measurements for the period 2018-2022.

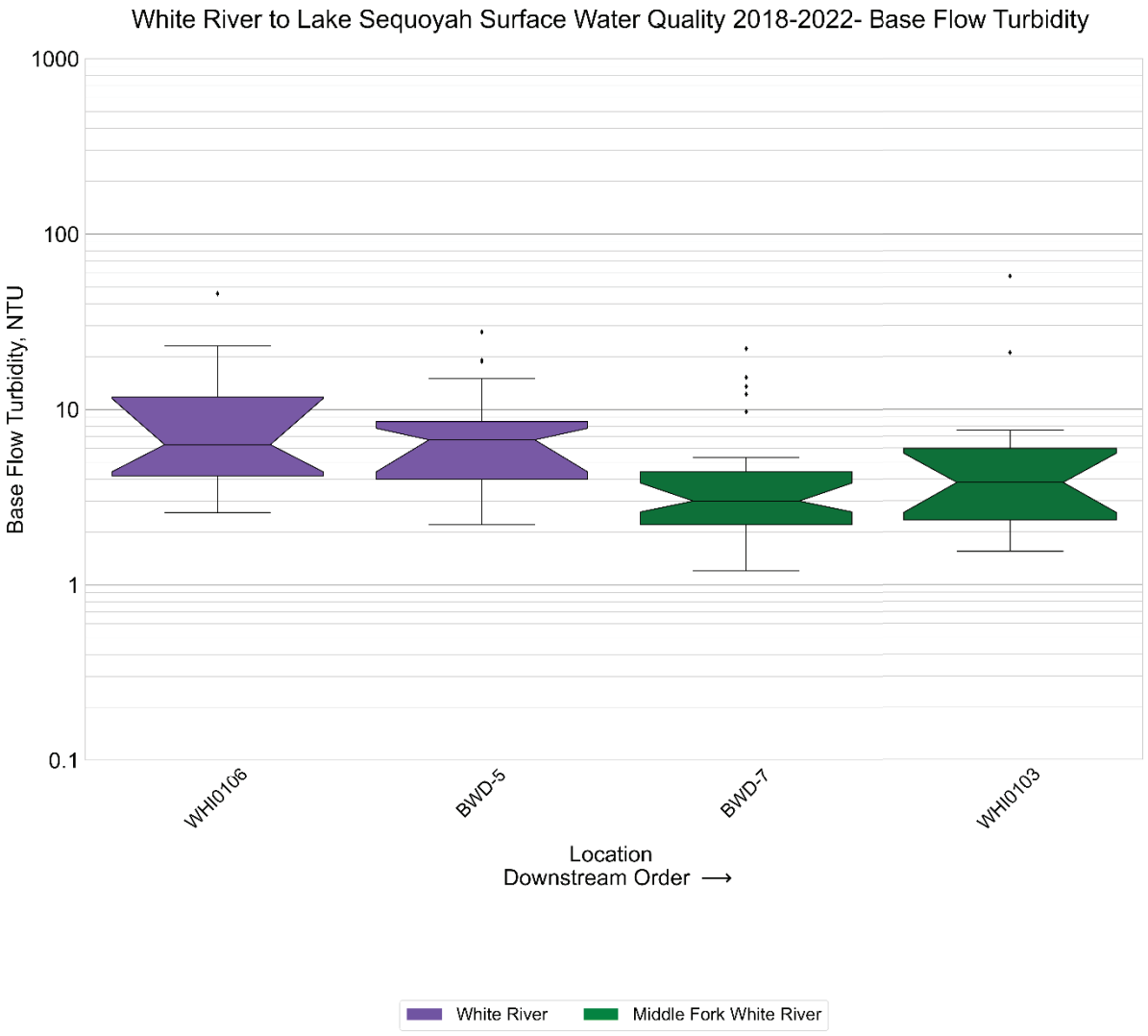


Figure 24. Box and whisker graph of Base Flow turbidity measurements from stations in the White River to Lake Se uoyah waterway segment with more than 10 values from 2018-2022.

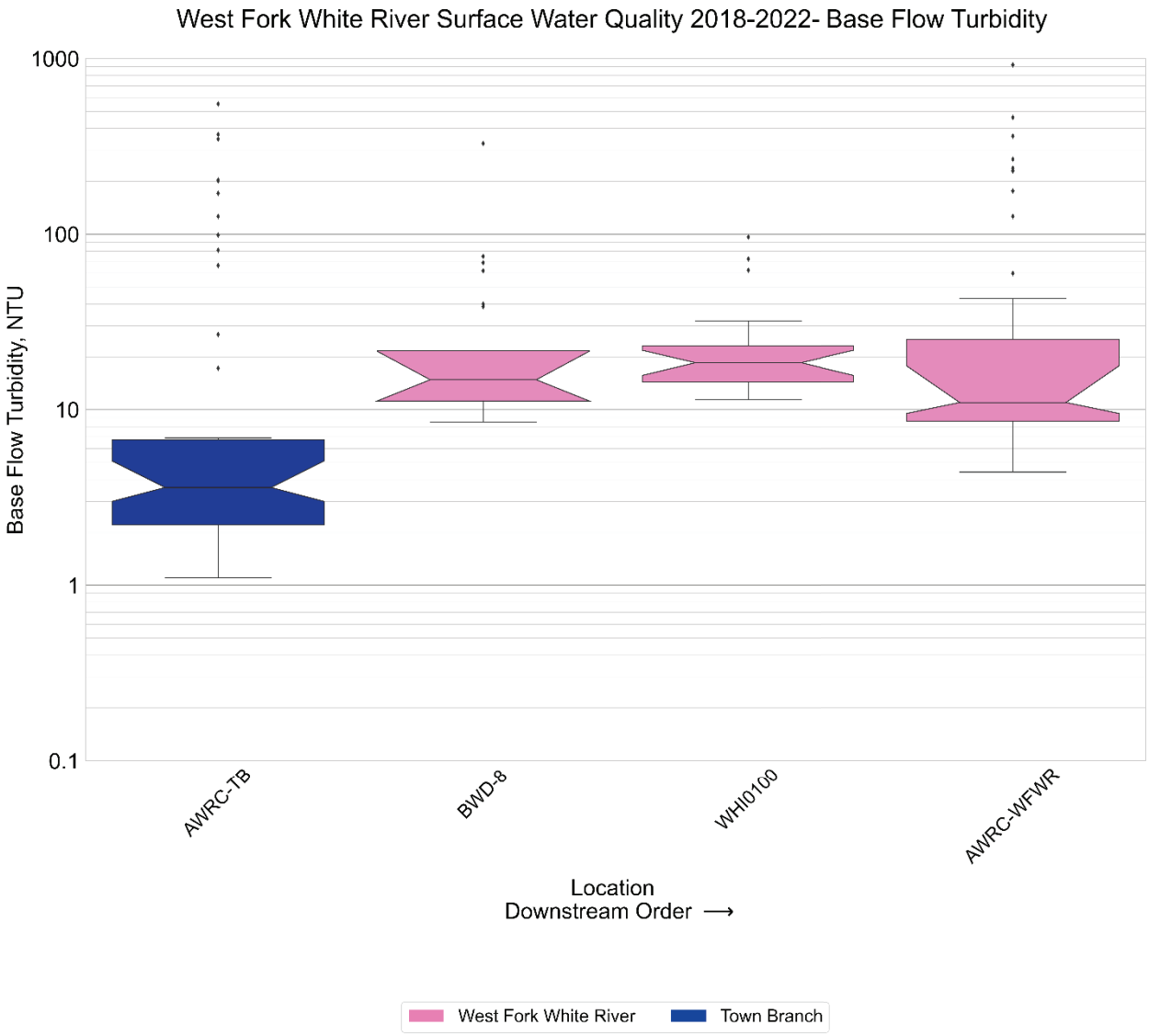


Figure 25. Box and whisker graph of Base Flow turbidity measurements from stations in the West Fork White River waterway segment with more than 10 values from 2018-2022. ote that stations 8 and WHI0100 are at the same location on the West Fork White River.

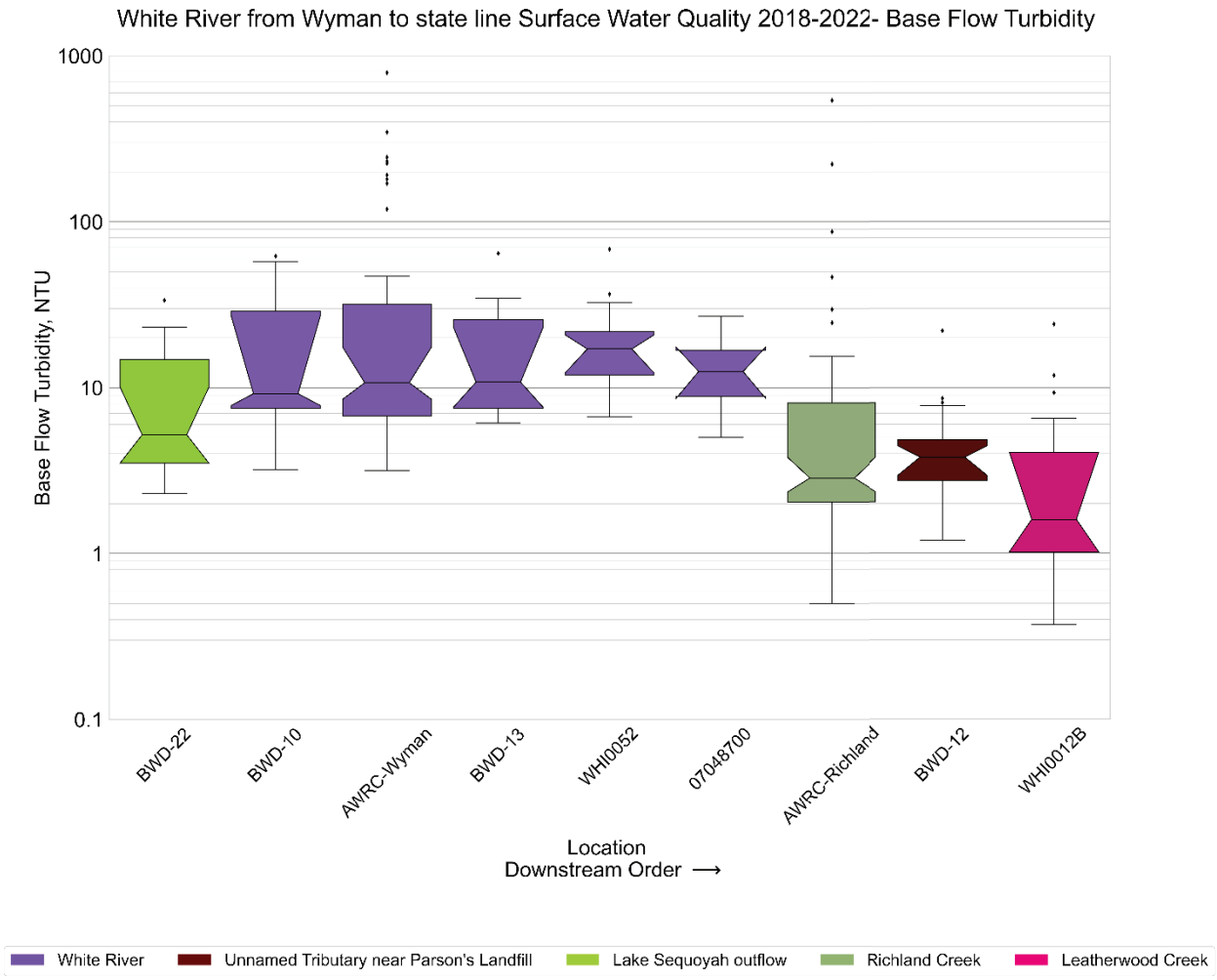


Figure 26. Box and whisker graph of Base Flow turbidity measurements from stations in the White River from Wyman to the state line waterway segment with more than 10 values from 2018-2022. ote that stations 10 and Wyman are at the same location on the White River upstream of Richland Creek, and stations WHI0052 and 07048700 are at the same location on the White River downstream of Richland Creek.

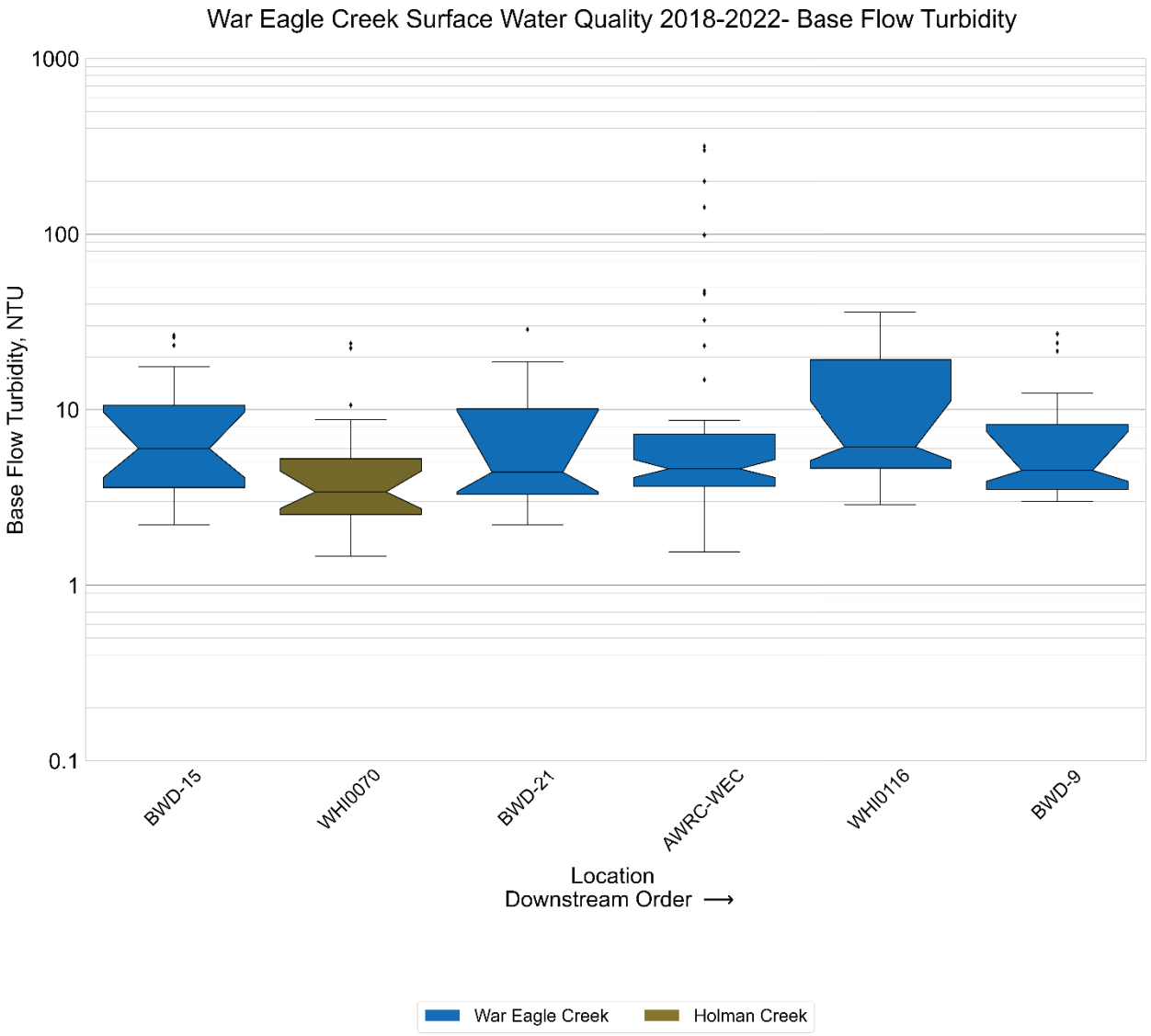


Figure 27. Box and whisker graph of Base Flow turbidity measurements from stations in the War Eagle Creek waterway segment with more than 10 values from 2018-2022.

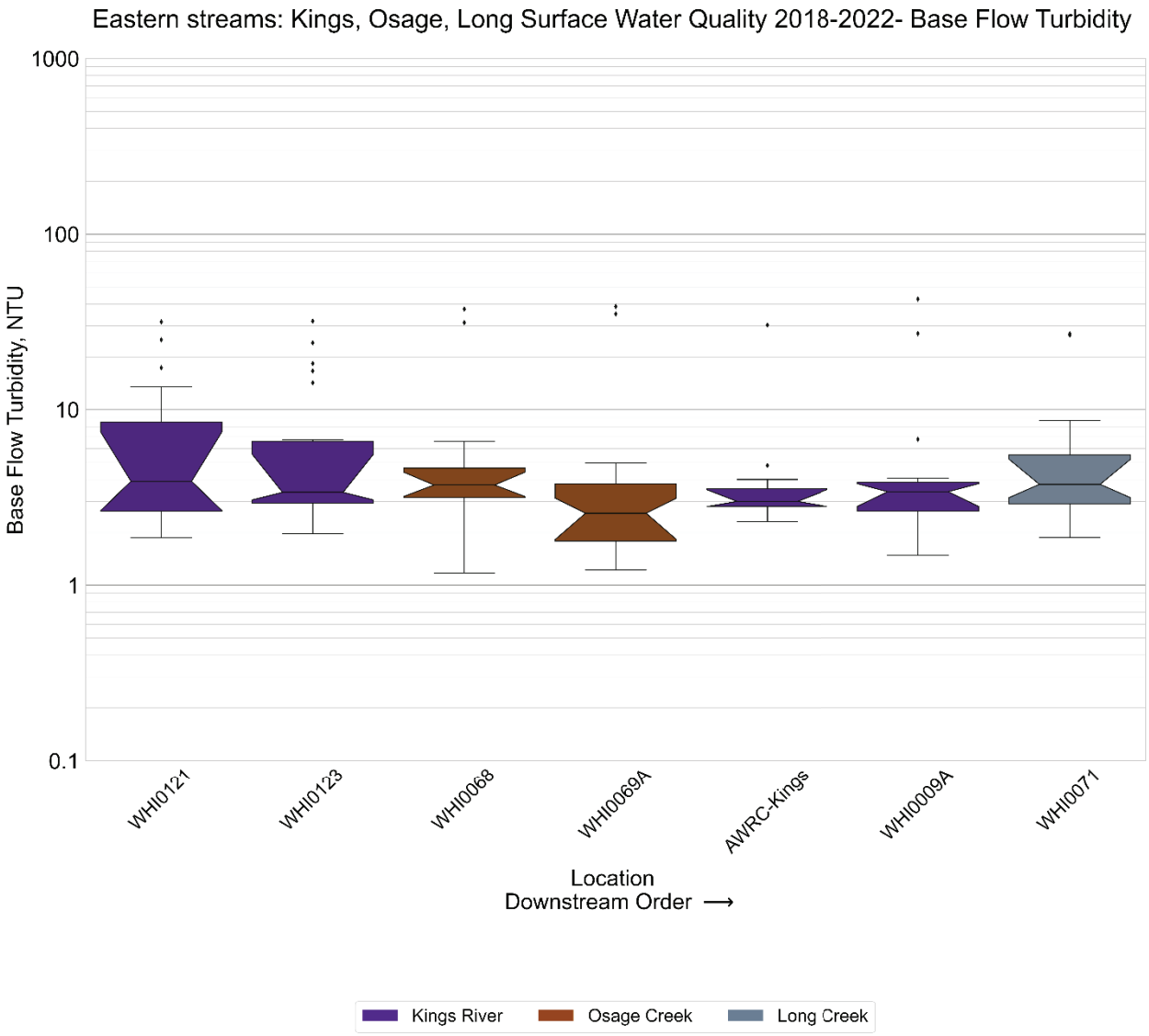


Figure 28. Box and whisker graph of Base Flow turbidity measurements from stations in the Eastern Streams waterway segment with more than 10 values from 2018-2022. ote that stations Kings and WHI0009 are at the same location on the Kings River.

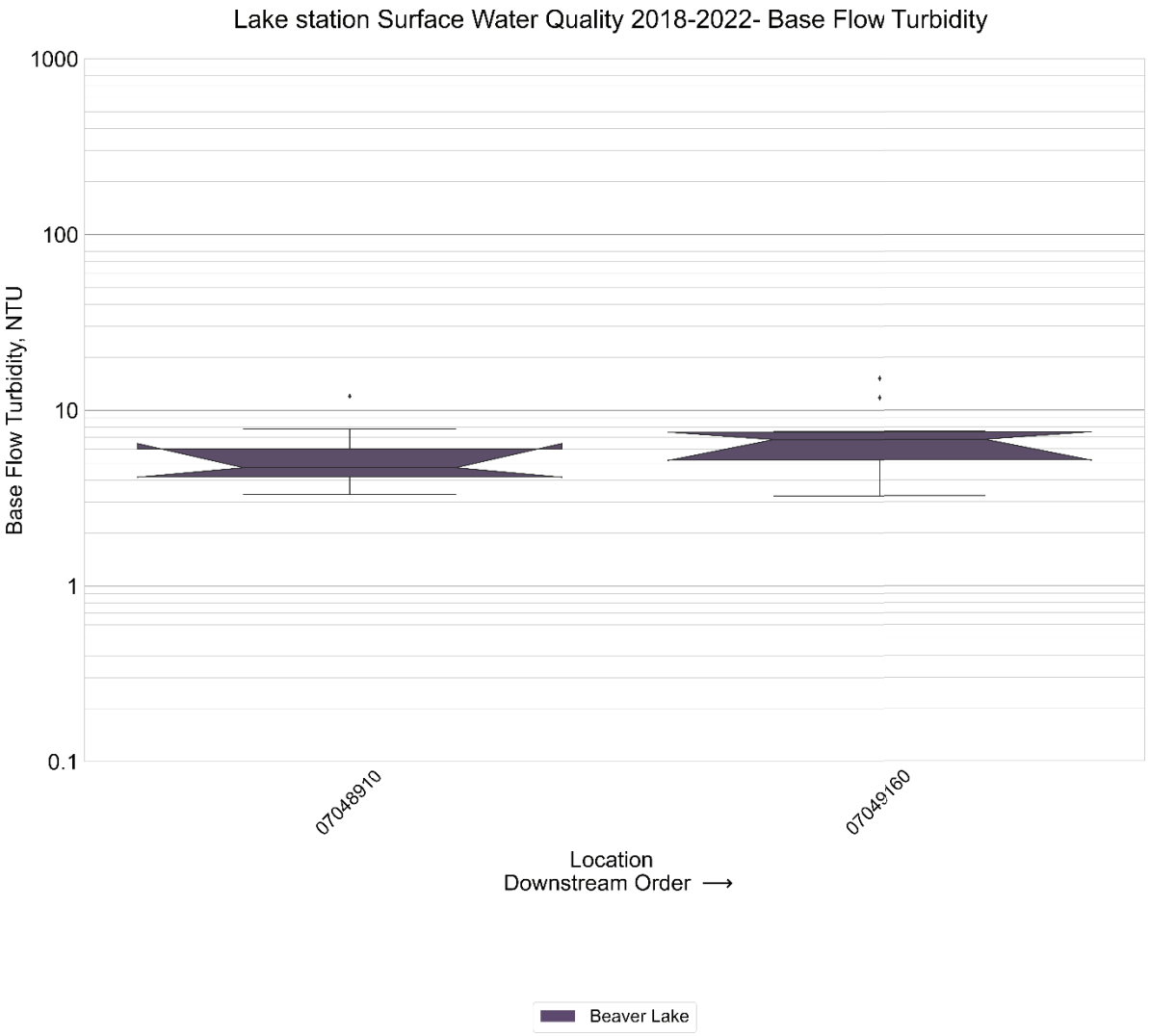


Figure 29. Box and whisker graph of Base Flow turbidity measurements from lake stations with more than 10 values from 2018-2022.

1.4.2 Total Suspended Solids

Total Suspended Solids TSS is a measure of solid material that can be filtered out of a water sample. This solid material can include organic debris as well as inorganic material such as soil particles. The tables below show summary statistics for TSS measurements from the Upper White River watershed from the period 2018-2022. Table 30 through Table 34 list summary statistics for stream TSS in the White River, West Fork White River, War Eagle Creek, and Eastern streams. Table 35 lists reservoir TSS measurements from 5 lake stations. The Kaplan Meier Method KM was used to estimate statistics, including percentiles and mean, using measurements below the detectable limit. ote that the sampling organi ations did not all use the same detection limit for TSS. WRC and H2O arks use ero 0.0 , while DE uses 1.0 or 2.0 mg/L.

Table 30. Summary statistics for stream TSS measurements in the White River to Lake Se uoyah during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
H2O arks	103	BC	15	0.0	0.5	1.1	1.0	1.7	2.2
DE	WHI0104	WR	12	2.0	2.0	2.0	2.0	2.0	2.5
H2O arks	104	WR	15	0.0	1.4	1.8	1.8	2.2	3.3
H2O arks	110	WR	2	0.7			1.1		1.5
DE	WHI0106	WR	49	2.0	2.0	2.0	2.2	2.8	9.3
DE	WHI0219	MFWR	12	2.0	2.0	2.0	2.8	2.0	11.0
H2O arks	201	MFWR	14	0.2	0.7	1.0	1.6	1.8	6.3
DE	WHI0103	MFWR	52	1.0	2.0	2.0	1.5	2.0	3.3

BC Baldwin Creek, WR White River, MFWR Middle Fork White River

Table 31. Summary statistics for stream TSS measurements in the West Fork White River and tributaries during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
H2O arks	102	WFWR	14	0.2	0.9	1.6	1.9	2.4	6.3
H2O arks	101	WFWR	10	0.7	1.4	2.0	2.7	4.4	6.0
DE	WHI0229	WFWR	13	2.0	2.0	2.0	3.3	2.0	18.2
H2O arks	200	WS	10	1.0	1.7	2.2	3.5	3.0	14.1
H2O arks	202	MC	8	0.9	1.4	1.9	2.3	3.4	4.2
H2O arks	206	SS	9	0.7	1.2	1.7	2.4	2.9	6.5
DE	WHI0223	TB	12	2.0	2.0	3.0	4.2	5.6	12.8
WRC	TB[a]	TB	130	0.4	2.1	3.7	81.1	49.7	761.7
H2O arks	210[a]	TB	14	0.0	1.8	3.0	3.1	3.6	6.6
DE	WHI0100	WFWR	52	2.0	3.7	7.3	9.0	9.8	87.5
WRC	WFWR	WFWR	129	1.1	6.5	10.9	102.5	123.8	993.1

Stations in this table with the same superscript letter are at the same location.
WFWR West Fork White River, WS Ward Slough, MC Mullins Creek, SS Spout Spring Creek, TB Town Branch

Table 32. Summary statistics for stream TSS measurements in the White River from Wyman to the state line waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
WRC	Wyman	WR	128	2.1	5.4	8.4	68.5	75.2	776.8
DE	WHI00052	WR	52	2.0	4.4	6.4	7.5	8.9	28.2
H2O arks	205	HoC	14	0.0	0.4	0.9	1.0	1.5	2.1
DE	WHI0221	LlC	12	2.0	2.0	2.0	2.1	2.0	3.0
WRC	Richland	RC	131	0.0	1.4	2.9	51.6	13.5	1839
DE	WHI0110	RC	12	2.0	2.0	2.1	3.7	3.9	10.0
H2O arks	300	BrC	13	0.5	0.8	1.6	3.4	3.7	15.4
H2O arks	306	PC	12	0.9	2.0	3.1	3.0	4.1	4.9
DE	WHI0012B	LwC	44	2.0	2.0	2.0	1.6	2.0	24.8

WR White River, HoC Hock Creek, LlC Lollars Creek, RC Richland Creek, BrC Brush Creek, PC Prairie Creek, LwC Leatherwood Creek

Table 33. Summary statistics for stream TSS measurements in War Eagle Creek during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
DE	WHI0227	WEC	12	2.0	2.0	2.0	2.0	2.0	2.3
H2O arks	109	WEC	11	0.2	1.1	1.7	2.1	3.0	4.9
H2O arks	307	HC	14	0.2	1.1	1.6	1.8	1.9	6.7
DE	WHI0070[b]	HC	52	1.0	2.0	2.0	2.03	2.3	12.2
H2O arks	308[b]	HC	14	0.1	1.7	2.3	2.2	2.6	4.1
H2O arks	301	WEC	9	1.9	2.6	4.5	4.1	4.7	8.0
H2O arks	302	C	13	0.1	0.8	1.3	1.2	1.5	2.4
H2O arks	303	ClC	15	0.0	0.3	0.8	1.1	1.8	3.5
WRC	WEC	WEC	131	0.0	3.3	5.9	55.7	36.8	1085
DE	WHI0116	WEC	52	2.0	2.0	2.8	4.3	4.8	22.5
H2O arks	304	CC	15	0.0	0.6	1.3	1.3	1.7	4.3
H2O arks	305	WEC	9	1.9	3.3	3.9	6.2	8.0	15.4

Stations in this table with the same superscript letter are at the same location.
WEC War Eagle Creek, HC Holman Creek, C lade Creek, ClC Clear Creek, CC Clifty Creek

Table 34. Summary statistics for stream TSS measurements in the Eastern streams during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easure s	ini u alue, g/L	25th Percentile , g/L	edian , g/L	ean, g/L	75th Percentile , g/L	a i u alue, g/L
DE	WHI0121	KR	51	1.0	2.0	2.0	1.9	2.3	8.8
DE	WHI0123	KR	44	1.7	2.0	2.0	2.7	2.4	13.2
DE	WHI0230	KC	11	2.0	2.0	2.0	3.8	2.1	21.5
DE	WHI0129	OC	11	2.0	2.0	2.0	4.6	2.0	29.0
DE	WHI0068	OC	44	1.3	2.0	2.0	3.5	3.8	14.8
DE	WHI0069 [c]	OC	48	2.0	2.0	2.0	3.3	3.8	15.2
WRC	Kings[c]	KR	36	0.3	1.7	2.5	42.3	4.6	657.5
DE	WHI0009	KR	50	2.0	2.0	2.0	3.9	2.9	33.5
DE	WHI0232	TC	10	2.0	2.0	2.0	3.0	2.0	12.2
DE	WHI0071	LC	48	1.5	2.0	2.8	4.0	4.3	17.5

Stations in this table with the same superscript letter are at the same location.
KR Kings River, KC Kenner Creek, OC Osage Creek, TC Terrapin Creek, LC Long Creek

Table 35. Summary statistics for reservoir TSS measurements from stations in Lake Se uoyah, Lake Wilson, and Beaver Lake during 2018-2022 stations listed in downstream order .

rg.	Station D	La e D	Sa le Location	o. of easures	in alue, g/L	25th Percentile g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a alue, g/L
DE	LWHI009	LS	Epilimnion	7	4.3	5.4	6.0	6.3	7.1	9.0
DE	LWHI014	LW	Epilimnion	11	2.0	2.1	2.5	3.1	3.9	6.3
DE	LWHI013B	BL	Epilimnion	5	2.3	2.3	3.8	3.3	4.0	4.3
DE	LWHI013C	BL	Epilimnion	4	2.0	2.0	2.0	2.0	2.0	2.0
DE	LWHI013	BL	Epilimnion	5	2.0	2.0	2.0	2.0	2.0	2.0

LS Lake Se uoyah, LW Lake Wilson, BL Beaver Lake

Figure 30 through Figure 34 show box and whisker graphs of TSS concentrations measured at stations in the Upper White River watershed with more than 10 measurements during the period 2018-2022. The highest median TSS concentration occurs at the WRC West Fork White River station WFWR , and the lowest median TSS concentration occurs at H2O ark Clear Creek station 303 . The median TSS concentrations at the Beaver Lake reservoir stations are lower than in the streams, which is not unexpected. However, the relatively high median TSS value from Lake Se uoyah is surprising. Settling that occurs in the reservoir is expected to result in lower epilimnion TSS concentrations. Overall, WRC stations reported higher median TSS than other organi ations. This is expected as WRC monitors storm flow, which captures large loading events.

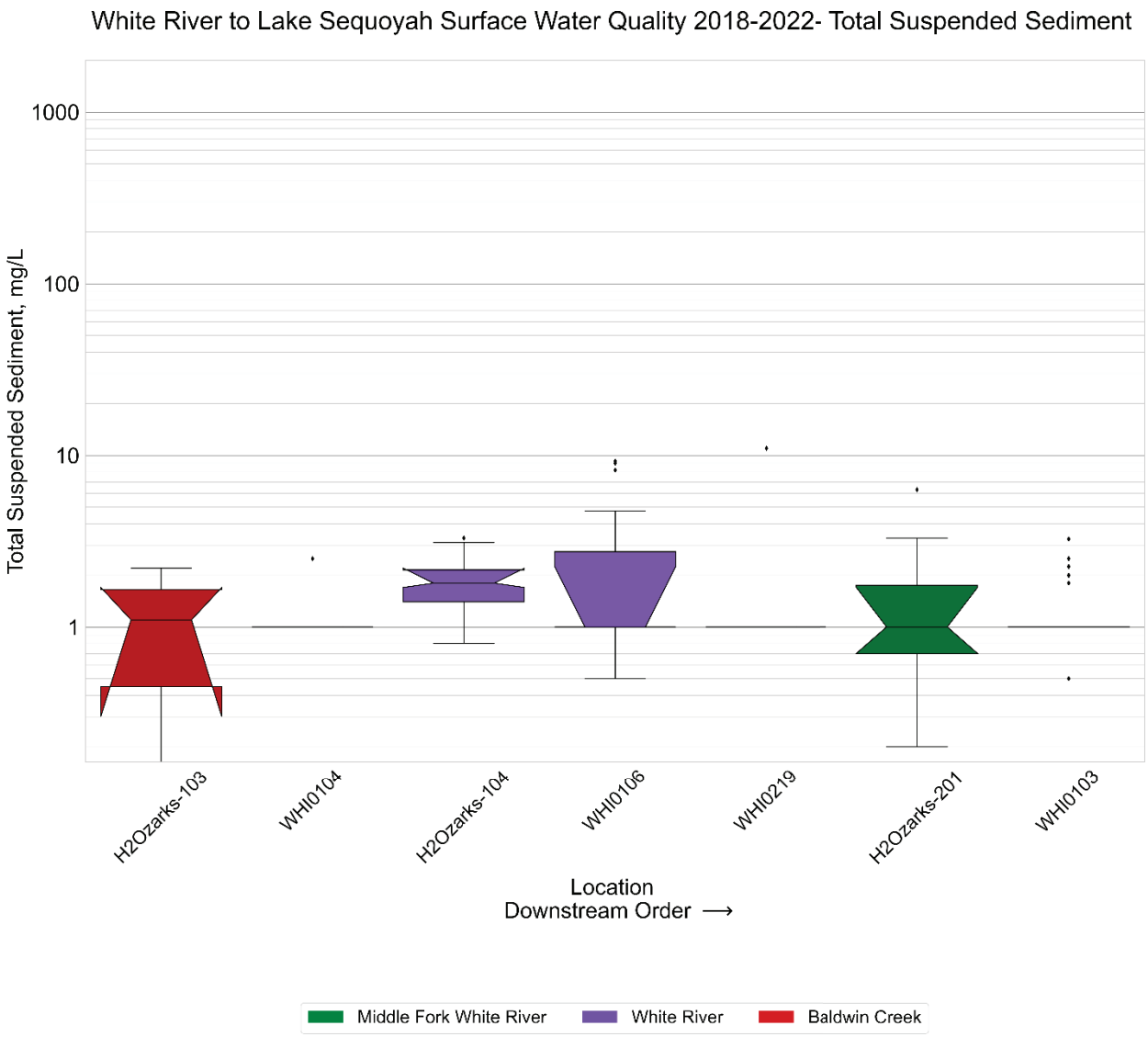


Figure 30. Box and whisker graph of TSS measurements from stations in the White River to Lake Se uoyah waterway segment with more than 10 values from 2018-2022.

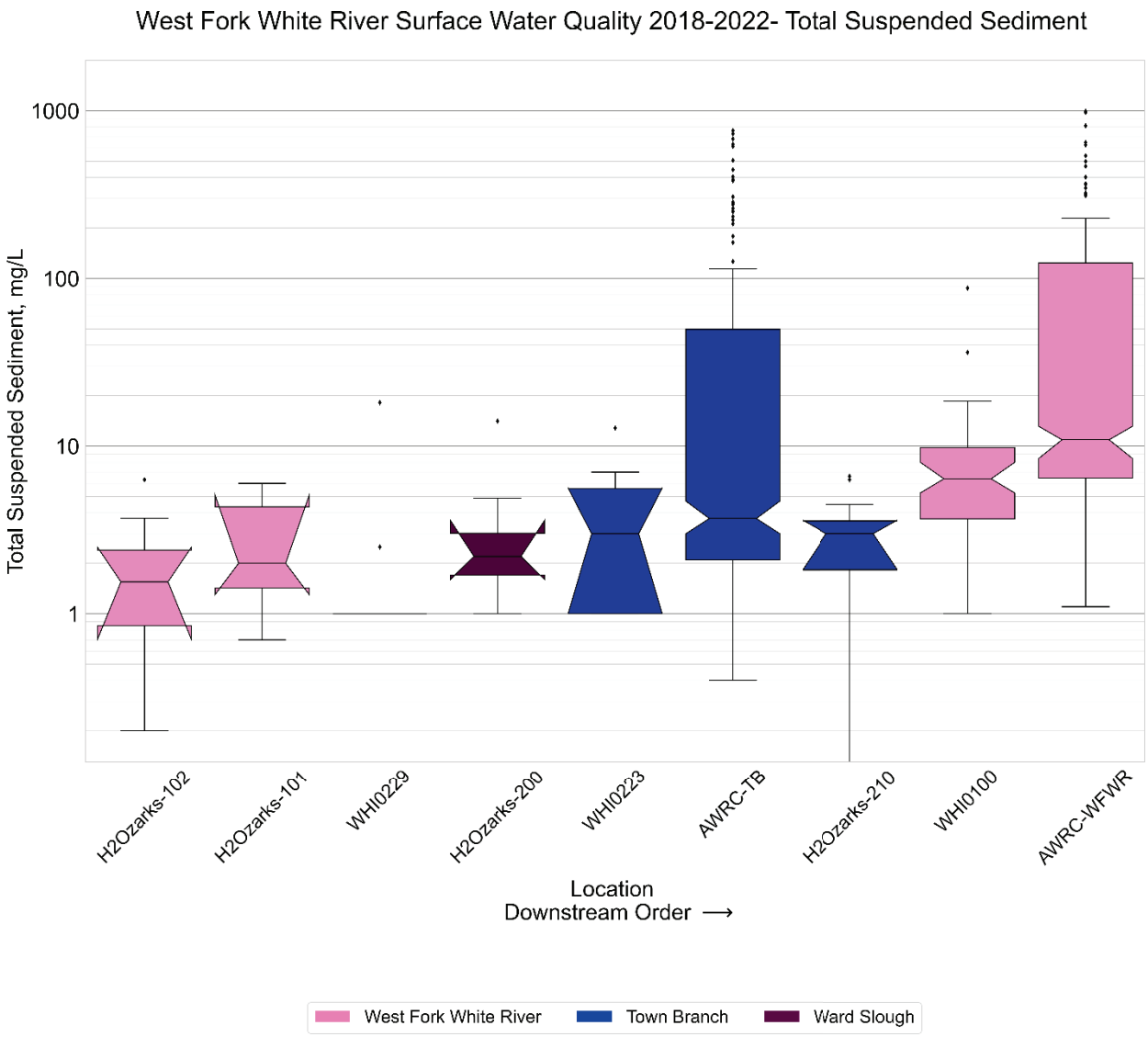


Figure 31. Box and whisker graph of TSS measurements from stations in the West Fork White River waterway segment with more than 10 values from 2018-2022. ote stations TB and 201 are at the same location on Town Branch.

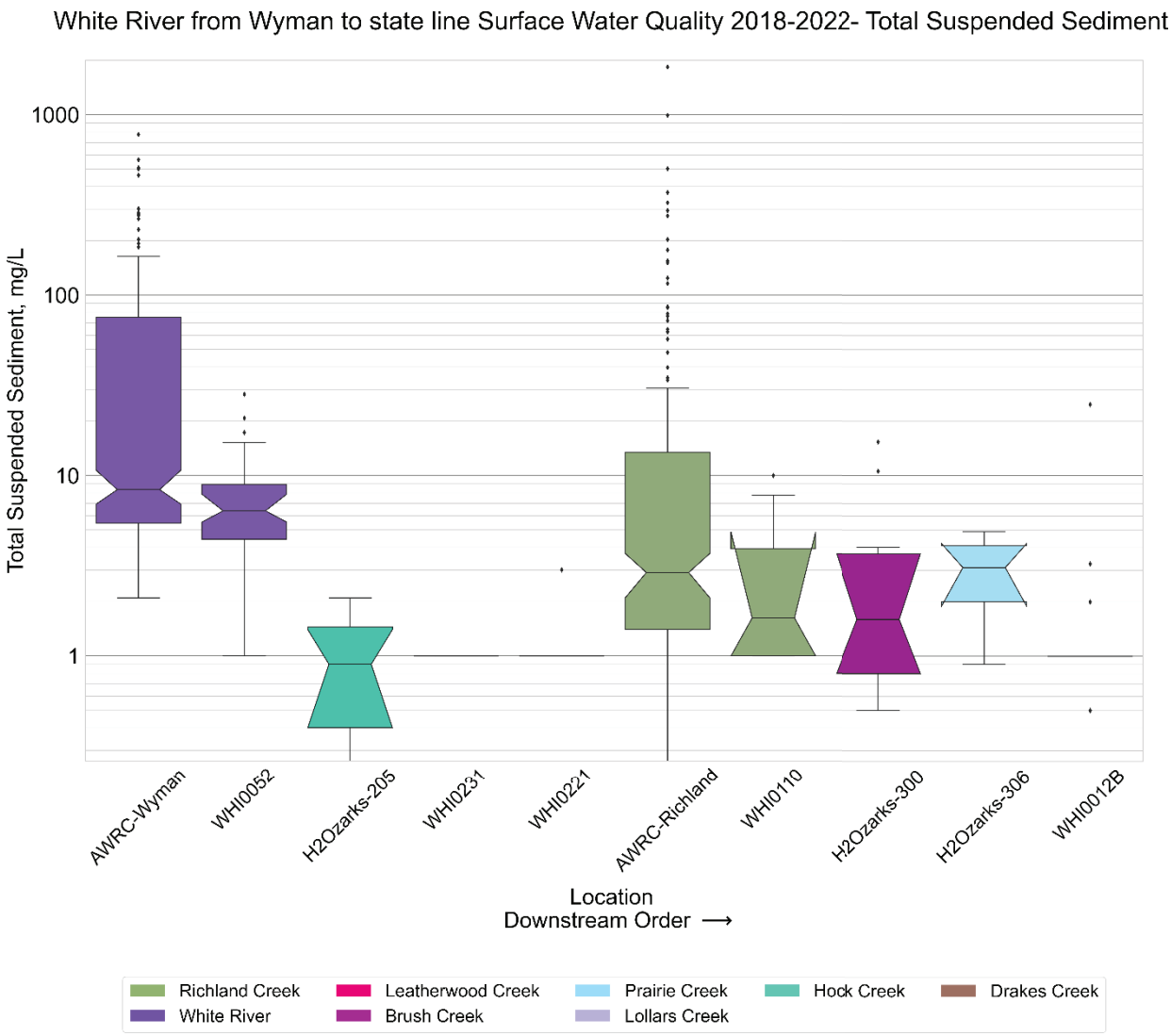


Figure 32. Box and whisker graph of TSS measurements from stations in the White River from Wyman to the state line waterway segment with more than 10 values from 2018-2022.

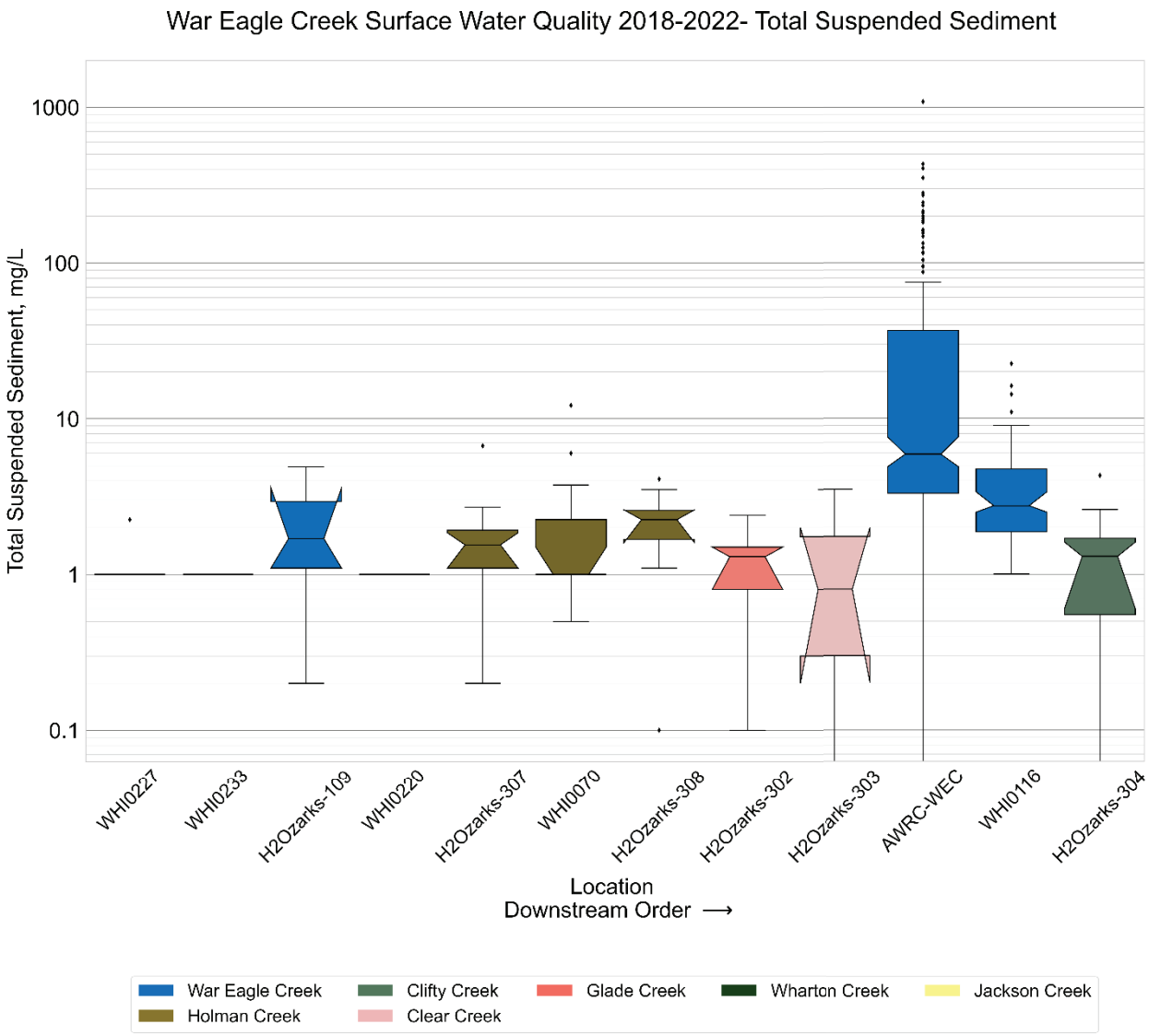


Figure 33. Box and whisker graph of TSS measurements from stations in the War Eagle Creek waterway segment with more than 10 values from 2018-2022. ote that stations WHI0070 and 308 are at the same location on Holman Creek.

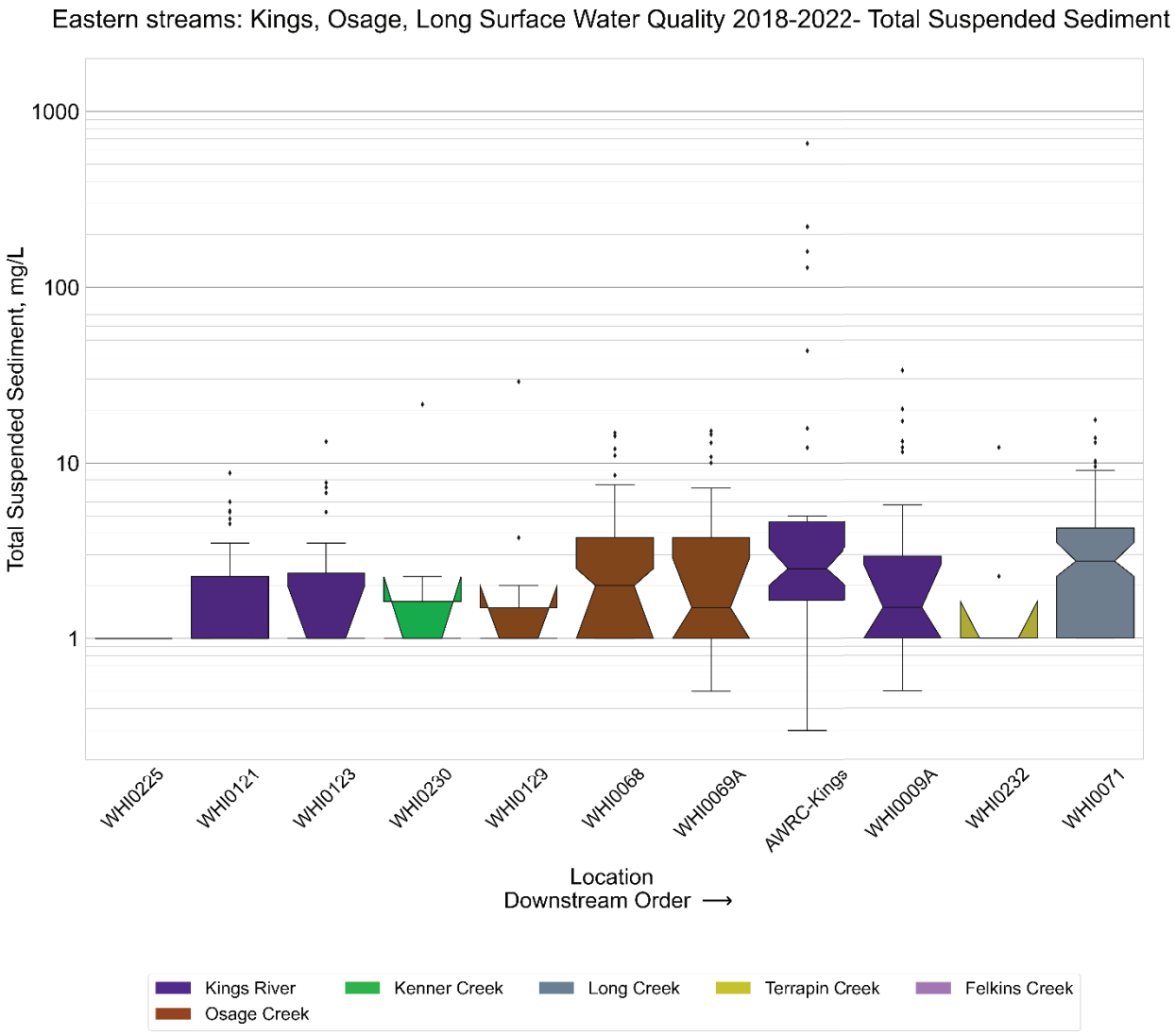


Figure 34. Box and whisker graph of TSS measurements from stations in the Eastern streams waterway segment with more than 10 values from 2018-2022. ote that stations Kings and WHI0009 are at the same location on the Kings River.

1.4.3 Suspended Sediment Concentration

The US S measures suspended sediment concentrations SSC in the Upper White River watershed instead of TSS. Table 36 lists summary statistics for available SSC measurements from the Upper White River watershed that were collected during the period 2018-2022. War Eagle Creek at War Eagle 07049050 has the highest median SSC followed by White River near Fayetteville 07048600 as the next highest. When comparing data from the same sampling period, the concentration ranges, i.e., minimum and maximum, appear very similar, although the median values appear to vary. Kruskal-Wallis test of the data from the five stations collected during the same sampling period indicates that SSC at these stations are not statistically different p-value 0.0672 .

Table 36. Summary statistics for SSC measurements from Upper White River watershed streams, 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rg.	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
US S	07048495	TB	24	2.0	4.0	6.0	88.7	83.9	725.0
US S	07048550	WFWR	37	2.0	10.0	12.0	100.8	31.0	1010.0
US S	07048600	WR	13	7.0	11.0	82.0	251.0	342.0	904.0
US S	07048700	WR	2	10.0			123.0		236.0
US S	07048780	RC	11	1.0	2.5	39.0	174.4	102.0	814.0
US S	07049050	WEC	11	3.0	6.5	412.0	411.2	595.5	1220.0
US S	07053250	C	1	49.0		49.0			49.0

TB Town Branch, WFWR West Fork White River, WR White River, RC Richland Creek, WEC War Eagle Creek, C ocum Creek

1.5 Water Temperature

Water temperature can affect fish and other a uatic creatures living in waterbodies, as well as water chemistry. Criteria for impairment is found in rkansas Pollution Control and Ecology Commission Section 2.502 of Rule 2, regulations for water uality standards of surface waters PCEC, 2022 . To determine stream temperature impairment, DE re uires at least 10 measurements. The Upper White Watershed falls within two ecoregions, the Boston Mountains 31ºC and O ark Highlands 29ºC . Lakes and reservoirs have a temperature criterion of 32ºC regardless of ecoregion. The criteria used for each station are from the Regulation 2 ecoregion boundaries however, some stations are sub ect to criteria change if the

proposed ecoregion boundaries are approved. Locations where more than 10% of measurements exceed the criteria temperature may be classified as impaired. Stations located on impaired waterway segments are highlighted in the tables below.

Table 37 through Table 41 list summary statistics for stream and reservoir temperature measurements from the period 2018-2022. Statistics in Table 42 lake stations were calculated using only measurements from the epilimnion less than 6 feet .

The highest median temperatures are from station 07048700 White River near oshen and WHI0219 MFWR south of Black Oak . Measured water temperatures at sixteen stations occasionally exceed the temperature water uality criterion. Exceedances of the water temperature criterion are rare enough that these stream reaches are not classified as impaired because of water temperature. early 11 miles of the West Fork White River is listed as impaired for temperature in the Draft 2020 303 d List see highlighted stations in Table 38 DE , 2020 . However, if EP approves the change in ecoregion boundaries, then temperatures would not exceed the updated criteria on the West Fork White River segment from 2018-2022. In a few instances US S, DE , and/or BWD measure temperature at the same location. t DE station WHI0052 and US S station 07048700 White River near oshen , the median temperatures are 36% different US S station is 7°C higher . However, the average temperatures are only 5% different US S station 1°C higher .

Figure 35 through Figure 40 show box and whisker graphs of water temperature measurements from monitoring locations in the Upper White River watershed with more than 10 measurements during the period 2018-2022. Median water temperatures at the monitoring locations are not significantly different, except for the White River below Beaver Lake dam 07049691 . The median water temperature at this station is statistically significantly lower than the median temperatures at the other monitoring locations and water temperature at this station varies less than at the other monitored locations. This is because of the influence of releases from Beaver Lake. The lower water temperatures at this location support the Beaver Lake tailwater trout fishery.

Table 37. Summary statistics for water temperature measurements from stations in the White River to Lake Se uoyah waterway segment from 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, deg C	25th Percentile, deg C	edian, deg C	ean, deg C	75th Percentile, deg C	a i u alue, deg C	Criteria, deg C	u ber of values criterion	Percent values criterion
H2O arks	103	BC	5	8.00	10.00	10.56	14.51	14.00	30.00	31	0	-
DE	WHI0104	WR	11	4.70	10.50	17.30	16.53	21.50	30.80	31	0	0%
H2O arks	104	WR	4	10.00	10.00	11.94	14.86	16.81	25.56	31	0	-
H2O arks	110	WR	2	14.50	18.65	22.81	22.81	26.96	31.11	31	1	-
DE	WHI0106	WR	51	5.40	10.10	14.90	16.40	24.00	28.50	31	0	0%
BWD	5	WR	58	2.40	9.33	13.85	16.07	24.75	30.40	31	0	0%
DE	WHI0219	MFWR	11	9.42	12.25	20.90	19.74	25.90	30.70	31	0	0%
BWD	7	MFWR	58	3.00	9.43	13.90	15.62	23.33	27.70	31	0	0%
H2O arks	201	MFWR	5	9.00	10.00	12.00	15.22	16.11	29.00	31	0	-
DE	WHI0103	MFWR	53	4.70	8.50	14.10	15.78	23.20	27.90	29	0	0%

BC Balwin Creek, WR White River, MFWR Middle Fork of the White River

DE re uires at least 10 samples to evaluate attainment of temperature criteria DE 2022 .

DE has proposed updating the ecoregion boundaries. If approved, this station would change ecoregions and be sub ect to different criteria.

Table 38. Summary statistics for water temperature measurements from stations in the West Fork White River waterway segment from 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, deg C	25th Percentile, deg C	edian, deg C	ean, deg C	75th Percentile, deg C	a i u alue, deg C	Criteria, deg C	u ber of values criterion	Percent values criterion
H2O arks	102	WFWR	5	4.44	12.22	15.00	15.44	17.78	27.78	31	0	-
DE	WHI0229	WFWR	11	9.60	12.45	19.70	19.82	25.80	32.40	31	1	9%
DE	WHI0223	TB	11	6.80	12.80	17.80	18.57	24.50	29.90	29	1	9%
H2O arks	210	TB	4	7.78	8.61	11.11	12.78	15.28	21.11	29	0	-
US S	07048495∞	TB	1652	0.10	8.70	15.40	15.59	23.70	28.90	29	0	0%
BWD	8[a]	WFWR	57	3.20	8.90	13.70	15.91	24.40	30.30	29	4	7%
DE	WHI0100[a]	WFWR	53	4.00	10.10	14.60	16.49	24.40	28.50	29	0	0%
US S	07048550∞	WFWR	1685	-1.50	8.50	15.00	16.07	25.00	30.90	29	75	4%

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

WFWR West Fork White River, TB Town Branch

DE re uires at least 10 samples to evaluate attainment of temperature criteria DE 2022 . Daily average US S data was used wherever available.

DE has proposed updating the ecoregion boundaries. If approved, this station would change ecoregions and be sub ect to different criteria.

Indicates stations are located on assessment units listed as impaired because of high temperatures on Draft 2020 and Draft 2022 303 d Lists.

∞ This is a continuous monitoring station. Statistics are calculated using reported daily median temperature values.

Table 39. Summary statistics for water temperature measurements from stations in the White River from Wyman to the state line waterway segment from 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, deg C	25th Percentile, deg C	edian, deg C	ean, deg C	75th Percentile, deg C	a i u alue, deg C	Criteria, deg C	u ber of values criterion	Percent values criterion
BWD	22	LSO	34	4.40	8.10	13.90	16.06	25.70	29.20	29	1	3%
BWD	10[b]	WR	57	3.90	9.70	14.00	16.00	24.60	31.40	29	2	4%
US S	07048600[b, ∞]	WR	1746	0.20	9.40	16.10	16.89	25.60	31.60	29	107	6%
BWD	23	WR	11	6.90	12.25	15.80	17.51	25.10	27.50	29	0	0%
BWD	13	WR	45	3.80	9.40	15.00	16.01	24.00	28.30	29	0	0%
DE	WHI0052[c]	WR	53	5.00	10.20	15.70	17.47	25.90	30.50	29	4	8%
US S	07048700[c]	WR	19	3.80	10.00	22.70	18.40	24.68	27.60	29	0	0%
H2O arks	205	HoC	5	8.00	10.00	13.33	14.67	14.00	28.00	29	0	-
DE	WHI0231	DC	11	5.42	11.00	16.70	15.68	20.50	24.30	29	0	0%
DE	WHI0221	LlC	11	4.83	10.10	16.80	15.86	21.00	26.50	29	0	0%
US S	07048780	RC	12	9.00	10.53	13.95	15.46	21.08	23.70	29	0	0%
DE	WHI0110	RC	11	7.70	11.70	18.70	17.87	23.15	32.80	29	1	9%
H2O arks	300	BrC	4	8.00	10.25	17.50	16.75	24.00	24.00	29	0	-
BWD	12	WR	50	4.50	9.30	13.60	14.83	21.35	25.20	29	0	0%
US S	07049691	WR	9	8.40	8.80	9.20	9.60	9.90	11.80	29	0	0%
DE	WHI0012B	LwC	44	5.10	8.93	13.50	13.61	17.25	25.10	29	0	0%

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

LSO Lake Se uoyah outflow, WR White River, HoC Hock Creek, DC Drakes Creek, LlC Lollars Creek, RC Richland Creek, BrC Brush Creek, LwC Leatherwood Creek

DE re uires at least 10 samples to evaluate attainment of temperature criteria DE 2022 . Daily average US S data was used wherever available.

DE has proposed updating the ecoregion boundaries. If approved, this station would change ecoregions and be sub ect to different criteria.

Indicates stations are located on assessment units on Draft 2022 303 d impairment list.

∞ This is a continuous monitoring station. Statistics are calculated using reported daily median temperature values.

Table 40. Summary statistics for water temperature measurements from stations in the War Eagle Creek waterway segment from 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, deg C	25th Percentile, deg C	edian, deg C	ean, deg C	75th Percentile, deg C	a i u alue, deg C	Criteria, deg C	u ber of values criterion	Percent values criterion
DE	WHI0227	WEC	11	5.95	10.75	17.50	17.38	23.45	31.10	31	1	9%
DE	WHI0233	C	11	5.88	10.50	17.60	16.96	23.60	28.80	31	0	0%
H2O arks	109	WEC	4	4.00	10.75	15.00	15.75	20.00	29.00	29	0	-
DE	WHI0220	WC	11	7.56	11.10	19.30	17.78	24.10	28.30	31	0	0%
BWD	15	WEC	58	3.30	9.45	14.75	16.57	24.80	30.20	29	4	7%
H2O arks	307	HC	5	4.17	13.89	14.44	13.72	14.44	21.67	29	0	-
DE	WHI0070[d]	HC	53	6.80	11.00	16.00	17.59	24.90	29.00	29	0	0%
H2O arks	308[d]	HC	5	5.56	13.33	14.44	15.33	15.56	27.78	29	0	-
BWD	21	WEC	57	2.90	9.70	14.60	16.42	23.90	28.70	29	0	0%
DE	WHI0116	WEC	53	5.40	10.40	15.40	16.57	24.10	27.70	29	0	0%
BWD	9[e]	WEC	58	3.50	9.73	14.95	16.97	25.18	29.70	29	3	5%
US S	07049050[e, ∞]	WEC	1570	0.30	9.20	14.50	15.73	23.70	29.70	29	0	0%

Stations in this table with the same superscript letter are at the same location.
WEC War Eagle Creek, C ackson Creek, WC Wharton Creek, HC Holman Creek
DE re uires at least 10 samples to evaluate attainment of temperature criteria DE 2022 .
DE has proposed updating the ecoregion boundaries. If approved, this station would change ecoregions and be sub ect to different criteria.
∞ This is a continuous monitoring station. Statistics are calculated using reported daily median temperature values.

Table 41. Summary statistics for water temperature measurements from stations in the Eastern Streams waterway segment from 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, deg C	25th Percentile, deg C	edian, deg C	ean, deg C	75th Percentile, deg C	a i u alue, deg C	Criteria, deg C	u ber of values criterion	Percent values criterion
DE	WHI0225	FC	10	6.22	10.63	14.85	17.50	26.33	31.40	31	1	10%
DE	WHI0121	KR	53	6.40	9.70	16.20	16.85	23.90	29.60	29	2	4%
DE	WHI0123	KR	53	6.10	9.90	15.70	16.98	25.20	28.10	29	0	0%
DE	WHI0230	KC	11	9.71	12.35	13.50	15.39	19.40	22.40	29	0	0%
DE	WHI0129	OC	11	7.34	12.20	14.00	16.14	20.90	27.10	29	0	0%
DE	WHI0068	OC	45	2.70	9.80	16.20	16.44	22.30	30.40	29	3	7%
DE	WHI0069	OC	49	3.10	9.80	15.80	15.96	22.20	29.50	29	1	2%
DE	WHI0009	KR	50	4.00	9.35	16.15	16.15	22.98	30.00	29	2	4%
US S	070453250	C	2	6.00	7.05	8.10	8.10	9.15	10.20	29	0	-
DE	WHI0232	TC	9	4.51	11.20	14.20	15.77	23.40	26.10	29	0	-
DE	WHI0071	LC	49	5.60	11.50	16.50	16.52	21.60	29.60	29	1	2%

FC Felkins Creek, KR Kings River, KC Kenner Creek, OC Osage Creek, C ocum Creek, TC Terrapin Creek, LC Long Creek
DE re uires at least 10 samples to evaluate attainment of temperature criteria DE 2022 .
DE has proposed updating the ecoregion boundaries. If approved, this station would change ecoregions and be sub ect to different criteria.

Table 42. Summary statistics for epilimnion water temperature measurements from Lake Stations from 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	La e D	u ber of easures	ini u alue, deg C	25th Percentile, deg C	edian, deg C	ean, deg C	75th Percentile, deg C	a i u alue, deg C	Criteria, deg C	u ber of values criterion	Percent values criterion
DE	LWHI009	LS	8	11.50	18.15	21.45	21.50	25.23	31.10	32	0	-
DE	LWHI014	LW	12	5.42	13.25	17.95	17.70	24.03	27.50	32	0	0%
US S	07048910	BL	22	3.8	10.5	22.8	19.9	27.5	30.03	32	0	0%
DE	LWHI013B	BL	5	5.57	5.64	27.20	19.32	28.20	30.00	32	0	-
US S	07049160	BL	22	4.84	9.84	19.81	16.67	21.98	24.18	32	0	0%
US S	07049187	BL	10	5.0	11.6	20.6	19.0	28.3	29.90	32	0	0%
US S	07049200	BL	22	5.8	11.1	24.1	20.4	27.8	30.95	32	0	0%
DE	LWHI013C[f]	BL	4	5.55	7.97	18.39	18.11	28.53	30.10	32	0	-
US S	07049500[f]	BL	22	5.9	10.9	25.1	20.5	28.4	29.80	32	0	0%
DE	LWHI013	BL	5	6.76	8.12	8.58	14.67	23.35	26.53	32	0	-
US S	07049690	BL	30	6.5	12.4	24.0	20.5	27.9	30.45	32	0	0%

Stations in this table with the same superscript letter are at the same location.
LS Lake Se uoyah, LW Lake Wilson, BL Beaver Lake
DE re uires at least 10 samples to evaluate attainment of temperature criteria DE 2022 .
Lakes/Reservoirs 32 ºC

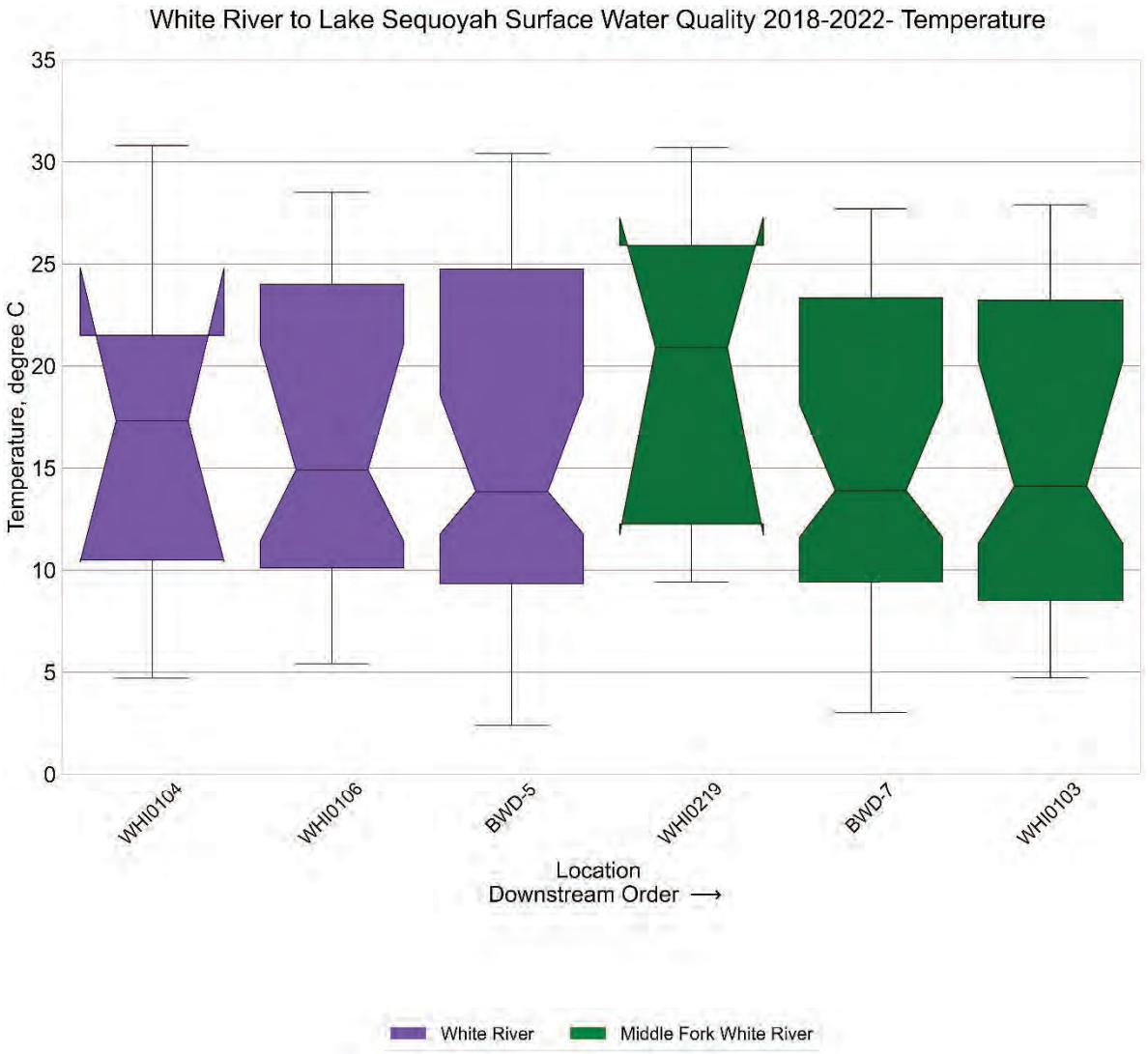


Figure 35. Box and whisker graph of stream temperature measurements from stations in the White River to Lake Se uoyah waterway segment with more than 10 values from 2018-2022.

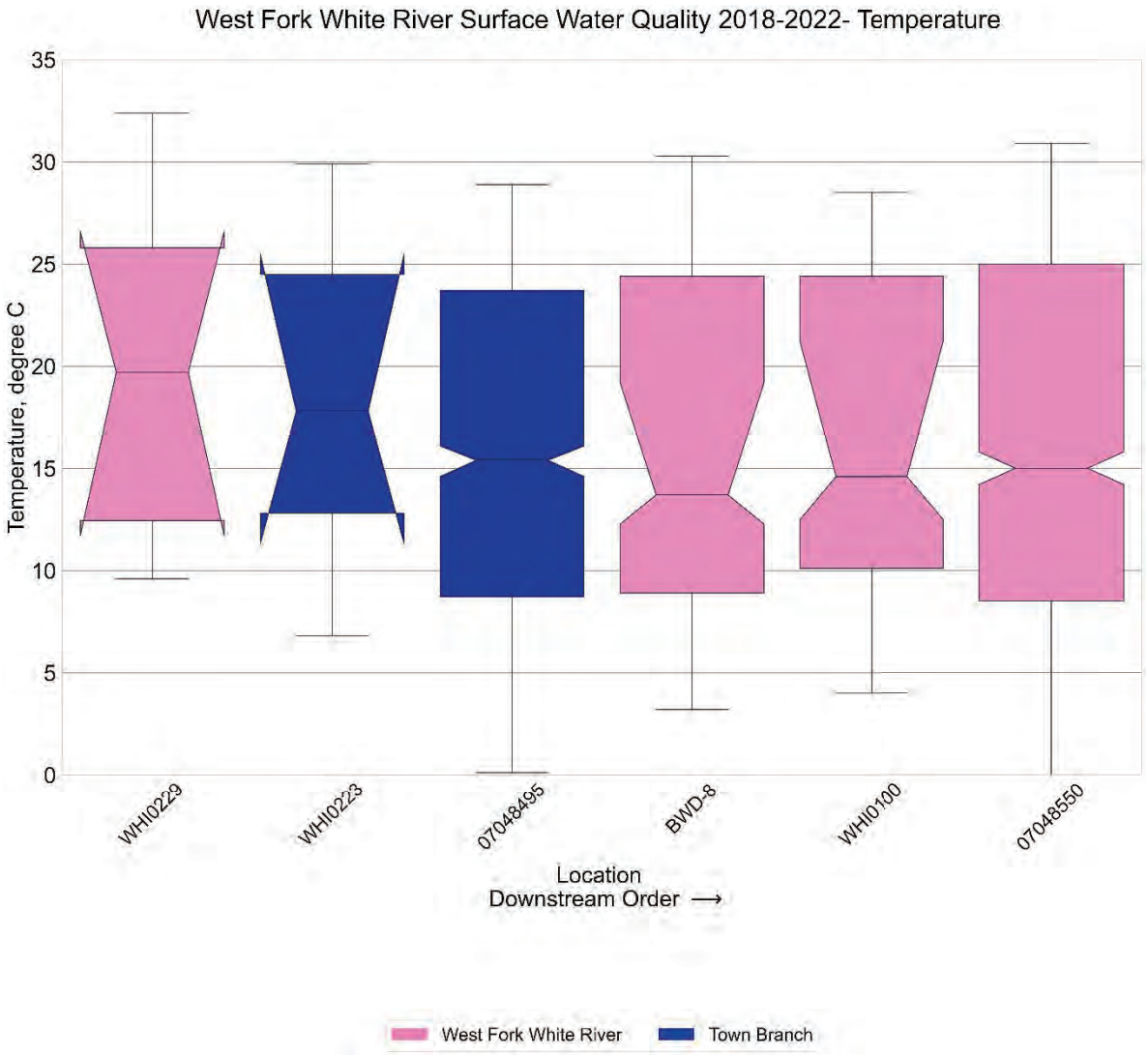


Figure 36. Box and whisker graph of stream temperature measurements from stations in the West Fork White River waterway segment with more than 10 values from 2018-2022. ote that stations 8 and WHI0100 are at the same location on the West Fork White River.

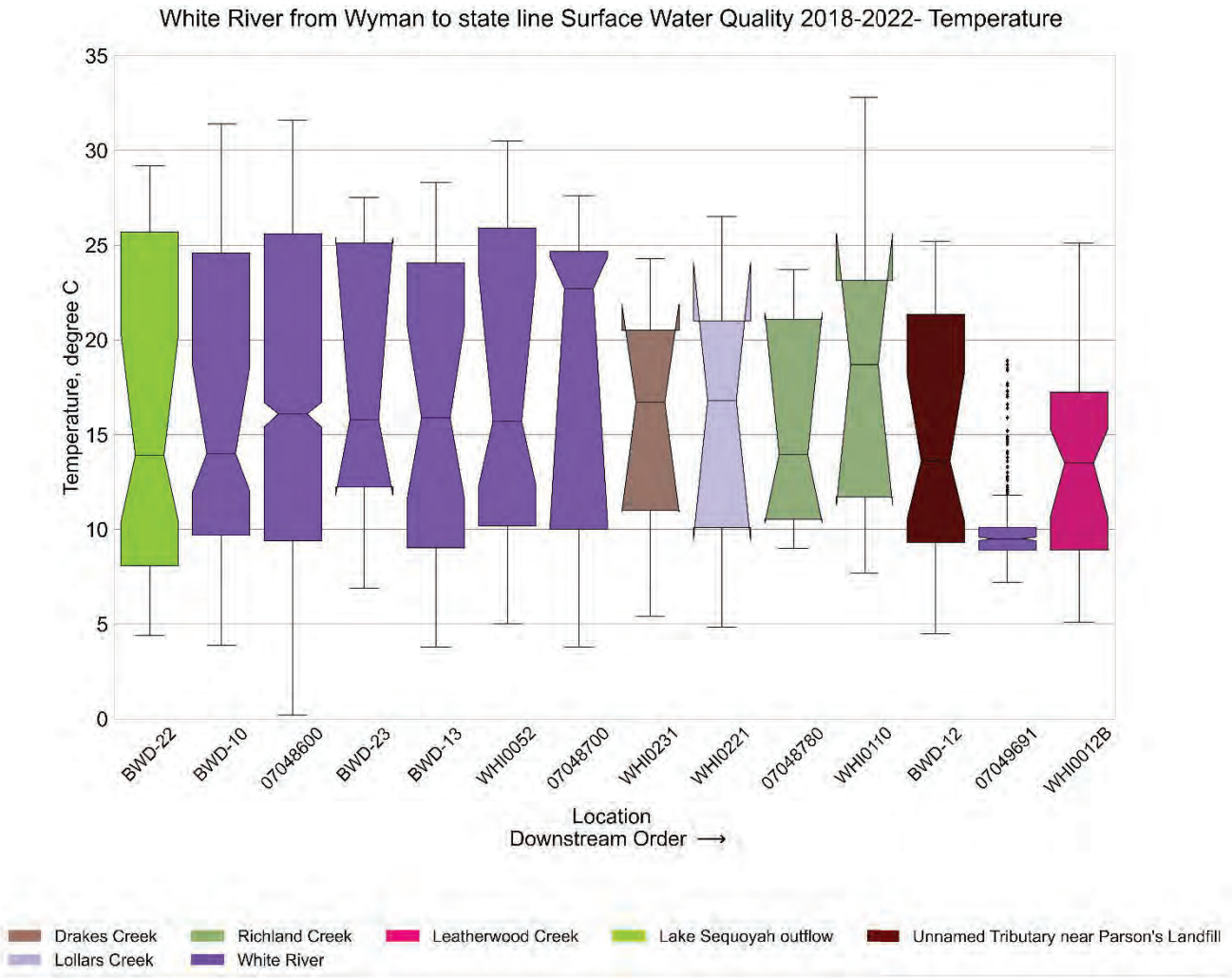


Figure 37. Box and whisker graph of stream temperature measurements from stations in the White River from Wyman to state line waterway segment with more than 10 values from 2018-2022. ote that stations 10 and 07048600 are at the same location on the White River upstream of Richland Creek, and stations WHI0052 and 07048700 are at the same location on the White River downstream of Richland Creek.

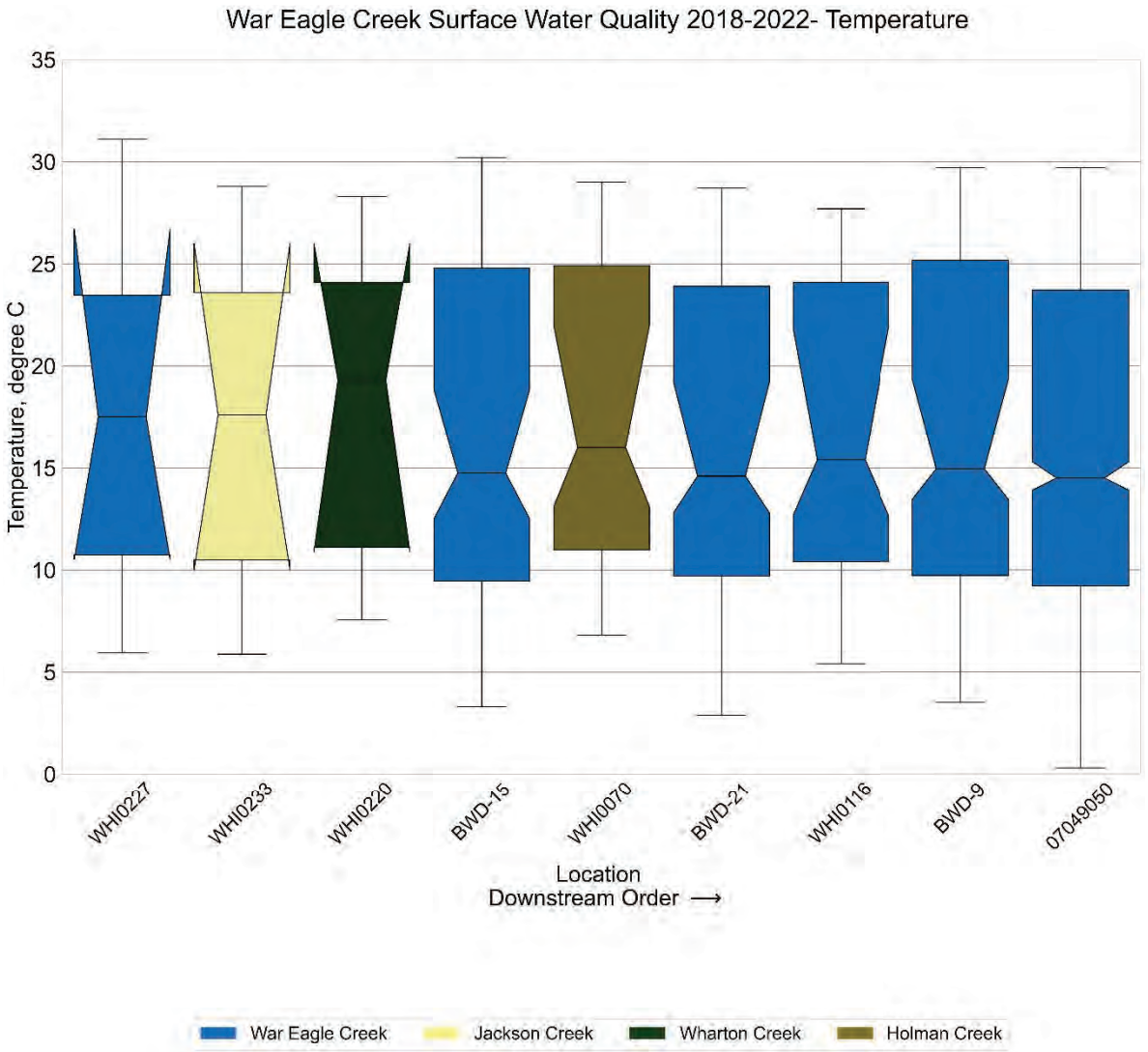


Figure 38. Box and whisker graph of stream temperature measurements from stations in the War Eagle Creek waterway segment with more than 10 values from 2018-2022. ote that stations 9 and 07049050 are at the same location on War Eagle Creek.

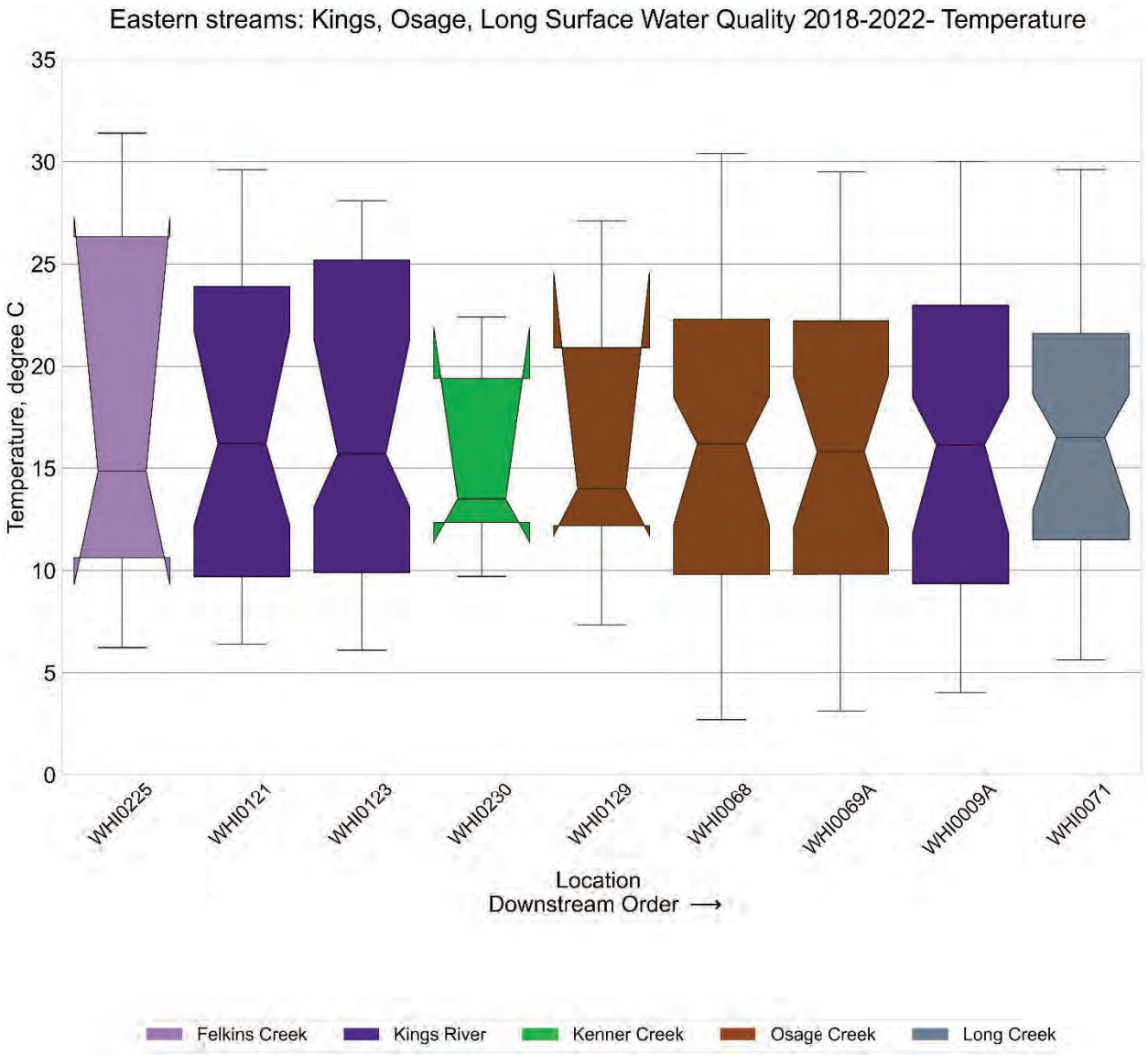


Figure 39. Box and whisker graph of stream temperature measurements from stations in the Eastern streams waterway segment with more than 10 values from 2018-2022.

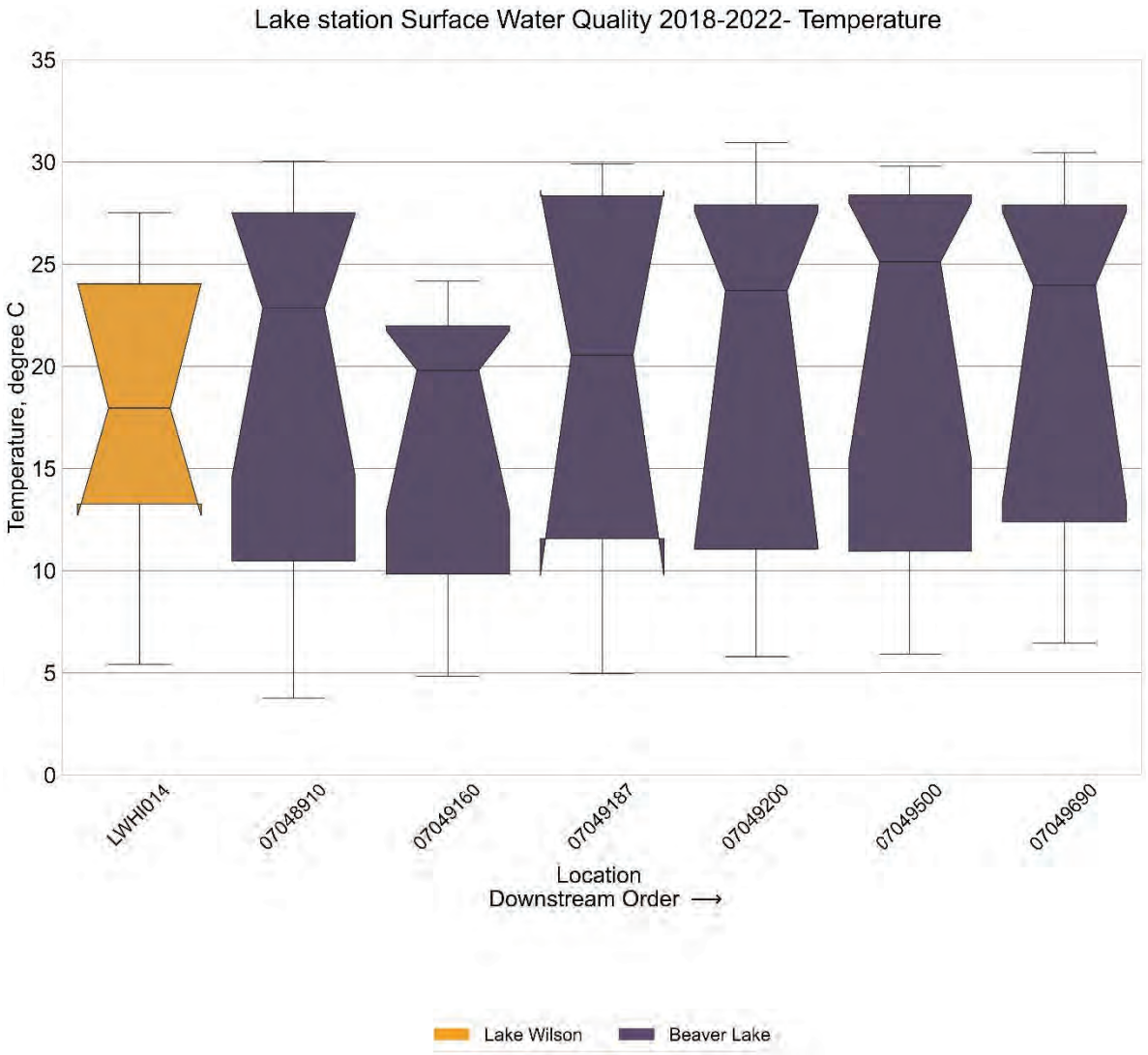


Figure 40. Box and whisker graph of reservoir epilimnion temperature measurements from stations in the Lake stations segment with more than 10 values from 2018-2022.

1.6 Dissolved Oxygen

Dissolved oxygen DO in water is used by fish and other a uatic creatures living in waterbodies. Summary statistics for stream DO measurements from the period 2018-2022 are provided in Table 43-Table 46. Table 47 lists summary statistics for lake epilimnion DO measurements from the period 2018-2022. Dissolved oxygen is evaluated based on two seasons. primary and critical. Primary season and critical season criteria are based on water temperature and minimum flows for the season, as well as ecoregion and watershed area PCEC, 2022 .

The highest median DO concentration occurs at Holman Creek WHI0070 . In the reservoirs, the highest median epilimnion DO concentration is at Lake Wilson LWHI014 . Overall, median DO concentrations at the reservoir stations are lower than those for stream stations. Beaver Lake by Lowell 07049200 has the lowest median DO concentration. ll the epilimnion DO measurements from Lake Se uoyah, Wilson Lake, and Beaver Lake meet the lake DO criterion 5 mg/L . ote that DE station LWHI013 and US S station 07049690 are both located near the dam.

Table 43. Summary statistics for stream DO measurements in the White River waterway segment from 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rg.	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
DE	WHI0104	WR	11	7.26	8.07	9.58	9.49	10.50	12.60
DE	WHI0106	WR	51	6.80	8.40	9.97	9.96	11.40	13.10
DE	WHI0219	MFWR	11	5.44	7.92	9.36	9.39	11.20	12.30
DE	WHI0103	MFWR	53	5.80	7.99	9.93	9.81	11.60	13.50
US S	07048600∞	WR	1745	5.40	7.30	9.40	9.26	11.00	14.10
DE	WHI0052[a]	WR	53	6.05	8.35	9.62	9.81	11.30	12.90
US S	07048700[a]	WR	19	5.54	7.55	8.60	8.79	9.50	12.60
DE	WHI0221	LlC	11	7.71	8.02	9.32	9.57	10.80	12.60
DE	WHI0231	DC	11	7.07	7.55	9.43	9.30	10.90	12.40
US S	07048780	RC	12	7.90	9.30	10.20	9.97	10.60	11.90
DE	WHI0110	RC	11	6.72	8.19	10.00	9.62	10.75	13.10
US S	07049691∞	WR	911	4.40	6.80	7.60	7.65	8.50	10.90
DE	WHI0012B	LwC	44	5.35	8.95	10.60	10.14	11.38	13.90

Stations in this table with the same superscript letter are at the same location.
WR White River, MFWR Middle Fork White River, DC Drakes Creek, LlC Lollars Creek, RC Richland Creek, LwC Leatherwood Creek
DE re uires at least 10 samples to evaluate attainment of DO criteria DE 2022 .
∞ This is a continuous monitoring station. Statistics are calculated using reported daily median DO values.
Indicates station is located on assessment unit included on both pproved 2018 and Draft 2020 303 d Lists for low DO levels.
Indicates station is located on assessment unit included on the Draft 2020 303 d List for low DO.

Table 44. Summary statistics for stream DO measurements in the West Fork White River waterway segment from 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rg.	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
DE	WHI0229	WFWR	10	7.26	9.17	9.87	9.99	11.43	12.20
DE	WHI0223	TB	11	6.02	8.30	9.64	9.79	11.05	14.40
US S	07048495	TB	24	6.50	7.43	9.20	9.38	10.60	13.50
DE	WHI0100	WFWR	53	5.49	7.35	9.47	9.25	11.20	13.10
US S	07048550	WFWR	6	7.10	9.05	9.75	9.42	10.38	10.50

WFWR West Fork White River, TB Town Branch
DE re uires at least 10 samples to evaluate attainment of DO criteria DE 2022 .
Indicates station is located on assessment unit included on both pproved 2018 and Draft 2020 303 d Lists for low DO.
Indicates station is located on assessment unit included on the Draft 2020 303 d List for low DO.

Table 45. Summary statistics for stream DO measurements in the War Eagle Creek waterway segment from 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rg.	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
DE	WHI0227	WEC	11	7.25	8.25	9.56	9.49	10.60	12.50
DE	WHI0233	C	11	6.24	8.14	9.40	9.22	10.55	11.50
DE	WHI0220	WC	11	3.53	8.16	9.90	9.37	11.00	12.60
DE	WHI0070	HC	53	7.03	9.38	10.80	10.94	12.40	14.80
DE	WHI0116	WEC	53	6.79	8.59	9.93	9.97	11.20	13.00
US S	07049050∞	WEC	1563	4.10	7.80	9.50	9.52	11.10	15.00

WEC War Eagle Creek, C ackson Creek, WC Wharton Creek, HC Holman Creek
DE re uires at least 10 samples to evaluate attainment of DO criteria DE 2022 .
∞ This is a continuous monitoring station. Statistics are calculated using reported daily median DO values.
Indicates station is located on assessment unit included on the Draft 2020 303 d List for low DO.

Table 46. Summary statistics for stream DO measurements in the Eastern Streams waterway segment from 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rg.	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
DE	WHI0225	FC	10	6.05	7.46	10.14	9.43	10.95	12.60
DE	WHI0121	KR	53	6.49	8.70	10.40	10.21	11.70	13.80
DE	WHI0123	KR	51	7.15	9.05	10.30	10.23	11.45	13.20
DE	WHI0230	KC	11	8.58	9.10	9.68	9.69	10.25	10.80
DE	WHI0129	OC	11	6.62	7.94	9.21	9.27	10.60	12.00
DE	WHI0068	OC	44	6.32	8.32	10.30	9.69	11.00	13.50
DE	WHI0069	OC	49	6.34	8.16	10.30	9.78	11.10	13.50
DE	WHI0009	KR	49	6.46	8.13	10.10	9.64	10.80	13.40
US S	07053250	C	2	12.10	12.20	12.30	12.30	12.40	12.50
DE	WHI0232	TC	9	6.64	8.38	9.63	9.84	11.00	12.40
DE	WHI0071	LC	49	6.97	9.46	10.60	10.35	11.30	13.10

FC Felkins Creek, KR Kings River, KC Kenner Creek, OC Osage Creek, C ocum Creek, LC Long Creek
DE re uires at least 10 samples to evaluate attainment of DO criteria DE 2022 .
Indicates station is located on assessment unit included on both pproved 2018 and Draft 2020 303 d Lists for low DO.

Table 47. Summary statistics for reservoir DO measurements from stations in Lake Se uoyah, Lake Wilson, and Beaver Lake during 2018-2022 stations listed in downstream order .

rg.	Station D	La e D	Sa le Location	o. of easures	in alue, g/L	25th Percentile g/L	edian, g/L	ean, g/L	75th Percentile , g/L	a alue, g/L
DE	LWHI009	LS	Epilimnion	7	6.12	6.38	6.72	9.43	11.95	16.50
DE	LWHI014	LW	Epilimnion	12	6.38	8.31	9.19	9.37	10.45	11.80
US S	07048910	BL	Epilimnion	22	5.20	7.00	8.50	8.67	10.25	12.30
DE	LWHI013B	BL	Epilimnion	5	8.00	8.82	9.96	10.02	11.60	11.70
US S	07049160	BL	Epilimnion	22	3.95	5.49	6.50	7.29	9.21	11.73
US S	07049187	BL	Epilimnion	9	7.47	8.50	9.48	9.26	9.83	10.87
US S	07049200	BL	Epilimnion	22	5.95	7.72	8.95	8.89	9.73	12.50
DE	LWHI013C[b]	BL	Epilimnion	4	8.30	8.72	9.26	9.41	9.95	10.80
US S	07049500[b]	BL	Epilimnion	22	7.45	8.38	9.00	9.28	10.24	11.85
DE	LWHI013	BL	Epilimnion	5	7.90	7.50	8.25	9.03	9.41	11.10
US S	07049690	BL	Epilimnion	31	7.60	8.10	8.45	8.81	9.40	11.30

Stations in this table with the same superscript letter are at the same location.
LS Lake Se uoyah, LW Lake Wilson, BL Beaver Lake
DE re uires at least 10 samples to evaluate attainment of DO criteria DE 2022 .

Figure 41 through Figure 44 show box and whisker graphs of all DO measurements from monitoring locations in the Upper White River watershed with more than 10 measurements during the period 2018-2022. The median DO concentration for the White River downstream of the Beaver Lake dam 07049691 is statistically significantly lower than the median DO concentrations at the rest of the stream stations, as well as the reservoir stations. This is because of the influence of releases from Beaver Lake.

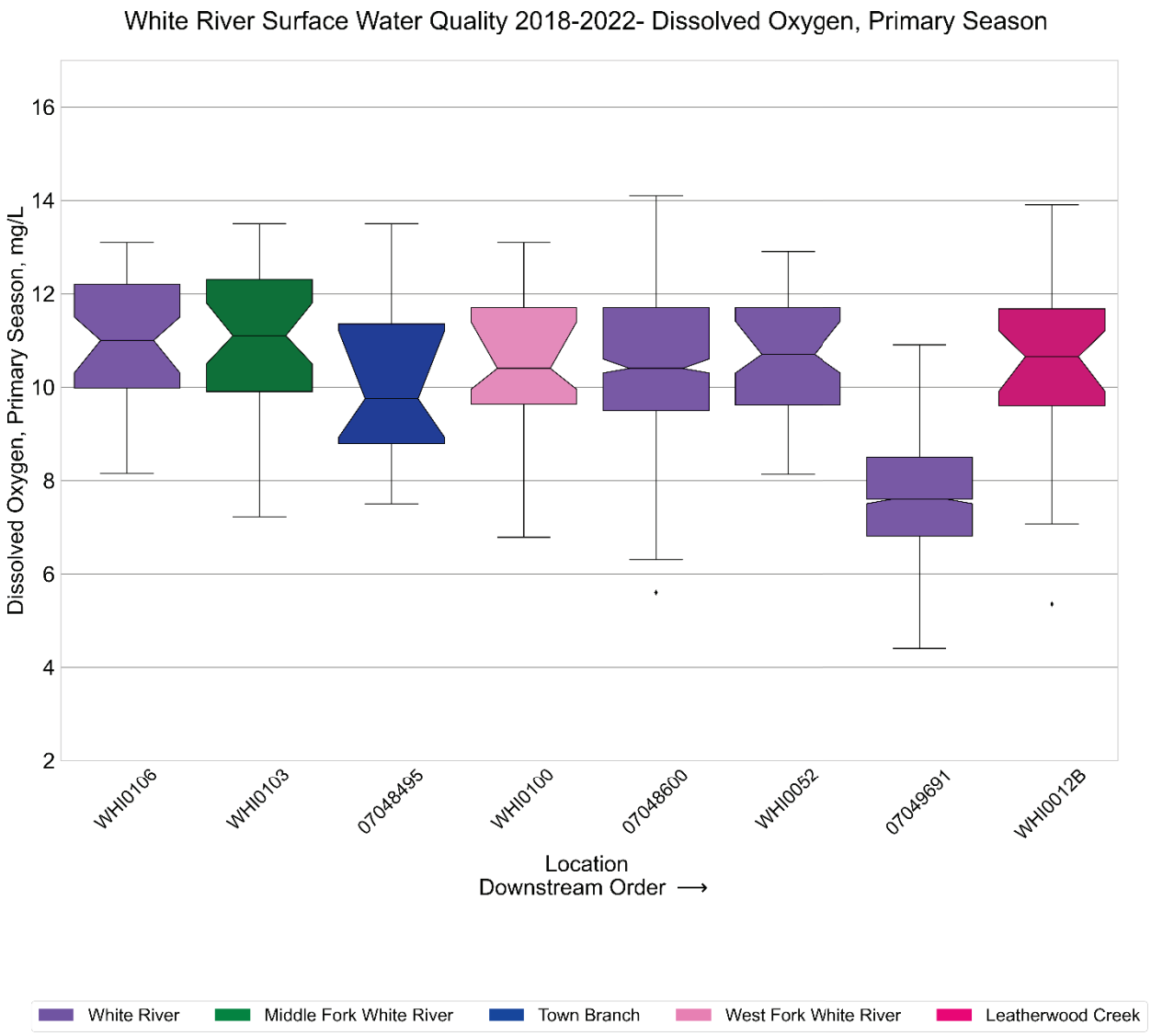


Figure 41. Box and whisker graph of DO measurements from White River Streams with more than 10 values from 2018-2022. ot that stations WHI0052 and 07048700 are at the same location on the White River.

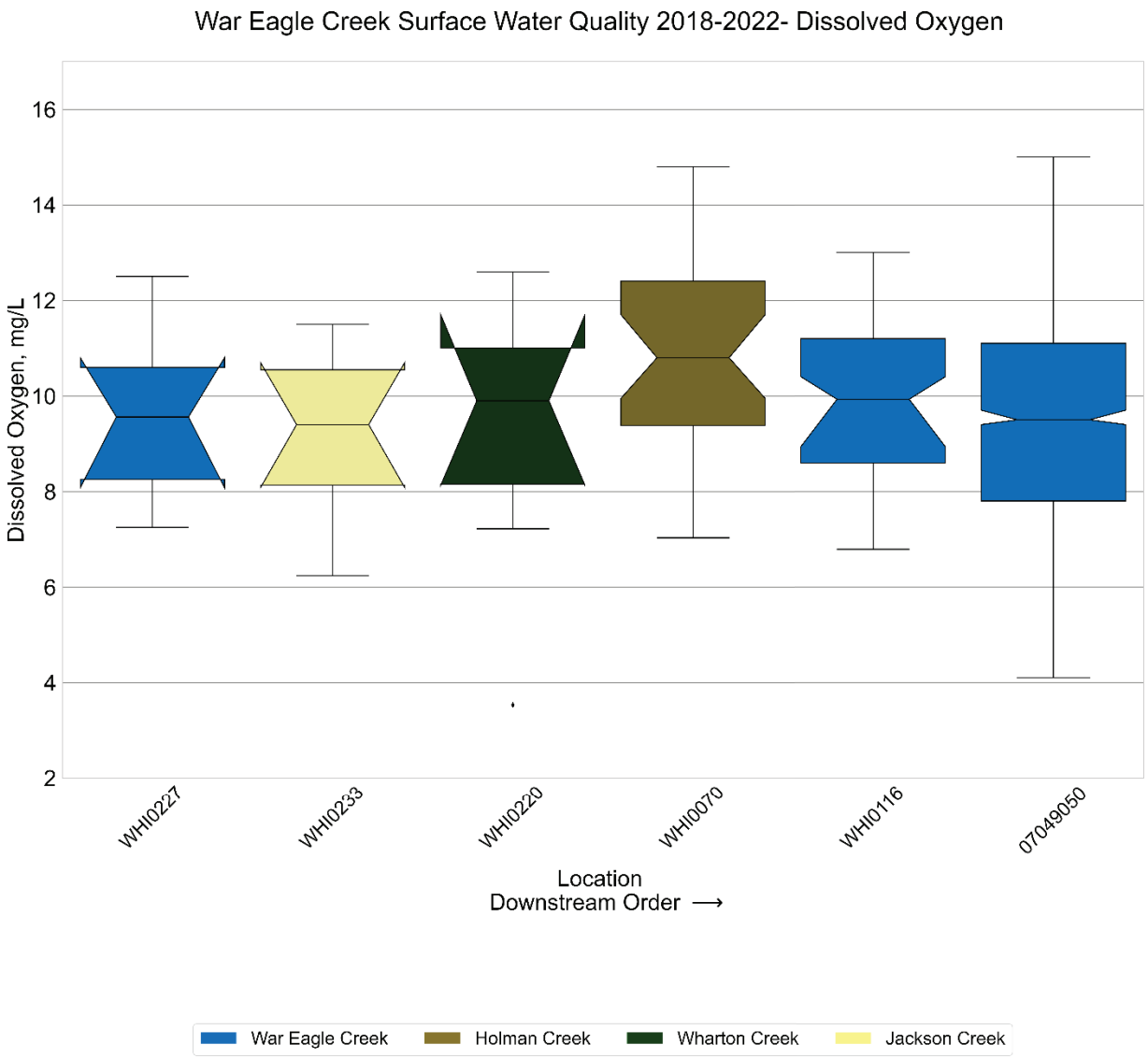


Figure 42. Box and whisker graph of DO measurements from War Eagle Creek with more than 10 values from 2018-2022.

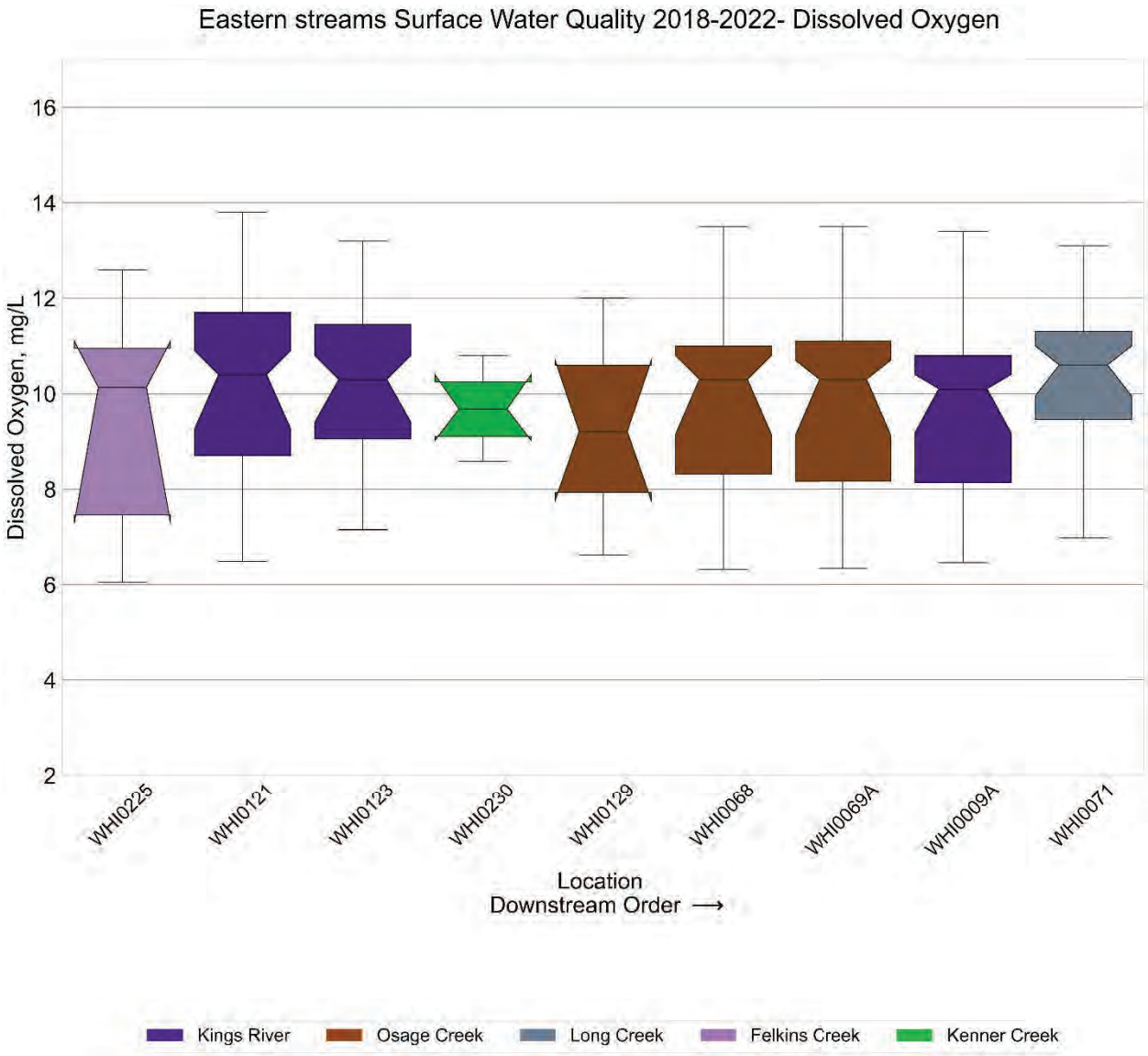


Figure 43. Box and whisker graph of DO measurements from Eastern Streams with more than 10 values from 2018-2022.

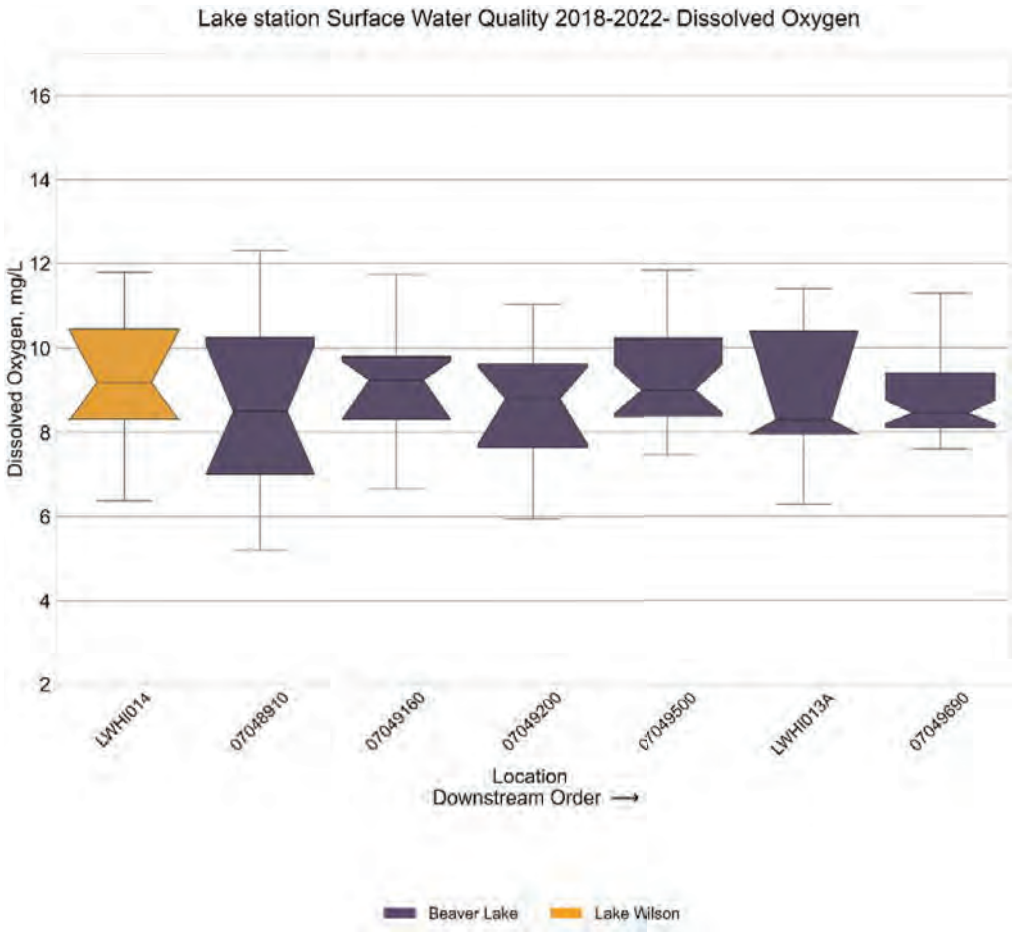


Figure 44. Box and whisker graph of DO measurements from Lake Stations with more than 10 values from 2018-2022.

PCEC Rule 2.505 defines separate numeric criteria that are used to evaluate stream DO conditions during the Primary Season when water temperature is 22 C or less, usually miC-September to miC-May , and during the Critical Season when water temperature is greater than 22 C, usually miC-May to miC-September PCEC, 2022 . Seasonal DO conditions are discussed in two subsections below. To determine DO impairment of stream water uality, DE re uires at least 10 measurements over two primary or critical seasons. To determine DO impairment of reservoir water uality, DE re uires at least 10 measurements over at least three years. Locations where more than 10% of at least 10 measurements do not meet DO criteria may be classified as impaired DE 2019 .

1.6.1 Primary Season

The Primary Season for DO water uality criteria is characteri ed by lower water temperatures less than 22° C and higher flows. DO concentrations are usually naturally higher during this season.

Table 48 through Table 52 list summary statistics for stream DO measurements from the Primary Season in 2018-2022. Included in the tables are listings of the number and percentage of Primary Season DO measurements from 2018-2022 that are lower than the Primary Season DO criteria that apply in the Upper White River watersheds 6 mg/L for O ark Highlands and Boston Mountains ecoregions 5 mg/L for reservoirs . Beaver Lake has one station where one epilimnion DO measurement did not meet the criterion. Only three stream stations had DO measurements below the Primary Season criterion, one on the White River near oshen, one below the dam on Beaver Lake, and one on Leatherwood Creek see Table 48 . Only the station on Leatherwood Creek is on an assessment unit currently listed as impaired because of low DO.

Table 48. Summary statistics for Primary Season DO measurements in the White River waterway segment from 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of values criterion	Percent values criterion
DE	WHI0104	WR	8	7.83	9.40	10.45	10.17	10.65	12.60	6	0	-
DE	WHI0106	WR	34	8.15	9.98	11.00	10.88	12.20	13.10	6	0	0%
DE	WHI0219	MFWR	6	7.55	9.46	10.85	10.58	11.93	12.30	6	0	-
DE	WHI0103	MFWR	37	7.22	9.92	11.20	10.94	12.35	13.50	6	0	0%
US S	07048600∞	WR	1144	5.60	9.50	10.40	10.46	11.70	14.10	6	1	1%
DE	WHI0052[a]	WR	33	8.13	9.62	10.70	10.69	11.70	12.90	6	0	0%
US S	07048700[a]	WR	9	8.60	9.00	9.60	10.24	11.40	12.60	6	2	-
DE	WHI0221	LlC	8	7.93	9.13	10.40	10.21	11.23	12.60	6	0	-
DE	WHI0231	DC	9	7.07	7.55	9.43	0.00	10.90	12.40	6	0	-
US S	07048780	RC	9	7.90	9.30	10.30	9.81	10.60	10.80	6	0	-
DE	WHI0110	RC	8	7.85	9.60	10.30	10.34	11.25	13.10	6	0	-
US S	07049691∞	WR	911	4.40	6.80	7.60	7.65	8.50	10.90	6	86	9%
DE	WHI0012B	LwC	40	5.35	9.60	10.65	10.43	11.68	13.90	6	1	3%

Stations in this table with the same superscript letter are at the same location.
WR White River, MFWR Middle Fork White River, DC Drakes Creek, LlC Lollars Creek, RC Richland Creek, LwC Leatherwood Creek
DE re uires at least 10 samples over 2 primary seasons to evaluate attainment of DO criteria DE 2022
∞ This is a continuous monitoring station. Statistics are calculated using reported daily median DO values.
Indicates station is located on an assessment unit included on both pproved 2018 and Draft 2020 303 d Lists for low DO.

Table 49. Summary statistics for Primary Season DO measurements in the West Fork White River waterway segment from 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of values criterion	Percent values criterion
DE	WHI0229	WFWR	6	9.14	10.30	11.15	10.94	11.78	12.20	6	0	-
DE	WHI0223	TB	7	8.83	9.67	10.20	11.05	12.30	14.40	6	0	-
US S	07048495	TB	18	8.10	9.20	9.80	10.36	11.50	13.50	6	0	0%
DE	WHI0100	WFWR	35	6.78	9.63	10.40	10.36	11.70	13.10	6	0	0%
US S	07048550	WFWR	5	9.00	9.20	10.30	9.88	10.40	10.50	6	0	-

WFWR West Fork White River, TB Town Branch
DE re uires at least 10 samples over 2 primary seasons to evaluate attainment of DO criteria DE 2022 .

Table 50. Summary statistics for Primary Season DO measurements in the War Eagle Creek waterway segment from 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of values	Percent values criterion
DE	WHI0227	WEC	8	8.42	9.29	10.30	10.21	10.93	12.50	6	0	-
DE	WHI0233	C	8	6.61	9.21	10.30	9.86	10.88	11.50	6	0	-
DE	WHI0220	WC	7	7.22	10.05	10.30	10.57	11.90	12.60	6	1	-
DE	WHI0070	HC	34	9.15	10.80	12.00	12.00	13.10	14.80	6	0	0%
DE	WHI0116	WEC	35	7.89	9.93	10.70	10.80	12.10	13.00	6	0	0%
US S	07049050∞	WEC	1096	4.10	9.40	10.40	10.44	11.50	15.00	6	0	0%

WEC War Eagle Creek, C ackson Creek, WC Wharton Creek, HC Holman Creek
DE re uires at least 10 samples over 2 primary seasons to evaluate attainment of DO criteria DE 2022 .
∞ This is a continuous monitoring station. Statistics are calculated using reported daily median DO values.

Table 51. Summary statistics for Primary Season DO measurements in the Eastern Streams waterway segment from 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of values criterion	Percent values
DE	WHI0225	FC	6	9.87	10.43	10.80	10.98	11.33	12.60	6	0	-
DE	WHI0121	KR	34	7.93	10.53	11.35	11.25	12.28	13.80	6	0	0%
DE	WHI0123	KR	32	8.57	10.38	11.05	11.14	12.40	13.20	6	0	0%
DE	WHI0230	KC	10	8.58	9.06	9.64	9.67	10.33	10.80	6	0	0%
DE	WHI0129	OC	8	7.27	9.03	10.05	9.94	10.95	12.00	6	0	-
DE	WHI0068	OC	31	7.24	9.72	10.80	10.53	11.15	13.50	6	0	0%
DE	WHI0069	OC	36	8.01	9.98	10.70	10.67	11.45	13.50	6	0	0%
DE	WHI0009	KR	35	7.50	9.80	10.40	10.40	11.20	13.40	6	0	0%
US S	07053250	C	2	12.10	12.20	12.30	12.30	12.40	12.50	6	0	-
DE	WHI0232	TC	6	9.24	9.92	10.90	10.88	11.90	12.40	6	0	-
DE	WHI0071	LC	37	6.97	9.95	10.80	10.72	11.50	13.10	6	0	0%

FC Felkins Creek, KR Kings River, KC Kenner Creek, OC Osage Creek, C ocum Creek, TC Terrapin Creek, LC Long Creek

DE re uires at least 10 samples over 2 primary seasons to evaluate attainment of DO criteria DE 2022 .

Indicates station is located on an assessment unit included on both pproved 2018 and Draft 2020 303 d Lists for low DO.

Table 52. Summary statistics for reservoir Primary Season DO measurements from stations in Lake Se uoyah, Lake Wilson, and Beaver Lake during 2018-2022 stations listed in downstream order .

rgani ation	Station D	La e D	Sa le Location	o. of easures	in alue, g/L	25th Percentile g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a alue, g/L	Criteria, g/L	u ber of values criterion	Percent values criterion
DE	LWHI009	LS	Epilimnion	4	6.12	9.11	11.95	11.63	14.48	16.50	5	0	-
DE	LWHI014	LW	Epilimnion	8	6.38	8.94	9.37	9.42	10.45	11.80	5	0	-
US S	07048910	BL	Epilimnion	11	5.20	7.80	10.30	9.72	10.90	12.30	5	0	0%
DE	LWHI013B	BL	Epilimnion	2	11.60	11.63	11.65	11.65	11.68	11.70	5	0	-
US S	07049160	BL	Epilimnion	16	3.95	5.27	6.43	7.14	9.22	11.73	5	2	13%
US S	07049187	BL	Epilimnion	4	9.70	9.73	10.12	10.20	10.75	10.87	5	0	-
US S	07049200	BL	Epilimnion	10	6.05	7.75	9.60	9.30	10.59	12.50	5	0	0%
DE	LWHI013C[b]	BL	Epilimnion	2	9.66	9.95	10.23	10.23	10.52	10.80	5	0	-
US S	07049500[b]	BL	Epilimnion	10	7.45	8.96	9.55	9.80	11.10	11.85	5	0	0%
DE	LWHI013	BL	Epilimnion	3	6.61	7.28	7.95	8.46	9.39	10.83	5	0	-
US S	07049690	BL	Epilimnion	14	8.30	8.56	9.60	9.62	10.63	11.30	5	0	0%

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

LS Lake Se uoyah, LW Lake Wilson, BL Beaver Lake

DE re uires at least 10 samples over three years to evaluate attainment of DO criteria DE 2022 .

Figures 42-44 show box and whisker graphs of Primary Season DO measurements from stream stations in the Upper White River watershed with more than 10 Primary Season measurements during 2018-2022. The lowest Primary Season median DO value is from the White River downstream of Beaver Lake dam 07049691 . This median value is statistically significantly lower than median values for the rest of the stream stations, and all but one reservoir station 07049160 . The DO concentrations at station 07049691 reflect the influence of releases from Beaver Lake. lthough Beaver Lake releases are managed to support the tailwater trout fishery, DO concentrations below the Primary Season criterion have been measured at station 07049691.

The next lowest stream median Primary Season DO concentration is from Kenner Creek, in the Osage Creek headwaters. The median DO concentration from this station is statistically significantly lower than the median DO concentration at a number of the other stream stations. However, all the Primary Season DO measurements from Kenner Creek meet the Primary Season DO criterion.

Interestingly, the highest median DO value is from Holman Creek, which is influenced by discharge from the Huntsville wastewater treatment plant. This median value is not statistically different from median values at most of the other stream stations.

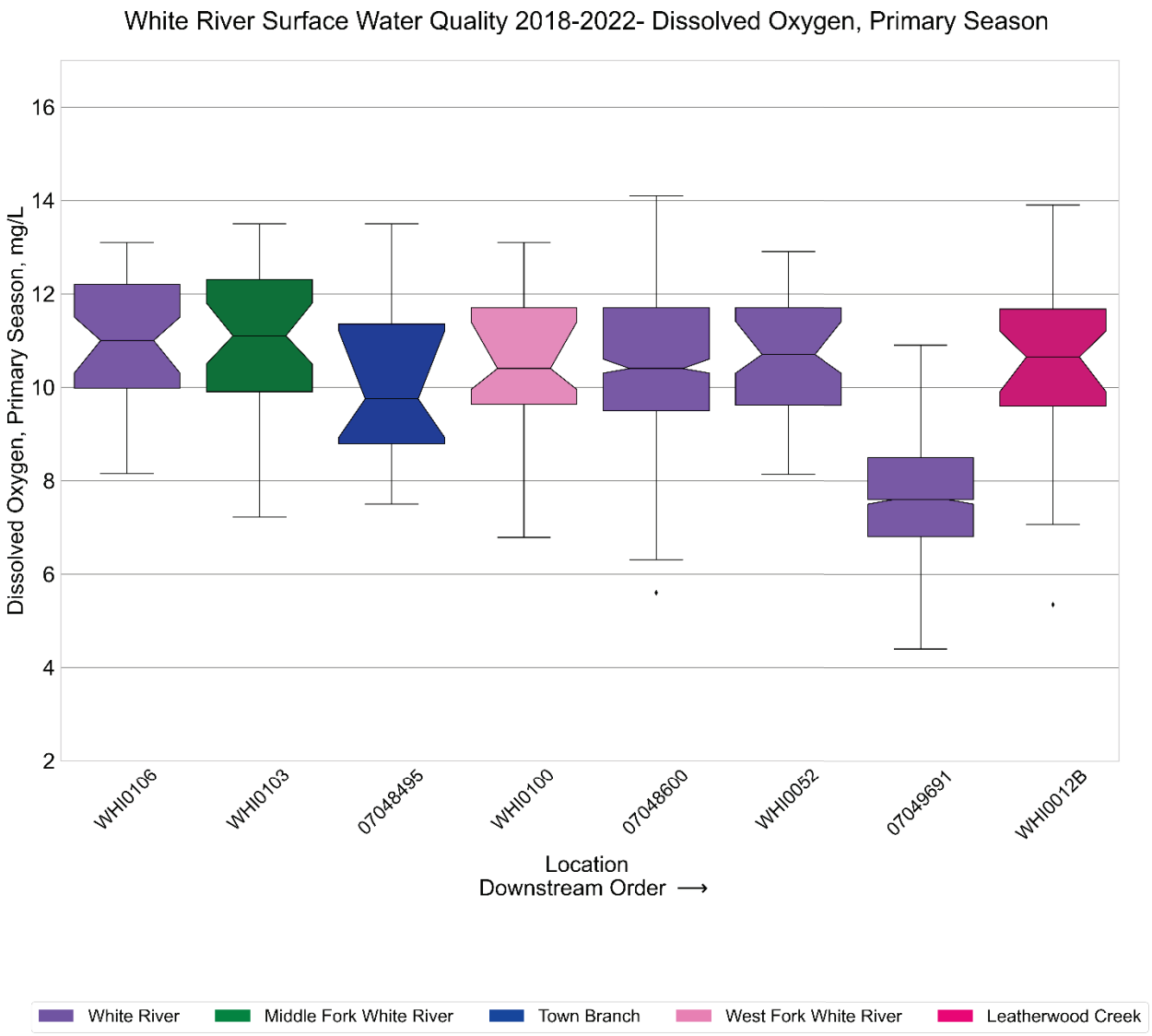


Figure 45. Box and whisker graph of Primary Season DO measurements from White River stations and its tributaries with more than 10 values from 2018-2022.

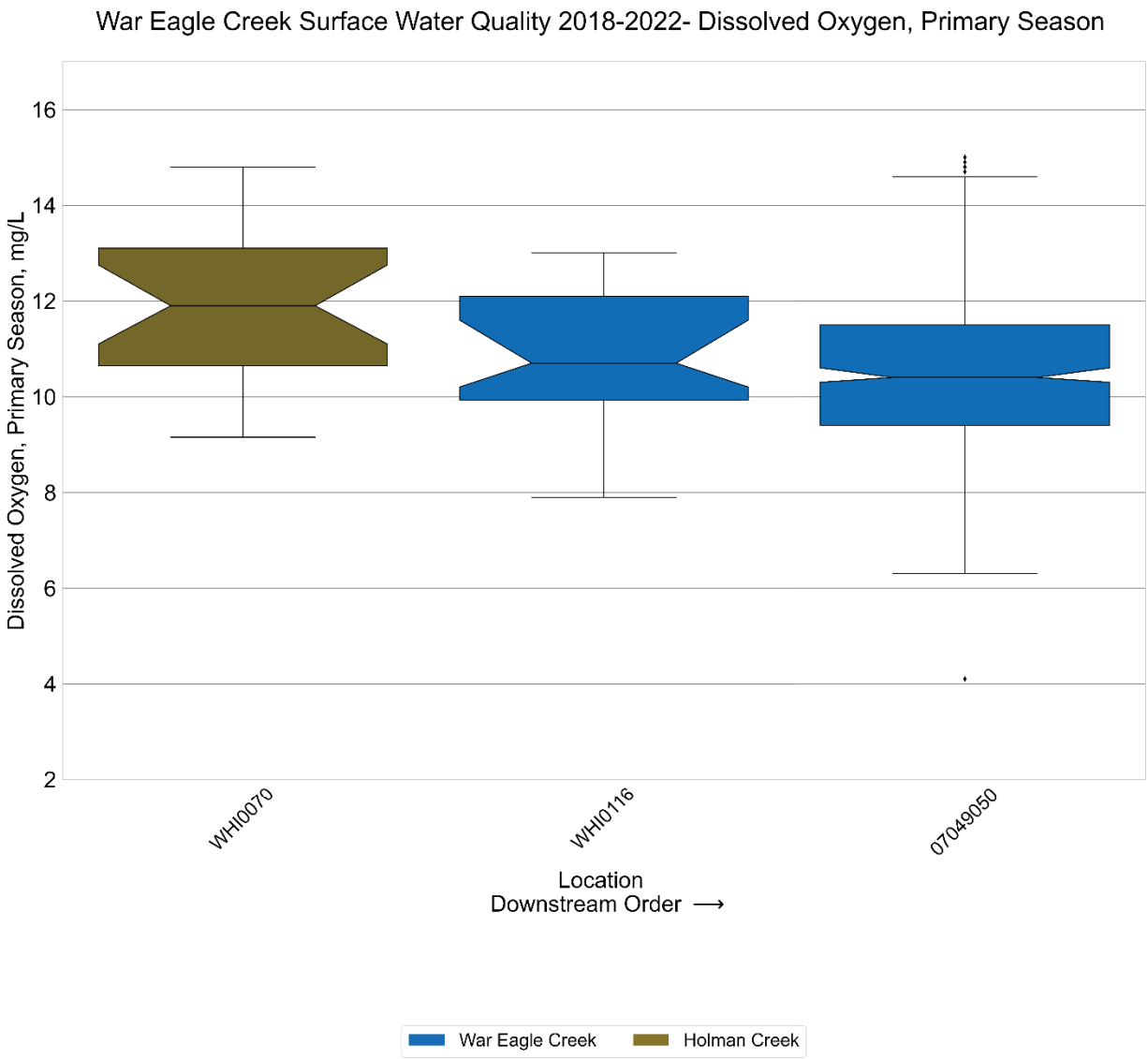


Figure 46. Box and whisker graph of Primary Season DO measurements from War Eagle Creek with more than 10 values from 2018-2022.

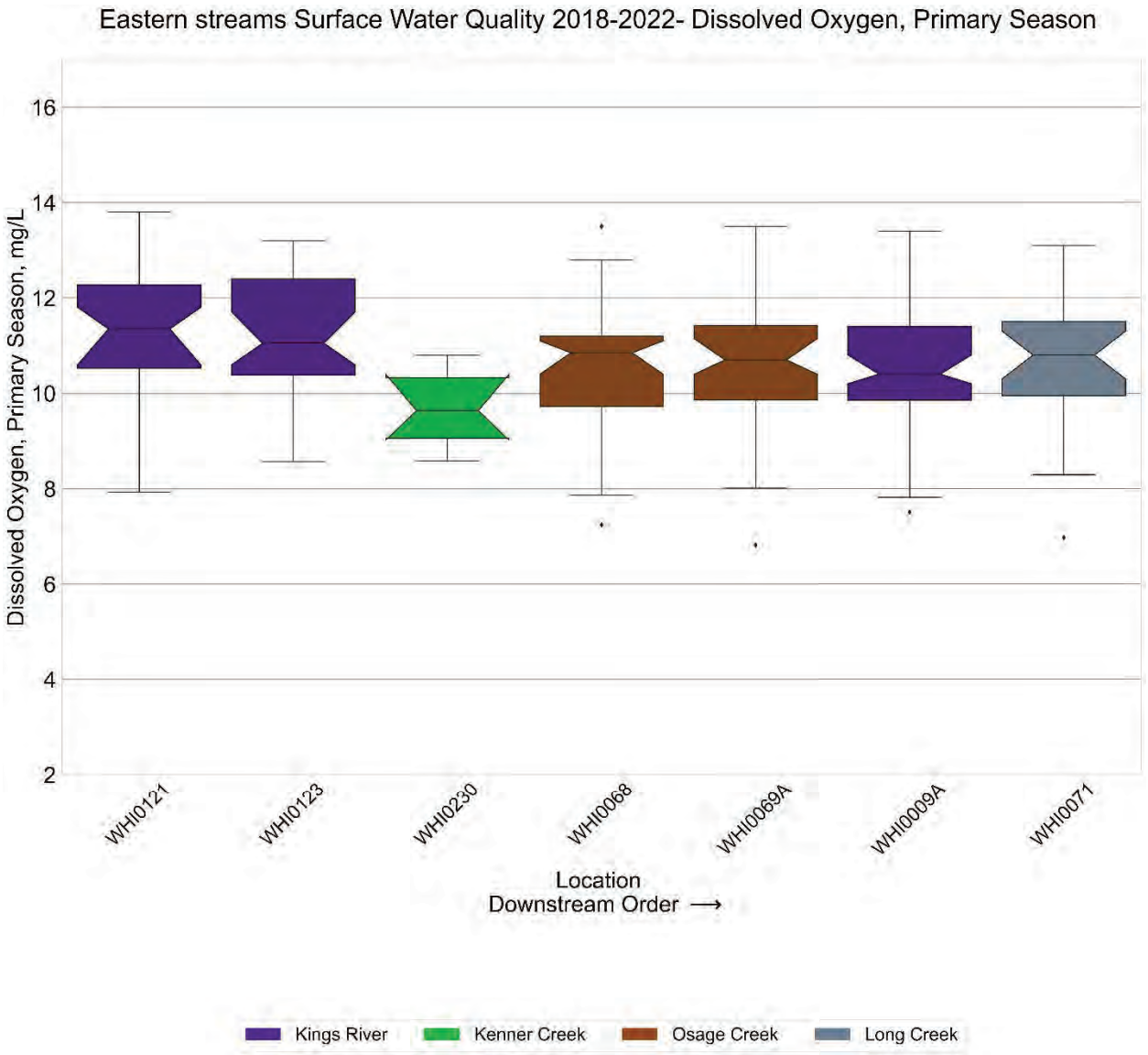


Figure 47. Box and whisker graph of Primary Season DO measurements from Eastern Stream stations with more than 10 values from 2018-2022.

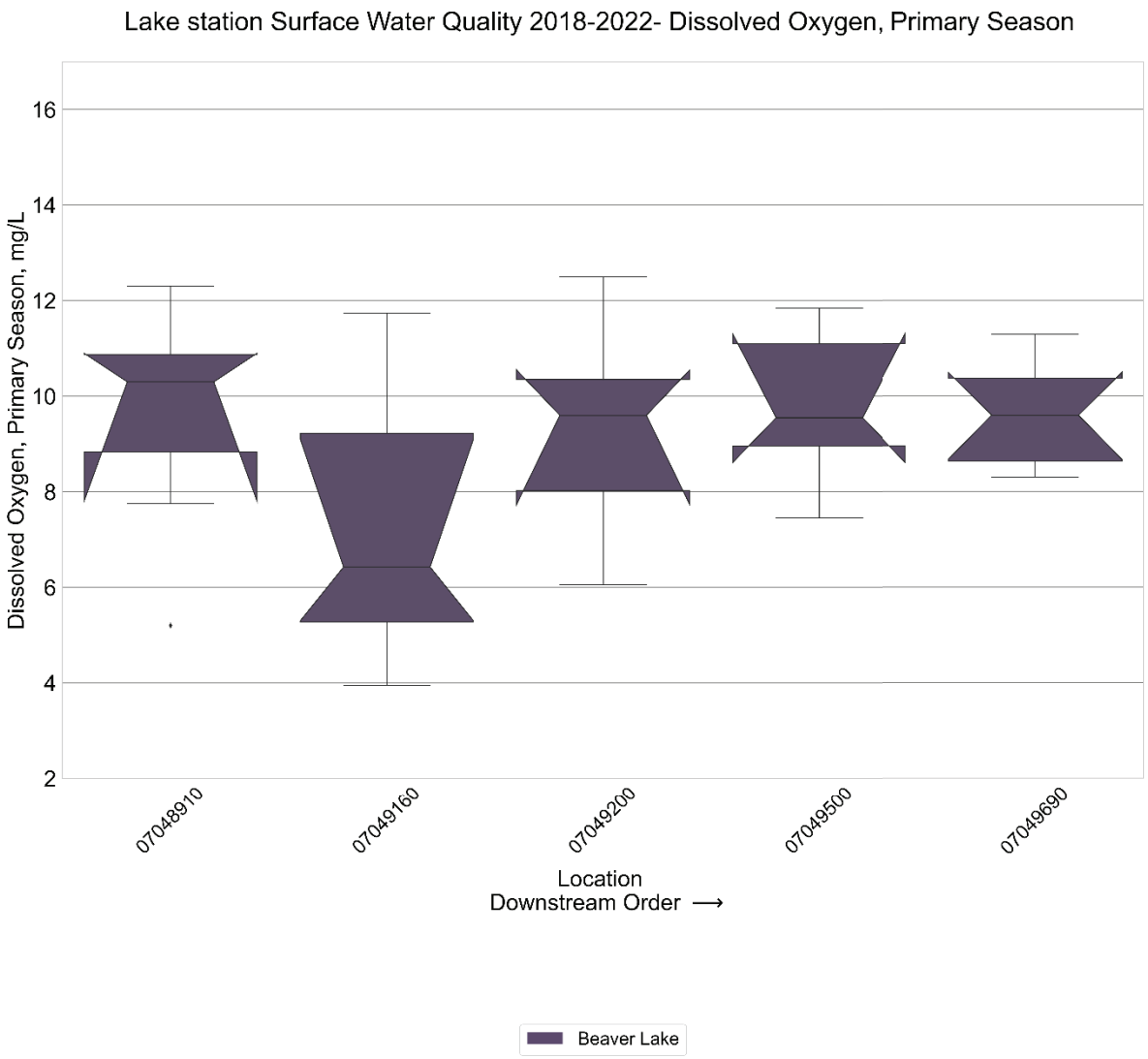


Figure 48. Box and whisker graph of Primary Season DO measurements from Lake Stations with more than 10 values from 2018-2022.

1.6.2 Critical Season

The Critical Season for DO water uality criteria is characteri ed by higher temperatures greater than 22°C and lower flows. DO concentrations naturally tend to be lower during this season. Table 53 through Table 56 list summary statistics for stream DO measurements from the Critical Season, 2018-2022. Table 57 lists summary statistics for reservoir epilimnion DO measurements from the Critical Season, 2018-2022. Included in the tables are listings of the number and percentage of Critical Season DO measurements from 2018-2022 that are lower than the Critical Season DO criteria for Upper White River watershed streams. Several stream assessment units in the Upper White River watershed are listed as impaired by low DO by DE . Water uality monitoring stations on these assessment units are highlighted in the tables below. Three stream stations with at least 10 measurements had one or more reported measurements lower than the applicable DO criterion. These stations are located on assessment units listed as impaired because of low Critical Season DO. ll but one Critical Season reservoir epilimnion DO measurements met the criterion Table 57 .

Table 53. Summary statistics for Critical Season DO measurements in the White River waterway segment from 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of values criterion	Percent values criterion
DE	WHI0104	WR	3	7.26	7.36	7.46	7.67	7.88	8.30	6	0	-
DE	WHI0106	WR	17	6.80	7.40	8.33	8.10	8.52	9.45	6	0	0%
DE	WHI0219	MFWR	5	5.44	6.68	8.17	7.97	9.16	9.68	6	1	-
DE	WHI0103	MFWR	16	5.80	6.85	7.11	7.40	8.18	9.47	6	2	13%
US S	07048600∞	WR	601	5.40	6.50	6.90	6.98	7.40	10.30	6	22	4%
DE	WHI0052[b]	WR	20	6.05	7.62	8.03	8.34	8.95	12.70	6	0	0%
US S	07048700[b]	WR	10	5.54	6.99	7.55	7.48	8.25	9.00	6	2	20%
DE	WHI0221	LlC	3	7.71	7.72	7.73	7.85	7.92	8.10	6	0	-
DE	WHI0231	DC	2	7.81	/	7.96	7.96	/	8.10	6	0	-
US S	07048780	RC	3	9.30	9.70	10.10	10.43	11.00	11.90	6	0	-
DE	WHI0110	RC	3	6.72	7.41	8.10	7.70	8.19	8.27	6	0	-
DE	WHI0012B	LwC	4	6.31	6.62	7.31	7.27	7.97	8.16	6	0	-

Stations in this table with the same superscript letter are at the same location.
WR White River, MFWR Middle Fork White River, DC Drakes Creek, LlC Lollars Creek, RC Richland Creek, LwC Leatherwood Creek
DE re uires at least 10 samples over 2 primary seasons to evaluate attainment of DO criteria DE 2022 .
∞ This is a continuous monitoring station. Statistics are calculated using reported daily median DO values.
Indicates station is located on an assessment unit included on both pproved 2018 and Draft 2020 303 d Lists for low DO.
Indicates station is located on an assessment unit included on Draft 2020 303 d List for low DO in the critical season.

Table 54. Summary statistics for Critical Season DO measurements in the West Fork White River waterway segment from 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of values criterion	Percent values criterion
DE	WHI0229	WFWR	5	7.26	8.17	9.25	178.00	9.53	856.00	6	0	-
DE	WHI0223	TB	4	6.02	7.30	7.77	7.59	8.06	8.79	6	0	-
US S	07048495	TB	6	6.50	6.85	7.00	7.01	7.20	7.50	6	0	-
DE	WHI0100	WFWR	18	5.49	6.78	6.99	7.07	7.76	7.95	6	2	11%
US S	07048550[c]	WFWR	1	7.10	7.10	7.10	/	7.10	7.10	6	0	-

Stations in this table with the same superscript letter are at the same location.
WFWR West Fork White River, TB Town Branch
DE re uires at least 10 samples over 2 primary seasons to evaluate attainment of DO criteria DE 2022 .
Indicates station is located on an assessment unit included on both pproved 2018 and Draft 2020 303 d Lists for low DO.
Indicates station is located on an assessment unit included on Draft 2020 303 d List for low DO in the critical season.

Table 55. Summary statistics for Critical Season DO measurements in the War Eagle Creek waterway segment from 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of values criterion	Percent values criterion
DE	WHI0227	WEC	3	7.25	7.30	7.35	7.56	7.72	8.08	6	0	-
DE	WHI0233	C	3	6.24	7.16	8.08	7.50	8.14	8.19	6	0	-
DE	WHI0220	WC	4	3.53	6.98	8.16	7.26	8.43	9.19	6	1	-
DE	WHI0070	HC	19	7.03	8.60	9.26	9.18	9.65	11.00	6	0	0%
DE	WHI0116	WEC	18	6.79	7.90	8.23	8.35	8.93	10.40	6	0	0%
US S	7049050∞	WEC	467	5.10	6.90	7.30	7.37	7.70	10.00	6	0	-

WEC War Eagle Creek, C ackson Creek, WC Wharton Creek, HC Holman Creek
DE re uires at least 10 samples over 2 primary seasons to evaluate attainment of DO criteria DE 2022 . Daily average
US S data was used wherever available.
∞ This is a continuous monitoring station. Statistics are calculated using reported daily median DO values.
Indicates station is located on an assessment unit included on Draft 2020 303 d List for low DO in the critical season.

Table 56. Summary statistics for Critical Season DO measurements in the Eastern Streams waterway segment from 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of values criterion	Percent values criterion
DE	WHI0225	FC	4	6.05	6.82	7.19	7.10	7.46	7.96	6	0	-
DE	WHI0121	KR	19	6.49	7.59	8.47	8.36	9.16	10.10	6	0	0%
DE	WHI0123	KR	19	7.15	8.03	9.04	8.69	9.23	10.30	6	0	0%
DE	WHI0230	KC	1	9.91	9.91	9.91	/	9.91	9.91	6	0	-
DE	WHI0129	OC	3	6.62	7.19	7.76	7.50	7.94	8.11	6	0	-
DE	WHI0068	OC	13	6.32	6.80	7.30	7.70	8.55	10.40	6	0	0%
DE	WHI0069	OC	13	6.34	6.60	7.26	7.56	8.03	9.61	6	0	0%
DE	WHI0009	KR	14	6.46	6.88	7.51	7.75	8.13	10.10	6	0	0%
DE	WHI0232	TC	3	6.64	7.45	8.26	7.76	8.32	8.38	6	0	-
DE	WHI0071	LC	12	7.84	8.50	8.75	9.21	10.40	11.20	6	0	0%

FC Felkins Creek, KR Kings River, KC Kenner Creek, OC Osage Creek, TC Terrapin Creek, LC Long Creek
DE re uires at least 10 samples over 2 primary seasons to evaluate attainment of DO criteria DE 2022 .
Indicates station is located on an assessment unit included onboth pproved 2018 and Draft 2020 303 d Lists for low DO.

Table 57. Summary statistics for reservoir Critical Season DO measurements from stations in Lake Se uoyah, Lake Wilson, and Beaver Lake during 2018-2022 stations listed in downstream order .

rgani ation	Station D	La e D	Sa le Location	o. of	in alue, g/L	25th Percentile g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a alue, g/L	Criteria, g/L	u ber of	Percent values criterion
DE	LWHI009	LS	Epilimnion	3	6.26	6.38	6.50	6.49	6.61	6.72	5	0	-
DE	LWHI014	LW	Epilimnion	4	8.05	8.26	8.74	9.28	9.76	11.60	5	0	-
US S	07048910	BL	Epilimnion	11	6.10	6.68	7.00	7.61	8.50	10.05	5	0	0%
DE	LWHI013B	BL	Epilimnion	3	8.00	8.41	8.82	8.93	9.39	9.96	5	0	-
US S	07049160	BL	Epilimnion	6	4.62	6.40	7.40	7.68	9.03	10.99	5	1	-
US S	7049187	BL	Epilimnion	5	7.47	8.13	8.50	8.50	8.93	9.48	5	0	-
US S	07049200	BL	Epilimnion	12	5.95	7.58	8.78	8.55	9.40	11.03	5	0	0%
DE	LWHI013C[d]	BL	Epilimnion	2	8.30	8.44	8.58	8.58	8.72	8.86	5	0	-
US S	07049500[d]	BL	Epilimnion	12	7.50	8.24	8.60	8.84	8.95	11.70	5	0	0%
DE	LWHI013	BL	Epilimnion	2	8.21	8.25	8.29	8.29	8.33	8.37	5	0	-
US S	7049690	BL	Epilimnion	17	7.60	7.80	8.10	8.15	8.40	9.05	5	0	0%

Stations in this table with the same superscript letter are at the same location.
LS Lake Se uoyah, LW Lake Wilson, BL Beaver Lake
DE re uires at least 10 samples over three years to evaluate attainment of DO criteria DE 2022 .

The lowest median stream Critical Season DO concentration was from West Fork White River WHI0100 . Interestingly, the highest median DO concentration during Critical Season was measured from Holman Creek WHI0070 near the Huntsville WWTP, though it is not statistically higher than median DO concentrations at most of the other monitoring locations.

Figure 49 through Figure 51 show box and whisker graphs of Critical Season DO measurements from stream stations in the Upper White River watershed with more than 10 Critical Season measurements during 2018-2022.

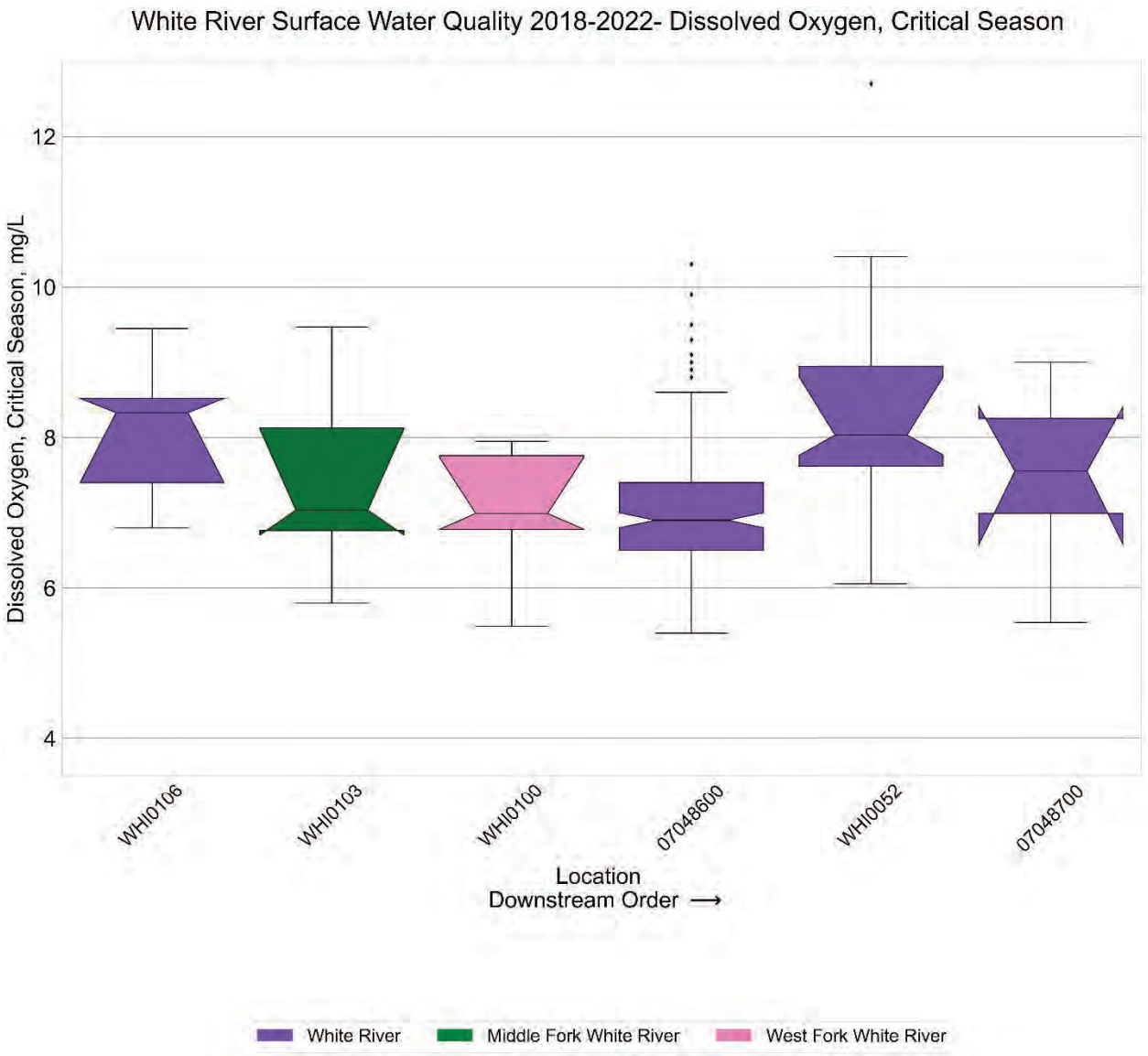


Figure 49. Box and whisker graph of Critical Season DO measurements from White River stations with more than 10 values from 2018-2022. ote that stations WHI0052 and 07048700 are at the same location on the White River.

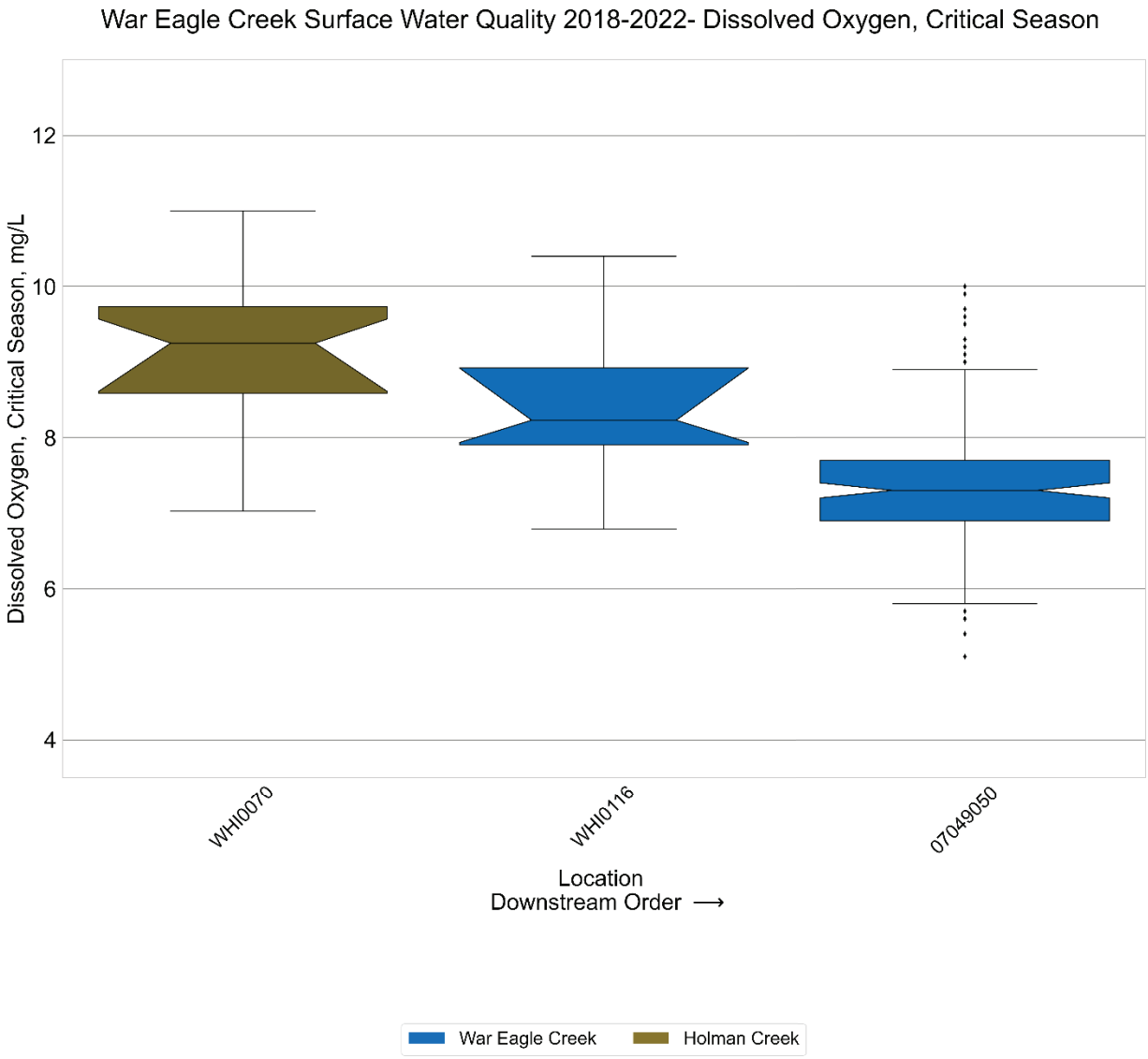
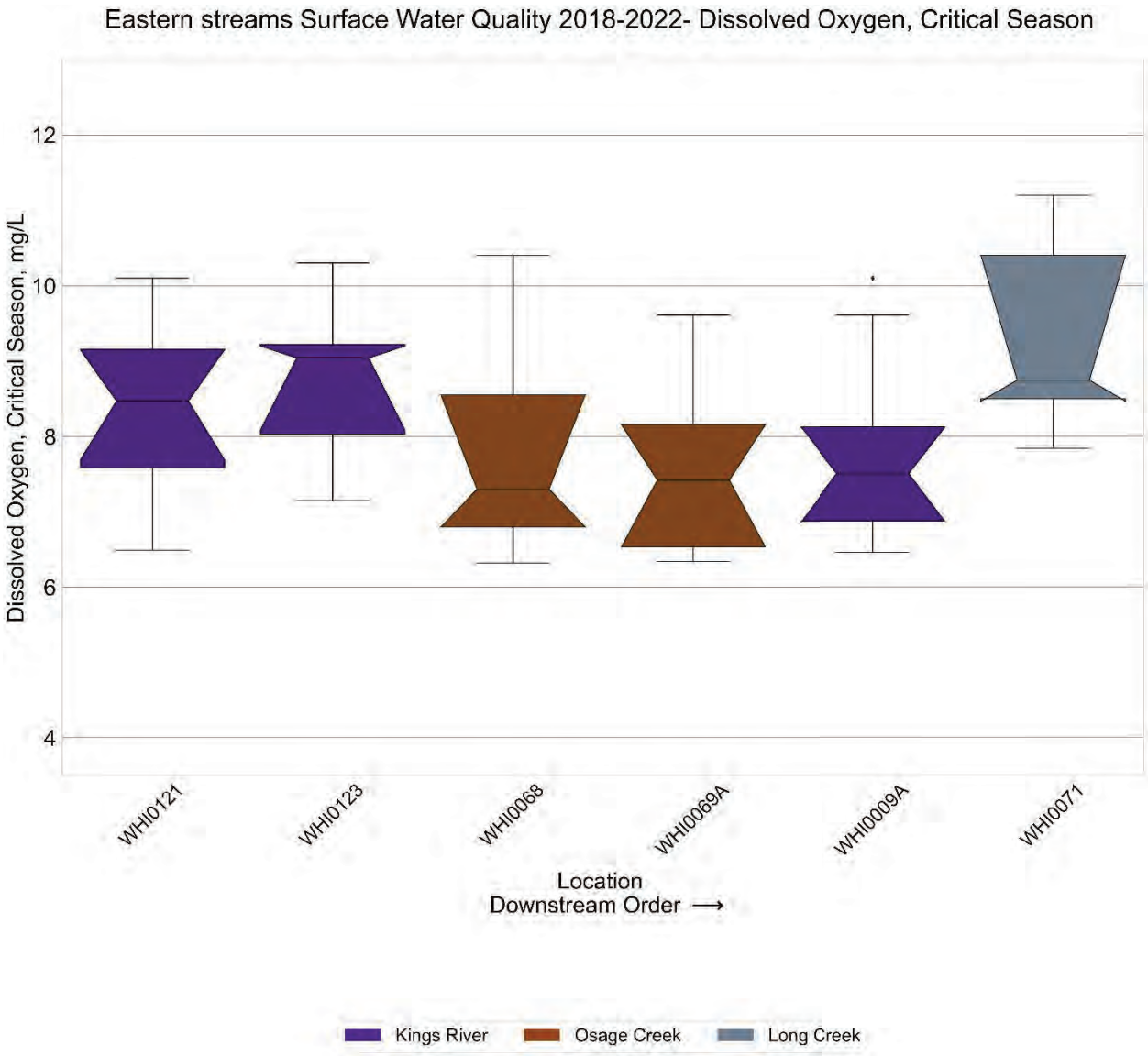


Figure 50. Box and whisker graph of Critical Season DO measurements from War Eagle Creek with more than 10 values from 2018-2022.


Eastern streams Surface Water Quality 2018-2022- Dissolved Oxygen, Critical Season
Dissolved Oxygen, Critical Season, mg/L
12
10
8
6
4
WHI0121
WHI0123
WHI0068
WHI0069A
WHI0009A
WHI0071
Location
Downstream Order ⟶
Kings River
Osage Creek
Long Creek

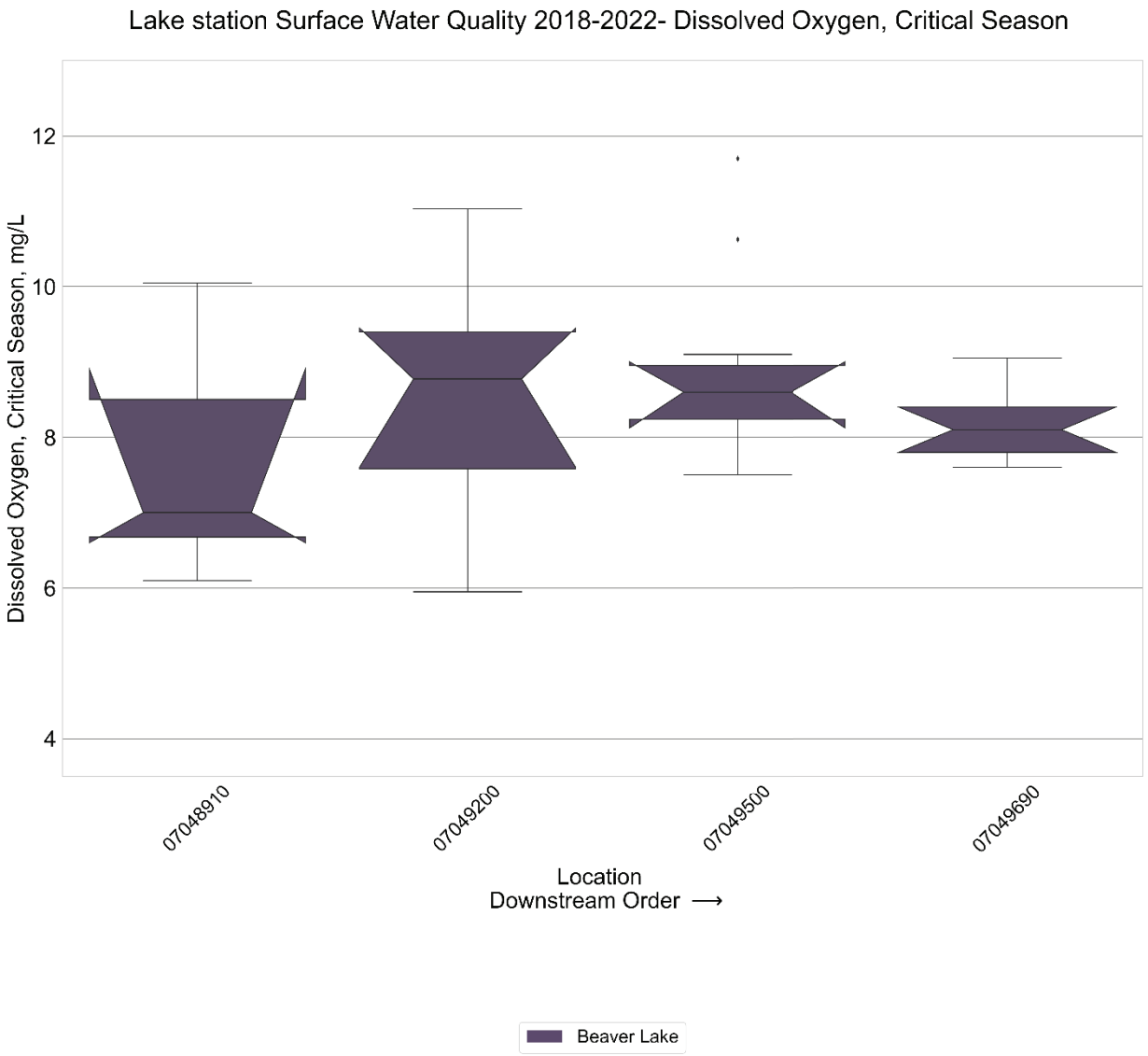


Figure 51. Box and whisker graph of Critical Season DO measurements from Eastern Stream stations with more than 10 values from 2018-2022.

1.6.3 Percent DO Saturation

Water temperature affects the ability of water to dissolve oxygen. More oxygen can be dissolved in cooler water than in warmer water, i.e., higher maximum DO concentrations are possible in cooler water than in warmer water. Percent DO saturation compares the measured DO concentration to the maximum possible DO concentration at the measured water temperature. Percent DO saturation values greater than 100% can occur during algae blooms.

Figure 52. Box and whisker graph of Critical Season DO measurements from Lake stations with more than 10 values from 2018-2022.

DE has used 125% DO saturation as a screening threshold for assessing nutrient impairment of waterbodies DE , 2016 .

Table 58 lists summary statistics for US S stream percent DO saturation measurements in the White River from the period 2018-2022. Table 59 lists summary statistics for all reservoir epilimnion percent DO saturation values from the period 2018-2022. DO saturation values greater than 125% occur in Beaver Lake. These values indicate relatively high levels of algal activity. Figure 53 is the box and whisker graph for lake stations with more than 10 measurements during 2018-2022.

Table 58. Summary statistics for stream percent DO saturation measurements in the White River to during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, %	25th Percentile, %	edian, %	ean, %	75th Percentile, %	a i u alue, %
US S	07048700	WR	6	75.3	82.4	92.7	89.7	95.8	101.8
US S	07049691	WR	2	71.0	72.0	73.0	73.0	74.0	75.0

WR White River

Table 59. Summary statistics for reservoir percent DO saturation measurements from stations in Beaver Lake during 2018-2022 stations listed in downstream order .

rgani ation	Station D	La e D	Sa le Location	o. of easures	in alue, %	25th Percentile %	edian, %	ean, %	75th Percentile, %	a alue, %
US S	07048910	BL	Epilimnion	21	57.5	86.5	93.5	96.5	99.0	134.0
US S	07049160	BL	Epilimnion	9	83.5	90.7	99.0	102.8	113.0	122.0
US S	07049187	BL	Epilimnion	22	69.0	85.8	98.8	101.2	119.9	141.5
US S	07049200	BL	Epilimnion	22	76.0	93.5	105.0	105.6	115.5	150.3
US S	07049500	BL	Epilimnion	21	57.5	86.5	93.5	96.5	99.0	134.0
US S	07049690	BL	Epilimnion	9	83.5	90.7	99.0	102.8	113.0	122.0

BL Beaver Lake

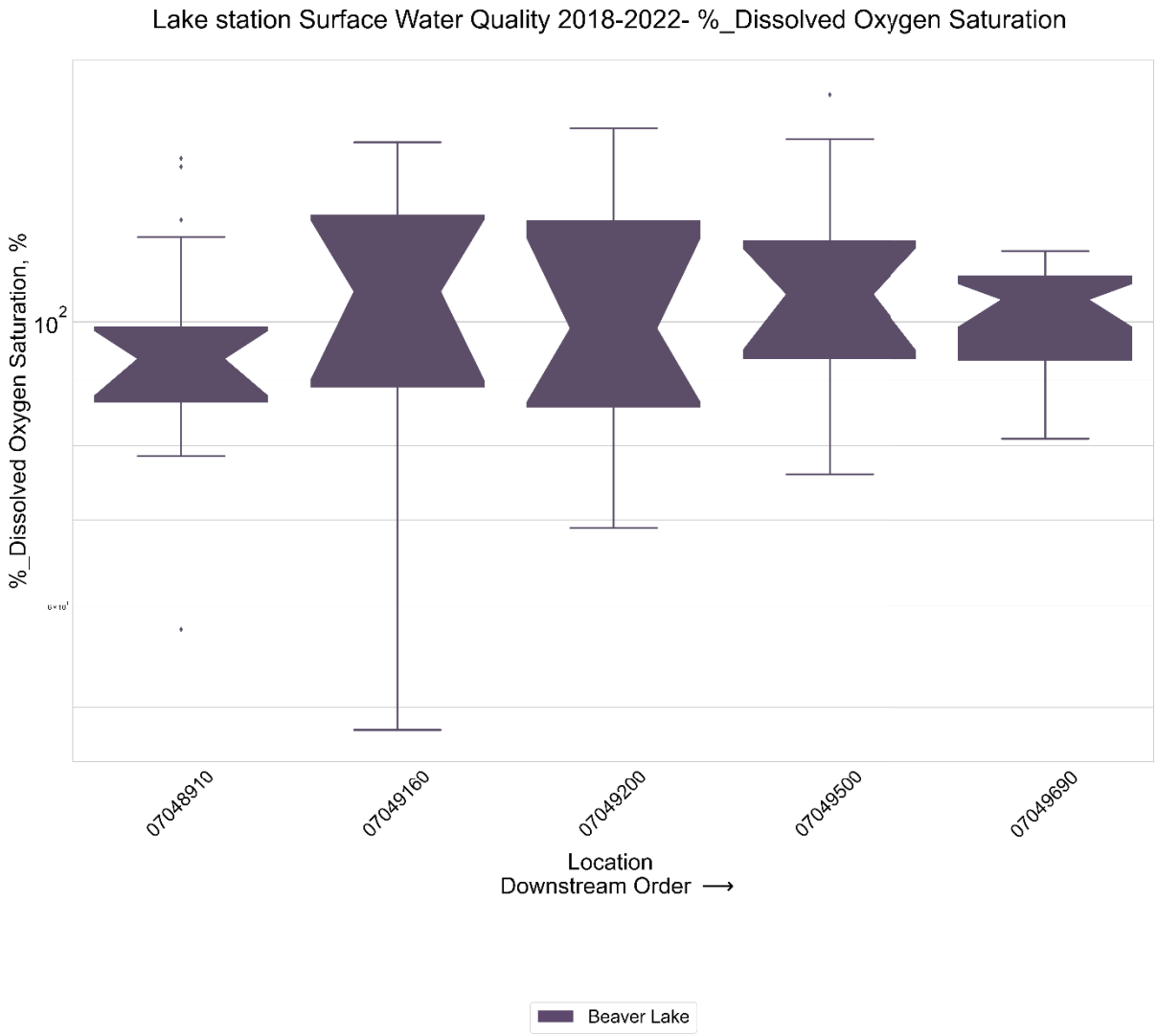


Figure 53. Box and whisker graph of Percent DO Saturation measurements from Lake stations with more than 10 values from 2018-2022.

Decomposition of large amounts of algae reduces DO levels in water. DO concentrations below the Critical Season criteria with at least 10 measurements occur at stations WHI0103 MFWR southwest of Elkins and WHI0100 WFWR on Dead Horse Mountain Rd. . Low DO levels and high percent DO saturation would suggest that algal blooms may be occurring at these locations that affect DO levels. This kind of response may be caused by excessive nutrients stimulating algal growth.

Because DE does not report percent saturation values, they were calculated for station WHI0100 and WHI0103. The 100% DO saturation value for each sampling date was calculated

using the reported water temperature degrees Celsius in the following e uation which assumes an atmospheric pressure of 760 mm Hg Exp 7.7117-1.3140 ln temperature 45.93 Munson, et al. 2017 . Percent DO saturation was calculated by dividing the reported DO concentration by the 100% DO saturation value for that date. Summary statistics for calculated percent DO saturation values from the Critical Season at selected DE stations are shown in Table 60. During the Critical Season, over 50% of DO concentrations at station WH0103 were greater than 100% 2018-2022. This suggests that low DO conditions at this station may be the result of algal blooms, although all of the calculated percent DO saturation values are lower than 125%. Only about one- uarter of Critical Season DO concentrations at station WHI0100 are greater than 100%. Therefore, algal blooms may occur less fre uently at this station.

Table 60. Summary statistics for calculated Critical Season percent DO saturation values for selected DE stations 2018-2022.

rgani ation	Station D	Strea D	u ber of easures	ini u alue, %	25th Percentile, %	edian, %	ean, %	75th Percentile, %	a i u alue, %
DE	WHI0103	MFWR	17	75	94	104	94	109	120
DE	WHI0100	WFWR	19	73	90	98	92	103	104

MFWR Middle Fork White River, WFWR West Fork White River

Table 61 lists summary statistics for calculated percent DO saturation for additional DE monitoring stations of interest. Over 75% of DO concentrations measured at WHI0070 Holman Creek and WHI0071 Long Creek represent DO saturation greater than 100%. Over 50% of DO concentrations measured at WHI0012B Leatherwood Creek represent DO saturation greater than 100%. In addition, percent DO saturation values greater than 125% have been measured at these stations. This suggests that algal blooms may occur fre uently at these locations, indicating poor water uality, even though DO concentrations meet water uality criteria.

Table 61. Summary statistics for calculated percent DO saturation for DE stations of interest, 2018-2022.

rgani ation	Station D	Strea D	u ber of easures	ini u alue, %	25th Percentile, %	edian, %	ean, %	75th Percentile, %	a i u alue, %
DE	WHI0070	HC	53	97	110	118	119	126	146
DE	WHI0012B	LwC	44	63	92	102	101	108	141
DE	WHI0071	LC	49	84	103	109	111	117	144

Biochemical Oxygen Demand

Biochemical Oxygen Demand BOD represents the amount of DO needed by aerobic microorganisms to decompose organic matter in a water sample at a specific water temperature. It is an indicator of the level of organic matter pollution in water, and the likelihood that ade uate DO levels can be maintained. BOD was measured at only three DE stations in the Upper White River watershed during 2018-2022, WHI0070 Holman Creek downstream of Huntsville , WHI0012B Leatherwood Creek downstream of Eureka Springs , and WHI0069 Osage Creek west of Pleasant alley . Summary statistics for BOD measurements at these stations are listed in Table 62. The Kaplan Meier Method KM was used to estimate statistics, including percentiles and average, using measurements below the detectable limit 0.2 mg/L . rkansas water uality regulations do not include numeric water uality criteria for BOD. Because DO and decomposition can be affected by temperature, Figure 54 shows a graph of BOD concentrations by month. In general, BOD appears to be highest in February and in late summer, peaking again in ugust. The highest maximum BOD value 2.0 mg/L occurred in Leatherwood Creek near Eureka Springs. The cause of this unusually high value is unknown. The Eureka Springs WWTP discharge is a possible source, however, there is no indication of unusually high BOD values in the WWTP discharge during the months when the stream BOD was unusually high EP Echo retrieval 10/30/2023 .

Table 62. Summary statistics for BOD values from 2018-2022.

Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
WHI0070	HC	51	0.20	0.38	0.53	0.63	0.75	1.87
WHI0012B	LwC	38	0.20	0.20	0.21	0.42	0.35	3.24
WHI0069	OC	44	0.20	0.33	0.45	0.53	0.72	1.33

HC Holman Creek, LwC Leatherwood Creek, OC Osage Creek

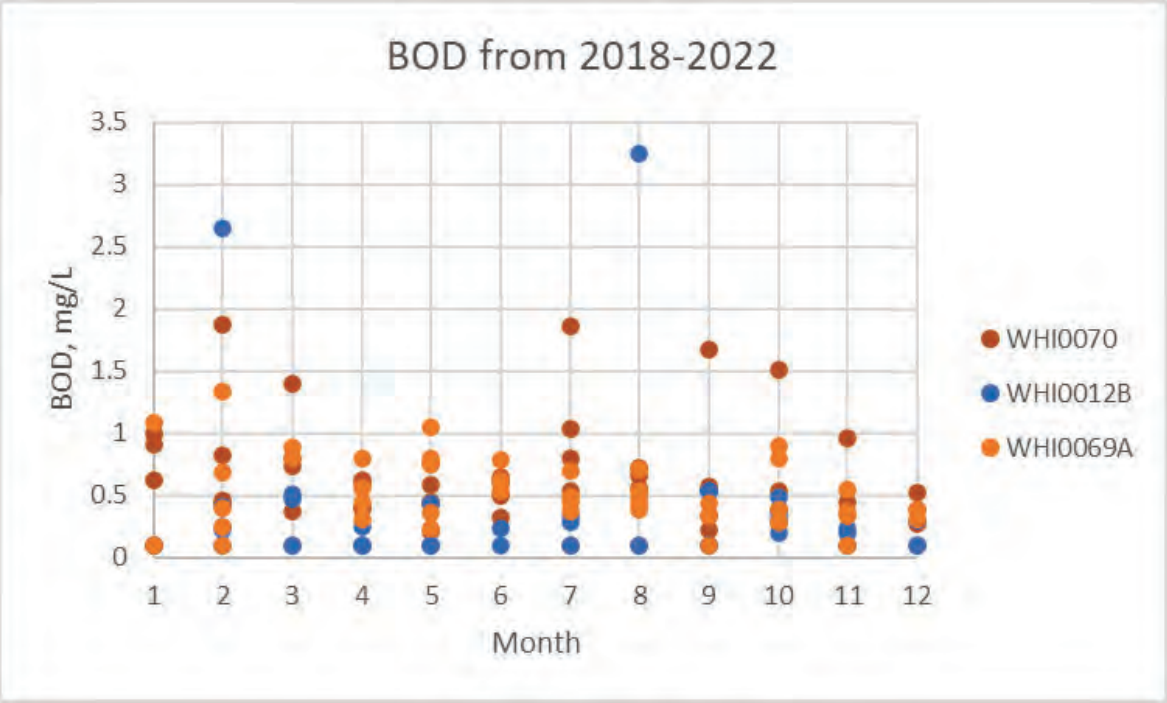


Figure 54. raph of BOD measurements during 2018-2022, by month.

1.7 Phosphorus

Phosphorus is a nutrient and is not harmful to humans or animals itself. However, it can stimulate algal growth in surface waters. Excessive algal growth has the potential to create conditions that are a nuisance or harmful to humans, a uatic organisms, or livestock, including low DO levels. rkansas water uality standards do not include numeric criteria for phosphorus PCEC, 2022 . portion of Osage Creek is listed as impaired because of high phosphorus. The suspected source of the phosphorus is an upstream municipal wastewater treatment plant DE 2020 . Thus, nonpoint sources of nutrients have not been identified specifically as contributing to water uality impairments in the Upper White River watershed. However, rkansas is a nutrient reduction target state for the ulf of Mexico Hypoxia Task Force lexander, et al., 2008 . Therefore, phosphorus levels are a concern in all rkansas watersheds.

Summary statistics for stream total phosphorus TP measurements from the period 2018-2022 are provided in Table 63 -Table 67 below. The stations were divided into six ma or waterway segments White River to Lake Se uoyah, West Fork White River, White River from Wyman to state line, War Eagle Creek, Eastern Streams, and Lake Stations for data analysis and visuali ation. Stations reported less than detection limit values 0.02 mg/L , so the Kaplan

Meier KM method was used for general statistics. The highest maximum TP concentration was measured in Holman Creek by H2O arks. DE measured the second highest maximum TP concentration at the same location. The high TP concentrations in Holman Creek may be caused by discharge from the Huntsville wastewater treatment plant upstream of this station. Table 66 lists summary statistics for total phosphorus TP measurements collected from lake stations in the Upper White River watershed during 2018-2022.

Table 63. Summary statistics for stream TP measurements in the White River to Lake Se uoyah during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
H2O arks	103	BC	15	0.000	0.004	0.007	0.008	0.013	0.021
DE	WHI0104	WR	12	0.020	0.020	0.020	0.023	0.023	0.040
H2O arks	104	WR	14	0.000	0.004	0.006	0.010	0.015	0.024
H2O arks	110	WR	2	0.000			0.000		0.000
DE	WHI0106	WR	47	0.020	0.020	0.020	0.026	0.030	0.080
BWD	5	WR	58	0.008	0.035	0.051	0.062	0.080	0.214
DE	WHI0219	MFWR	12	0.020	0.020	0.020	0.023	0.020	0.040
BWD	7	MFWR	58	0.009	0.030	0.051	0.059	0.079	0.170
H2O arks	201	MFWR	14	0.000	0.000	0.004	0.006	0.011	0.023
DE	WHI0103	MFWR	51	0.020	0.020	0.020	0.023	0.020	0.08

BC Baldwin Creek, WR White River, MFWR Middle Fork White River

Table 64. Summary statistics for stream TP measurements in the West Fork White River during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentil e, g/L	a i u alue, g/L
H2O arks	102	WFWR	14	0.000	0.003	0.007	0.011	0.014	0.045
H2O arks	101	WFWR	10	0.000	0.004	0.006	0.008	0.011	0.020
DE	WHI0229	WFWR	13	0.020	0.020	0.020	0.024	0.020	0.060
H2O arks	200	WS	10	0.000	0.008	0.010	0.009	0.012	0.015
H2O arks	202	MC	8	0.000	0.018	0.023	0.027	0.030	0.072
H2O arks	206	SS	9	0.002	0.024	0.031	0.030	0.039	0.066
DE	WHI0223	TB	12	0.020	0.020	0.025	0.029	0.040	0.050
WRC	TB[a]	TB	130	0.000	0.012	0.022	0.110	0.144	0.724
H2O arks	210[a]	TB	14	0.002	0.010	0.015	0.017	0.022	0.040
US S	07048495[a]	TB	24	0.010	0.021	0.027	0.116	0.139	0.536
BWD	8[b]	WFWR	58	0.013	0.038	0.068	0.079	0.095	0.310
DE	WHI0100[b]	WFWR	51	0.020	0.020	0.026	0.032	0.035	0.110
WRC	WFWR	WFWR	129	0.000	0.016	0.026	0.130	0.190	1.374

Stations in this table with the same superscript letter are at the same location.
WFWR West Fork White River, WS Ward Slough, MC Mullins Creek, SS Spout Spring Branch, TB Town Branch

Table 65. Summary statistics for stream TP measurements in the White River to the state line during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
BWD	22	LSO	35	0.015	0.048	0.072	0.086	0.099	0.206
BWD	10[c]	WR	58	0.008	0.050	0.079	0.086	0.123	0.220
WRC	Wyman[c]	WR	128	0.000	0.019	0.029	0.109	0.166	0.783
US S	07048600[c]	WR	14	0.021	0.054	0.159	0.334	0.599	0.909
BWD	23	WR	11	0.060	0.089	0.124	0.138	0.171	0.295
BWD	13	WR	45	0.021	0.057	0.084	0.105	0.133	0.318
DE	WHI0052[e]	WR	51	0.020	0.026	0.030	0.035	0.040	0.090
US S	07048700[e]	WR	22	0.011	0.028	0.042	0.050	0.052	0.298
DE	WHI0221	LlC	12	0.020	0.020	0.020	0.027	0.030	0.060
DE	WHI0231	DC	12	0.020	0.020	0.020	0.024	0.023	0.050
H2O arks	205	HoC	14	0.000	0.005	0.009	0.010	0.012	0.024
WRC	Richland[d]	RC	131	0.000	0.009	0.018	0.090	0.076	1.931
US S	07048780[d]	RC	13	0.010	0.020	0.106	0.232	0.217	0.953
DE	WHI0110	RC	12	0.020	0.020	0.020	0.028	0.040	0.040
H2O arks	300	BrC	13	0.014	0.018	0.026	0.027	0.035	0.045
BWD	12	UT	50	0.020	0.049	0.086	0.089	0.123	0.189
H2O arks	306	PC	12	0.003	0.008	0.009	0.014	0.013	0.038
DE	WHI0012B	LwC	42	0.020	0.033	0.080	0.140	0.230	0.490

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

LSO Lake Se uoyah outflow, WR White River, DC Drakes Creek, HoC Hock Creek, LlC Lollars Creek, RC Richland Creek, BrC Brush Creek, UT Unnamed tributary below Parson s Landfill, PC Prairie Creek, LwC Leatherwood Creek

Table 66. Summary statistics for stream TP measurements in War Eagle Creek during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
DE	WHI0227	WEC	12	0.020	0.020	0.020	0.022	0.020	0.040
DE	WHI0233	C	12	0.020	0.020	0.020	0.023	0.020	0.050
H2O arks	109	WEC	11	0.000	0.010	0.015	0.014	0.019	0.028
DE	WHI0220	WC	12	0.020	0.020	0.020	0.023	0.030	0.030
BWD	15	WEC	58	0.010	0.035	0.051	0.061	0.078	0.162
H2O arks	307	HC	14	0.003	0.009	0.014	0.017	0.027	0.033
DE	WHI0070[f]	HC	50	0.030	0.120	0.230	0.447	0.553	2.490
H2O arks	308[f]	HC	14	0.027	0.069	0.152	0.593	0.304	5.561
BWD	21[g]	WEC	57	0.014	0.050	0.080	0.087	0.107	0.336
H2O arks	301[g]	WEC	9	0.007	0.013	0.014	0.015	0.015	0.027
H2O arks	302	C	13	0.005	0.016	0.018	0.023	0.033	0.046
H2O arks	303	ClC	15	0.005	0.015	0.017	0.019	0.022	0.042
WRC	WEC	WEC	131	0.000	0.012	0.025	0.101	0.125	1.153
DE	WHI0116	WEC	50	0.020	0.020	0.030	0.040	0.040	0.330
H2O arks	304	CC	15	0.005	0.010	0.013	0.017	0.025	0.038
BWD	9[h]	WEC	56	0.012	0.037	0.061	0.073	0.074	0.490
H2O arks	305[h]	WEC	9	0.005	0.013	0.017	0.020	0.019	0.042
US S	07049050[h]	WEC	12	0.009	0.026	0.333	0.410	0.701	1.220

Stations in this table with the same superscript letter are at the same location.
WEC War Eagle Creek, C ackson Creek, WC Wharton Creek, HC Holman Creek, C lade Creek, ClC Clear Creek, CC Clifty Creek

Table 67. Summary statistics for stream TP measurements in Eastern Streams during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
DE	WHI0225	FC	10	0.020	0.020	0.020	0.023	0.020	0.040
DE	WHI0121	KR	48	0.020	0.020	0.020	0.026	0.030	0.130
DE	WHI0123	KR	45	0.020	0.020	0.020	0.026	0.030	0.070
DE	WHI0230	KC	11	0.020	0.020	0.020	0.026	0.030	0.050
DE	WHI0129	OC	11	0.020	0.020	0.020	0.027	0.025	0.060
DE	WHI0068	OC	40	0.020	0.020	0.030	0.033	0.040	0.090
DE	WHI0069	OC	47	0.020	0.020	0.030	0.037	0.050	0.080
WRC	Kings[i]	KR	36	0.000	0.005	0.011	0.059	0.019	0.418
DE	WHI0009 [i]	KR	48	0.020	0.020	0.020	0.029	0.033	0.070
US S	07053250	C	1	0.096	0.096	0.096	/	0.096	0.096
DE	WHI0232	TC	9	0.020	0.020	0.020	0.023	0.020	0.040
DE	WHI0071	LC	47	0.020	0.035	0.050	0.052	0.060	0.140

Stations in this table with the same superscript letter are at the same location.
FC Felkins Creek, KR Kings River, KC Kenner Creek, OC Osage Creek, C ocum Creek TC Terrapin Creek, LC Long Creek
Indicates station is located on an assessment unit included onDraft 2020 303 d List for impairment.

Table 68. Summary statistics for reservoir TP measurements from stations in Lake Se uoyah, Lake Wilson, and Beaver Lake during 2018-2022 stations listed in downstream order .

rgani ation	Station D	La e D	Sa le Location	o. of easures	in alue, g/L	25th Percentile g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a alue, g/L
DE	LWHI009	LS	Epilimnion	8	0.020	0.028	0.030	0.034	0.043	0.050
DE	LWHI014	LW	Epilimnion	12	0.020	0.020	0.020	0.023	0.023	0.040
US S	07048910	BL	Epilimnion	22	0.020	0.024	0.030	0.033	0.040	0.084
DE	LWHI013B	BL	Epilimnion	4	0.020	0.020	0.020	0.025	0.025	0.040
US S	07049160	BL	Epilimnion	21	0.014	0.021	0.022	0.028	0.039	0.061
US S	07049187	BL	Epilimnion	7	0.013	0.017	0.022	0.036	0.045	0.095
US S	07049200	BL	Epilimnion	21	0.011	0.013	0.015	0.030	0.038	0.104
DE	LWHI013C	BL	Epilimnion	4	0.020	0.020	0.020	0.025	0.025	0.040
US S	07049500	BL	Epilimnion	16	0.007	0.008	0.009	0.014	0.014	0.054
US S	LWHI013	BL	Epilimnion	5	0.020	0.020	0.020	0.021	0.020	0.025
US S	07049690	BL	Epilimnion	12	0.003	0.004	0.005	0.005	0.005	0.013

Stations in this table with the same superscript letter are at the same location.
LS Lake Se uoyah, LW Lake Wilson, BL Beaver Lake

Figure 55 through Figure 60 show box and whisker graphs of total phosphorus measurements from 2018-2022 at stations with more than ten measurements. These graphs indicate that TP data collected by different organi ations are not necessarily comparable to each other. This is likely because of differences in sampling protocols and/or analysis methods among the organi ations. For the most part, median values for each organi ations stations are not significantly different. However, the median TP concentration from H2O arks station 308 on Holman Creek is significantly higher than median concentrations at all other H2O arks stations in the watershed. Similarly, the median TP concentration at DE station WHI0070 on Holman Creek is significantly higher than median concentrations at all other DE stations in the watershed, except perhaps WHI0012B Leatherwood Creek . The median TP concentration at DE station WHI0071 on Long Creek is higher than median TP concentration at all other DE stations except WHI0070 and WHI0012B. Higher TP concentrations in Holman Creek and Leatherwood Creek WHI0012B may be from municipal wastewater treatment plants discharging upstream.

Holman Creek 308, WHI0070 and Richland Creek Richland have the highest maximum TP levels from 2018-2022. However, War Eagle Creek 07049050 and Holman Creek WHI0070 have the highest median TP concentrations.

Median total phosphorus measurements at the reservoir stations are not significantly different than the median values at the stream stations. The Beaver Lake stations exhibit a decreasing trend in TP concentrations along the length of the reservoir.

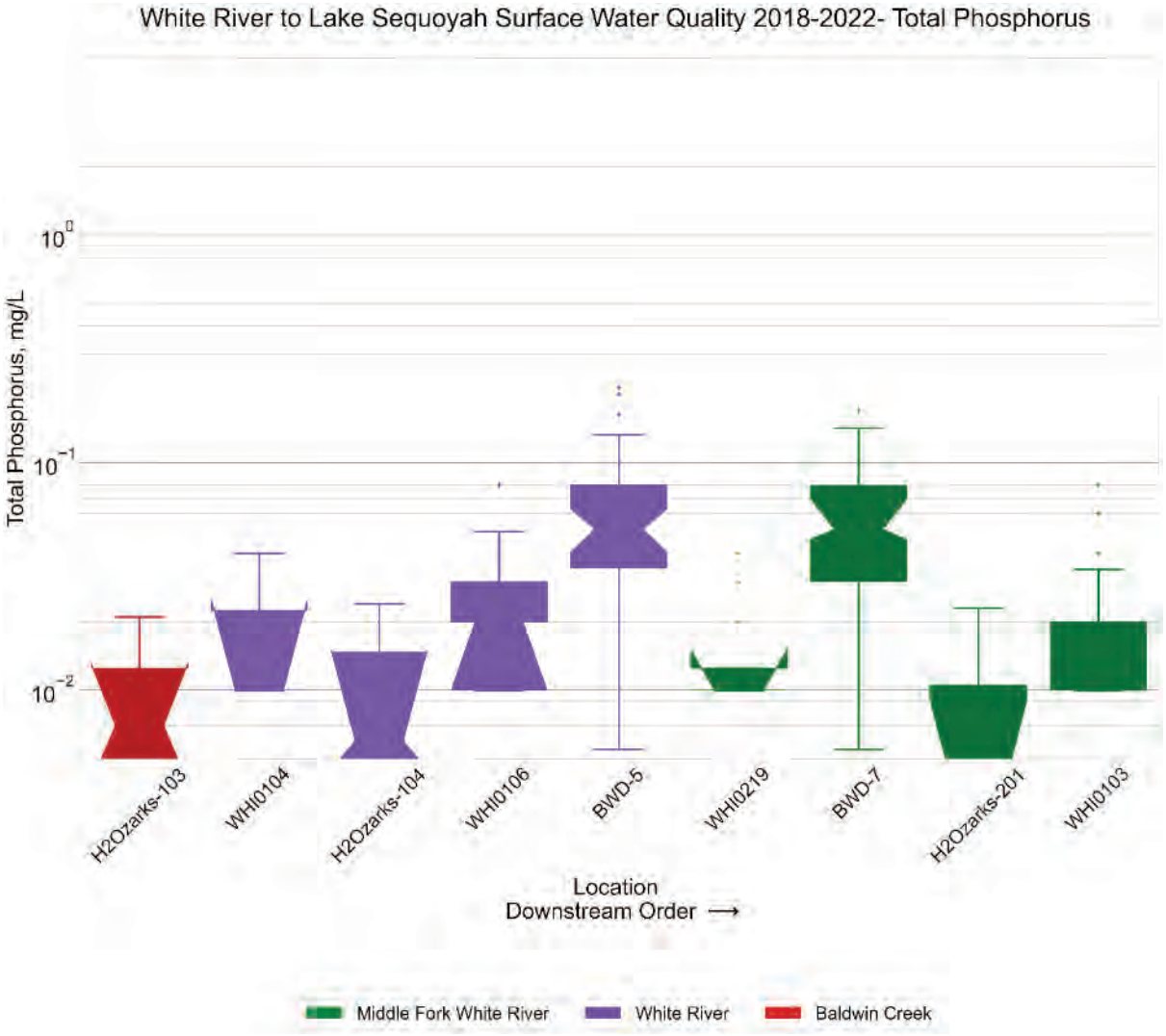


Figure 55. Box and whisker graph of Total Phosphorous measurements from White River to Lake Se uoyah waterway segment with more than 10 values from 2018-2022.

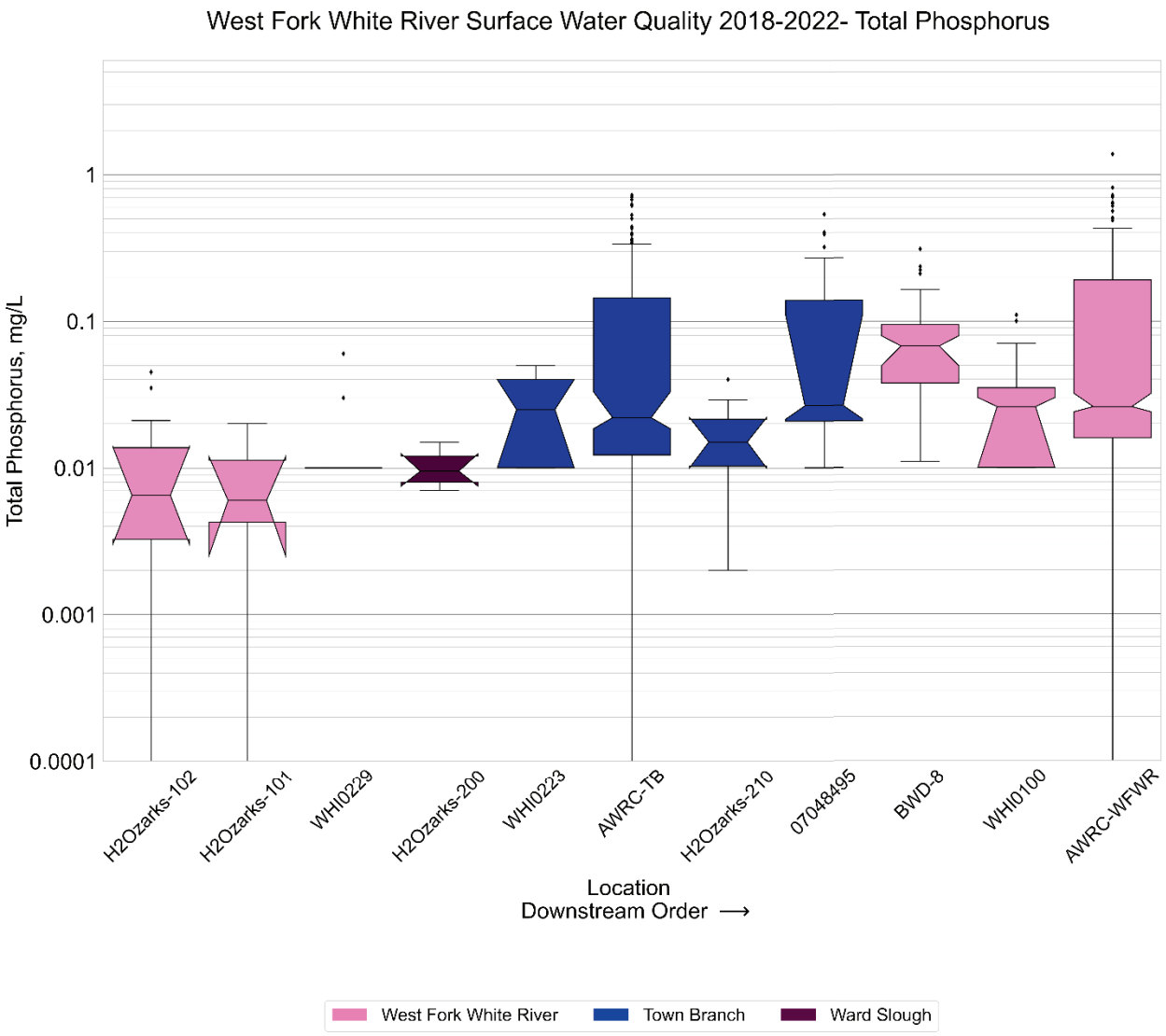


Figure 56. Box and whisker graph of Total Phosphorous measurements from West Fork White River waterway segment with more than 10 values from 2018-2022. ote that stations TB, 210, and 07048495 are at the same location on Town Branch and stations BWC-8 and WHI0100 are at the same location on West Fork White River.

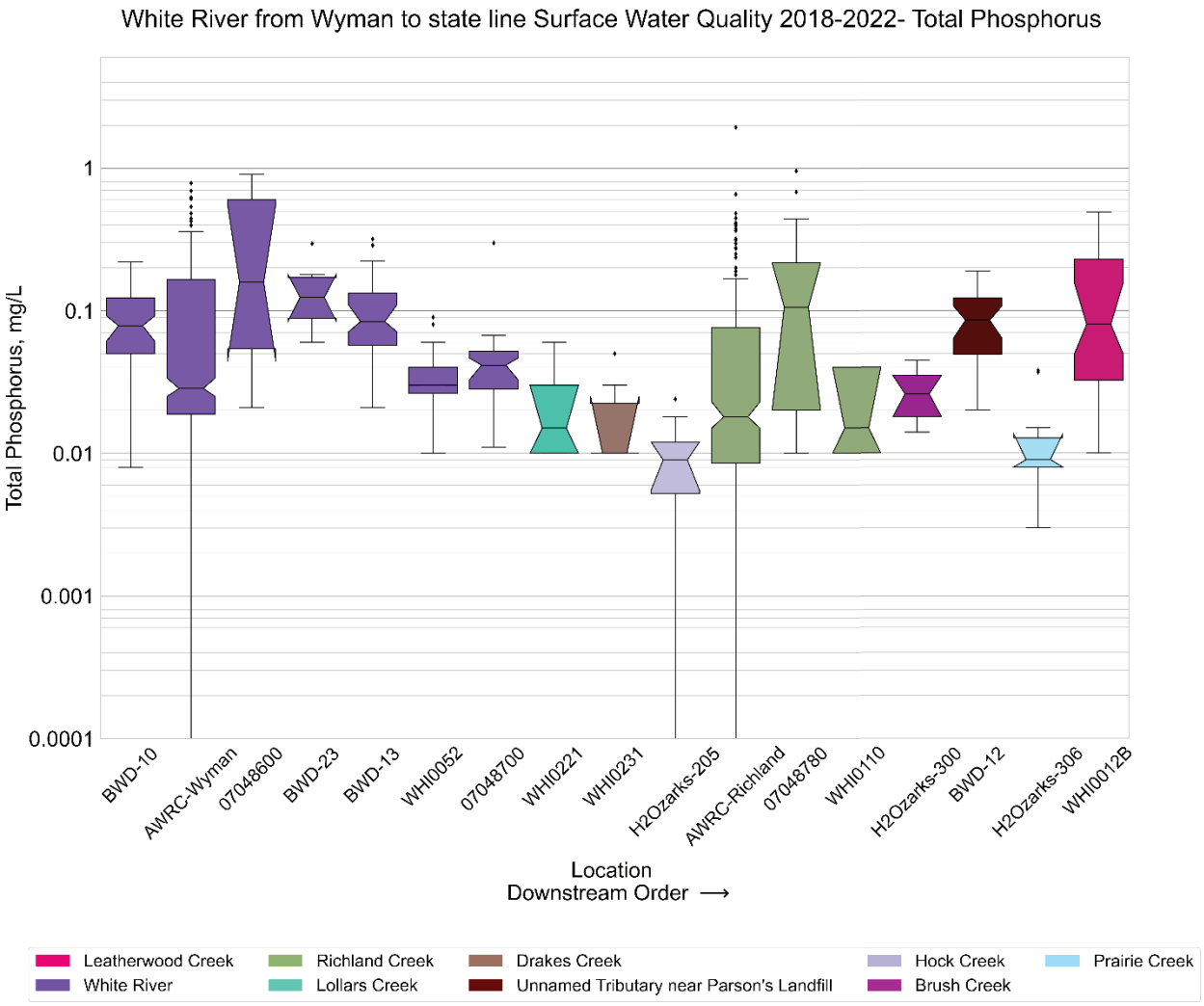


Figure 57. Box and whisker graph of Total Phosphorous measurements from White River from Wyman to state line waterway segment with more than 10 values from 2018-2022. ote that stations 10, Wyman, and 07048600 are at the same location on the White River upstream of Richland Creek stations Richland and 07048780 are at the same location on Richland Creek and stations WHI0052 and 07048700 are at the same location on the White River downstream of Richland Creek.

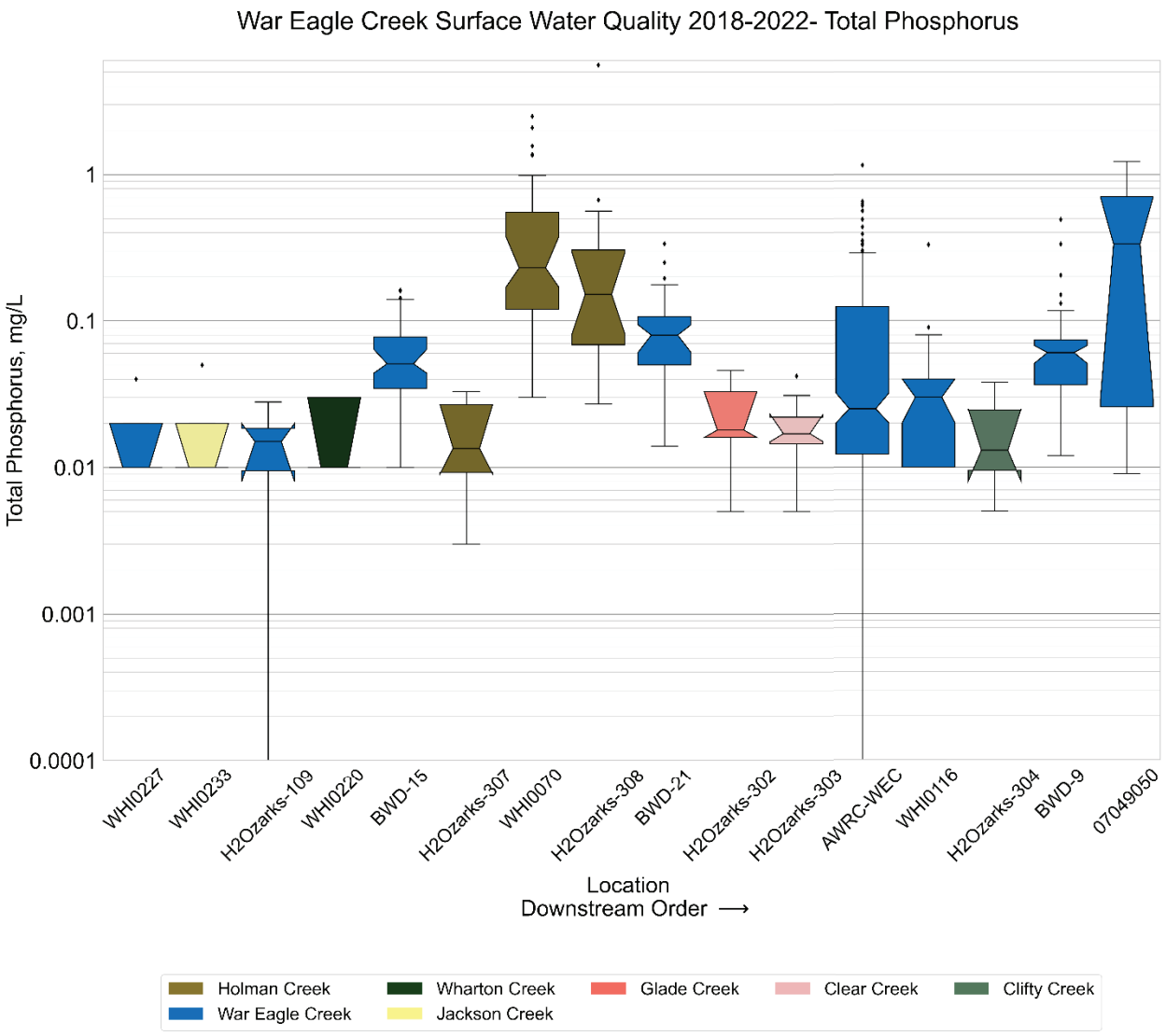


Figure 58. Box and whisker graph of Total Phosphorous measurements from War Eagle Creek waterway segment with more than 10 values from 2018-2022. ote that stations WHI0070 and 308 are at the same location on Holman Creek stations 21 and 301 are at the same location on War Eagle Creek upstream of lade Creek and Clear Creek and stations BWC-9 and 07049050 are at the same location on War Eagle Creek downstream of Clifty Creek.

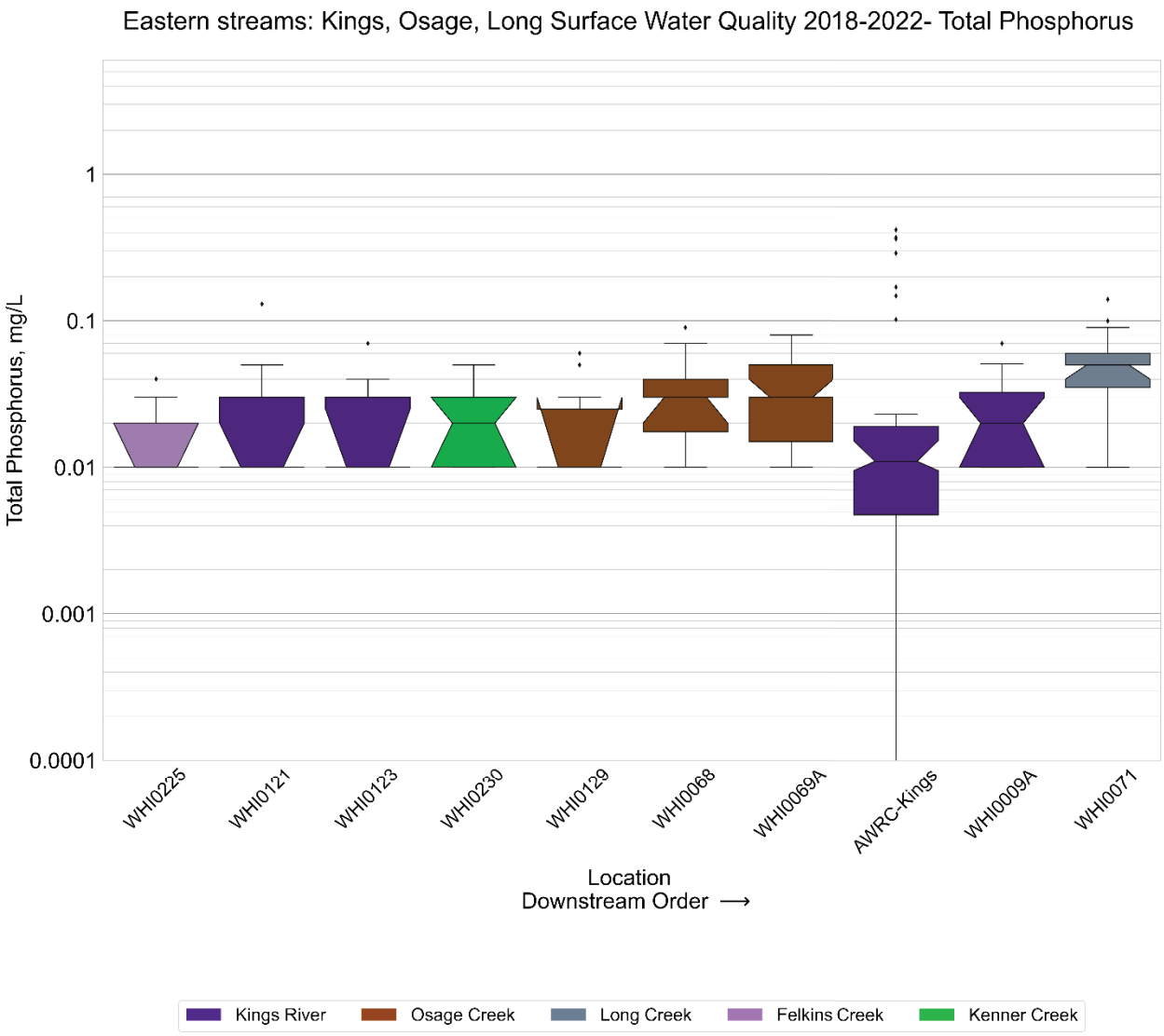


Figure 59. Box and whisker graph of Total Phosphorous measurements from Eastern Streams waterway segment with more than 10 values from 2018-2022. ote that stations Kings and WHI0009 are at the same location on Kings River.

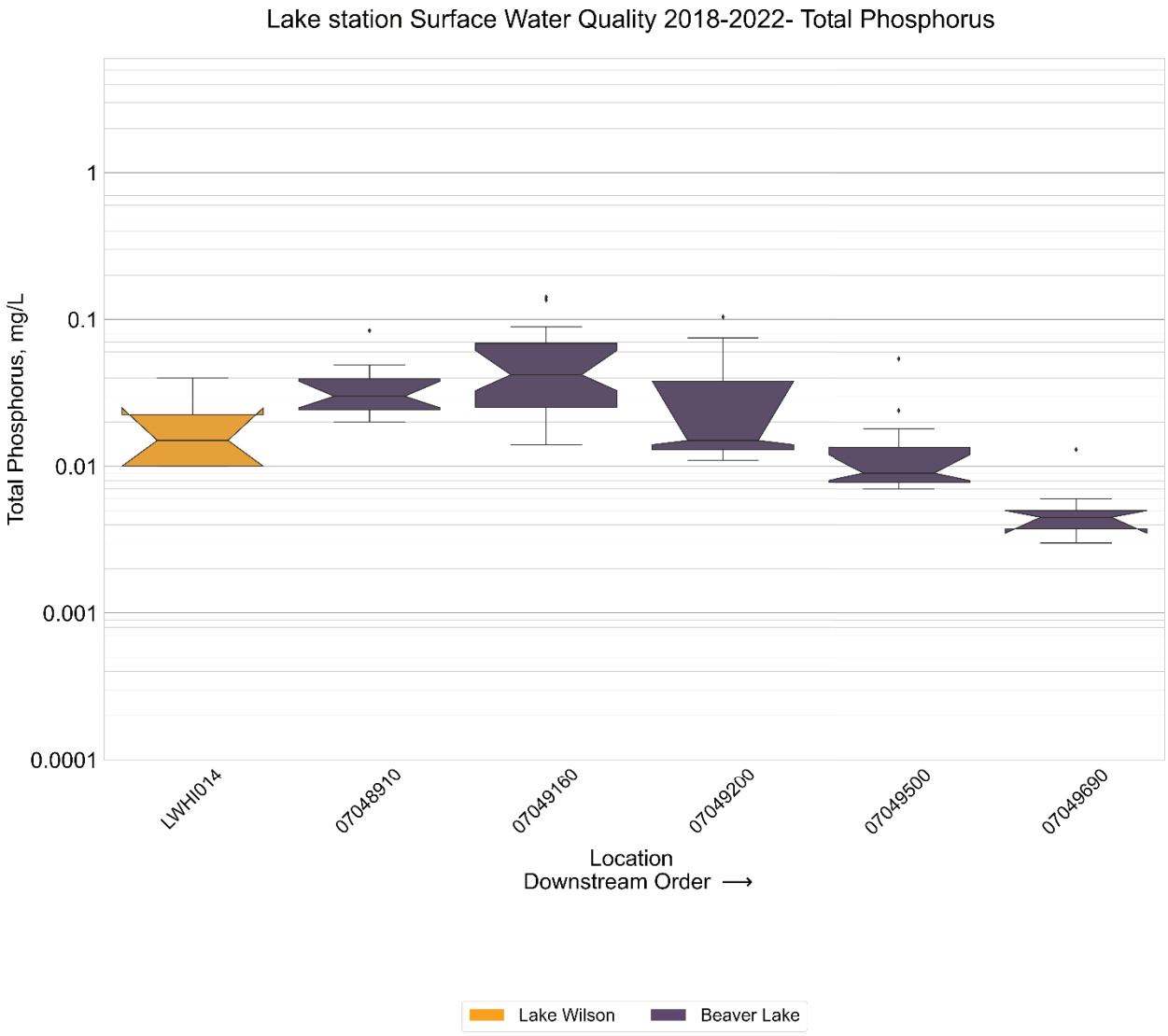


Figure 60. Box and whisker graph of Total Phosphorous measurements from lake stations with more than 10 values from 2018-2022.

1.8 Nitrogen

itrogen is a nutrient and can stimulate algal growth. Excessive algal growth has the potential to create conditions that are a nuisance or harmful to humans, a uatic organisms, or livestock, including low DO levels. The only numeric water uality standards for nitrogen that are specified in the rkansas Water uality Standards are the criteria for ammonia nitrogen, which are dependent on temperature and pH PCEC, 2022 . dditionally, DE uses the numeric value of 10 mg/L nitrate nitrogen as a maximum allowable in-stream value for

maintaining the designated use of domestic water supply. Therefore, ammonia nitrogen and nitrate nitrite nitrogen measurements are evaluated in subsections below.

In addition, total nitrogen measurements are evaluated. rkansas water uality standards do not include numeric criteria for nitrogen PCEC, 2022 . Portions of Town Branch and Holman Creek downstream of the Huntsville wastewater treatment plant are listed as impaired because of nitrate from the municipal wastewater treatment plant. o other impairments because of nitrogen have been identified in the Upper White River watershed DE 2020 . Thus, nonpoint sources of nutrients have not been identified specifically as contributing to water uality impairments in this watershed. However, rkansas is a nutrient reduction target state for the ulf of Mexico Hypoxia Task Force. Therefore, nitrate and total nitrogen levels are a concern in all rkansas watersheds.

Since 2018, DE has been utili ing a laboratory method that produces a direct measurement of total nitrogen, which is more efficient than the traditional procedure of measuring total K eldahl nitrogen TK and nitrate nitrite nitrogen and summing the results to calculate total nitrogen. However, data from the new method is not available prior to May 2018 for water samples collected in the Upper White River watershed. For data prior to May 2018, for DE stations, evaluation of total nitrogen is conducted on total nitrogen values calculated from nitrate nitrite nitrogen and TK measurements.

1.8.1 Ammonia Nitrogen

Under certain conditions of pH and temperature, ammonia nitrogen can be toxic to a uatic life. mmonia can also reduce dissolved oxygen concentrations in water through bacterial conversion of ammonia to nitrate and encouraging excessive algal or plant growth.

Table 69 through Table 71 list summary statistics for ammonia nitrogen measurements from the Upper White River watershed during 2018-2022. lmost all ammonia nitrogen measurements are reported as less than the detection limit. ote that US S and DE have different detection limits for ammonia nitrogen. The detection limit for the US S data is 0.01 mg/L, and for DE the detection limit is 0.03 mg/L. The Kaplan Meier KM Method was used to estimate summary statistics using EP s ProUCL tool USEP , 2022 . The highest reported ammonia nitrogen concentration during 2018-2022 occurred at Osage Creek station WHI0069 . The station with the highest median ammonia nitrogen values are from Wilson and

Beaver Lakes. Because the ma ority of the ammonia nitrogen measurements are reported as less than detection, no graphs of the data are provided.

Table 69. Summary statistics for Western Stream measurements from 2018-2022 for ammonia nitrogen stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
DE	WHI0104	WR	12	0.03	0.03	0.03	0.03	0.03	0.03
DE	WHI0106	WR	49	0.03	0.03	0.03	0.031	0.03	0.04
DE	WHI0103	WFWR	52	0.03	0.03	0.03	0.03	0.03	0.04
DE	WHI0223	TB	12	0.03	0.03	0.03	0.03	0.03	0.04
US S	7048495	TB	9	0.01	0.02	0.03	0.03	0.04	0.05
DE	WHI0100	WFWR	51	0.03	0.03	0.03	0.03	0.03	0.14
US S	07048600	WR	11	0.02	0.03	0.03	0.04	0.04	0.09
DE	WHI0052[a]	WR	52	0.03	0.03	0.03	0.03	0.03	0.10
US S	07048700[a]	WR	14	0.01	0.02	0.025	0.03	0.04	0.08
US S	07048780	RC	7	0.01	0.01	0.02	0.02	0.04	0.05
DE	WHI0070	HC	52	0.03	0.03	0.03	0.08	0.03	0.76
DE	WHI0116	WEC	52	0.03	0.03	0.03	0.03	0.03	0.24
US S	07049050	WEC	9	0.01	0.02	0.03	0.03	0.04	0.05
DE	WHI0012B	LwC	43	0.03	0.03	0.03	0.05	0.03	0.76

Stations in this table with the same superscript letter are at the same location.
WR White River, WFWR West Fork White River, TB Town Branch, RC Richland Creek, HC Holman Creek, WEC War Eagle Creek, LwC Leatherwood Creek

Table 70. Summary statistics for Eastern Stream measurements from 2018-2022 for ammonia nitrogen stations listed in downstream order, first row is farthest upstream station .

rgani at ion	Station D	Strea D	u ber of	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
DE	WHI0121	KR	51	0.03	0.03	0.03	0.03	0.03	0.06
DE	WHI0123	KR	51	0.03	0.03	0.03	0.03	0.03	0.1
DE	WHI0129	OC	10	0.03	0.03	0.03	0.03	0.03	0.04
DE	WHI0068	OC	45	0.03	0.03	0.03	0.03	0.03	0.04
DE	WHI0069	OC	48	0.03	0.03	0.03	0.03	0.03	1.09
DE	WHI0009	KR	49	0.03	0.03	0.03	0.03	0.03	0.03
DE	WHI0232	TC	10	0.03	0.03	0.03	0.03	0.03	0.03
DE	WHI0071	LC	47	0.03	0.03	0.03	0.03	0.03	0.05

KR Kings River, OC Osage Creek, TC Terrapin Creek, LC Long Creek

Table 71. Summary statistics for reservoir ammonia nitrogen measurements from stations in Lake Se uoyah, Lake Wilson, and Beaver Lake during 2018-2022 stations listed in downstream order .

rg.	Station D	La e D	Sa le Location	o. of easures	in alue, g/L	25th Percentile g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a alue, g/L
DE	LWHI009	LS	Epilimnion	8	0.03	0.03	0.03	0.04	0.06	0.10
DE	LWHI014	LW	Epilimnion	11	0.03	0.03	0.04	0.04	0.04	0.14
DE	LWHI013B	BL	Epilimnion	3	0.03			0.03		0.04
US S	07049187	BL	Epilimnion	2	0.04			0.05		0.05
US S	07049200	BL	Epilimnion	11	0.01	0.02	0.04	0.04	0.06	0.08
DE	LWHI013C[b]	BL	Epilimnion	4	0.03	0.03	0.03	0.04	0.03	0.07
US S	07049500[b]	BL	Epilimnion	4	0.01	0.01	0.02	0.02	0.02	0.03
DE	LWHI013	BL	Epilimnion	5	0.03			0.03		
US S	07049690	BL	Epilimnion	4	0.01	0.02	0.02	0.02	0.02	0.02

Stations in this table with the same superscript letter are at the same location.
LS Lake Se uoyah, LW Lake Wilson, BL Beaver Lake

1.8.2 Nitrate + Nitrite Nitrogen

Table 72 through Table 77 list summary statistics for nitrate nitrite nitrogen measurements from the Upper White River watershed during 2018-2022. lmost all measurements are below the 10 mg/L drinking water criterion. The highest nitrate nitrite nitrogen value, and only value above 10 mg/L, during 2018-2022 was measured at Holman Creek station WHI0070 . This station is downstream of a municipal wastewater treatment plant outfall. The next highest value was measured on Long Creek WHI0071 . lthough Town Branch recorded a couple of high measurements, the median nitrate nitrate at Town Branch is not significantly high.

The seasonal pattern of nitrate nitrite measurements at the Holman Creek station WHI0070 , where higher concentrations occur during the summer when runoff is low and there is less dilution, and lower concentrations during the winter and spring when runoff is high and there is more dilution, is characteristic of locations where water uality is influenced by a point source discharge Figure 61 . However, the seasonal patterns in the nitrate nitrite measurements the Long Creek station WHI0071 follow the seasonal flow pattern, suggesting that nonpoint sources are the greatest influence because the lowest values occur during the dry season, and the highest values occur during the wet season Figure 61 . itrate is easily dissolved in water and transported by runoff to surface water.

Table 72. Summary statistics for stream nitrate nitrite nitrogen measurements in the White River to Lake Se uoyah during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
DE	WHI0104	WR	12	0.16	0.27	0.30	0.39	0.43	1.04
DE	WHI0106	WR	47	0.05	0.18	0.28	0.27	0.36	0.56
DE	WHI0219	MFWR	12	0.24	0.28	0.36	0.53	0.53	1.47
DE	WHI0103	MFWR	52	0.06	0.19	0.38	0.42	0.55	1.81

WR White River, MFWR Middle Fork White River

Table 73. Summary statistics for stream nitrate nitrite nitrogen measurements in the West Fork White River during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
DE	WHI0229	WFWR	8	0.05	0.05	0.29	0.24	0.30	1.07
DE	WHI0223	TB	12	0.39	0.44	0.49	0.53	0.61	0.73
US S	07048495	TB	24	0.18	0.41	0.61	0.85	0.78	4.68
DE	WHI0100	WFWR	49	0.05	0.13	0.24	0.28	0.41	0.98
DE	WFWR	WFWR	36	0.02	0.13	0.29	0.28	0.41	0.51

WFWR West Fork White River, TB Town Branch

Table 74. Summary statistics for stream nitrate nitrite nitrogen measurements in the White River to the state line during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
WRC	Wyman[a]	WR	35	0.05	0.20	0.29	0.32	0.44	0.85
US S	07048600[a]	WR	14	0.10	0.25	0.34	0.35	0.42	0.72
DE	WHI0052[c]	WR	51	0.05	0.36	0.44	0.54	0.55	3.33
US S	07048700[c]	WR	22	0.08	0.39	0.47	0.53	0.60	1.23
DE	WHI0221	LlC	12	0.10	0.23	0.29	0.49	0.77	1.44
DE	WHI0231	DC	12	0.19	0.50	0.64	0.97	1.47	2.18
WRC	Richland[b]	RC	36	0.36	0.71	0.95	1.03	1.22	2.26
US S	07048780[b]	RC	13	0.47	0.57	1.08	1.00	1.22	1.84
DE	WHI0110	RC	11	0.13	0.52	0.66	0.75	0.80	2.06
DE	WHI0012B	LwC	35	0.05	0.20	0.29	0.32	0.44	0.85

Stations in this table with the same superscript letter are at the same location.
WR White River, Drakes Creek, LlC Lollars Creek, RC Richland Creek, LwC Leatherwood Creek

Table 75. Summary statistics for stream nitrate nitrite nitrogen measurements in War Eagle Creek during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
DE	WHI0227	WEC	12	0.10	0.12	0.15	0.29	0.33	0.98
DE	WHI0233	C	12	0.33	0.47	0.49	0.81	0.76	2.49
DE	WHI0220	WC	12	0.29	0.30	0.56	0.73	0.85	1.96
DE	WHI0070	HC	52	0.76	1.81	2.20	3.06	3.96	11.10
WRC	WEC	WEC	36	0.64	1.26	1.48	1.57	2.00	2.65
DE	WHI0116	WEC	52	0.78	1.22	1.54	1.56	1.78	2.76
US S	07049050	WEC	12	0.15	0.64	1.08	1.12	1.43	2.30

WEC War Eagle Creek, C ackson Creek, WC Wharton Creek, HC Holman Creek

Table 76. Summary statistics for stream nitrate nitrite nitrogen measurements in Eastern Streams during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
DE	WHI0225	FC	10	0.06	0.08	0.12	0.13	0.19	0.23
DE	WHI0121	KR	51	0.14	0.35	0.46	0.49	0.56	1.29
DE	WHI0123	KR	52	0.26	0.64	0.85	0.87	1.05	1.84
DE	WHI0230	KC	11	0.19	0.37	0.63	0.55	0.65	0.95
DE	WHI0129	OC	11	0.18	0.37	0.44	0.48	0.57	0.99
DE	WHI0068	OC	41	0.05	0.19	0.72	0.72	1.21	2.06
DE	WHI0069	OC	44	0.05	0.15	0.68	0.76	1.24	2.16
DE	WHI0009	KR	42	0.05	0.12	0.67	0.64	1.02	1.78
US S	07053250	C	1	5.97	5.97	5.97	/	5.97	5.97
DE	WHI0232	TC	10	0.06	0.10	0.13	0.19	0.17	0.74
DE	WHI0071	LC	49	0.98	1.57	2.05	2.13	2.60	3.50

FC Felkins Creek, KR Kings River, KC Kenner Creek, OC Osage Creek, C ocum Creek, TC Terrapin Creek, LC Long Creek

Table 77. Summary statistics for reservoir nitrate nitrite nitrogen measurements from stations in Lake Se uoyah, Lake Wilson, and Beaver Lake during 2018-2022 stations listed in downstream order .

rgani ation	Station D	La e D	Sa le Location	o. of easures	in alue, g/L	25th Percentile g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a alue, g/L
DE	LWHI009	LS	Epilimnion	6	0.05	0.08	0.15	0.22	0.18	0.83
DE	LWHI014	LW	Epilimnion	9	0.05	0.06	0.19	0.17	0.28	0.37
US S	07048910	BL	Epilimnion	16	0.01	0.13	0.25	0.26	0.38	0.61
DE	LWHI013B	BL	Epilimnion	1	0.05	0.05	0.14	0.08	0.10	0.14
US S	07049160	BL	Epilimnion	15	0.01	0.63	1.10	1.07	1.45	2.19
US S	07049187	BL	Epilimnion	7	0.04	0.30	0.46	0.58	0.79	1.38
US S	07049200	BL	Epilimnion	16	0.02	0.18	0.55	0.62	1.09	1.32
DE	LWHI013C[d]	BL	Epilimnion	2	0.05	0.09	0.18	0.14	0.18	0.24
US S	07049500[d]	BL	Epilimnion	9	0.10	0.25	0.62	0.56	0.78	1.0
DE	LWHI013	BL	Epilimnion	3	0.05	0.06	0.22	0.17	0.24	0.24
US S	07049690	BL	Epilimnion	18	0.05	0.14	0.27	0.26	0.34	0.55

Stations in this table with the same superscript letter are at the same location.
LS Lake Se uoyah, LW Lake Wilson, BL Beaver Lake

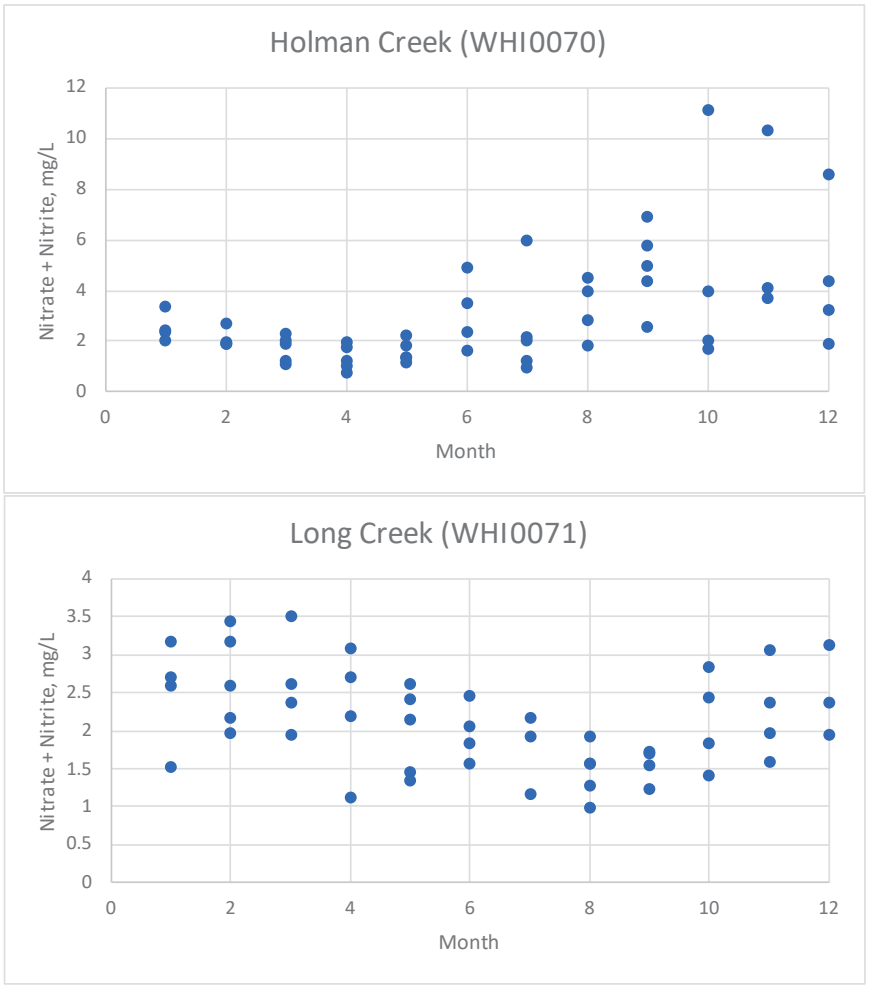


Figure 61. raphs of nitrate nitrite nitrogen measurements by month of the year at highest median stations to exhibit seasonal patterns.

Figure 62 through Figure 67 show box and whisker graphs of nitrate nitrite nitrogen measurements from stations with greater than ten measurements from the period 2018-2022. In Figure 64, Richland Creek median nitrate nitrite concentrations are higher than White River median concentrations, which increases downstream of Richland Creek confluence, indicating Richland Creek may be loading nitrate nitrite into the White River. In Figure 65, the median nitrate nitrite concentration at the Holman Creek station is significantly higher than all other stream stations see discussion above , except WHI0071 Long Creek . The significantly higher nitrate nitrite concentrations are likely because of the influence of Huntsville wastewater treatment plant discharge on Holman Creek. War Eagle Creek median nitrate nitrite concentration increases downstream of Holman Creek, suggesting loading from tributaries, including Holman Creek. In Figure 66, Kings River median nitrate nitrite concentrations increase significantly between stations WHI0121 and WHI0123.

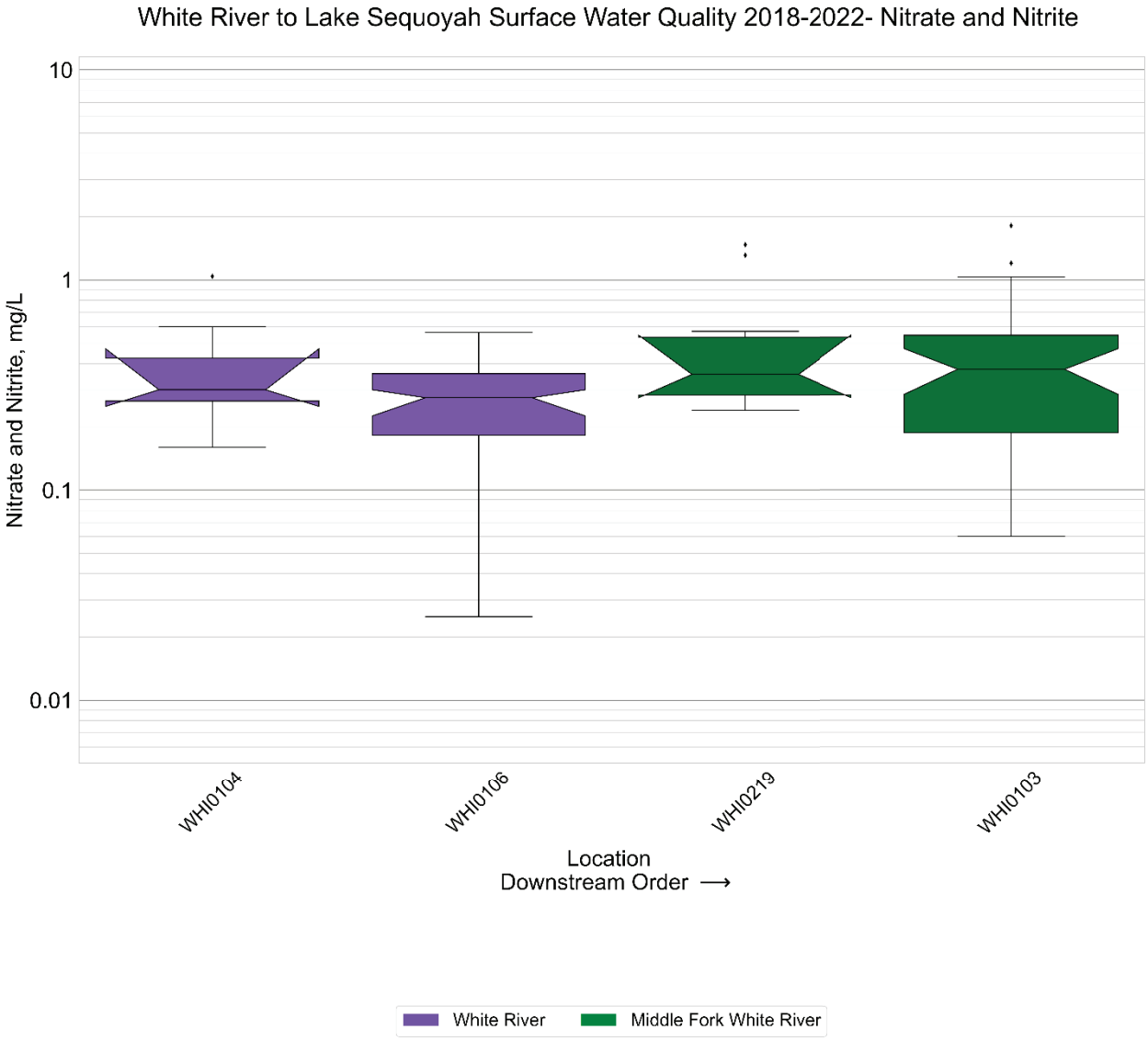


Figure 62. Box and whisker graph of nitrate nitrite measurements from stream stations in the White River to Lake Se uoyah waterway segment more than 10 values from 2018-2022.

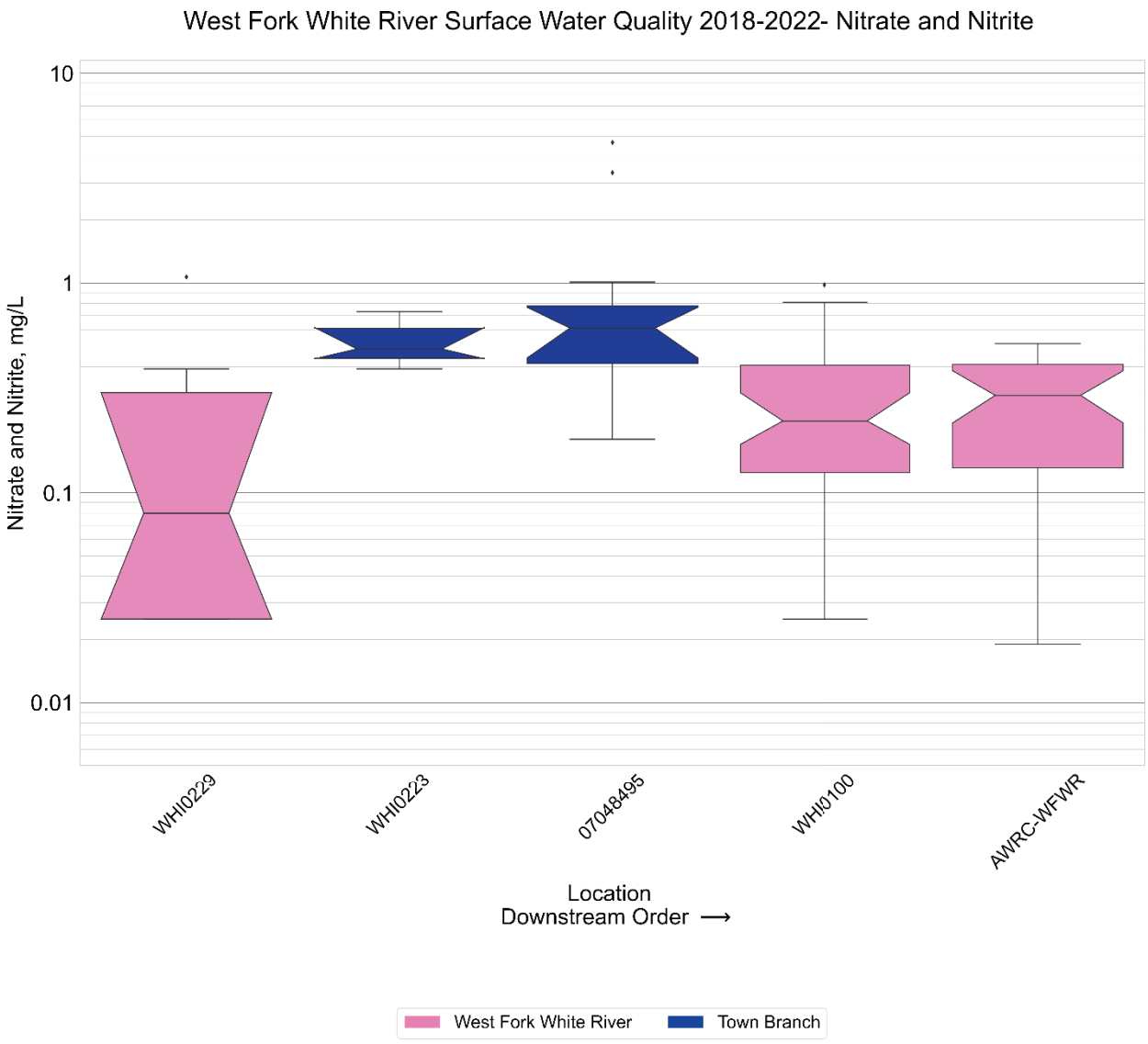


Figure 63. Box and whisker graph of nitrate nitrite measurements from stream stations in the West Fork White River waterway segment more than 10 values from 2018-2022.

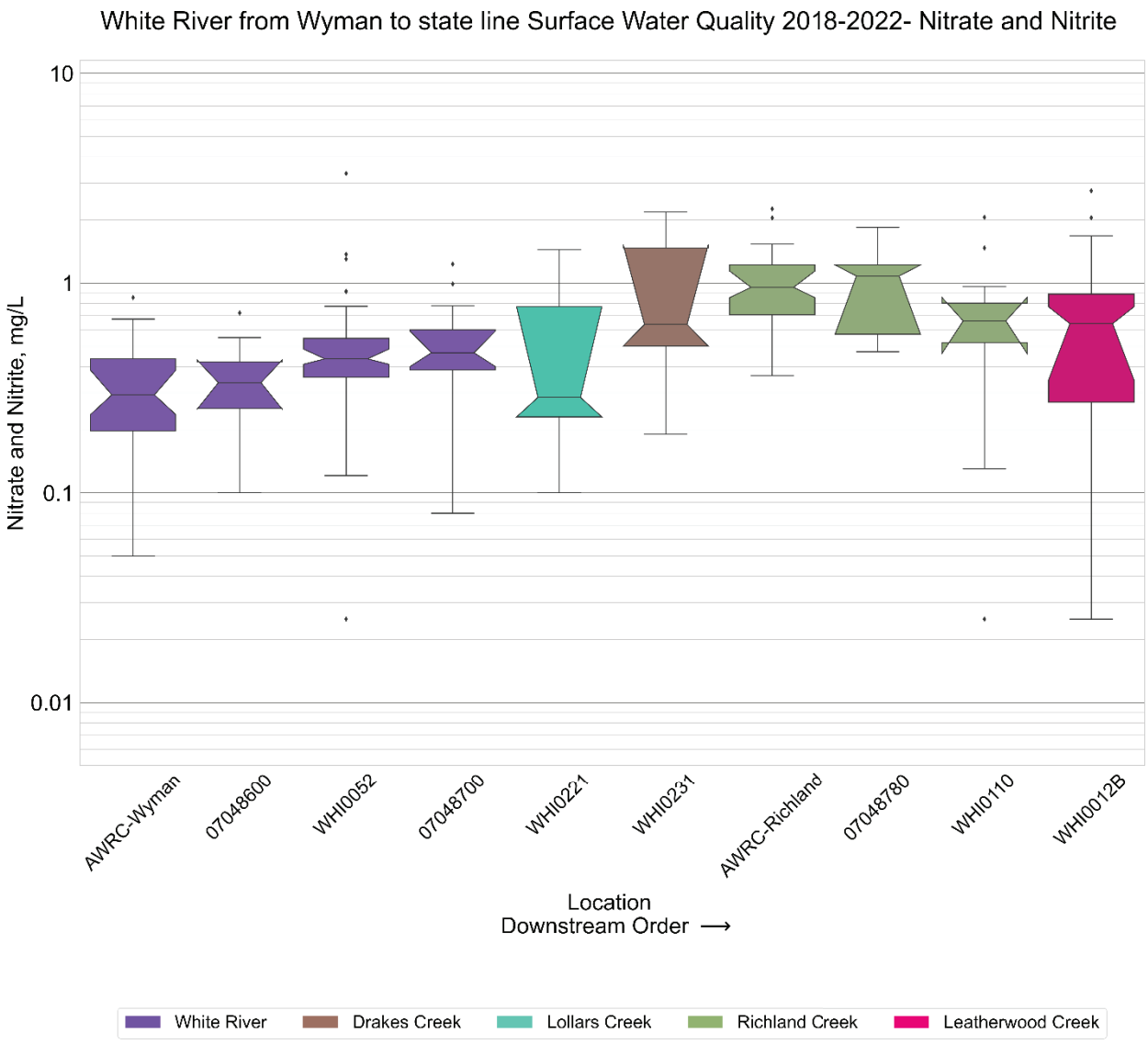


Figure 64. Box and whisker graph of nitrate nitrite measurements from stream stations in the White River from Wyman to the state line waterway segment more than 10 values from 2018-2022. ote that stations Wyman and 07048600 are at the same location on the White River, Richland and 07048780 are at the same location, and stations WHI0052 and 07048700 are at the same location.

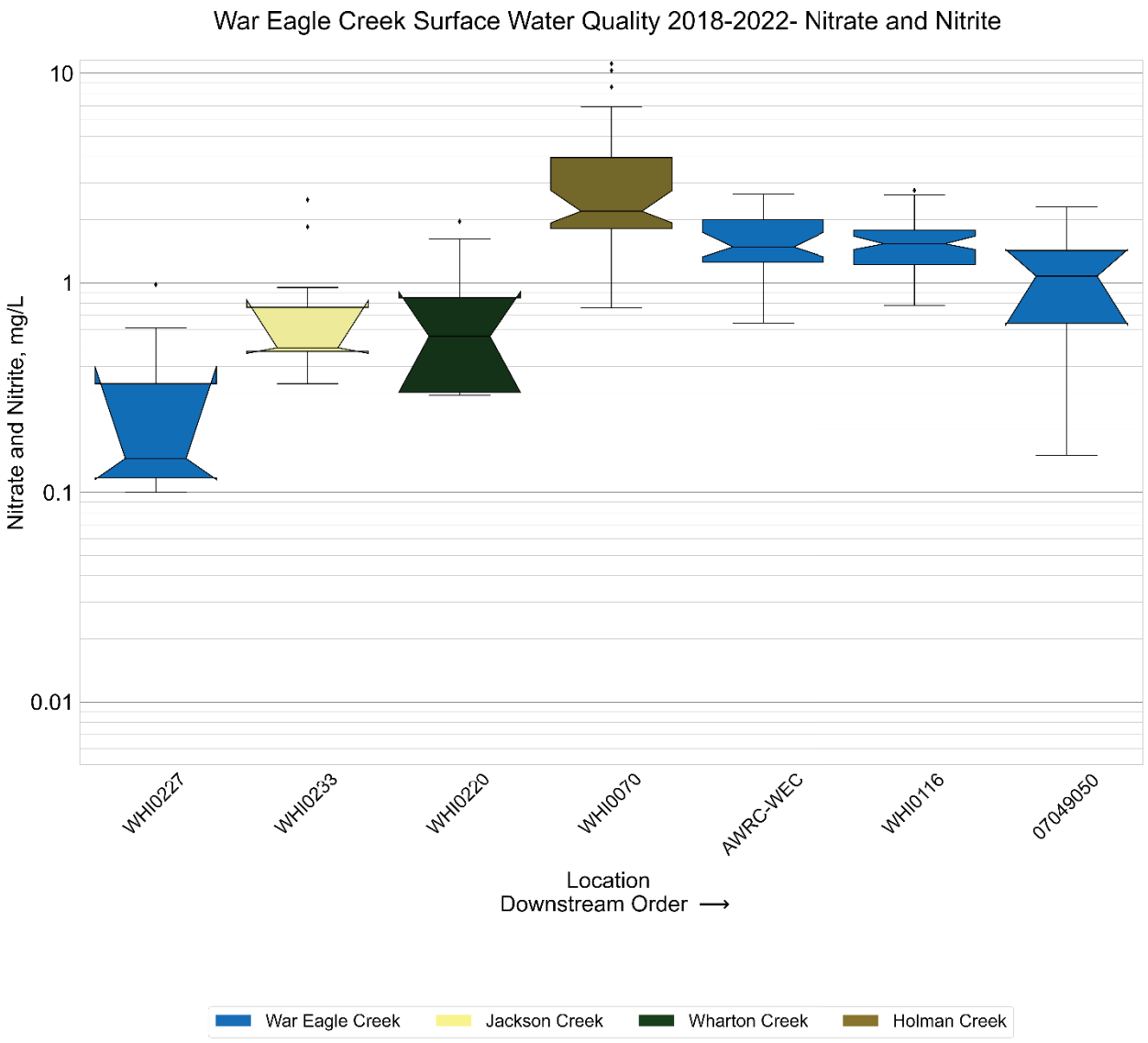


Figure 65. Box and whisker graph of nitrate nitrite measurements from stream stations in the War Eagle Creek waterway segment more than 10 values from 2018-2022.

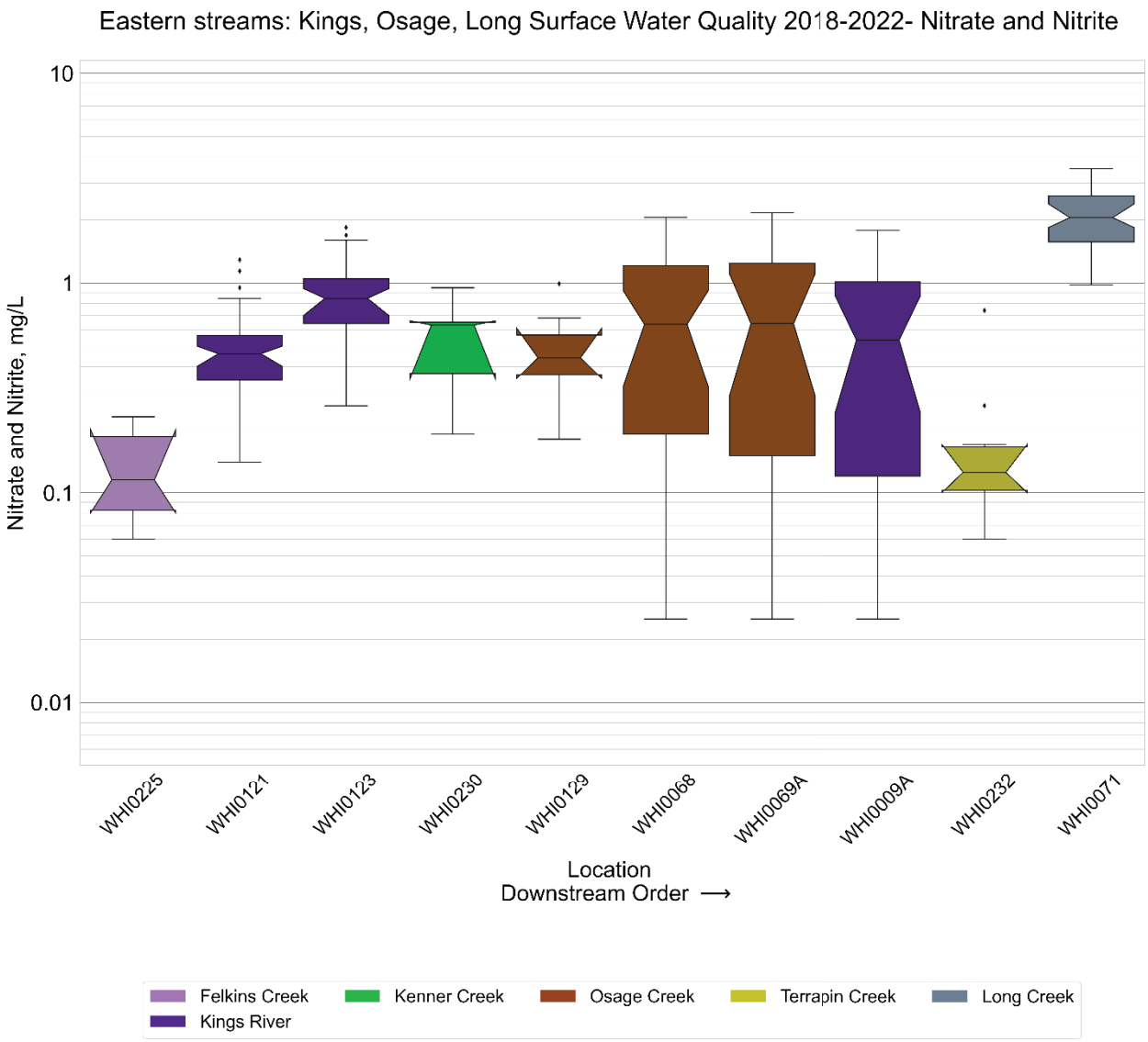


Figure 66. Box and whisker graph of nitrate nitrite measurements from stream stations in the Eastern Streams waterway segment more than 10 values from 2018-2022.

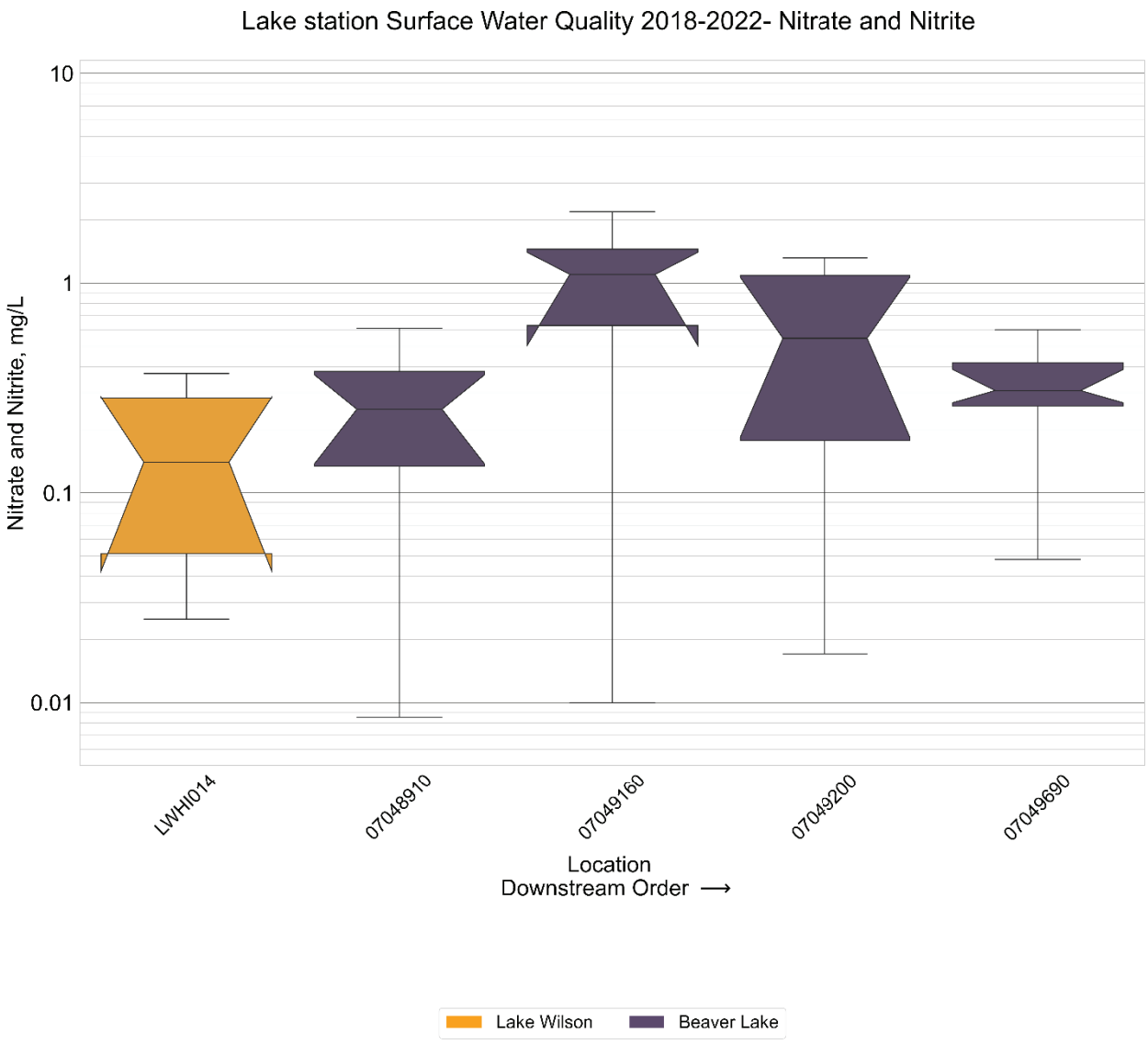


Figure 67. Box and whisker graph of nitrate nitrite measurements from lake stations with more than 10 values from 2018-2022.

1.8.3 Total Nitrogen

Table 78 through Table 83 list summary statistics for total nitrogen data from the Upper White River watershed during 2018-2022. The stations were divided into six ma or waterway segments White River to Lake Se uoyah, West Fork White River, White River from Wyman to state line, War Eagle Creek, Eastern Streams, and Lake Stations for data analysis and visuali ation. The highest maximum total nitrogen value was measured at Holman Creek WHI0070 downstream of the Huntsville wastewater treatment plant.

Table 78. Summary statistics for stream T measurements in the White River to Lake Se uoyah during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
H2O arks	103	BC	15	0.06	0.10	0.11	0.26	0.21	1.91
DE	WHI0104	WR	12	0.23	0.35	0.39	0.47	0.47	1.13
H2O arks	104	WR	14	0.22	0.26	0.33	0.33	0.37	0.48
H2O arks	110	WR	2	0.15	0.20	0.24	0.24	0.29	0.33
DE	WHI0106	WR	46	0.15	0.30	0.38	0.38	0.44	0.71
BWD	5	WR	57	0.08	0.30	0.38	0.42	0.51	1.03
DE	WHI0219	MFWR	12	0.19	0.39	0.51	0.64	0.64	1.62
BWD	7	MFWR	57	0.05	0.32	0.52	0.60	0.77	2.05
H2O arks	201	MFWR	14	0.08	0.31	0.53	0.56	0.82	1.08
DE	WHI0103	MFWR	50	0.13	0.29	0.44	0.49	0.63	1.92

BC Baldwin Creek, WR White River, MFWR Middle Fork White River

Table 79. Summary statistics for stream T measurements in the West Fork White River during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
H2O arks	102	WFWR	14	0.23	0.41	0.51	0.50	0.60	0.76
H2O arks	101	WFWR	10	0.13	0.36	0.42	0.39	0.50	0.56
DE	WHI0229	WFWR	13	0.12	0.17	0.35	0.36	0.46	1.19
H2O arks	200	WS	10	0.14	0.29	0.32	0.40	0.53	0.86
H2O arks	202	MC	8	0.88	0.95	1.21	1.17	1.28	1.55
H2O arks	206	SS	9	0.60	1.04	1.20	1.86	2.84	3.92
DE	WHI0223	TB	12	0.57	0.66	0.73	0.74	0.81	0.97
WRC	TB[a]	TB	130	0.32	0.80	1.06	1.09	1.28	2.74
H2O arks	210[a]	TB	14	0.47	0.82	0.88	0.92	0.95	1.30
US S	07048495[a]	TB	24	0.52	0.80	1.00	1.33	1.30	5.30
BWD	8[b]	WFWR	57	0.21	0.32	0.41	0.51	0.62	1.34
DE	WHI0100[b]	WFWR	50	0.18	0.33	0.37	0.47	0.51	1.13
WRC	WFWR	WFWR	129	0.15	0.39	0.52	0.73	0.96	2.94

Stations in this table with the same superscript letter are at the same location.
WFWR West Fork White River, WS Ward Slough, MC Mullins Creek, SS Spout Spring Branch, TB Town Branch

Table 80. Summary statistics for stream T measurements in the White River from Wyman to the state line during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
BWD	22	LSO	34	0.15	0.37	0.46	0.52	0.58	1.41
BWD	10[c]	WR	57	0.27	0.39	0.48	0.52	0.59	1.41
WRC	Wyman[c]	WR	128	0.23	0.42	0.57	0.68	0.84	2.40
US S	07048600[c]	WR	14	0.37	0.68	0.99	1.25	1.73	2.90
BWD	23	WR	11	0.51	0.71	0.96	1.65	1.50	6.18
BWD	13	WR	44	0.28	0.52	0.68	1.02	1.18	3.80
DE	WHI0052[e]	WR	50	0.27	0.57	0.71	0.87	0.92	4.43
US S	07048700[e]	WR	22	0.51	0.71	0.87	0.94	1.08	2.10
DE	WHI0221	LlC	12	0.20	0.31	0.37	0.54	0.66	1.56
DE	WHI0231	DC	12	0.52	0.58	0.83	1.10	1.51	2.33
H2O arks	205	HoC	14	0.32	0.70	0.99	1.12	1.62	2.11
WRC	Richland[d]	RC	131	0.44	1.01	1.28	1.40	1.65	4.70
US S	07048780[d]	RC	13	0.96	1.30	1.60	1.67	2.00	2.80
DE	WHI0110	RC	12	0.13	0.72	0.82	0.93	0.91	2.25
H2O arks	300	BrC	13	0.40	3.44	4.21	4.18	4.56	7.04
BWD	12	WR	49	0.36	1.19	2.32	2.27	3.03	4.91
H2O arks	306	PC	12	0.99	1.73	2.00	2.10	2.27	4.81
DE	WHI0012B	LwC	41	0.18	0.35	0.88	0.93	1.16	2.99

Stations in this table with the same superscript letter are at the same location.
LSO Lake Se uoyah outflow, WR White River, Drakes Creek, HoC Hock Creek, LlC Lollars Creek, RC Richland Creek, BrC Brush Creek, PC Prairie Creek, LwC Leatherwood Creek

Table 81. Summary statistics for stream T measurements in War Eagle Creek during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
DE	WHI0227	WEC	12	0.16	0.21	0.24	0.38	0.44	1.07
DE	WHI0233	C	12	0.42	0.55	0.60	0.89	0.80	2.62
H2O arks	109	WEC	11	0.20	0.33	0.48	0.50	0.60	1.16
DE	WHI0220	WC	12	0.37	0.40	0.67	0.83	0.87	2.11
BWD	15	WEC	57	0.24	0.44	0.58	0.65	0.75	1.78
H2O arks	307	HC	14	0.45	0.91	0.97	1.04	1.18	1.73
DE	WHI0070[f]	HC	48	0.96	2.08	2.59	3.58	4.51	13.00
H2O arks	308[f]	HC	14	1.19	1.93	3.19	3.67	4.85	7.98
BWD	21[g]	WEC	56	0.49	0.95	1.21	1.28	1.54	3.12
H2O arks	301[g]	WEC	9	0.86	1.22	1.27	1.26	1.39	1.52
H2O arks	302	C	13	3.06	3.75	3.96	3.97	4.18	4.89
H2O arks	303	ClC	15	3.44	3.73	3.91	4.11	4.31	5.48
WRC	WEC	WEC	131	0.57	1.40	1.72	1.73	2.04	3.81
DE	WHI0116	WEC	48	0.28	1.37	1.72	1.71	1.92	2.96
H2O arks	304	CC	15	3.44	3.56	3.98	4.03	4.23	5.07
BWD	9[i]	WEC	57	0.73	1.27	1.59	1.64	1.96	2.76
H2O arks	305[i]	WEC	9	1.18	1.85	2.01	1.95	2.16	2.64
US S	07049050[i]	WEC	12	1.10	1.88	2.15	2.21	2.45	3.90

Stations in this table with the same superscript letter are at the same location.
WEC War Eagle Creek, C ackson Creek, WC Wharton Creek, HC Holman Creek, C lade Creek, ClC Clear Creek, CC Clifty Creek

Table 82. Summary statistics for stream T measurements in Eastern Streams during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
DE	WHI0225	FC	10	0.11	0.14	0.19	0.20	0.26	0.31
DE	WHI0121	KR	46	0.24	0.48	0.59	0.63	0.74	1.45
DE	WHI0123	KR	47	0.46	0.76	0.94	1.01	1.19	2.03
DE	WHI0230	KC	11	0.40	0.46	0.69	0.65	0.76	1.08
DE	WHI0129	OC	11	0.37	0.46	0.59	0.62	0.65	1.13
DE	WHI0068	OC	42	0.15	0.37	0.82	0.88	1.33	2.19
DE	WHI0069	OC	46	0.24	0.47	0.84	0.98	1.42	2.44
WRC	Kings	KR	36	0.17	0.36	0.81	0.84	1.04	2.08
DE	WHI0009	KR	44	0.12	0.35	0.77	0.81	1.18	1.91
US S	07053250	C	1	6.41	6.41	6.41	/	6.41	6.41
DE	WHI0232	TC	10	0.12	0.20	0.23	0.30	0.32	0.83
DE	WHI0071	LC	45	1.28	1.83	2.27	2.33	2.79	3.60

Stations in this table with the same superscript letter are at the same location.
FC Felkins Creek, KR Kings River, KC Kenner Creek, OC Osage Creek, C ocum Creek, TC Terrapin Creek, LC Long Creek

Table 83. Summary statistics for reservoir T measurements from stations in Lake Se uoyah, Lake Wilson, and Beaver Lake during 2018-2022 stations listed in downstream order .

rgani ation	Station D	La e D	Sa le Location	o. of easures	in alue, g/L	25th Percentile g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a alue, g/L
DE	LWHI009	LS	Epilimnion	9	0.41	0.49	0.58	0.61	0.62	1.21
DE	LWHI014	LW	Epilimnion	12	0.39	0.49	0.60	0.58	0.64	0.76
US S	07048910	BL	Epilimnion	17	0.42	0.60	0.72	0.80	0.93	1.40
DE	LWHI013B	BL	Epilimnion	3	0.16	0.46	0.75	0.71	0.98	1.21
US S	07049160	BL	Epilimnion	14	0.40	0.80	1.40	1.27	1.58	2.40
US S	07049187	BL	Epilimnion	6	0.41	0.61	0.76	0.92	1.19	1.70
US S	07049200	BL	Epilimnion	16	0.25	0.51	0.87	0.94	1.35	1.70
DE	LWHI013C[k]	BL	Epilimnion	2	0.34	0.52	0.71	0.71	0.89	1.07
US S	07049500[k]	BL	Epilimnion	9	0.31	0.53	0.9	0.79	0.95	1.20
DE	LWHI013	BL	Epilimnion	5	0.34	0.35	0.41	0.41	0.46	0.47
US S	07049690	BL	Epilimnion	22	0.21	0.31	0.43	0.43	0.50	0.71

Stations in this table with the same superscript letter are at the same location.
LS Lake Se uoyah, LW Lake Wilson, BL Beaver Lake

Figure 68 through Figure 73 show box and whisker graphs of total nitrogen measurements from stations with more than 10 measurements from the period 2018-2022. Baldwin Creek Figure 68 has the lowest median total nitrogen concentration, and this median is significantly lower than median values of the other graphed stream stations in the Upper White River watershed. The Brush Creek station Figure 70 has the highest median total nitrogen concentration, which is significantly higher than median values at the rest of the graphed stream stations in this watershed. Median total nitrogen concentrations in Town Branch Figure 69 are higher than median concentrations in West Fork White River WFWR , which raises total nitrogen levels in downstream WFWR. Median total nitrogen concentrations in Holman Creek Figure 71 are statistically significantly higher than median concentrations for the ma ority of the War Eagle Creek stations probably because of the influence of Huntsville wastewater treatment plant discharge. Other tributaries to War Eagle Creek lade Creek, Clear Creek, Clifty Creek , are also significantly higher than the main branch of War Eagle Creek, which increases in total nitrogen as it flows downstream Figure 71 . Median total nitrogen in Long Creek WHI0071 is statistically significantly higher than other streams in the Eastern waterway segment Figure 72 .

Median total nitrogen concentrations in the reservoirs are similar to median concentrations in headwater streams. It appears that the median total nitrogen concentration in Beaver Lake at the dam is significantly lower than median concentrations at other locations in the reservoir, and in Lake Wilson Figure 73 .

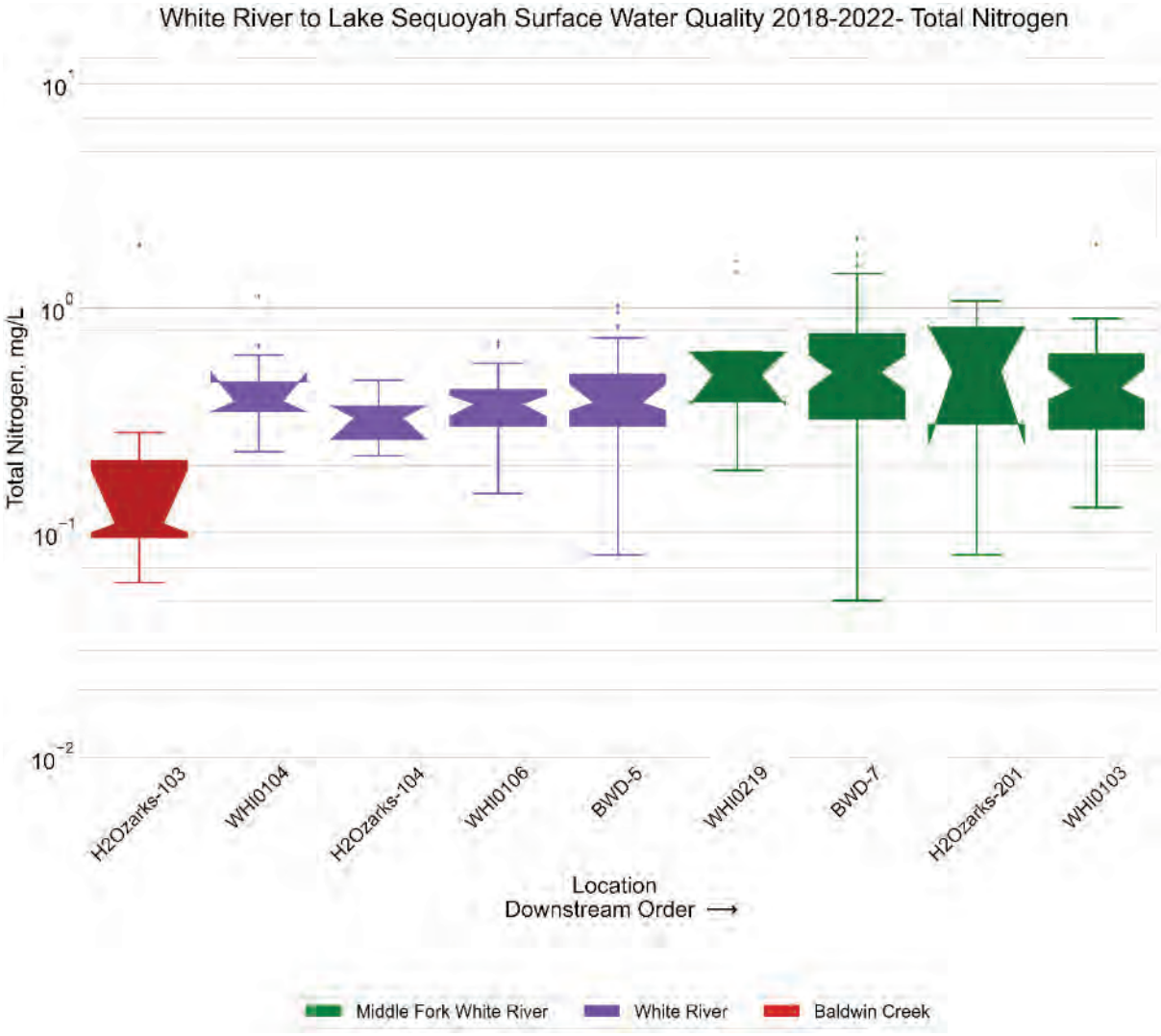


Figure 68. Box and whisker graph of Total itrogen measurements from stations in the White River to Lake Se uoyah waterway segment with more than 10 values from 2018-2022.

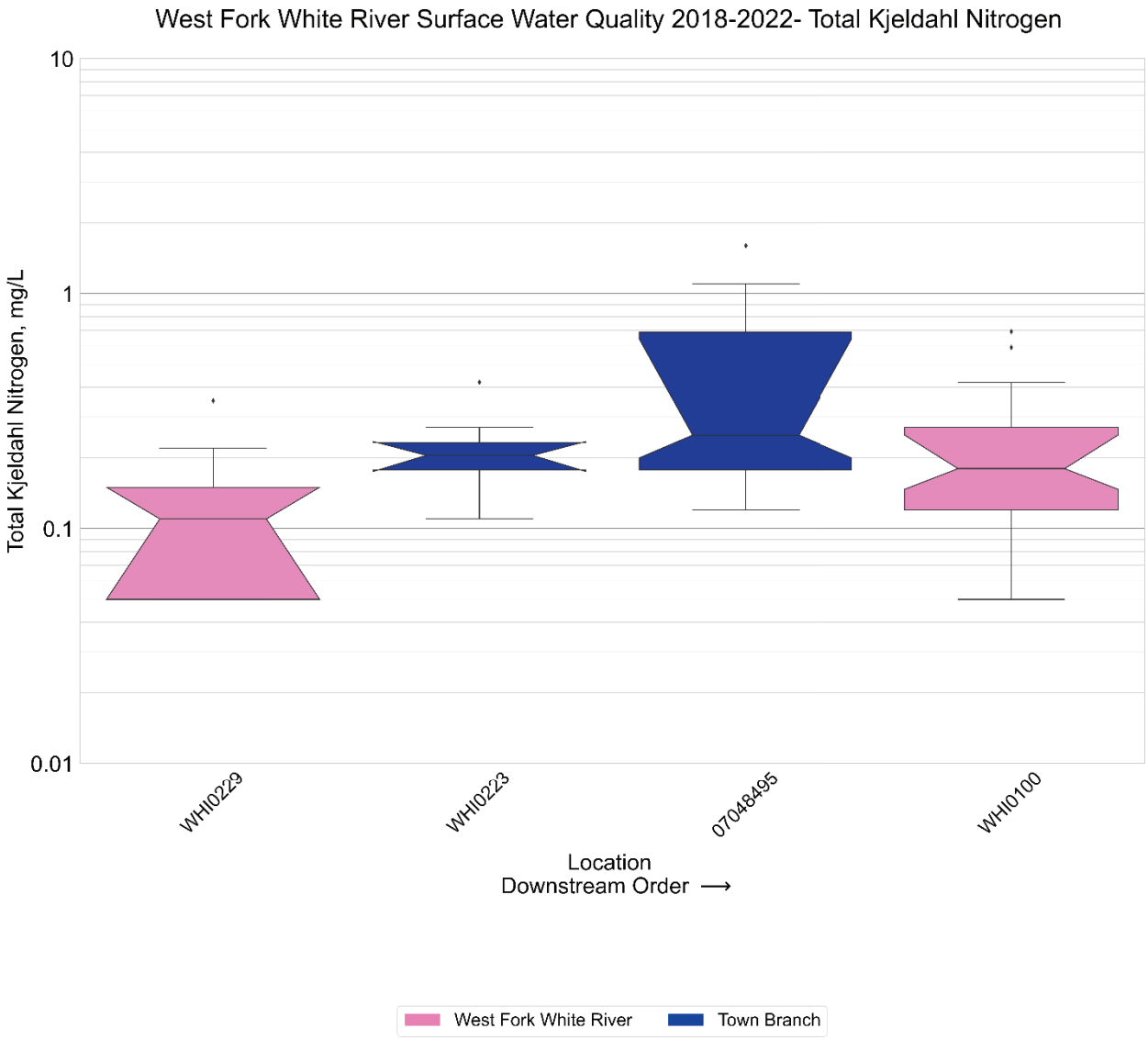


Figure 69. Box and whisker graph of Total itrogen measurements from stations in the West Fork White River waterway segment with more than 10 values from 2018-2022. ote that stations TB, 210, and 07048495 are at the same location on Town Branch and stations BWC-8 and WHI0100 are at the same location on the West Fork White River.

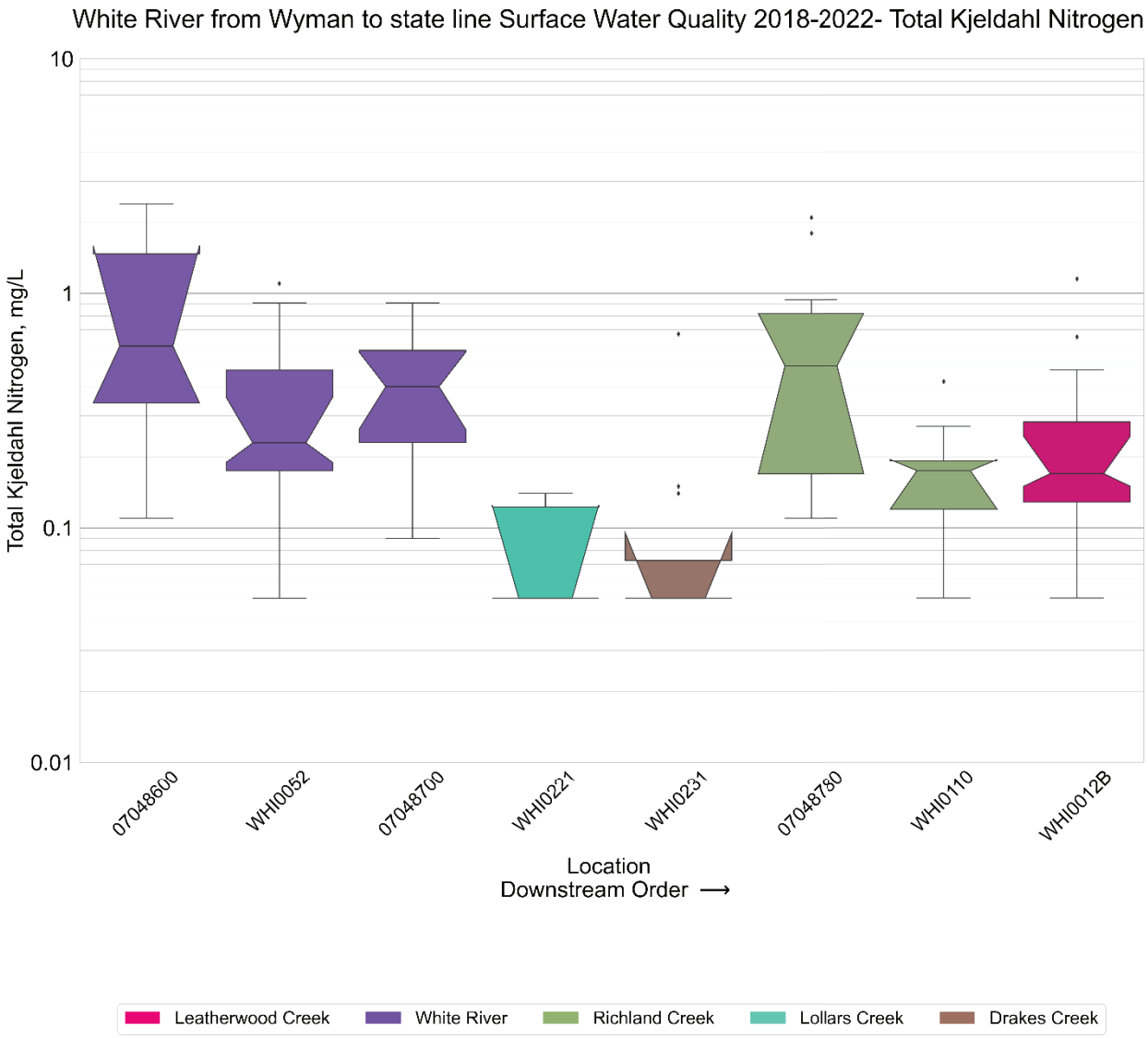


Figure 70. Box and whisker graph of Total itrogen measurements from stations in the White River from Wyman to the state line waterway segment with more than 10 values from 2018-2022. ote that stations 10, Wyman, and 07048600 are at the same location on the White River stations Richland and 07048780 are at the same location on Richland Creek and stations WHI0052 and 07048700 are at the same location on the White River downstream of Richland Creek.

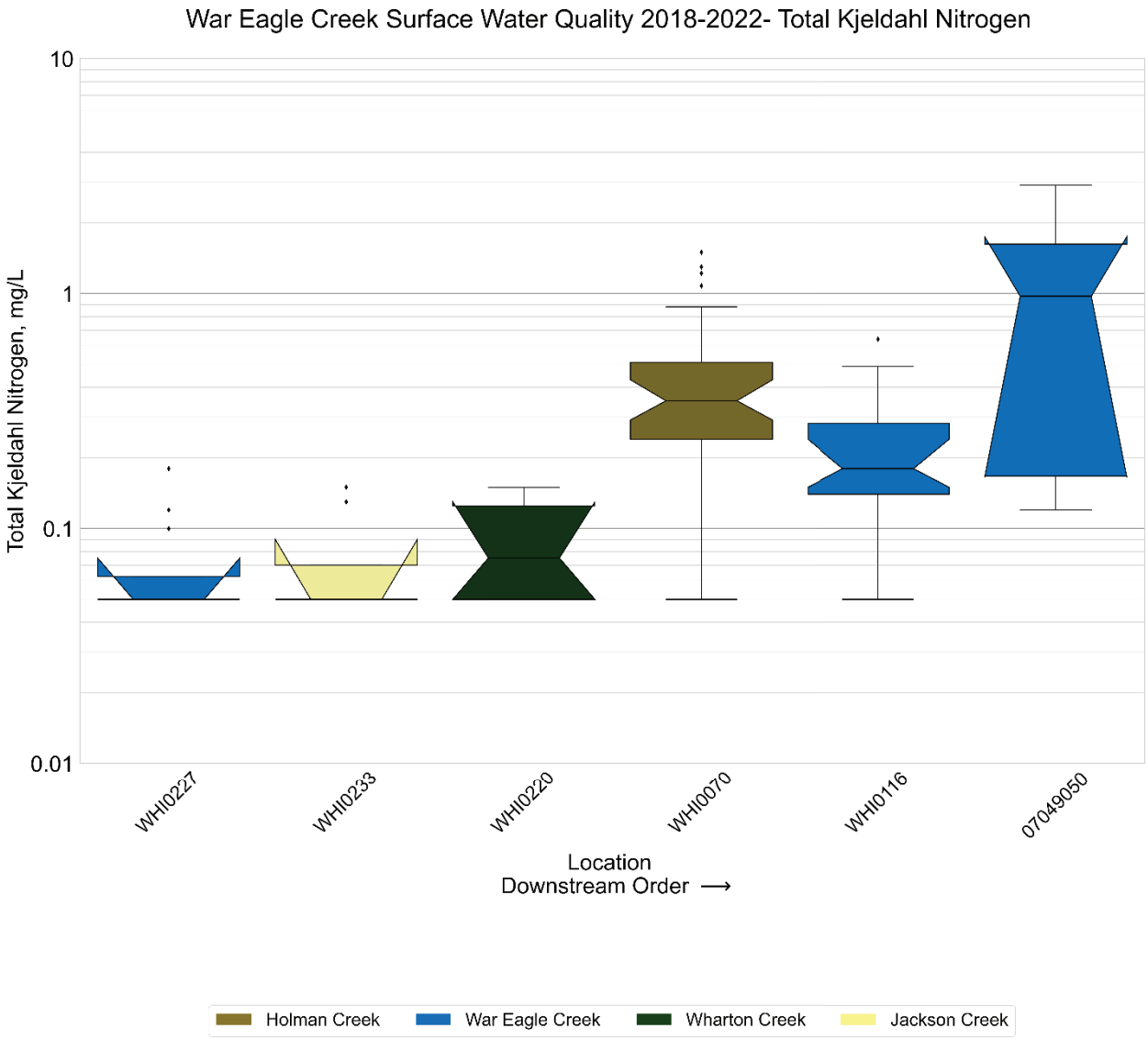


Figure 71. Box and whisker graph of Total itrogen measurements from stations in the War Eagle Creek waterway segment with more than 10 values from 2018-2022. ote that stations WHI0070 and 308 are at the same location on Holman Creek and stations BWC-9, 305, and 07049050 are at the same location on War Eagle Creek.

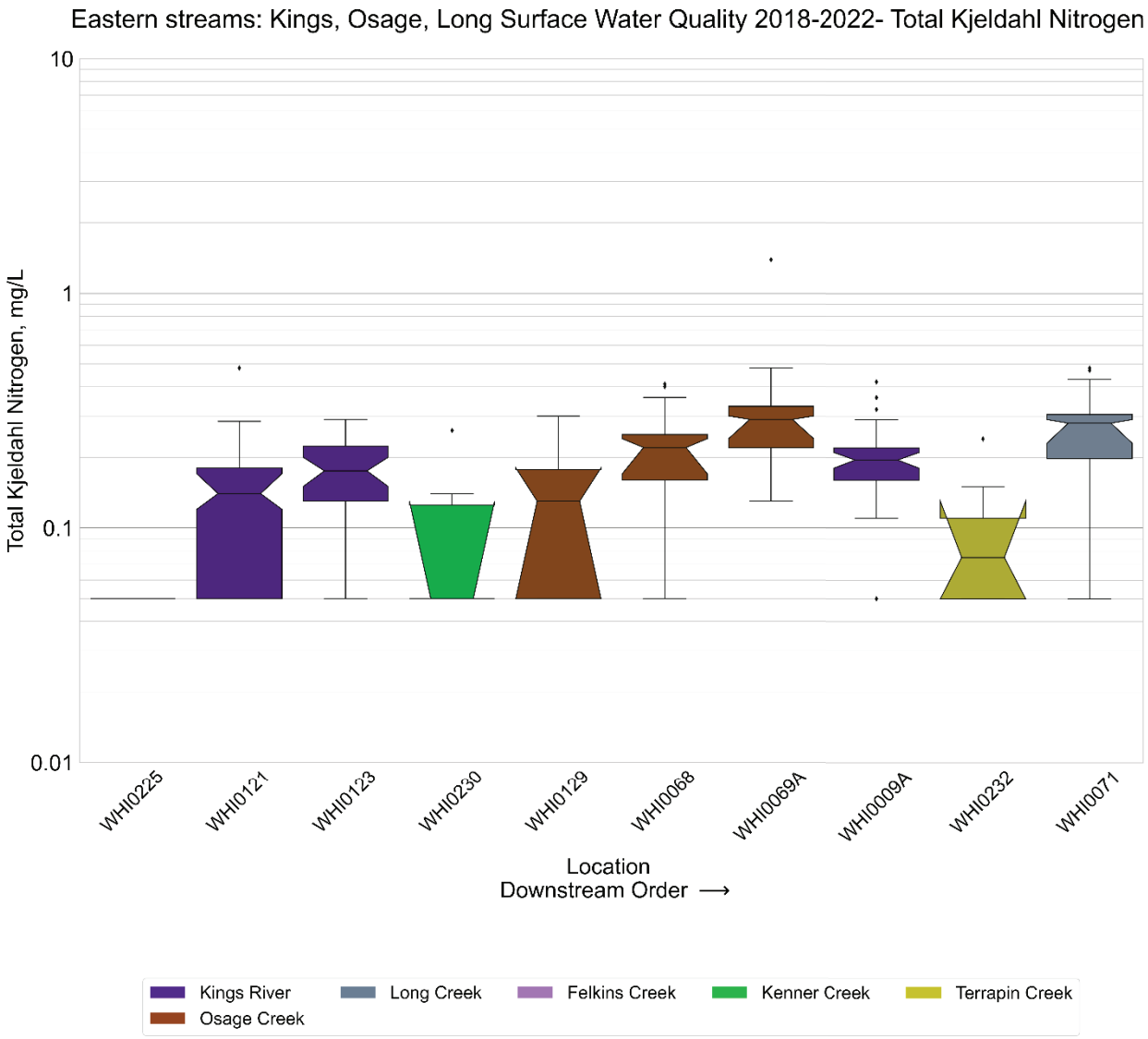


Figure 72. Box and whisker graph of Total itrogen measurements from stations in the Eastern streams waterway segment with more than 10 values from 2018-2022. ote that stations Kings and WHI0009 are at the same location on Kings River.

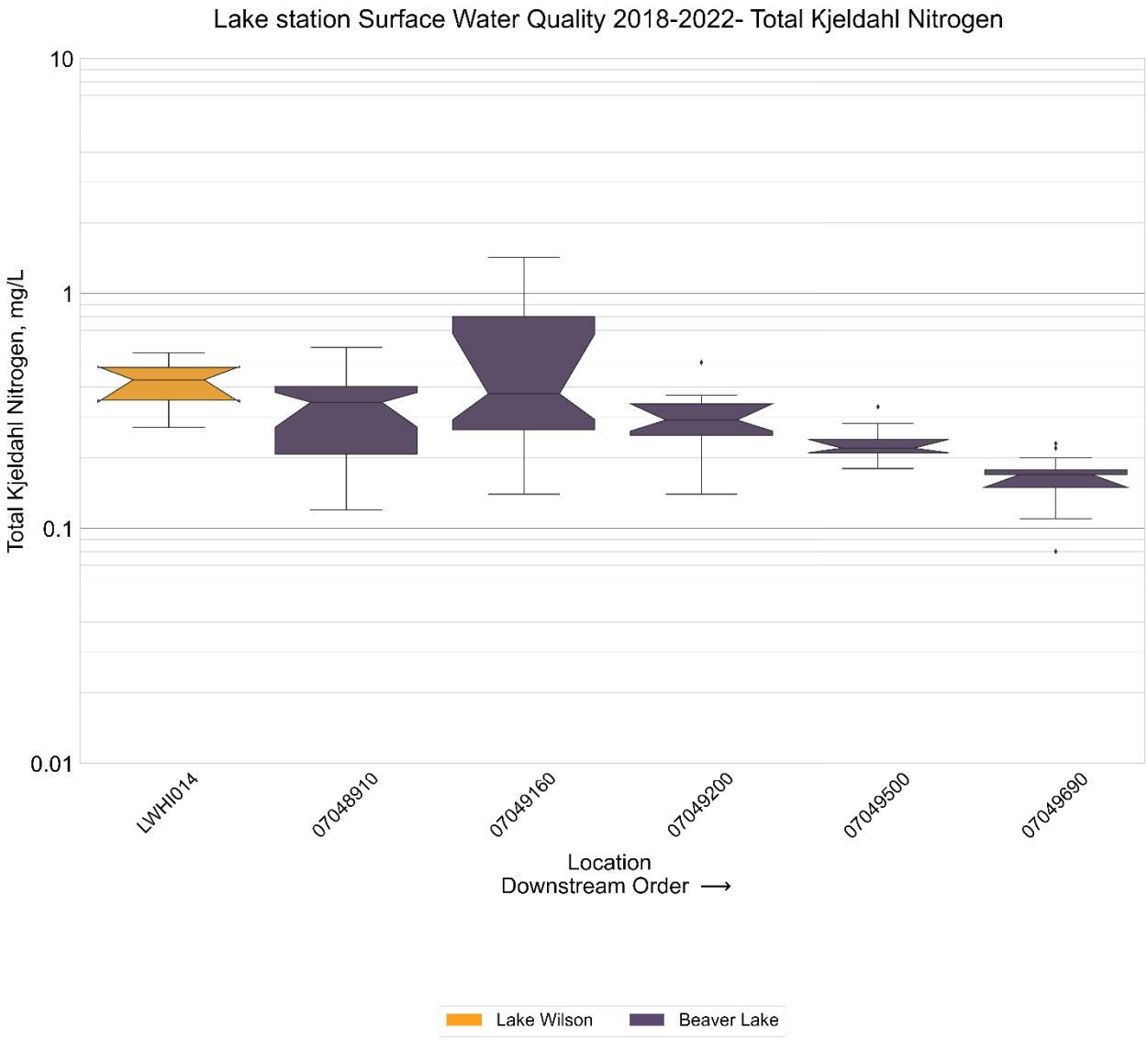


Figure 73. Box and whisker graph of Total itrogen measurements from lake stations with more than 10 values from 2018-2022.

1.9 Minerals

This section characteri es levels of total dissolved solids TDS and sulfate in the Upper White River watershed. TDS is a measure of the organic and inorganic compounds dissolved in water. Common compounds dissolved in water include calcium, chloride, and sulfate. The concentration of TDS affects the water balance in the cells of a uatic organisms. TDS levels can also affect the suitability of water for industrial uses or irrigation. TDS was measured by DE , H2O arks, and US S during 2018-2022. Segments of the West Fork White River and Kings River are listed as impaired on the pproved 2018 and Draft 2020 303 d Lists because of high TDS levels DE , 2019 DE , 2020 .

Sulfate is the most common form of sulfur, an essential plant nutrient, in well-oxygenated natural waters. However, at very high concentrations sulfates can be toxic to cattle and affect water pH and solubility of metals and other substances. Sulfate was measured by WRC, DE and US S during 2018-2022. early 30 miles of the West Fork White River is listed as impaired on the pproved 2018 and Draft 2020 303 d Lists because of high sulfate levels DE , 2019 DE , 2020 .

Summaries of TDS and sulfate measurements from the period 2018-2022 are provided in the subsections below. In these summaries, monitoring stations were divided into six groups White River to Lake Se uoyah, West Fork White River, White River from Wyman to state line, War Eagle Creek, Eastern Streams, and Lake Stations for ease of data analysis and visuali ation.

umeric minerals criteria for lakes apply to measurements taken from depths less than 1 meter PCEC, 2022 . Therefore, measurements taken ust from the epilimnion are summari ed below. To determine stream mineral impairment, DE re uires at least 10 measurements distributed over two years. Site specific minerals criteria have been set for some waterbodies in the watershed. ll other waterbodies have the same numeric criteria. Locations where more than 25% of at least 10 measurements do not meet numeric criteria may be classified as impaired PCEC, 2022 . eology and riparian soil type have significant influence on dissolved ions in streams in the Upper White watershed Scott Haggard, 2021 . Significant differences in water uality standards are used in the O ark Highlands and Boston Mountains ecoregions. Research found that TDS and sulfate were significantly greater in the O ark Highlands than the Boston Mountains ecoregion Scott Haggard, 2021 .

1.9.1 Total Dissolved Solids

Table 84 through Table 88 list summary statistics for TDS measurements from surface waters in the Upper White River watershed during the period 2018-2022. Included in these tables is a listing of the applicable numeric water uality criteria from Rule 2, and the number and percentage of measurements that exceed the applicable criteria. The TDS criterion for waterbodies without site specific criteria is 500 mg/L. Fifty-two stations sampled 2018-2022 have more than 10 TDS measurements. However, at 14 stream stations with more than 10 measurements, the measurements were all from one year, so they do not meet the DE data re uirements for evaluating water uality standards. Stations WHI0100 and WHI0009 are located on stream reaches listed as impaired because of high TDS, and we found they exceeded DE criteria during 2018-2022. Town Branch in Huntsville is also listed as impaired because of TDS but was not sampled 2018-2022 DE 2020 . The stations located on assessment units listed as impaired are highlighted in the tables below.

Table 84. Summary statistics for stream TDS measurements from stations in White River to Lake Se uoyah waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of alues Criteria	Percentage of alues Criteria
H2O arks	103	BC	15	14.2	22.4	26.9	56.6	34.1	280.7	500	0	0%
DE	WHI0104	WR	11	22.5	26.5	27.5	28.1	30.8	33.0	160	0	-
H2O arks	104	WR	14	8.0	22.8	27.5	36.4	33.9	154.7	160	0	0%
H2O arks	110	WR	2	34.00	36.73	39.45	39.45	42.18	44.90	500	0	-
DE	WHI0106	WR	51	26.5	34.3	38.0	42.4	47.8	118.0	500	0	0%
DE	WHI0219	MFWR	12	51.0	55.8	62.5	69.2	85.9	93.0	500	0	-
H2O arks	201	MFWR	14	55.8	62.3	65.9	67.1	68.3	86.2	500	0	0%
DE	WHI0103	MFWR	53	51.0	60.0	70.0	70.6	83.0	94.0	500	0	0%

BC Baldwin Creek, WR White River, MFWR Middle Fork of the White River
DE re uires at least 10 samples collected over two years to evaluate attainment of the TDS criteria PCEC 2022 . This data was collected from ust one year or there are fewer than 10 measurements.

Table 85. Summary statistics for stream TDS measurements from stations in West Fork White River waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of alues Criteria	Percentage of alues Criteria
H2O arks	102	WFWR	14	39.1	45.0	47.4	61.1	54.1	220.9	150	1	7%
H2O arks	101	WFWR	10	77.1	84.4	96.2	99.0	111.5	133.3	150	0	0%
DE	WHI0229	WFWR	13	35.5	83.0	96.5	101.6	130.0	144.0	150	0	-
H2O arks	200	WS	10	206.0	231.8	292.3	281.0	316.0	357.8	500	0	0%
H2O arks	202	MC	8	245.5	283.0	303.5	315.7	352.6	395.6	500	0	-
H2O arks	206	SS	9	233.6	261.3	276.4	276.6	295.6	317.3	500	0	-
DE	WHI0223	TB	12	184.0	255.0	265.5	266.4	286.0	346.0	500	0	-
H2O arks	210[a]	TB	14	21.1	227.3	260.4	245.0	291.7	308.7	500	0	0%
US S	07048495[a]	TB	24	79.0	145.6	209.5	202.3	273.5	343.0	500	0	0%
DE	WHI0100	WFWR	53	82.0	105.0	115.0	130.1	162.0	224.0	150	15	28%

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

WFWR West Fork White River, Ward Slough, MC Mullins Creek, SS Spout Spring Branch, TB Town Branch

DE re uires at least 10 samples collected over two years to evaluate attainment of the TDS criteria. This data was collected from ust one year PCEC 2022 .

Indicates station is located on assessment unit classified as impaired on pproved 2018 and Draft 2020 and 2022 303 d Lists because of high TDS.

Table 86. Summary statistics for stream TDS measurements from stations in White River from Wyman to state line waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of alues Criteria	Percentage of alues Criteria
US S	07048600	WR	14	41.0	55.8	65.0	73.7	73.8	165.0	160	1	7%
DE	WHI0052[b]	WR	53	51.5	68.0	79.5	97.4	124.0	277.0	160	2	4%
US S	07048700[b]	WR	21	59.0	73.5	92.3	108.6	136.0	193.0	160	3	14%
DE	WHI0221	LlC	12	30.0	37.6	41.5	41.2	44.1	58.5	500	0	-
DE	WHI0231	DC	12	41.5	49.4	52.0	51.1	54.6	56.5	500	0	-
H2O arks	205	HoC	14	44.4	58.9	63.6	63.4	68.2	78.4	500	0	0%
US S	07048780	RC	12	47.0	63.8	88.0	92.4	105.3	185.0	500	0	0%
DE	WHI0110	RC	12	73.5	83.6	92.8	103.2	126.3	145.0	500	0	-
H2O arks	300	BrC	13	169.8	200.7	218.7	233.3	244.8	396.4	500	0	0%
H2O arks	306	PC	12	120.0	169.1	181.1	187.9	187.6	344.6	500	0	0%
DE	WHI0012B	LwC	44	130.0	174.0	199.0	205.3	235.5	276.0	500	0	0%

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

WR White River, DC Drake s Creek, HoC Hock Creek, LlC Lollars Creek, RC Richland Creek, BrC Brush Creek, PC Prairie Creek, LwC Leatherwood Creek

DE re uires at least 10 samples collected over two years to evaluate attainment of the TDS criteria. This data was collected from ust one year PCEC 2022 .

Table 87. Summary statistics for stream TDS measurements from stations in War Eagle Creek waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of alues Criteria	Percentage of alues Criteria
DE	WHI0227	WEC	12	35.0	39.9	47.5	48.5	57.8	63.5	500	0	-
DE	WHI0233	C	12	36.5	48.0	53.8	60.5	74.6	97.0	500	0	-
H2O arks	109	WEC	11	42.4	48.8	59.1	63.3	74.5	98.9	500	0	0%
DE	WHI0220	WH	12	69.0	84.4	99.0	103.2	126.3	139.0	500	0	-
H2O arks	307	HC	14	84.9	97.2	118.9	122.6	141.6	178.4	621	0	0%
DE	WHI0070[c]	HC	53	96.0	160.0	187.0	251.0	329.0	900.0	621	1	2%
H2O arks	308[c]	HC	14	116.9	137.6	223.1	226.9	305.1	374.7	621	0	0%
H2O arks	301	WEC	9	56.9	80.9	89.8	95.9	96.7	146.9	500	0	-
H2O arks	302	C	13	33.6	154.2	173.6	174.1	208.4	228.9	500	0	0%
H2O arks	303	ClC	15	103.3	125.1	144.4	144.4	157.7	212.0	500	0	0%
DE	WHI0116	WEC	53	79.5	96.5	115.0	123.0	152.0	188.0	500	0	0%
H2O arks	304	CC	15	154.2	165.8	186.0	184.5	201.7	215.6	500	0	0%
H2O arks	305[d]	WEC	9	94.2	99.8	115.7	118.4	127.7	162.7	500	0	-
US S	07049050[d]	WEC	12	56.0	75.5	81.0	95.8	115.3	158.0	500	0	0%

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

WEC War Eagle Creek, C ackson Creek, WH Wharton Creek, HC Holman Creek, C lade Creek, ClC Clear Creek, CC Clifty Creek

DE re uires at least 10 samples collected over two years to evaluate attainment of the TDS criteria. This data was collected from ust one year PCEC 2022 .

Table 88. Summary statistics for stream TDS measurements from stations in Eastern portion Kings River, Osage Creek, and Long Creek waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ati on	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of alues Criteria	Percentage of alues Criteria
DE	WHI0225	FC	10	33.5	38.5	44.3	45.7	50.3	62.0	500	0	-
DE	WHI0121	KR	52	54.5	65.5	78.8	89.8	113.5	151.0	150	1	2%
DE	WHI0123	KR	53	74.0	92.0	108.0	113.3	136.0	161.0	150	3	6%
DE	WHI0230	KC	11	65.0	78.5	93.5	98.4	114.5	144.0	150	0	-
DE	WHI0129	OC	11	64.5	78.3	83.0	96.1	116.5	142.0	500	0	-
DE	WHI0068	OC	44	99.5	129.8	142.0	142.9	157.0	188.0	500	0	0%
DE	WHI0069	OC	49	103.0	140.0	168.0	175.9	210.0	299.0	500	0	0%
DE	WHI0009	KR	49	100.0	124.0	139.0	139.2	154.0	180.0	150	15	31%
DE	WHI0232	TC	10	41.5	47.9	50.8	65.1	87.3	102.0	500	0	-
DE	WHI0071	LC	48	144.0	176.3	201.5	203.2	230.0	264.0	500	0	0%

FC Felkins Creek, KR Kings River, KC Kenner Creek, OC Osage Creek, TC Terrapin Creek, LC Long Creek

DE re uires at least 10 samples collected over two years to evaluate attainment of the TDS criteria. This data was collected from ust one year PCEC 2022 .

Indicates station is located on assessment unit classified as impaired on both pproved 2018 and Draft 2020 303 d Lists because of high TDS.

Table 89. Summary statistics for TDS measurements from Lake Stations at during 2018-2022 stations listed in downstream order, first row is farthest upstream station . ll lake stations data analy ed is from the epilimnion.

rgani ation	Station D	La e D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of alues Criteria	Percentage of alues Criteria
DE	LWHI009	LS	8	41.5	45.4	54.5	56.4	63.5	80.0	500	0	-
DE	LWHI014	LW	12	87.5	97.4	103.5	104.1	110.5	118.0	500	0	0%
US S	07048910	BL	22	65.0	73.8	87.5	87.8	99.5	120.0	160	0	0%
DE	LWHI013B	BL	5	18.0	79.0	85.0	75.2	95.0	99.0	160	0	-
US S	07049160	BL	21	73.0	90.0	95.0	94.2	97.0	114.0	160	0	0%
US S	07049187	BL	6	65.0	71.5	79.5	81.7	88.3	106	160	0	-
US S	07049200	BL	21	61.0	81.0	84.0	83.5	88.0	96.0	160	0	0%
DE	LWHI013C[e]	BL	4	75.5	77.4	82.8	82.6	88.0	89.5	160	0	-
US S	07049500[e]	BL	16	71.0	79.0	85.5	83.3	88.3	90.0	160	0	0%
DE	LWHI013	BL	5	32.5	84.9	85.2	75.3	85.6	88.5	160	0	-
US S	07049690	BL	22	80.0	86.3	87.5	89.5	92.0	103.0	160	0	0%

Stations in this table with the same superscript letter are at the same location.
LS Lake Se uoyah, LW Lake Wilson, BL Beaver Lake
DE re uires at least 10 samples collected over two years to evaluate attainment of the TDS criteria PCEC 2022 .

Figure 74 through Figure 79 show box and whisker graphs of TDS measurements from stations in each waterway segment with more than 10 measurements from the period 2018-2022. Median TDS concentrations, although variable, increase from upstream to downstream. The highest median TDS value is for the Ward Slough station H2O arks 200 followed by stations on Town Branch in Fayetteville WHI0233, H2O arks 210 . The lowest median TDS values are from the upper portion of the White River.

Median TDS concentrations for West Fork White River stations are statistically significantly higher than the median concentrations for the upper White River and Baldwin Creek stations, particularly downstream of the Town Branch confluence Figure 75 . West Fork White River median TDS concentrations are not significantly different from median TDS concentrations at White River stations downstream of Lake Se uoyah.

Median TDS concentrations for Beaver Lake stations are statistically significantly lower than the median TDS concentration from Wilson Lake.

In at least some instances, higher median TDS concentrations appear to be associated with municipal wastewater treatment plant discharge and development, e.g., Holman Creek in Figure 77 and Leatherwood Creek in Figure 76. Research has shown that geology, and anthropogenic activities, can influence TDS levels in streams Scott Haggard, 2021 .

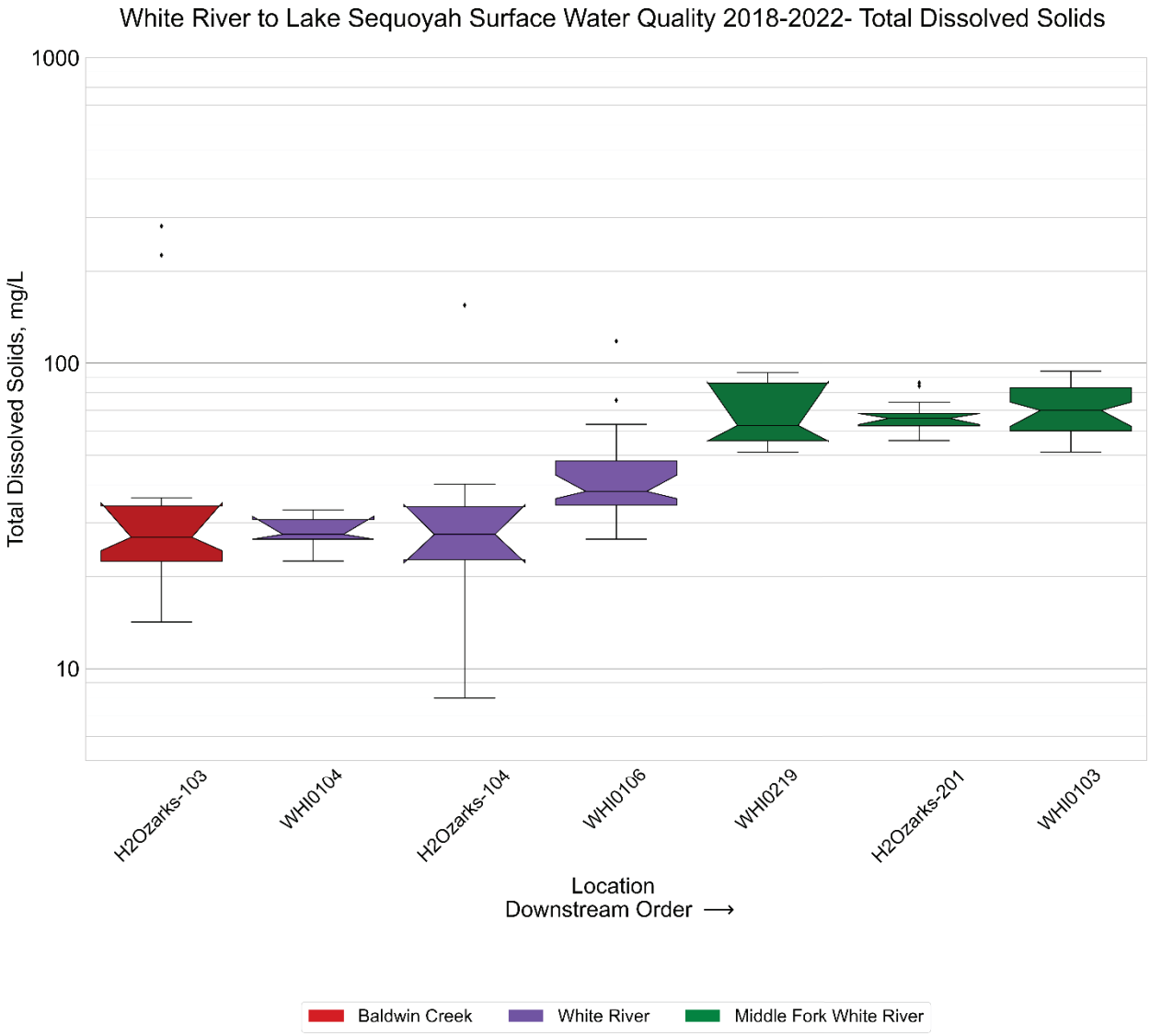


Figure 74. Box and whisker graph of TDS measurements in White River to Lake Se uoyah waterway segment from stations with more than 10 values from 2018-2022.

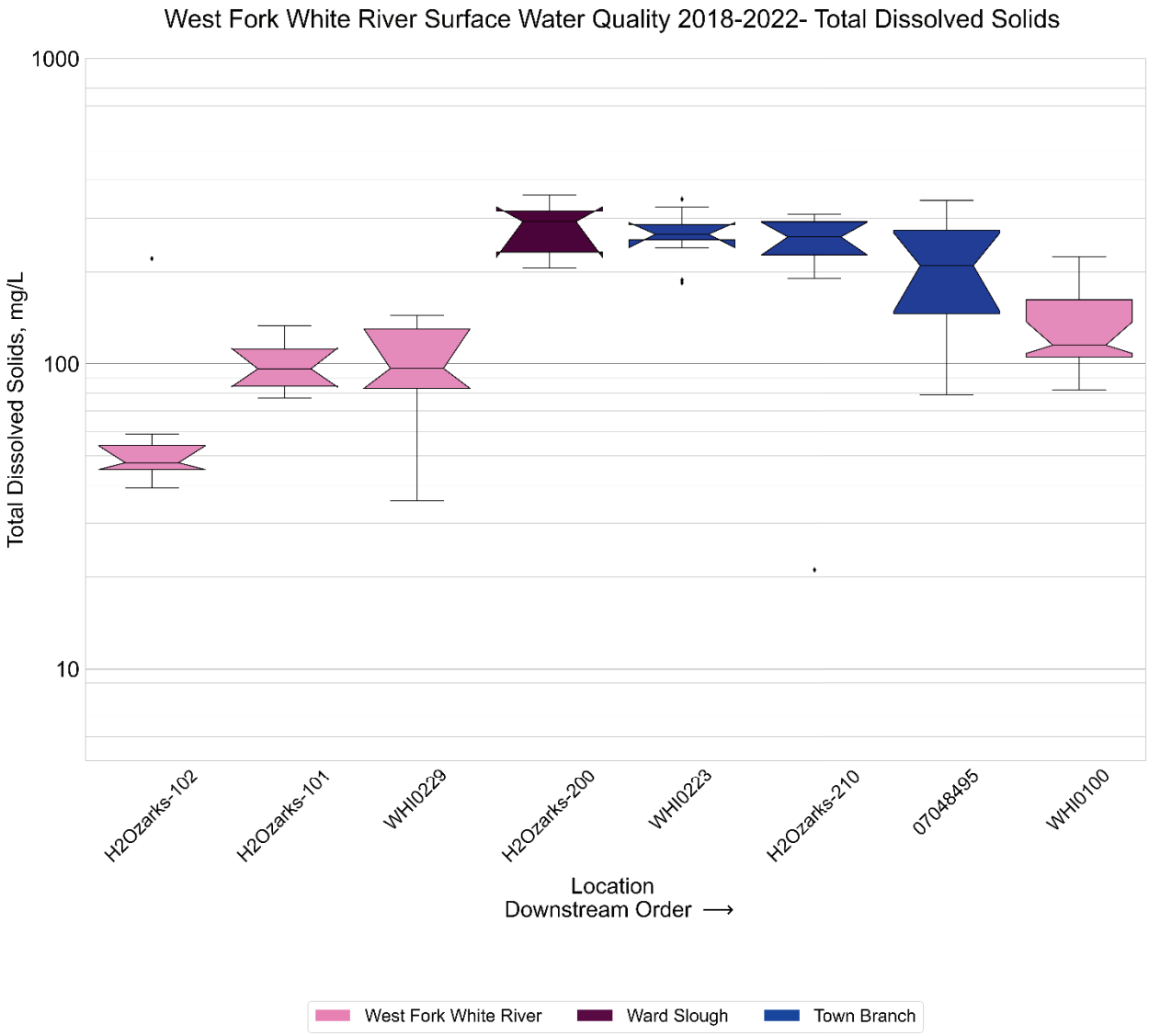


Figure 75. Box and whisker graph of TDS measurements in West Fork White River waterway segment from stations with more than 10 values from 2018-2022. ote that stations 210 and 07048495 are at the same location on Town Branch.

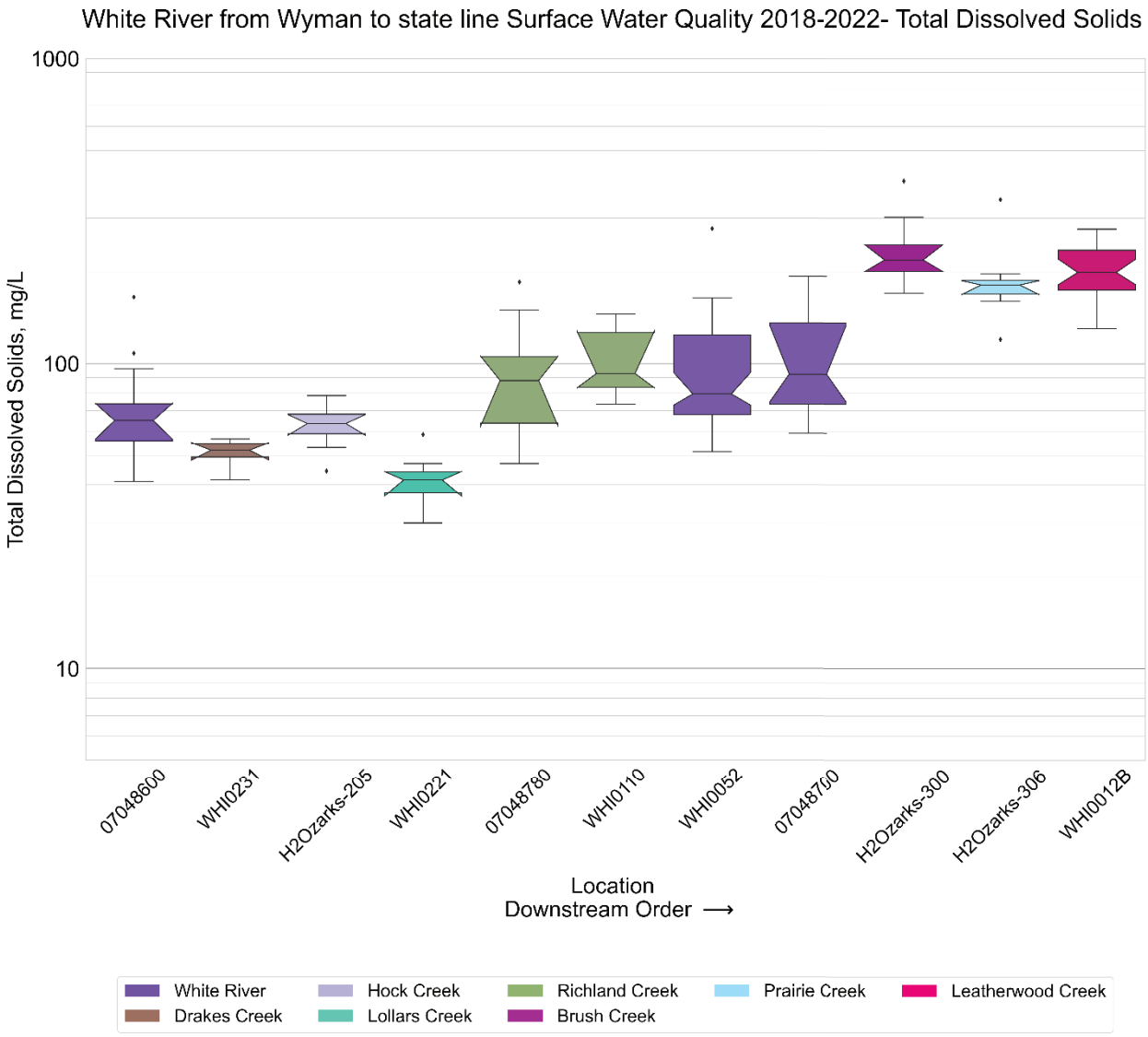


Figure 76. Box and whisker graph of TDS measurements in White River from Wyman to the state line waterway segment from stations with more than 10 values from 2018-2022. ote that stations WHI0052 and 07048700 are at the same location on the White River.

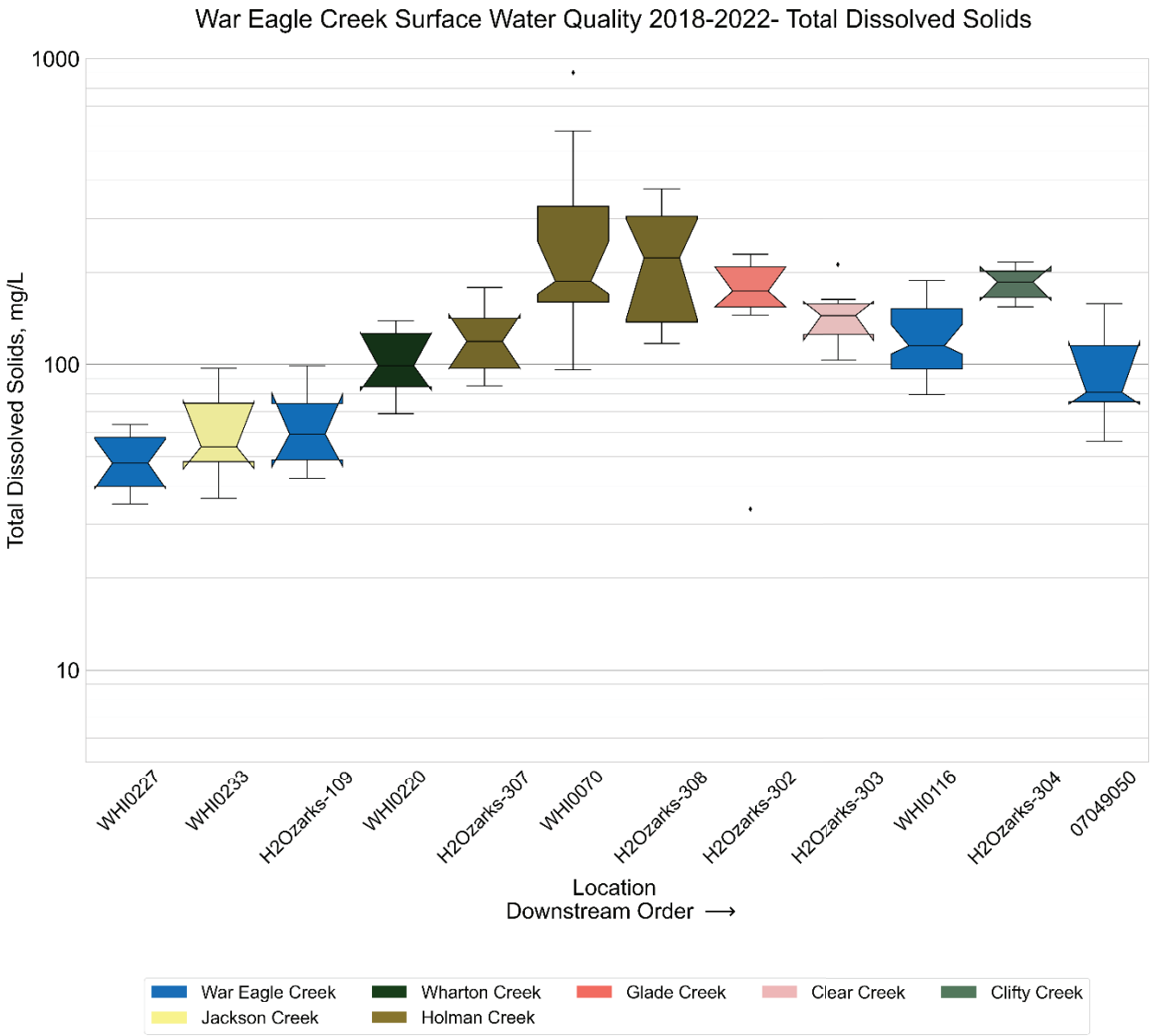


Figure 77. Box and whisker graph of TDS measurements in War Eagle Creek waterway segment from stations with more than 10 values from 2018-2022. ote that stationsWHI0070 and 308 are at the same location on Holman Creek.

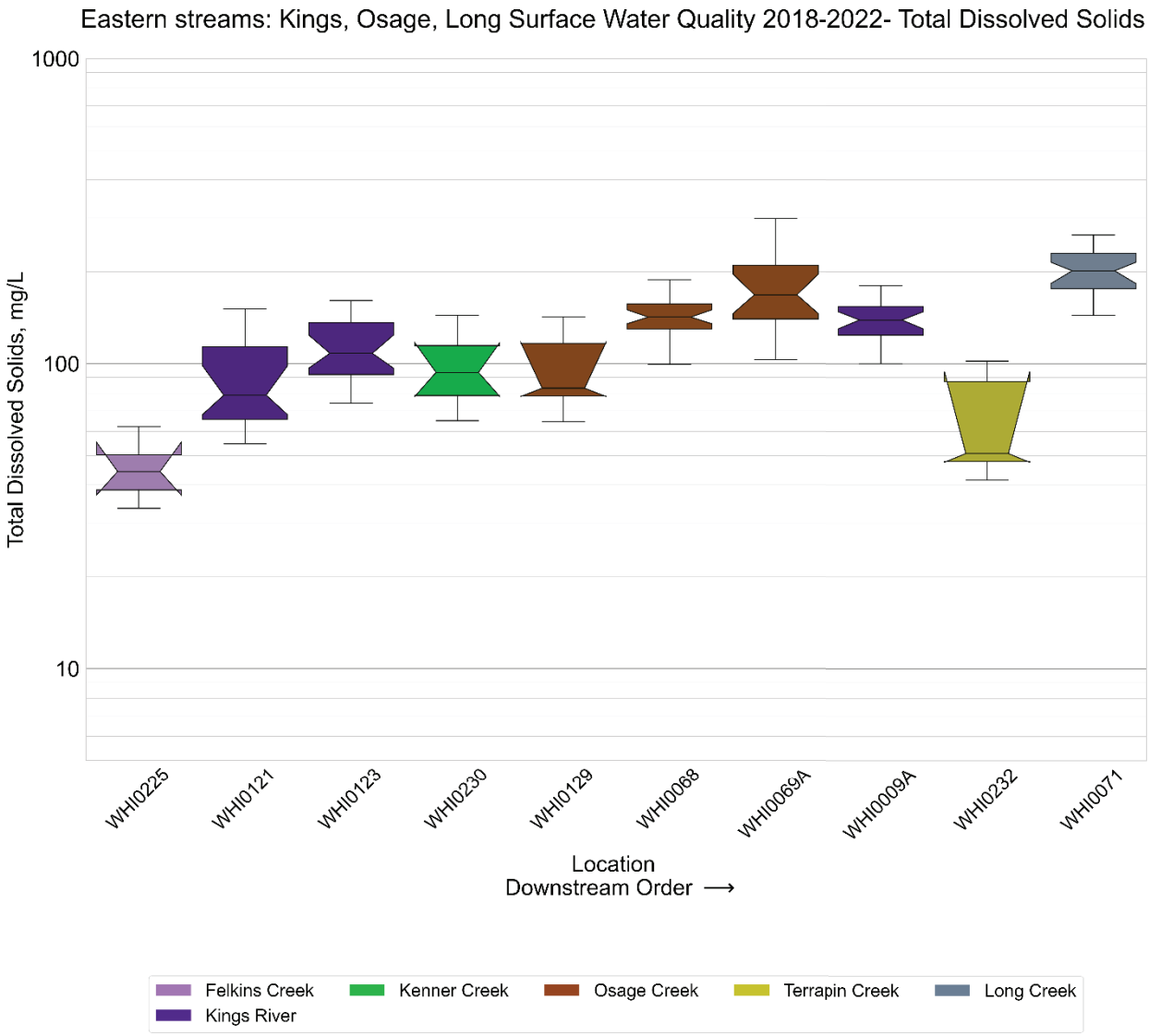


Figure 78. Box and whisker graph of TDS measurements in Eastern Streams waterway segment from stations with more than 10 values from 2018-2022.

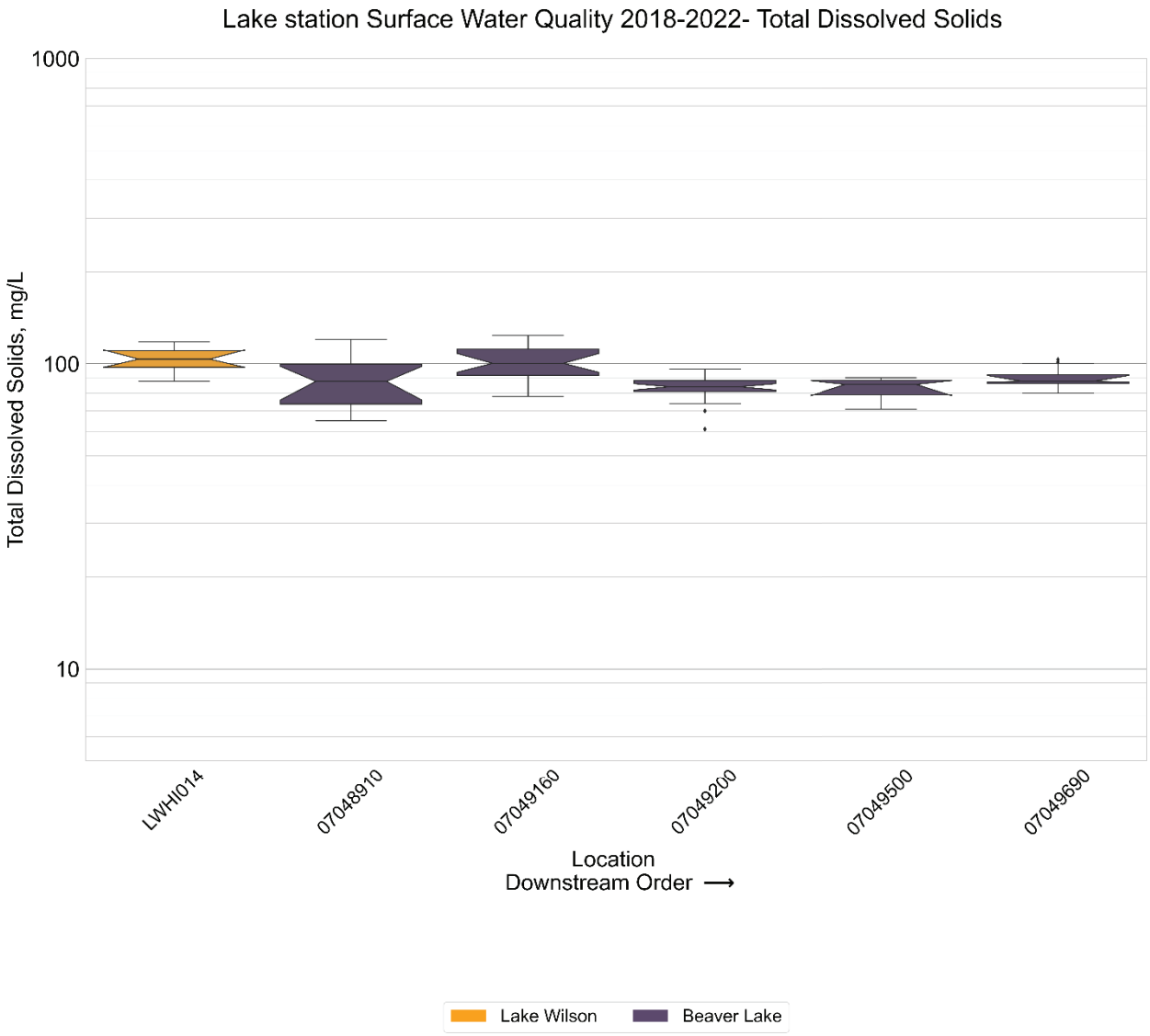


Figure 79. Box and whisker graph of TDS measurements in lake stations with more than 10 values from 2018-2022.

1.9.2 Sulfate

Table 90 through Table 95 list summary statistics for sulfate measurements from surface waters in the Upper White River watershed during the period 2018-2022. Included in these tables is a listing of the applicable sulfate numeric water uality criteria and the number and percentage of measurements that exceed the applicable criteria. The sulfate criterion for waterbodies without site specific criteria is 250 mg/L. Forty-four stations sampled 2018-2022 have more than 10 sulfate measurements. However, at 13 stream stations with more than 10 measurements, the measurements were all from one year, so they do not meet the DE data re uirements for evaluating water uality standards. Stations WHI0052, Wyman, WHI0229, WHI0100, and WFWR are located on stream reaches on the West Fork White River listed as impaired because of high sulfate DE 2020 . Stations on impaired waterways are highlighted in the tables below.

The highest median sulfate concentrations are at the stations on Town Branch in Fayetteville. The median sulfate concentrations for all three Town Branch stations are not statistically significantly different from each other, but they are statistically significantly greater than the median concentrations at other stream stations in the watershed. The lowest median sulfate concentration is from the upper White River WHI0104 . The median sulfate concentration at this station is statistically significantly lower than the median concentrations at other stations in the watershed. Research found that geology and riparian soils may have significant influence on sulfate in the West Fork White River Scott Haggard, 2021 . WHI0104 is located in the Boston Mountains ecoregion, whereas the Town Branch stations are located in the O ark Highlands ecoregion, supporting this research.

Table 90. Summary statistics for stream sulfate measurements from stations in White River to Lake Se uoyah waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of alues Criteria	Percentage of alues Criteria
DE	WHI0104	WR	12	1.81	2.24	2.33	2.37	2.66	2.88	20	--	--
DE	WHI0106	WR	51	2.46	3.15	3.40	4.26	4.03	32.10	20	1	2%
DE	WHI0219	MFWR	12	3.46	4.88	5.82	6.73	7.61	16.00	250	--	--
DE	WHI0103	MFWR	53	4.65	5.51	6.43	6.66	7.69	10.20	250	0	0%

WR White River, MFWR Middle Fork of the White River

DE re uires at least 10 samples collected over two years to evaluate attainment of the sulfate criteria PCEC, 2022 . This data was collected from ust one year.

Table 91. Summary statistics for stream sulfate measurements from stations in West Fork White River waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of alues Criteria	Percentage of alues Criteria
DE	WHI0229	WFWR	13	3.15	11.60	17.60	16.75	23.40	25.60	20	--	--
DE	WHI0223	TB	12	29.80	59.83	63.35	65.07	70.33	99.10	250	--	--
WRC	TB[a]	TB	130	9.14	26.24	55.80	50.23	65.16	102.30	250	0	0%
US S	07048495[a]	TB	24	8.92	30.28	47.85	49.79	69.48	95.00	250	0	0%
DE	WHI0100	WFWR	53	13.10	18.10	22.70	25.41	31.70	47.50	20	31	58%
WRC	WFWR	WFWR	129	0.32	11.75	21.13	22.38	33.03	44.81	20	69	53%

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

TB Town Branch, WFWR West Fork White River

DE re uires at least 10 samples collected over two years to evaluate attainment of the sulfate criteria PCEC 2022 . This data was collected from ust one year.

Indicates station is located on assessment unit classified as impaired on both pproved 2018 and Draft 2020 303 d Lists because of high sulfate.

Table 92. Summary statistics for stream sulfate measurements from stations in White River from Wyman to state line waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of alues Criteria	Percentage of alues Criteria
WRC	Wyman[b]	WR	128	2.45	8.13	10.36	12.25	14.70	33.29	20	14	11%
US S	07048600[b]	WR	14	2.76	5.25	8.09	10.23	10.65	36.90	20	1	7%
DE	WHI0052[d]	WR	53	7.10	9.05	11.50	14.27	17.80	44.10	20	10	19%
US S	07048700[d]	WR	21	6.20	9.74	11.44	15.62	20.70	39.40	20	6	29%
DE	WHI0221	LlC	12	3.09	4.22	4.36	4.43	4.65	5.57	250	--	--
DE	WHI0231	DC	12	4.12	5.10	5.61	5.49	6.20	6.42	250	--	--
WRC	Richland[c]	RC	131	2.12	6.92	8.74	9.19	11.28	23.71	250	0	0%
US S	07048780[c]	RC	13	3.17	4.56	6.38	7.10	9.05	11.60	250	0	0%
DE	WHI0110	RC	12	5.65	8.51	9.78	9.56	11.18	13.20	250	--	--
DE	WHI0012B	LwC	42	4.41	6.67	9.41	9.87	13.25	16.50	250	0	0%

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

WR White River, DC Drakes Creek, LlC Lollars Creek, RC Richland Creek LwC Leatherwood Creek

DE re uires at least 10 samples collected over two years to evaluate attainment of the sulfate criteria PCEC 2022 . This data was collected from ust one year.

Indicates station is located on assessment unit classified as impaired on pproved 2018 303 d List because of high sulfate.

Table 93. Summary statistics for stream sulfate measurements from stations in War Eagle Creek waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of alues Criteria	Percentage of alues Criteria
DE	WHI0227	WEC	12	2.54	3.12	3.41	3.37	3.62	4.21	250	--	--
DE	WHI0233	C	12	3.39	4.21	5.16	4.81	5.21	6.48	250	--	--
DE	WHI0220	WC	12	4.17	5.88	7.68	7.38	8.85	10.00	250	--	--
DE	WHI0070	HC	53	5.88	16.30	22.30	27.23	34.30	64.60	48	6	11%
WRC	WEC	WEC	131	1.52	4.81	6.17	6.32	7.48	13.32	250	0	0%
DE	WHI0116	WEC	53	4.63	5.99	6.56	6.99	7.69	15.10	250	0	0%
US S	07049050	WEC	12	3.35	3.76	4.67	4.68	5.47	6.32	250	0	0%

WEC War Eagle Creek, C ackson Creek, WC Wharton Creek, HC Holman Creek

DE re uires at least 10 samples collected over two years to evaluate attainment of the sulfate criteria PCEC 2022 . This data was collected from ust one year.

Table 94. Summary statistics for stream sulfate measurements from stations on Eastern streams Kings River, Osage Creek, and Long Creek waterway segment during 2018-2022 stations listed in downstream order, first row is farthest upstream station .

rgani ation	Station D	Strea D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of alues Criteria	Percentage of alues Criteria
DE	WHI0225	FC	10	2.45	2.79	3.34	3.43	3.70	4.82	250	0	-
DE	WHI0121	KR	52	3.81	4.52	5.15	5.60	6.79	9.74	20	0	0%
DE	WHI0123	KR	53	3.85	4.56	5.01	5.10	5.40	7.68	20	0	0%
DE	WHI0230	KC	11	2.82	4.30	4.86	5.09	6.09	6.78	250	0	-
DE	WHI0129	OC	11	3.03	4.81	5.24	5.22	5.84	6.97	250	0	-
DE	WHI0068	OC	45	4.09	6.49	7.38	7.53	8.22	12.50	250	0	0%
DE	WHI0069	OC	48	4.52	8.12	12.10	14.22	18.35	34.20	250	0	0%
WRC	Kings[e]	KR	36	2.57	6.19	7.96	9.02	11.80	19.19	20	0	0%
DE	WHI0009 [e]	KR	49	3.39	6.01	6.74	7.73	9.23	14.00	20	0	0%
US S	07053250	C	1	6.86	6.86	6.86		6.86	6.86	20	0	-
DE	WHI0232	TC	10	3.30	6.08	6.50	8.00	10.37	15.40	250	0	-
DE	WHI0071	LC	48	7.30	10.06	13.00	14.97	19.45	29.10	250	0	0%

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

FC Felkins Creek, KR Kings River, KC Kenner Creek, OC Osage Creek, C ocum Creek, TC Terrapin Creek, LC Long Creek

DE re uires at least 10 samples collected over two years to evaluate attainment of the sulfate criteria PCEC 2022 . This data was collected from ust one year.

Table 95. Summary statistics for sulfate measurements from Lake Stations at during 2018-2022 stations listed in downstream order, first row is farthest upstream station . ll lake stations data analy ed is from the epilimnion.

rgani ation	Station D	La e D	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L	Criteria, g/L	u ber of alues Criteria	Percentage of alues Criteria
DE	LWHI009	LS	8	3.90	4.79	5.31	5.40	5.57	7.89	250	0	-
DE	LWHI014	LW	12	2.99	3.95	4.68	4.73	5.61	6.31	250	0	0%
US S	07048910	BL	22	5.19	7.57	7.96	8.31	8.36	12.50	250	0	0%
DE	LWHI013B	BL	5	2.69	8.36	8.81	8.26	9.65	11.80	250	0	-
US S	07049160	BL	21	4.00	4.97	5.43	5.56	5.85	8.48	250	0	0%
US S	07049187	BL	6	5.39	5.83	6.15	6.06	6.35	6.50	250	0	-
US S	07049200	BL	21	5.10	5.69	5.89	6.19	6.19	6.50	250	0	0%
DE	LWHI013C[f]	BL	4	6.52	6.58	6.73	7.13	7.28	8.55	250	0	-
US S	07049500[f]	BL	16	5.52	5.78	5.94	6.30	6.30	8.36	250	0	0%
DE	LWHI013	BL	5	3.10	6.25	6.32	5.85	6.66	6.93	250	0	-
US S	07049690	BL	22	5.40	5.63	5.77	5.84	6.03	6.45	250	0	0%

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

LS Lake Se uoyah, LW Lake Wilson, BL Beaver Lake

DE re uires at least 10 samples to evaluate attainment of the sulfate criteria DE 2022 .

Figure 80 through Figure 85 show box and whisker graphs of sulfate measurements from stations with more than 10 measurements for the period 2018-2022. Median sulfate concentrations are highest on Town Branch and WFWR Figure 81 . lso note that median sulfate concentrations from Middle Fork White River stations are higher than from the upper White River stations Figure 80 . The median sulfate concentration for the Lollars Creek station Figure 82 is significantly lower than the median sulfate concentrations for other stations in Richland Creek and the White River.

On War Eagle Creek Figure 83 , the median sulfate concentration for the headwater station WHI0227 is statistically significantly lower than the median sulfate concentrations for War Eagle Creek downstream of Holman Creek. Median sulfate concentrations of all the tributaries are also significantly higher than the median at headwaters station WHI0227. This suggests that tributary inflows increase the sulfate levels in War Eagle Creek.

In the Eastern streams Figure 84 , median sulfate concentrations at the farthest downstream Osage Creek station WHI0069 and Kings River stations Kings/WHI0009 are statistically significantly higher than upstream stations. Osage Creek appears to contribute to higher sulfate concentrations in the Kings River.

The median sulfate concentration at Beaver Lake station 07048910 most upstream is significantly higher than median concentrations at other Beaver Lake stations Figure 85 . Sulfate increases again at the Beaver Lake station where War Eagle Creek enters the reservoir, but then decreases as you move toward the dam.

s with TDS, geology may significantly contribute sulfate to surface waters Scott Haggard, 2021 . So, these patterns may be a result of geological influences, or accumulation of sulfate, or a combination.

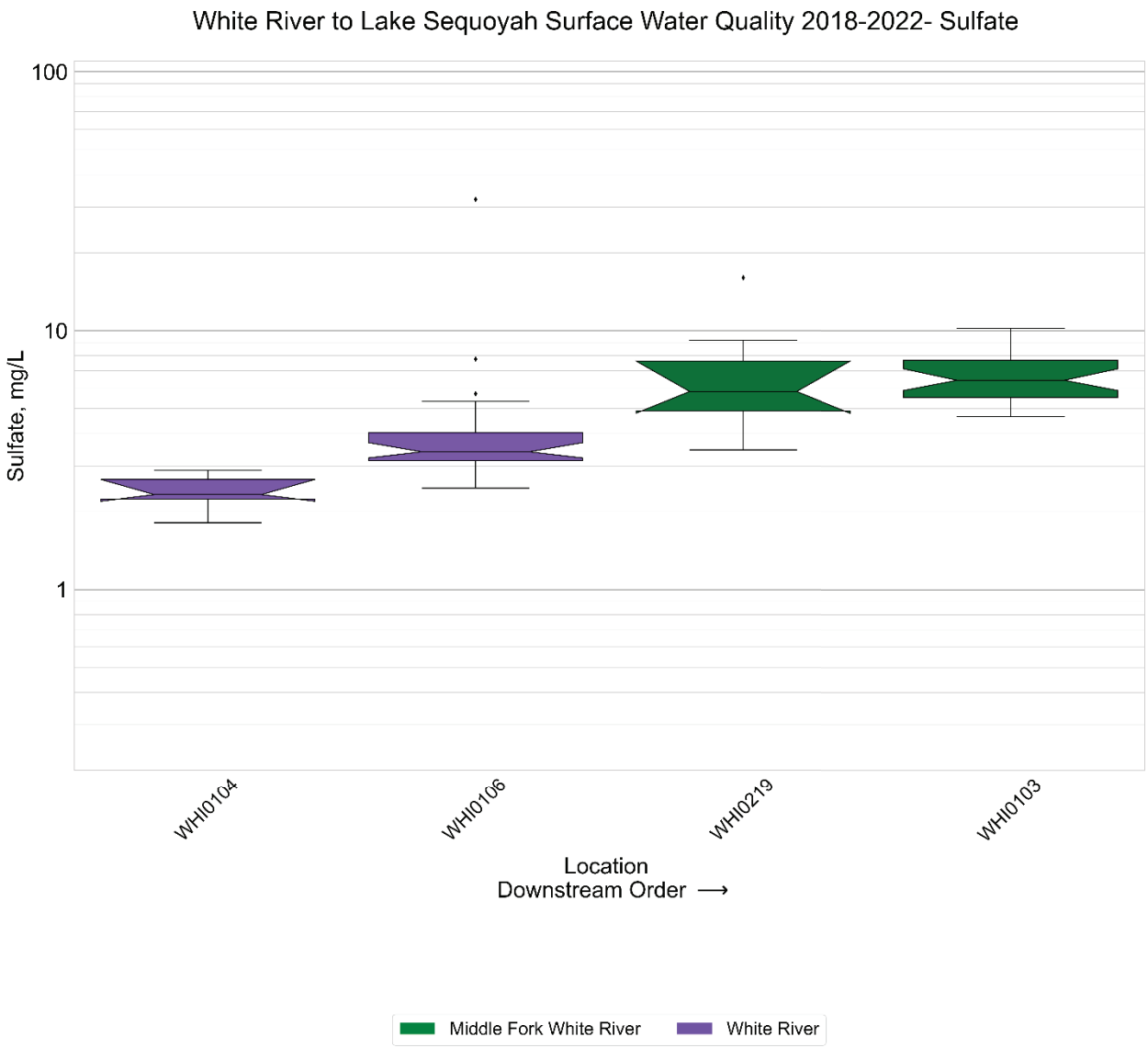


Figure 80. Box and whisker graph of Sulfate measurements in White River to Lake Se uoyah waterway segment from stations with more than 10 values from 2018-2022.

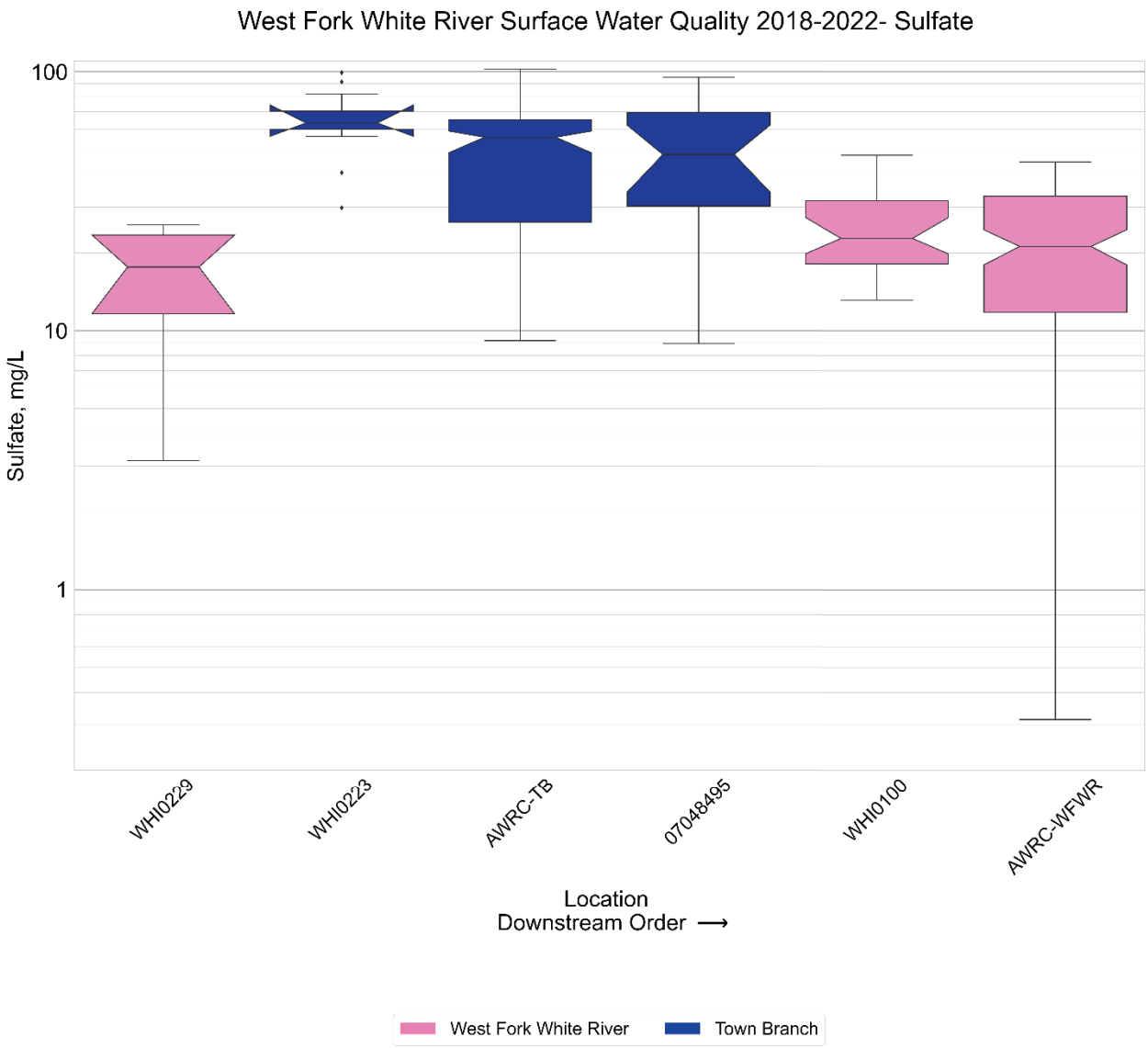


Figure 81. Box and whisker graph of Sulfate measurements in West Fork White River waterway segment from stations with more than 10 values from 2018-2022. ote that stations TB and 07048495 are at the same location on Town Branch.

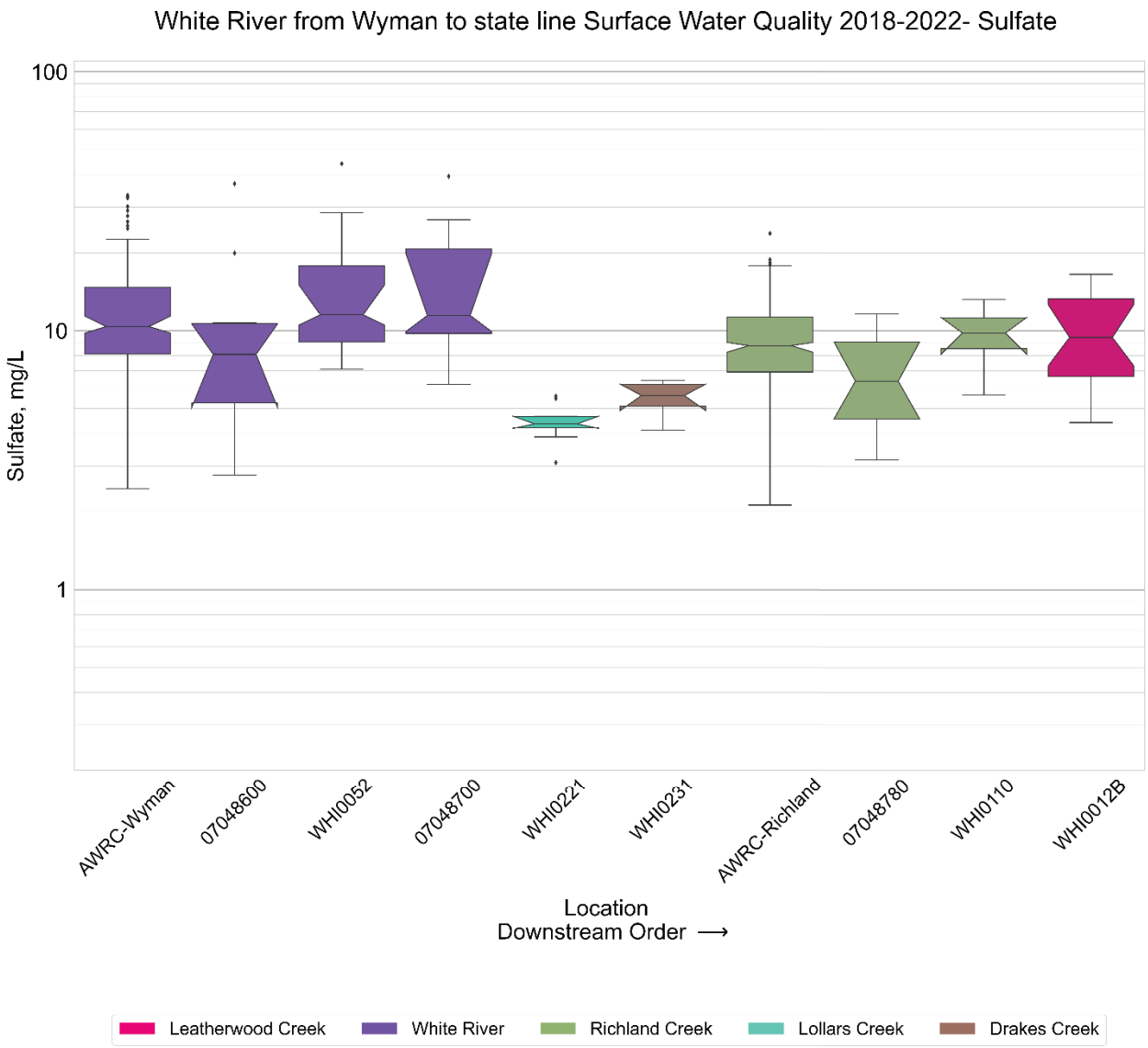


Figure 82. Box and whisker graph of Sulfate measurements in White River to State Line waterway segment from stations with more than 10 values from 2018-2022. ote that stations Wyman and 07048600 are at the same location on the White River upstream of Richland Creek, stations Richland and 07048780 are at the same location on Richland Creek, and stations WHI0052 and 07048700 are at the same location on the White River downstream of Richland Creek.

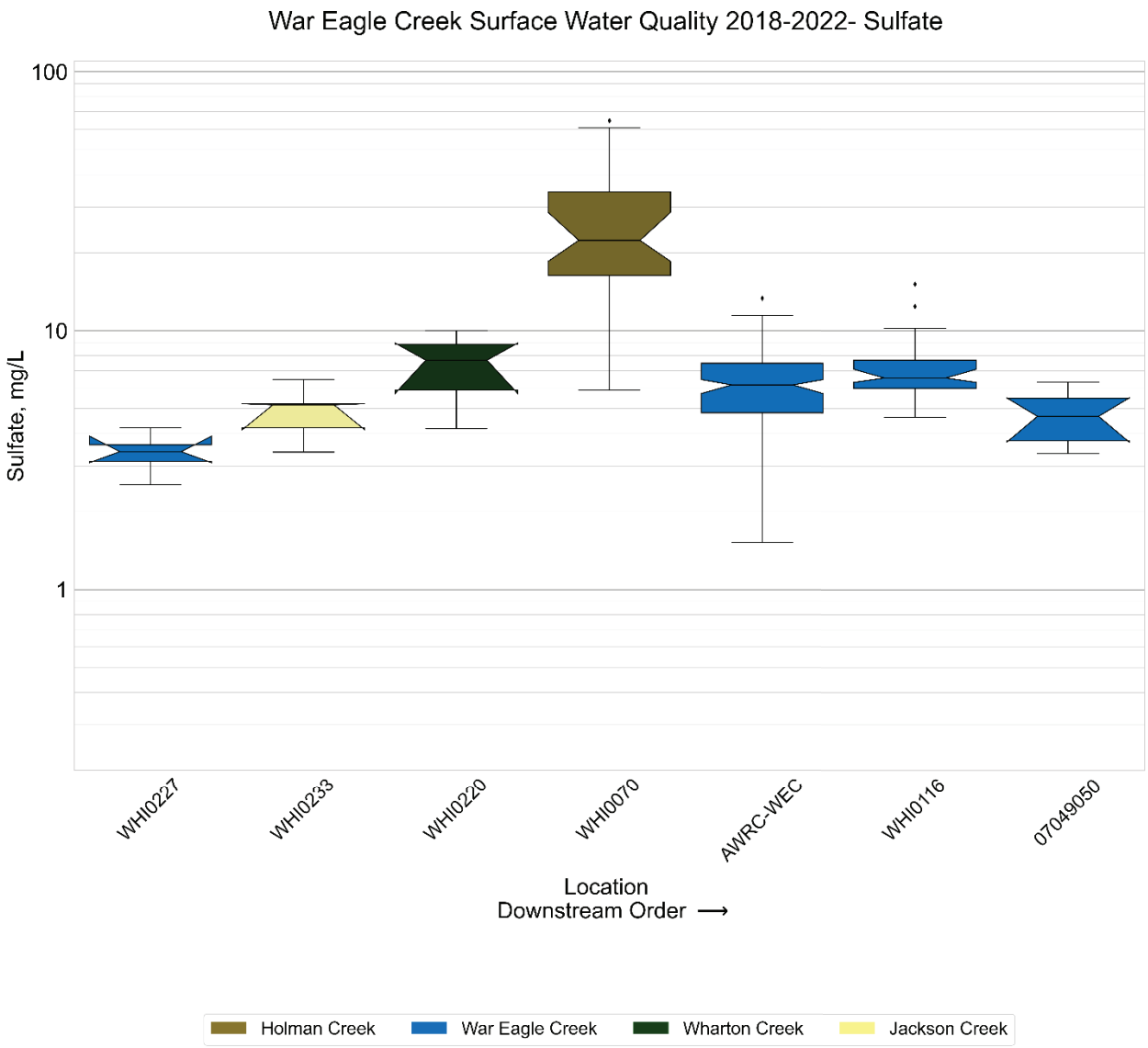


Figure 83. Box and whisker graph of Sulfate measurements in War Eagle Creek waterway segment from stations with more than 10 values from 2018-2022.

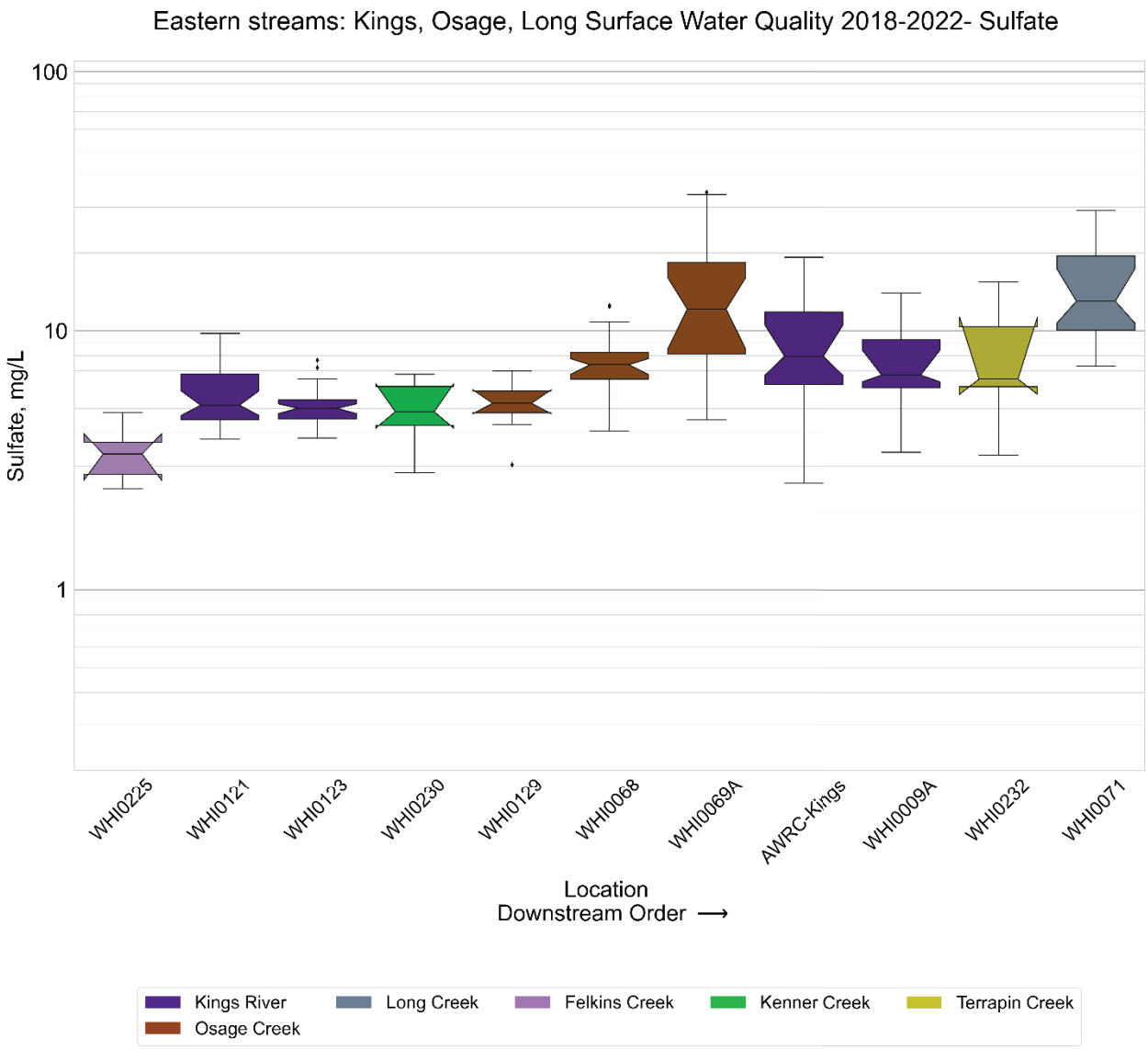


Figure 84. Box and whisker graph of Sulfate measurements in Eastern Streams waterway segment from stations with more than 10 values from 2018-2022. ote that stations Kings and WHI0009 are at the same location on Kings River.

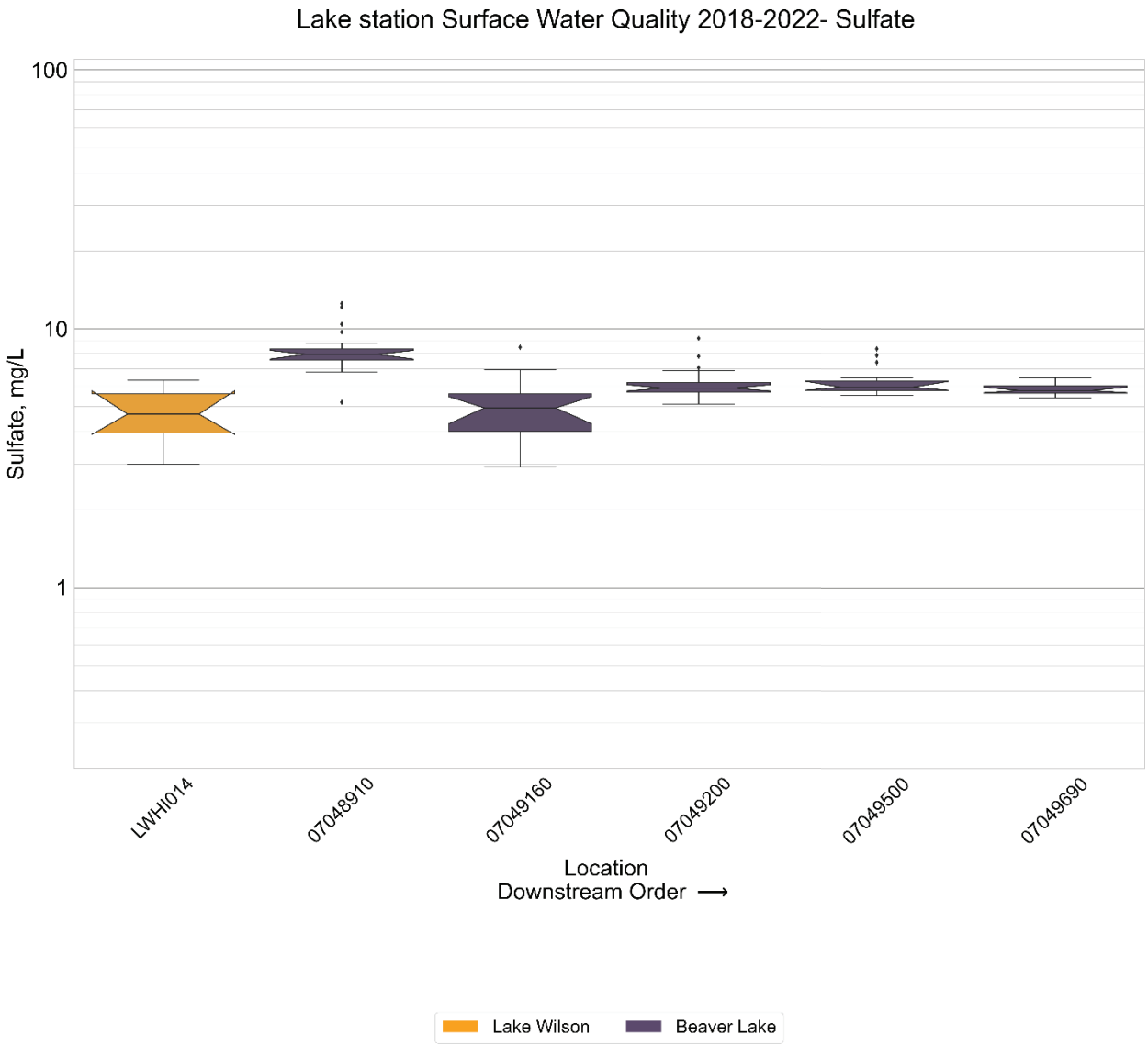


Figure 85. Box and whisker graph of Sulfate measurements in lake stations with more than 10 values from 2018-2022.

1.10 Data Gaps

Several water uality data gaps were identified during inventorying and analy ing recent water uality data. Beaver Lake is the only waterbody in this watershed with pathogen impairments. So far, US S seems to be the only agency that has collected *E.Coli* data suitable for use in evaluating attainments of water uality criteria for Primary and Secondary Contact Recreation. US S has collected *E.Coli* data ade uate for standards evaluation in White River, Richland Creek, War Eagle Creek, and Beaver Lake during 2018-2020, and Long Creek and ocum Creek in 2011. The most recent DE sampling on Kings River is from 2008 not ade uate for standard evaluation . Long Creek, ocum Creek, Osage Creek and tributaries were last sampled in 2005 data not ade uate for standard evaluation .

Town Branch in Huntsville is listed as impaired for minerals TDS and sulfate , but there has been no data collected from this stream since the site-specific water uality study in 2013 BMc, 2013 .

WHI0051 is listed as the station used to identify impairment of West Fork White River, but it hasn t been sampled since 2013.

1.11 Summary

Recent *E.Coli* measurements confirm bacteria impairments, with stream stations having higher median values than the lake stations. The highest median *E.Coli* measurements are from Richland Creek and the White River after the Richland Creek confluence. Potential sources of *E.Coli* affecting monitored locations included both point sources and nonpoint sources developed areas, pasture, septic systems . s noted previously, no monitored streams in the Upper White River watershed are listed as impaired because of high *E.Coli* levels.

Low pH values in the Upper White River watershed appear to be largely a result of low buffering capacity i.e., alkalinity in the streams. This is a function of the underlying geology of the areas of the watershed within the Boston Mountains physiographic region, which has little carbonate rock. The Middle Fork Beaver Reservoir stations have the highest alkalinity measurements in the watershed, and the highest pH measurements.

For the most part, sediment parameters data from monitored stream locations show higher turbidity and TSS in West Fork White River and War Eagle Creek reaches than other areas of the watershed. Restoration pro ects have been done in the West Fork White River over

the last several years, and Base Flow turbidity is expected to be reduced by 53% in this stream reach as a result EP , 2022 .

Water temperatures were consistent across all the graphed stations however, nearly 11 miles of the West Fork White River is listed as impaired for temperature in the Draft 2020 303 d List and 1.9 miles of the White River downstream of the WFWR confluence is listed as impaired for temperature on the Draft 2022 303 d List.

In our analysis, DO levels at monitored locations in the Upper White River watershed are supportive of a uatic life, especially during the Primary Season. The Critical Season for DO water uality criteria is characteri ed by higher temperatures greater than 22ºC and lower flows. DO concentrations naturally tend to be lower during this season. DE lists several stream assessment units listed as impaired for DO during Critical Season in the Upper White River watershed. Several of these stream segments did have measurements below the impairment criteria.

Phosphorus levels measured in the streams are relatively similar throughout the watershed where more than 10 measurements were taken . TP data collected by different organi ations are not necessarily comparable to each other. This is likely because of differences in sampling protocols and/or analysis methods among the organi ations. Holman Creek 308, WHI0070 and Richland Creek Richland have the highest maximum TP levels from 2018-2022. However, War Eagle Creek 07049050 and Holman Creek WHI0070 have the highest median TP concentrations.

lmost all ammonia nitrogen measurements are reported as less than the detection limit. The highest reported ammonia nitrogen concentration during 2018-2022 occurred at Osage Creek station WHI0069 . The station with the highest median ammonia nitrogen is WHI0012B Leatherwood Creek , which is impaired for DO.

lmost all measurements are below the 10 mg/L drinking water criterion for nitrate nitrite. The highest nitrate nitrite nitrogen value, and only value above 10 mg/L, during 2018-2022 was measured at Holman Creek station WHI0070 downstream from the WWTP. The next highest values were measured on Town Branch 07048495 and Long Creek WHI0071 . The seasonal patterns from Town Branch and Long Creek stations follow the seasonal flow pattern, suggesting that nonpoint sources are the greatest influence.

For total nitrogen, the Brush Creek station H2O arks 300 has the highest median total nitrogen concentration, which is significantly higher than median values at the other stream stations in this watershed with ten or more measurements. Holman Creek stations had the highest maximum measurements, which is likely because of the WWTP. Overall, tributaries to War Eagle Creek had higher median total nitrogen concentrations than other waterways in the watershed.

Median TDS concentrations, although variable, increase from upstream to downstream. In at least some instances, higher median TDS concentrations appear to be associated with municipal wastewater treatment plant discharge and development, e.g., Holman Creek and Leatherwood Creek. Research has shown that geology, and anthropogenic activities, can influence TDS levels in streams Scott Haggard, 2021 . The highest median TDS value is for the Ward Slough station H2O arks 200 followed by stations on Town Branch in Fayetteville WHI0233, H2O arks 210 . The lowest median TDS values are from the upper portion of the White River.

The highest median sulfate concentrations are at the stations on Town Branch in Fayetteville. In the longer/ma or streams, i.e., White River, War Eagle Creek, Kings River, and Osage Creek, median sulfate concentrations appear to increase significantly from the headwaters downstream. Research found that geology and riparian soils may have significant influence on sulfate in the West Fork White River Scott Haggard, 2021 . This would account for the differences in headwater areas located in Boston Mountains ecoregion and increase as water moves downstream through O ark Highlands ecoregion.

APPENDIX D

FTN Evaluation of Long-Term Water Quality Trends and Annual Pollutant Loads

Flow-normali ed load calculations and trend analyses performed by rant and Haggard 2023 focused on tributaries to Beaver Lake and evaluated data from West Fork White River, White River, Richland Creek and War Eagle Creek. DE and BWD have sampled other streams in the Upper White River watershed during the 2010 2022 period evaluated by rant and Haggard. We selected BWD and DE stations to expand the evaluation of water uality trends in the Upper White River watershed. Table 1 lists the BWD and DE stations analy ed. We evaluated the following parameters analy ed by rant and Haggard nitrate nitrogen, total nitrogen T , total phosphorus TP , total suspended solids TSS , sulfate, and chloride. We also analy ed total dissolved solids TDS , turbidity, and dissolved oxygen DO , as these are parameters that are not meeting water uality standards in some watershed streams. ll of these parameters are monitored at the DE stations. However, of the analy ed parameters BWD monitors only T , TP, and turbidity see Table 1 .

Table 1. BWD and DE stations for trend analysis, with available parameters for trend analysis. indicates the parameter is monitored at the listed station.

onitoring rgani ation	Station D	Strea	itrate	T	TP	TSS	Sulfate	Chloride	TDS	Turbidit	D
DE	WHI0106	White River Durham									
BWD	7	Middle Fork White River CO Rd 51									
DE	WHI0103	Middle Fork White River Elkins									
BWD	5	White River Elkins									
DE	WHI0052	White River oshen									
BWD	10	White River Wyman									
BWD	13	White River Banks Farm									
BWD	15	War Eagle Creek old Hwy 412									
BWD	9	War Eagle Creek Mill									
DE	WHI0070	Holman Creek									

Table 1. BWD and DE stations for trend analysis, with available parameters for trend analysis. indicates the parameter is monitored at the listed station continued .

onitoring rgani ation	Station D	Strea	itrate	T	TP	TSS	Sulfate	Chloride	TDS	Turbidit	D
DE	WHI0116	War Eagle Creek Hindsville									
DE	WHI0123	Kings River labam									
DE	WHI0068	Osage Creek									
DE	WHI0009	Kings River Berryville									
DE	WHI0071	Long Creek									

Flow data is necessary for flow-normali ed load calculation and trend analysis. However, the BWD and DE stations selected for analysis were not located where daily measured flow data was available e.g., US S flow gages . Instead, we used flow results from the SW T model predicted for the locations of the BWD and DE sampling stations. Output from this SW T model included predicted daily flows at the locations of the BWD and DE sampling stations. The flow calibration of the SW T model is very good at monitored locations FT ssociates, Ltd. 2024 . The Upper White River SW T model simulates the period 1996 through 2021. Therefore, our trend analysis period was set to 2010 2021, slightly shorter than the period used by rant and Haggard 2023 . Our analysis used calendar years in the trend analysis, instead of water years as was done by rant and Haggard 2023 .

s in rant and Haggard 2023 , trend analysis of flow-normali ed concentrations was conducted using an algorithm created by US S. This algorithm, called Weighted Regressions on Time, Discharge and Season WRTDS , accounts for the influence of time, discharge, and season in determining trends in water uality at a specified site Hirsch et al., 2010 Sprague et al., 2011 . This approach removes the influence of the random variability of stream flow, which can make determining patterns in concentrations difficult. The WRTDS analyses were carried out using the statistical software R, version 4.3.1, R Core Team 2023 , combined with the packages E RET Hirsch and De Cicco 2015 and E RETci Hirsch, rchfield and De Cicco 2015 . The E RET package was used to develop flow-normali ed concentrations and loads, while the statistical test WRTDS Bootstrap Test in E RETci was used to analy e the flow-normali ed data for statistically significant trends. The WRTDS Bootstrap Test produces a p-value that characteri es the probability of observed water uality changes being random over time. s in rant and Haggard 2023 , p-values were used to categori e trends as highly likely

p 0.05 , likely 0.05 p 0.10 , and no change p 0.10 . Results from WRTDS trend analyses of flow-normali ed concentrations are summari ed in Tables 2 and 3.

Table 2. Summary of results of WRTDS trend analysis on BWD flow-normali ed concentrations. Stations are listed in upstream to downstream order from left to right.

	Percent change at WD Stations					
Anal te	**5**	**7**	**10**	**13**	**15**	**9**
T	-4.2	-4.3	-3.8	-3.6	-4.2	C
TP	C	C	4.9	C	C	C
Turbidity	C	C	C	C	C	C

denotes trends that are likely i.e. 0.05 p 0.10 denotes trends that are very likely i.e. p_0.05 C denotes no change i.e., p 0.10

Table 3. Summary of results of WRTDS trend analysis on DE flow-normali ed concentrations. Stations are listed in upstream to downstream order from left to right.

	Percent change at D Stations								
Anal te	**W 0106**	**W 0103**	**W 0052**	**W 0070**	**W 0116**	**W 0123**	**W 0068**	**W 0009A**	**W 0071**
Cl	-3.5	-2.9	-4.8	C	-3.6	-1.9	-3.2	C	C
SO_4	C	-2.6	-3.3	C	-0.97	C	C	C	2.3
O_3	C	-4.4	-4.9	C	C	C	-4.5	C	C
T	-3.6	-4.7	-4.3	C	C	C	-4.3	-3.9	C
TP	-1.9	C	-2.7	C	-6.7	-6.8	-7.1	-8.3	-3.8
TDS	C	C	-2	-1.4	C	C	C	C	C
TSS	C	-3.5	C	C	C	C	C	C	C
DO	0.87	0.91	0.91	2.8	0.89	1.8	C	-1	C
Turbidity	8.2	C	C	C	C	C	C	C	C

denotes trends that are likely i.e. 0.05 p 0.10 denotes trends that are very likely i.e. p_0.05 C denotes no change i.e., p 0.10

One station we analy ed shares a location with one of the WRC stations BWD station 10 is at the same location as WRC station Wyman. Table 4 shows a comparison of trend analysis results for T and TP, the two parameters sampled by both WRC and BWD. s this comparison shows, results from analysis of the two data sets are different, even though they were collected at the same location over the same time period. We are most concerned about the results of the TP data analysis, which show trends in different directions. This calls into uestion our assumption that the FT analysis results are comparable to the WRC analysis results.

Table 4. Comparison of trend analysis results using data collected by different organi ations WRC and BWD at the same location and slightly different analysis approaches.

Anal te	Percent Change	
	W an (AW C)	10 (WD)
T	C	-3.8
TP	-3.3	4.9

denotes trends that are likely i.e. 0.05 p 0.1 denotes trends that are very likely i.e. p_0.05 C denotes no change i.e., p 0.10

Since there were what we had hoped were minor differences in the data and approach used in the FT trend analysis compared to the WRC analysis, we conducted an additional analysis to see if these differences are the cause of the different results. We performed a trend analysis of the BWD T and TP data using the WRC method, i.e., using flow records from US S station 07048600, and water uality data from the period 2010-2022, organi ed by water year. The results of this analysis are shown in Table 5.

Table 5. Results of trend analysis of BWD nutrient concentrations from Station 10 using WRC method and its elements.

Anal te	Percent Change in WD 10 Data		
	S S flo , 2010-2022, ater ear	S S flo , 2010-2022, calendar ear	S S flo , 2010-2021, calendar ear
T	C	C	-3.6
TP	7.9	8.6	6.1

denotes trends that are likely i.e. 0.05 p 0.1 denotes trends that are very likely i.e. p_0.05 C denotes no change i.e., p 0.10

These results also show an increasing trend in TP. dditional analyses were conducted on the BWD Site 10 data using selected elements of the WRC approach to evaluate the influence of the differences between WRC and FT analysis approaches. Results of these additional trend analyses are also shown in Table 5. ll trend analysis results of BWD TP data show an increasing trend, the opposite of the WRC TP trend analysis results. s a result, we conclude that the differences in sampling fre uency and timing used by WRC and BWD result in data sets that can indicate different trend directions in concentration. Since DE uses a sampling fre uency and timing that is like that used by BWD i.e., monthly sampling , trend analysis results of DE data sets may also be different from results that would be given from a data set

collected according to the WRC protocol, at least for some parameters. This calls into uestion the comparability of trend analysis results for BWD and DE data to those for WRC data.

Increasing trends in DO observed at six of the stations may or may not indicate improving water uality. Excessive productivity resulting from nutrient pollution can also cause DO concentrations to increase. Under conditions of excessive productivity, DO saturation values greater than 100% are common, i.e., DO supersaturation. Therefore, in some cases, high DO concentrations are an indicator of poor water uality. Thus, DO saturation conditions were evaluated at these stations. Figure 1 shows graphs of DO concentrations reported for 2010-2021 at the six stations with increasing DO trends.

Figure 2 shows graphs of percent DO saturation at the same stations over this period. The 100% DO saturation value for each sampling date was calculated using the reported water temperature degrees Celsius in the following e uation which assumes an atmospheric pressure of 760 mm Hg Exp 7.7117-1.3140 ln temperature 45.93 Munson, et al. 2017 . Percent DO saturation was calculated by dividing the reported DO concentration by the 100% DO saturation value for that date.

t two of the stations, WHI0070 and WHI0123, it appears that the number of percent DO saturation values above 100% has increased recently, to the point that there are few values lower than 95% after 2017. These conditions suggest that the increase in DO at these stations does not reflect water uality improvement and that excessive productivity is occurring. This may also be the case at station WHI0116.

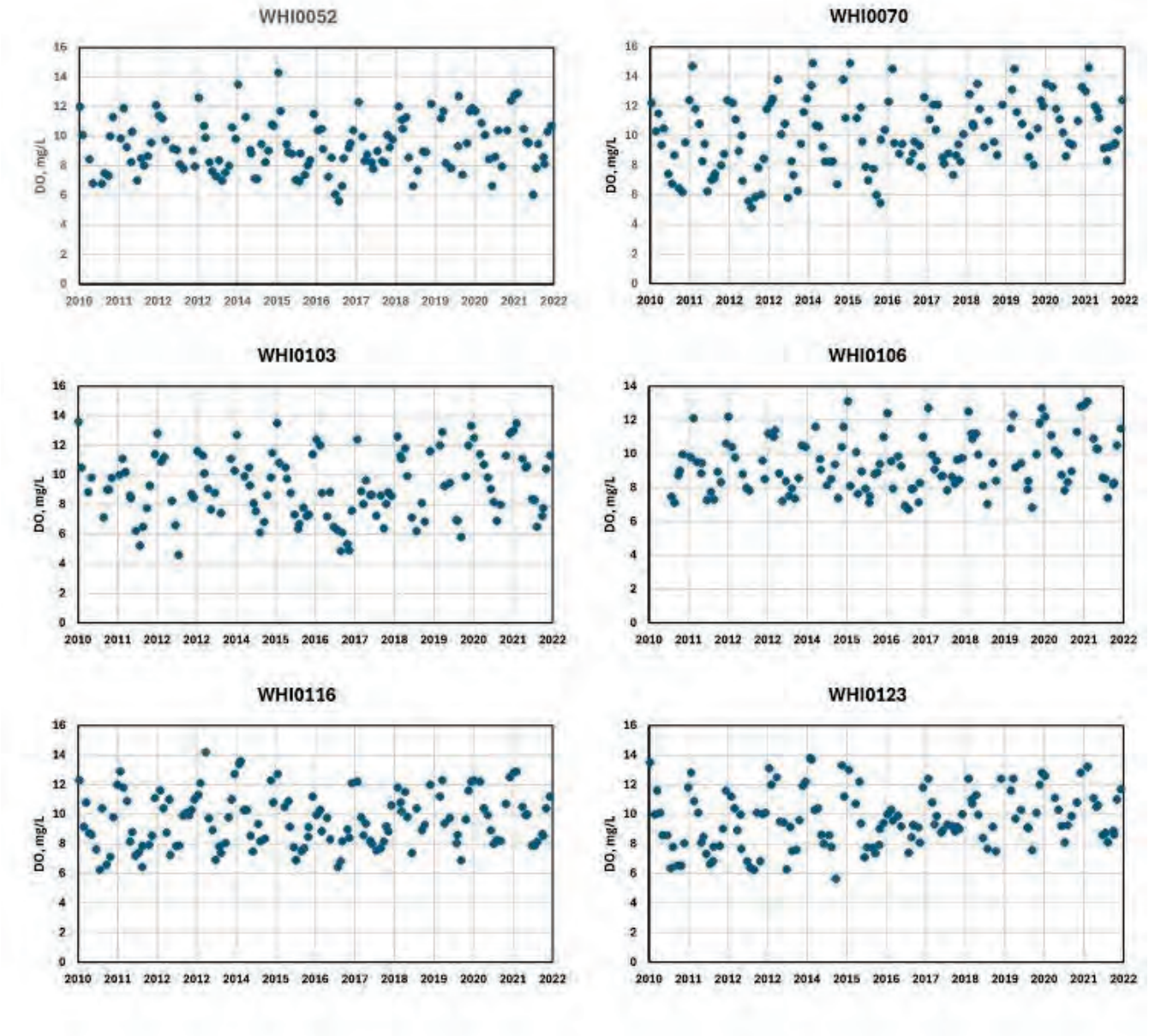


Figure 1. Time series graphs of DO measurements at six stations with increasing DO trends.

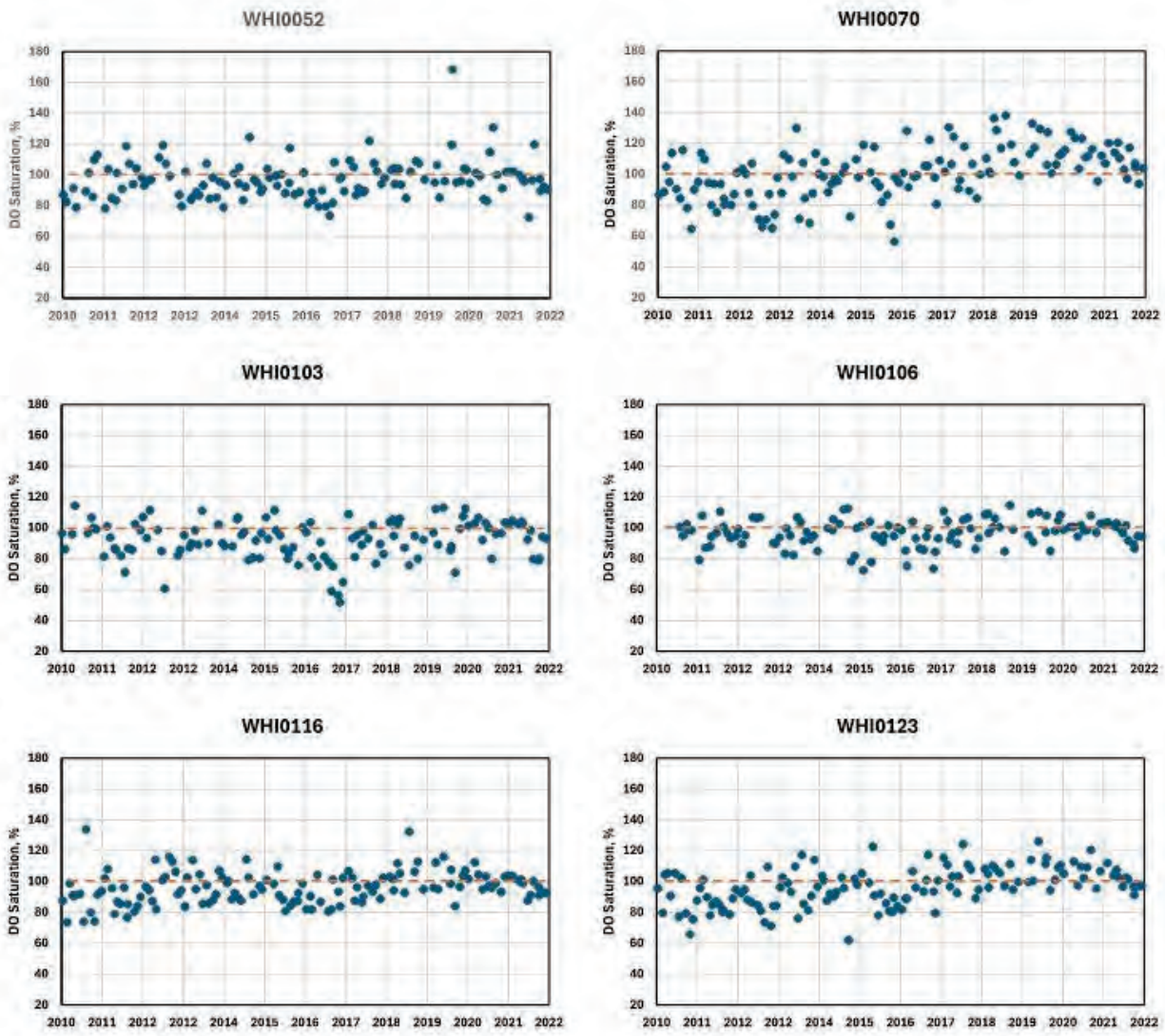


Figure 2. Time series graphs of DO saturation at six stations with increasing DO trends.

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APPENDIX E

Characterization of Current Groundwater Quality in Upper White River Watershed

1.0 GROUNDWATER QUALITY ASSESSMENT

Measurements of selected parameters of concern collected during 2018-2022 by DE and US S are summari ed below. The data used for this summary was downloaded in March 2023 from online databases managed by DE and US S DE 2023, US S 2022 . Regarding human health, the primary water uality parameters of concern are nitrate, pathogens, and toxics. We also looked at phosphorus, sulfate and TDS in groundwater as a possible source of nutrients and minerals to surface water.

Monitored springs reflect water uality in the Springfield Plateau a uifer. Movement of contaminants through karst systems in northwest rkansas can have a significant impact on surface water and groundwater uality DE 2008 . t US S White River gage 07050000, at Beaver, R, and Kings River gage 07050500, near Berryville, R, the US S estimated that around one third of flow is from groundwater US S 2024 .

1.1 Nitrate and Nitrite in Groundwater

itrite and nitrate were measured once by US S at a well and a spring in the watershed, in 2019 Table 1 . itrate nitrite nitrogen was measured at two DE spring stations during 2018 Table 2 . ll nitrate nitrite nitrogen measurements from groundwater springs and a well collected from the Upper White River watershed were lower than the 10 mg/L drinking water standard. Researchers have suggested that a conservative estimate of background nitrate concentrations for the Springfield Plateau and O ark a uifers is 0.4 mg/L T. Kresse, et al. 2011, T. Kresse, et al. 2014 . Several studies of groundwater uality in orthwest rkansas have looked at nitrate levels and factors that appear to influence it. The results of these studies indicate that elevated nitrate levels in groundwater occur where more than 40% of the land cover is agricultural, near septic systems, and in areas where karst features are more prevalent T. Kresse, et al. 2014 .

Table 1. US S groundwater nitrate and nitrite measurements in Upper White River watershed 2018-2022 US S 2022 .

Station D	Source	A uifer (de th)	u ber of easures	itrite, g/L	itrate, g/L	itrate itrite, g/L
362334093444601	Sycamore Spring	Boone Formation surface	1	0.001	1.56	1.56
355200093541901	Well	Bloyd Shale 45 feet	1	0.01	0.03	0.04

Table 2. DE groundwater spring nitrate nitrite measurements in Upper White River watershed 2018-2022 DE 2023 .

Station D	S ring a e	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
WHI0209	Withrow Spring	7	2.33	2.42	2.46	2.88	2.92	4.66
WHI0207	War Eagle Cave Spring	7	2.14	2.23	2.33	2.71	2.78	4.48

1.2 Pathogens

The fre uent presence of pathogens in the Springfield Plateaus a uifer limits its use as a drinking water supply. Sources of these pathogens are related to agricultural and urban land use. One study found that concentrations of pathogen-indicator bacteria i.e., E. coli in spring water increased by several orders of magnitude during storm events. This study also found that bacteria can be transported by groundwater to streams far from sources, and that bacteria survived in groundwater at least four months, probably in sediments Davis, Hamilton and Brahana 2005 .We found only one measurement of *E. coli* in the monitored springs of the Upper White River watershed, from 2009. sample from Sycamore Spring Boone formation of the O ark a uifer was found to have 500 cfu/100 mL US S WIS . This value is greater than the primary contact water uality criteria for surface waters. This information suggests that groundwater may contribute to stream and reservoir pathogen loads, particularly during rain events.

1.3 Phosphorus

Phosphorus is typically strongly bound to clays and organic matter in soils, so very little phosphorus is transported in the dissolved state Kresse et al., 2014 . EP currently has no drinking water standard for phosphorus. Total phosphorus concentrations reported for Withrow Spring and War Eagle Cave Spring do not appear to be significantly different from stream concentrations and are lower than the target stream total phosphorus for the O ark Highlands 0.07 mg/L Table 4 . Thus, this data indicates that groundwater inputs are not likely to contribute to surface water total phosphorus concerns.

Table 3. US S groundwater orthophosphate as phosphorus measurements in Upper White River watershed 2018-2022 US S 2022 .

Station D	Source	A uifer (de th)	u ber of easures	rtho hos hate as P, g/L
362334093444601	Sycamore Spring	Boone Formation surface	1	0.045
355200093541901	Well	Bloyd Shale 45 feet	1	0.006

Table 4. DE groundwater spring nitrate nitrite measurements in Upper White River watershed 2018-2022 DE 2023 .

Station D	S ring a e	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
WHI0209	Withrow Spring	9	0.020	0.022	0.028	0.0259	0.030	0.030
WHI0207	War Eagle Cave Spring	9	0.020	0.024	0.030	0.0273	0.030	0.034

1.4 Minerals

Sulfate levels are generally low in the a uifers of the O ark Highlands and Boston Mountains. s is shown in Table 5, sulfate concentrations measured in groundwater of the Upper White River watershed are lower than the surface water uality criteria, and the O ark Highlands ecoregion reference stream value of 17 mg/L.

Table 5. roundwater sulfate data from Upper White River watershed 2018-2022 DE 2023, US S 2022 .

Station D	Source a e	u ber of easures	ini u alue, g/L	25th Percentil e, g/L	edian , g/L	ean , g/L	75th Percentil e, g/L	a i u alue, g/L
WHI0209	Withrow Spring	7	2.37	2.72	3.00	3.05	3.46	3.67
WHI0207	War Eagle Cave Spring	7	2.35	2.56	2.73	2.95	3.39	3.67
362334093444601	Sycamore Spring	2	7.17	-	-	7.24	-	7.32
355200093541901	Bloyd Shale a uifer	1	3.95	-	-	-	-	-

US S did not measure TDS at their groundwater sampling locations in the Upper White River. Maximum TDS concentrations measured by DE in springs of the Upper White River watershed are lower than the O ark Highlands ecoregion reference stream value of 240 mg/L both springs are in the O ark Highlands ecoregion Table 6 .

Table 6. roundwater TDS data from Upper White River watershed 2018-2022 DE 2023 .

Station D	S ring a e	u ber of easures	ini u alue, g/L	25th Percentile, g/L	edian, g/L	ean, g/L	75th Percentile, g/L	a i u alue, g/L
WHI0209	Withrow Spring	8	84.5		155.5	137.6	160.5	164.0
WHI0207	War Eagle Cave Spring	8	87.5		158.5	139.8	162.5	168.0

1.5 Toxics

DE and US S measured metals concentrations in springs and a well during the period 2018-2022. EP has established drinking water Maximum Contaminant Levels MCL for many of the metals measured in the groundwater in Upper White River watershed EP 2023 . These MCLs are intended to protect human health. Table 7 lists the metals drinking water MCLs with levels reported in the groundwater samples from 2018-2022. Measured metals concentrations do not exceed the drinking water MCLs.

Table 7. Drinking water MCLs for metals compared to reported concentrations.

etal	Drin ing ater CL, g/L	D re orted total recoverable values 2018-2022, g/L	S S easure ent, g/L (dissolved)
ntimony	0.006	0.025	0.000046-0.000196
rsenic	0.01	0.001	0.00026-0.00031
Barium	2	0.029-0.038	0.0475-0.0516
Beryllium	0.004	0.0005	0.0001-0.0002
Cadmium	0.005	0.0003	0.00003-0.000065
Chromium	0.1	0.002	0.0003-0.0005
Copper	1.3	0.003	0.0008-0.0019
Fluoride	4.0	-	-
Lead	0.015	0.0005	0.000021-0.000108
Selenium	0.05	0.003	0.00022-0.00038
Thallium	0.002	0.0005	0.00003-0.00004

DE did not measure organics in the springs during 2018-2022. US S did measure organics in Sycamore Spring station 362334093444601 , but not in the sampling well. Table 8 lists the 25 organics for which US S tested. Measurements of these organics were all reported as less than detection. s a result, there is no indication that metals or pesticides in groundwater are a human or wildlife health concern.

Table 8. US S samples from Sycamore Spring were analy ed for organic compounds.

rganic a e	PA Drin ing Water CL	se
2,6-Diethylaniline	-	herbicide
inphos-Methyl	-	Insecticide
Benfluralin	-	Herbicide
Carbaryl	-	Insecticide
Carbofuran	0.04 mg/L	Insecticide
Cis-Permethrin	-	Insecticide no longer used
Dimethyl tetrachloroterephthalate DCP	-	Herbicide
EPTC	-	Herbicide
Ethalfluralin	-	Herbicide
Ethoprop	-	Insecticide
Linuron	-	Herbicide
Methyl parathion	-	Insecticide
Metribu in	-	Herbicide
Molinate	-	Herbicide
apropamide	-	Herbicide
Pebulate	-	Herbicide
Pendimethalin	-	Herbicide
Propanil		Herbicide
Propargite		Insecticide

Table 8. US S samples from Sycamore Spring were analy ed for organic compounds continued .

rganic a e	PA Drin ing Water CL	se
Propy amide		Herbicide
Tebuthiuron		Herbicide
Terbacil		Herbicide
Thiobencarb		Herbicide
Triallate		Herbicide
Trifluralin		Herbicide

1.6 Summary

itrate plus nitrite levels measured in springs are below the nitrate drinking water standard of 10 mg/L but are higher than the estimated natural background nitrate concentration for the Springfield Plateau and O ark a uifers, 0.4 mg/L. roundwater may contribute nitrate to surface waters in the Upper White River watershed.

Pathogens, including E. coli, are known to be present in the a uifers of the region. *E. coli* levels in springs have been shown to increase significantly during rain events, suggesting that groundwater may be a pathway for pathogen loads to surface waters. Bacteria have been shown to survive in groundwater systems as long as four months.

Total phosphorus concentrations measured in springs are lower than the target stream total phosphorus for the O ark Highlands identified in this plan, 0.07 mg/L. This suggests that groundwater probably does not contribute significantly to surface water nutrient issues.

roundwater sulfate and TDS concentrations measured 2018-2022 in the Upper White River watershed are below the surface water criteria applicable in their subbasins, and the O ark Highlands ecoregion reference stream concentrations. This suggests that groundwater probably does not contribute to exceedances of minerals criteria in surface waters.

Barium is the only potentially toxic pollutant that has been measured above detection levels in groundwater of the Upper White River watershed 2018-2022. However, measured barium levels are lower than the drinking water maximum contaminant level.

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APPENDIX F

Estimation of Septic System Numbers for Upper White River Watershed

The approaches used to derive or estimate locations of septic systems in the Upper White River watershed are described below. Table 1 lists estimates of the number of septic systems in each HUC12 of the Upper White River watershed within rkansas.

- table of parcel IDs associated with septic tank permits was provided by City of Fayetteville.
- rkansas Department of Health permitted septic tank locations in Benton County are from the Benton County public-facing web server.
- Fayetteville and Springdale eospatial sewer infrastructure data was available from each city s web feature service. We selected 911 addresses within each city that represent buildings likely to be served by sewage infrastructure e.g. residences and businesses . We identified real estate parcels that contain one of those addresses. Of those real estate parcels, we identified those that intersect sewer mains or sewer service lines, and those that are both a within a subdivision newer than 2013 and b less than 200 from a sewer main. Real estate parcels within each city that did not have those characteristics were marked as having a septic tank and were checked against real estate information from Washington County provided by DataScout.
- For smaller towns in Washington County including Prairie rove, Lincoln, and Tontitown we used real estate information from Washington County provided by DataScout to mark locations of rkansas Department of Health septic tank permits.
- ny areas outside the city limits of any town/city that offers sewage service in Washington County were treated the same as within city limits until the edge of the sewer service area was reached.
- Outside city limits in Washington County From the 911 address points, we removed the address types least likely to include sewage facilities barns, chicken houses, etc. and classified those remaining as buildings with septic tanks. We spot-checked the information in Washinton County s real estate info DataScout to make sure we didn t overlook any pockets of centrali ed wastewater facilities in our analysis.
- Municipalities outside of Benton and Washington Counties with sewer service We referred to city and county websites, along with the University of orth Carolina s Water and Wastewater Rates Dashboard website https //dashboards.efc.sog.unc.edu/ar to identify areas where sewer service is available. In those areas, we used real estate information on illow to determine the approximate limits of the sewer service area. reas were typically limited to ma or roads and the core of the city limits. ll houses within these areas were categori ed as having sewer. ll other houses were categori ed as having septic systems.

- Municipalities outside of Benton and Washington Counties without sewer service, and areas outside of city limits We used the same procedure as outside city limits in Washington County. We also spot-checked the information on illow to make sure we didn t overlook any pockets of centrali ed wastewater facilities in this analysis.

Table 1. Estimates of the number of septic systems in the HUC12s of the Upper White River watershed.

C12 D u ber	C12 a e	sti ate of Se tic Tan s
110100010101	East Prong White River-White River	89
110100010102	Fleming Creek-White River	83
110100010103	Mill Creek-Headwaters White River	86
110100010201	Dry Creek-Middle Fork White River	28
110100010202	reasy Creek-Middle Fork White River	72
110100010203	Koger Branch-Middle Fork White River	178
110100010301	Delaney Creek-White River	143
110100010302	Crosses Creek-White River	143
110100010303	Lake Se uoyah	370
110100010401	London Creek-West Fork White River	243
110100010402	Winn Creek-West Fork White River	194
110100010403	Rock Creek-West Fork White River	430
110100010404	Town Branch-West Fork White River	349
110100010501	Lollars Creek	115
110100010502	Hock Creek-Richland Creek	240
110100010503	Cherry Creek-Richland Creek	219
110100010504	Dry Creek-Richland Creek	405
110100010601	Dry Fork-War Eagle Creek	79
110100010602	Seals Creek-War Eagle Creek	111
110100010603	ackson Creek-War Eagle Creek	114
110100010604	Wharton Creek	111
110100010605	Reed Creek-War Eagle Creek	161
110100010606	Holman Creek	158
110100010607	Berry Branch-War Eagle Creek	251
110100010608	lade Creek-War Eagle Creek	167
110100010609	Clear Creek-War Eagle Creek	186
110100010610	Clifty Creek-War Eagle Creek	177
110100010611	Beaver Lake-War Eagle Creek	267
110100010701	Roberts Creek-Beaver Lake	911
110100010702	Brush Creek-Beaver Lake	370
110100010703	Beaver Lake	1145
110100010704	Phillips Creek-Beaver Lake	1324
110100010705	Bear Creek-Beaver Lake	1762
110100010706	West Fork Little Clifty Creek-Beaver Lake	202
110100010707	Long Hollow-Beaver Lake	129
110100010708	orth Fork orth Clifty Creek-Beaver Lake	138
110100010709	Fords Creek-Beaver Lake	648

Table 1. Estimates of the number of septic systems in the HUC12s of the Upper White River watershed continued .

C12 D u ber	C12 a e	sti ate of Se tic Tan s
110100010710	Beaver Dam-Beaver Lake	300
110100010801	Butler Creek	30
110100010802	Leatherwood Creek	106
110100010803	Cedar Creek-Table Rock Lake	146
110100010804	Haddock Creek-Table Rock Lake	12
110100010806	Owl Creek-Table Rock Lake	46
110100010901	Headwaters Kings River	41
110100010902	Felkins Creek	30
110100010903	Sweden Creek-Kings River	109
110100010904	Spanker Branch-Kings River	199
110100010905	Big Onion Creek-Kings River	164
110100010906	Upper Dry Fork	88
110100010907	Lower Dry Fork	123
110100010908	Pine Creek-Upper Kings River	147
110100011001	Kenner Creek	55
110100011002	Headwaters Osage Creek	82
110100011003	Dog Branch-Osage Creek	77
110100011004	ackson Lake-Osage Creek	125
110100011005	Warden Branch-Osage Creek	275
110100011101	Upper Piney Creek-Kings River	110
110100011102	Lower Piney Creek	74
110100011103	Rockhouse Creek-Kings River	60
110100011104	Keels Creek	149
110100011105	Pine Creek-Kings River	160
110100011106	Clabber Creek-Kings River	347
110100011107	Sweetwater Creek-Kings River	79
110100011201	Headwaters Indian Creek	196
110100011202	Indian Creek	20
110100011203	Little Indian Creek	46
110100011301	Bobo Creek-Long Creek	163
110100011302	Terrapin Creek	274
110100011303	Lick Branch-Long Creek	468
110100011304	South Fork Dry Creek-Dry Creek	195
110100011305	Callens Branch-Dry Creek	200
110100011306	Braswell Branch- ucum Creek	212
110100011307	ocum Creek-Table Rock Lake	177
110100011308	Long Creek-Table Rock Lake	149
110100011402	Cricket Creek-Table Rock Lake	366
110100011403	Brush Creek-Table Rock Lake	10

APPENDIX G

Ranking of Upper White River HUC12 Sub-watersheds for Management and Protection

To identify HUC12 sub-watersheds to recommend for additional management of nonpoint source pollution under this plan, and for protection, available information was used to rank the 69 HUC12 sub-watersheds of the Upper White River watershed with at least 50% of their area in Arkansas.

1.1 Sub-Watersheds Recommended for Additional Management

Three sets of water quality-related information were used to rank HUC12 sub-watersheds for additional management of nonpoint sources:

- Water quality impairment,
- Modeled loads, and
- Water quality natural resource concerns from the NRCS State Resources Assessment.

Scores were developed for each HUC12 sub-watershed based on this information. The methods used to develop these scores are described in the following subsections. The HUC12 sub-watersheds were then ranked based on a total score calculated by summing the scores from all of the information categories (see subsection 1.1.4).

1.1.1 Water Quality Impairment

Over 135 miles of streams and over 3,000 acres of Beaver Lake in the Upper White River watershed were classified as impaired on the final 2018 and/or draft 2020 Arkansas 303(d) lists (DEQ 2020, 2021). Some HUC12 sub-watersheds have more than one impaired assessment unit, and some have assessment units impaired because of more than one pollutant. To rank the HUC12 sub-watersheds, scores were assigned to each sub-watershed based solely on if there are any impaired waterbodies present. HUC12 sub-watersheds with one or more impaired waterbodies were assigned a score of one. All other sub-watersheds were assigned a score of zero. Figure 1 summarizes the water quality impairment scores for each of the HUC12 sub-watersheds. Both the final 2018 303(d) List and the draft 2020 303(d) List were used to assign scores. Scores were first assigned based on the 2018 303(d) List. Then, scores of one were added to sub-watersheds that did not have impaired waterbodies on the 2018 303(d) List but did have impaired waterbodies on the 2020 303(d) List.

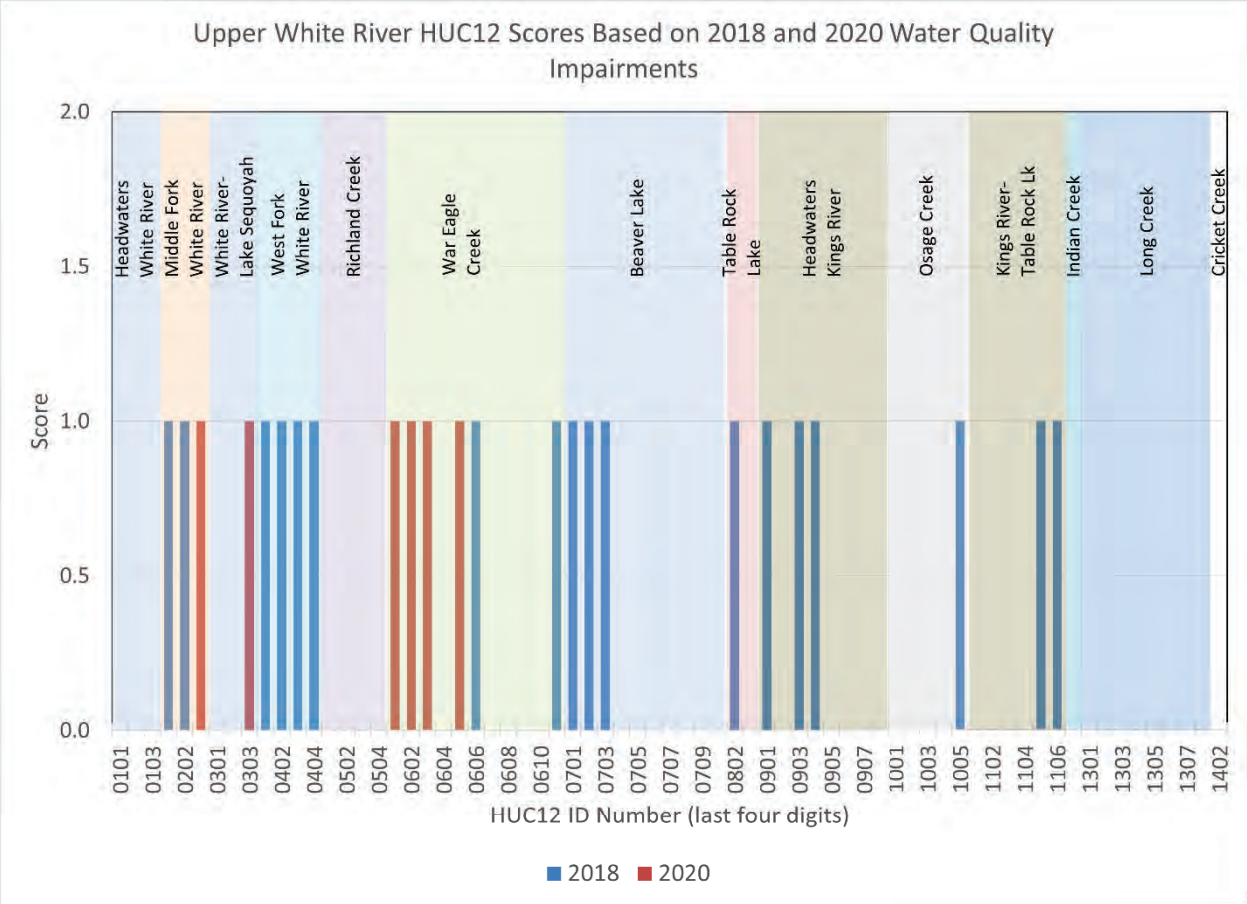


Figure 1. Summary of scores based on final 2018 303(d) and draft 2020 303(d) list.

1.1.2 Modeled Nonpoint Source Pollutant Flux

A recent SWAT modeling project of the Upper White River watershed estimated average annual nonpoint source flux of total nitrogen, total phosphorus, and suspended sediment from each of the HUC12 sub-watersheds (FTN Associates, Ltd. 2024). The flux of pollutants is the load leaving a HUC12 minus any load coming into the HUC12. Using flux to rank the HUC12s means that streambank erosion inputs are accounted for. Flux values can be negative. Negative flux values indicate that pollutant loads are being reduced in the HUC12 by nutrient uptake (nitrogen and phosphorus) or sedimentation (sediment).

Separate scores were assigned to the HUC12 sub-watersheds for total nitrogen, total phosphorus, and sediment yields. HUC12 scores were normalized flux values. The modeled flux of pollutants from nonpoint sources for the HUC12 sub-watersheds were normalized by dividing each value by the maximum value from all the sub-watersheds. For example, total nitrogen flux

scores were calculated by determining the highest total nitrogen flux from all of the sub-watersheds and then dividing the total nitrogen flux for each HUC12 sub-watershed by that maximum flux. In several HUC12 sub-watersheds the SWAT model predicted negative sediment flux, indicating that sedimentation exceeded erosion. Because erosion, turbidity, and sedimentation are all water quality concerns, the scores for sediment were calculated using the absolute value of the sediment flux. The three scores for each HUC12 sub-watershed are listed in Attachment 1 and graphed in Figure 2.

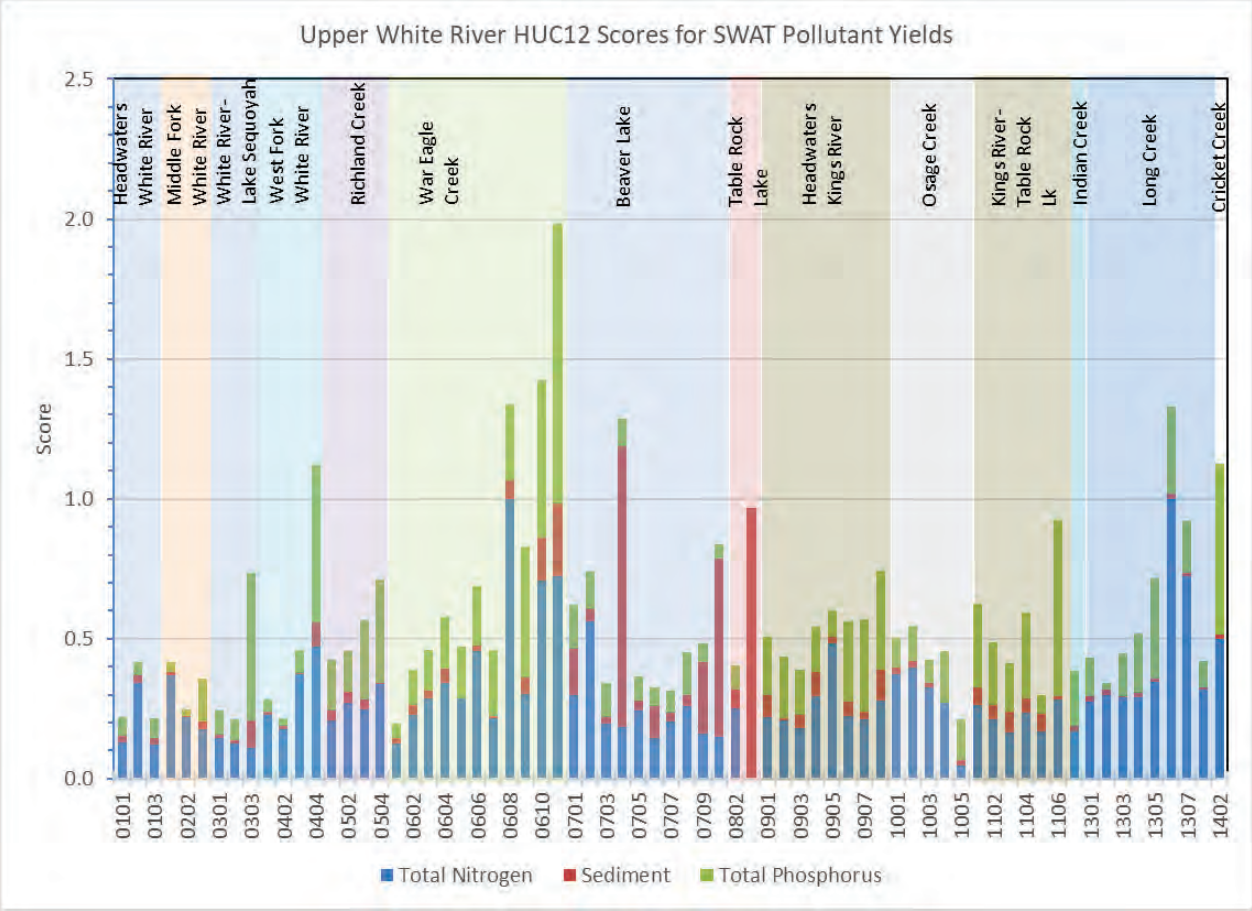


Figure 2. Summary of HUC12 scores based on simulated nonpoint source yields of nutrients and sediment.

1.1.3 Natural Resources Assessment Water Quality Concerns

Scores were assigned to HUC12 sub-watersheds based on area-weighted risks assigned to HUC12 sub-watersheds for water quality degradation resource concerns in the US Natural

Resources Conservation Service (NRCS) 2015 Arkansas State Resource Assessment (NRCS 2016). Area-weighted risks for five water quality degradation natural resource concerns were summed for each HUC12 sub-watershed:

- Excess nutrients in surface water and groundwater.
- Excess sediment in surface water.
- Petroleum, heavy metals, and other pollutants transported to receiving water sources.
- Pesticides and herbicides transported to surface water and groundwater.
- Excess pathogens and chemicals from manure, biosolids, or compost applications.

Scores for each HUC12 sub-watershed were calculated by dividing the sum of the risks for each sub-watershed by the maximum sum of risks from all the sub-watersheds. Score calculations for this characteristic are shown in Attachment 2. HUC12 sub-watershed scores for this characteristic are graphed in Figure 3.

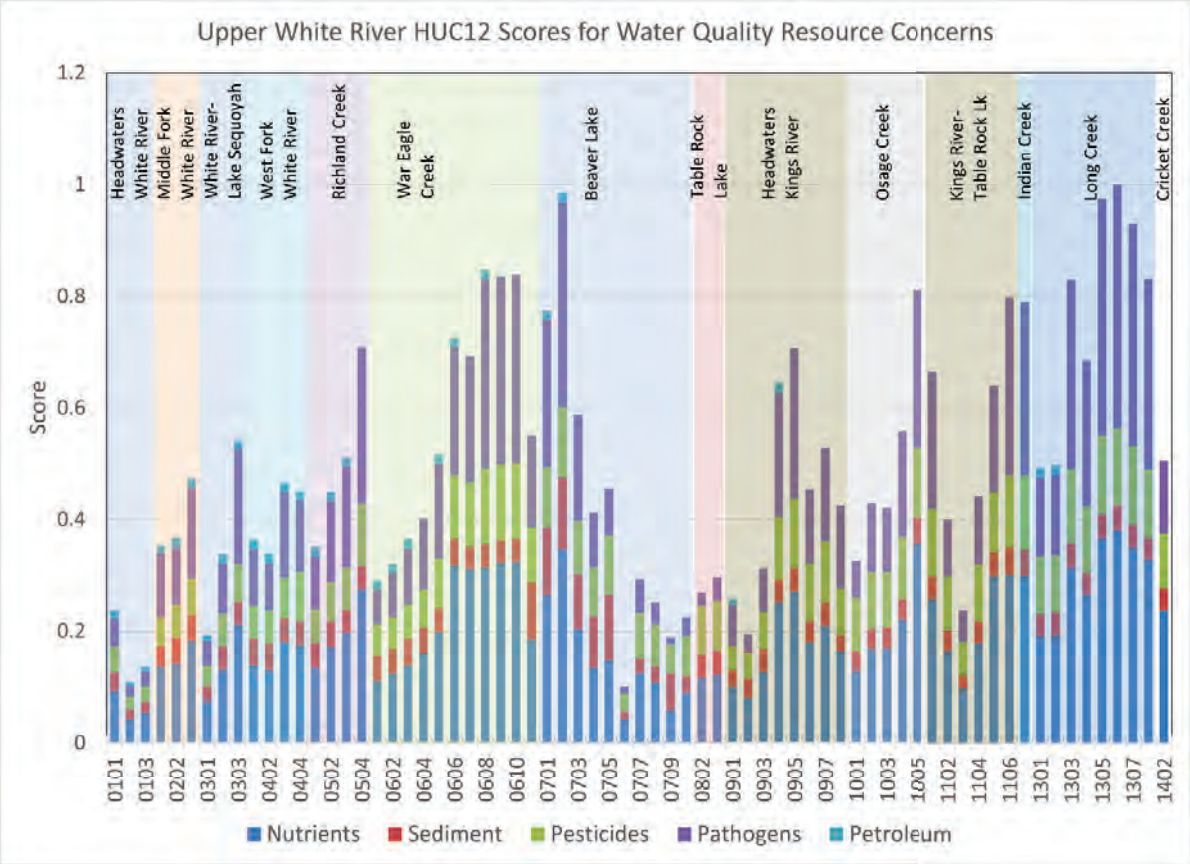


Figure 3. Summary of HUC12 scores based on NRCS water quality natural resource concerns risks.

1.1.4 Ranking of HUC12 Sub-watersheds for Additional Management

Scores for all the ranking characteristics were summed to identify HUC12 sub-watersheds with the greatest number of water quality-related concerns. Total scores for each of the HUC12 sub-watersheds are graphed in Figure 4. Figure 5 is a map of the total scores. A scoring summary table for all the HUC12 sub-watersheds is included as Attachment 3.

The HUC12 sub-watersheds were assigned to categories based on their total scores as summarized in Table 1. Eleven HUC12 sub-watersheds have total scores greater than 2.1 (Category 1) (see blue line in Figure 4). These are the sub-watersheds that are recommended as the focus for the watershed management plan. The recommended sub-watersheds are listed in Table 2.

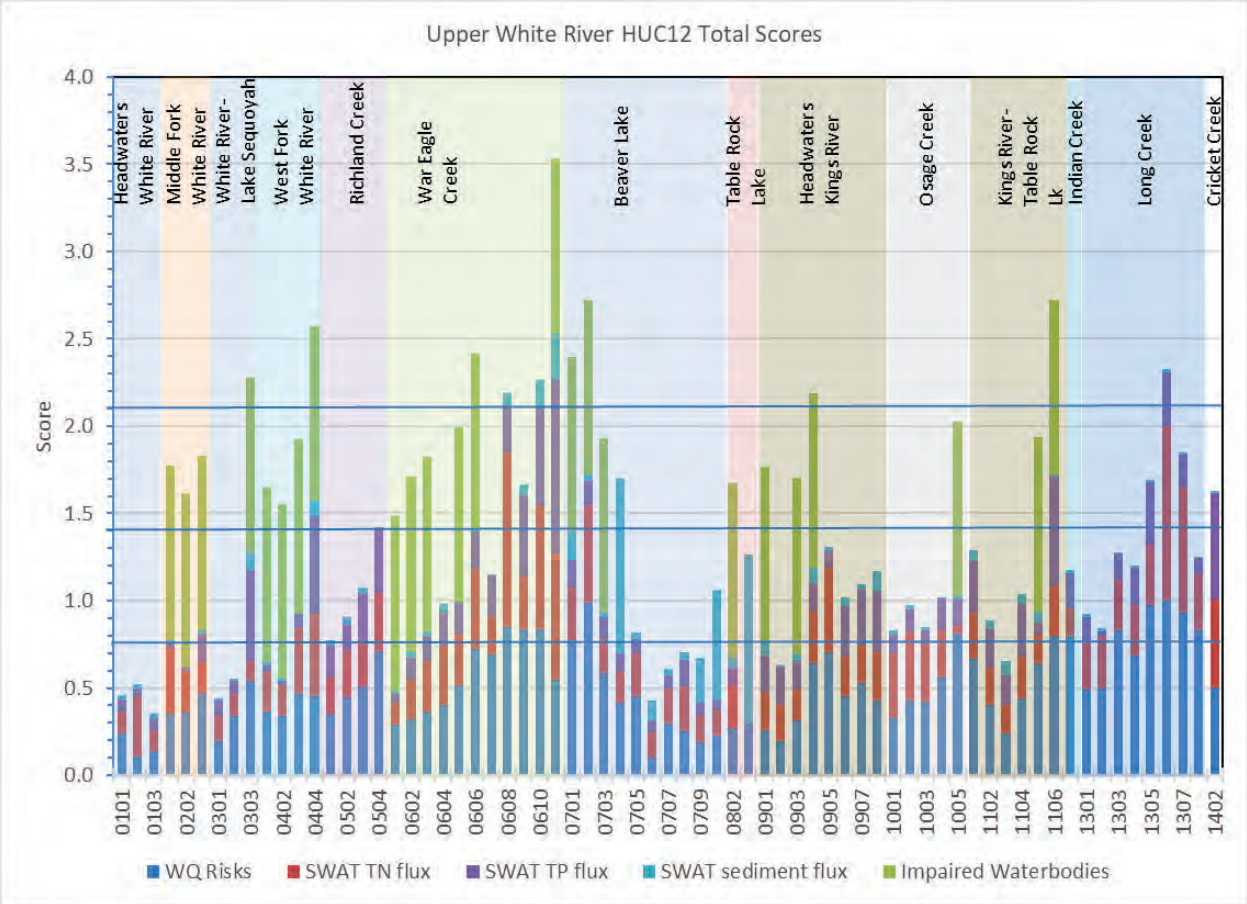


Figure 4. Summary of HUC12 total ranking scores for management of nonpoint pollution.

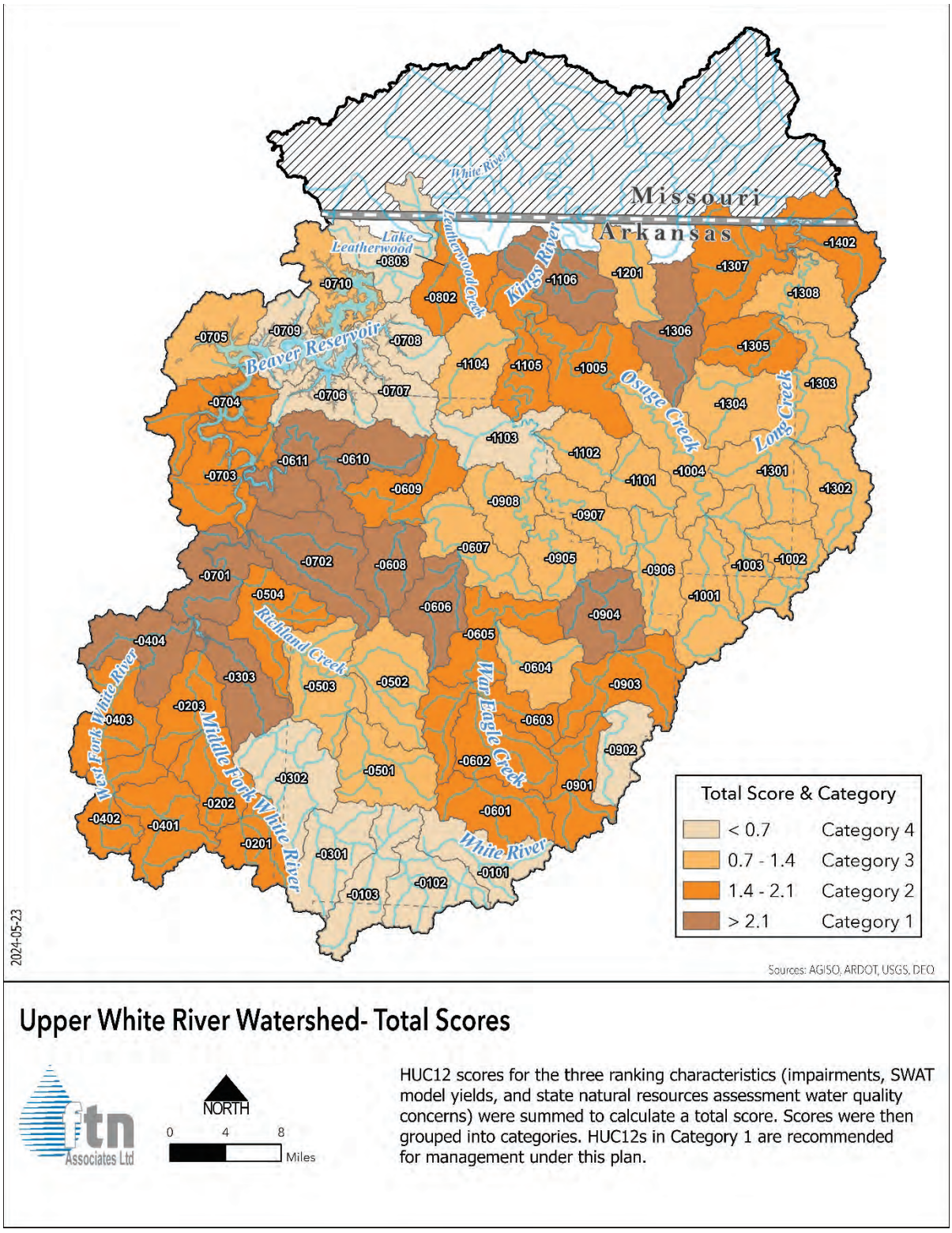


Figure 5. Map of HUC12 sub-watershed ranking scores for management of nonpoint source pollutants.

Table 1. Summary of total score categories.

Category	Associated Ranking Total Score Ranges
Category 1	>2.1
Category 2	2.1-1.4
Category 3	1.4-0.75
Category 4	<0.75

Table 2. Category 1 HUC12 sub-watersheds recommended for nonpoint source managment in the Upper White River watershed.

HUC12 ID Number	HUC12 Name	Ranking Score (out of 5 possible)
110100010303	Lake Sequoyah	2.28
110100010404	Town Branch-West Fork White River	2.57
110100010606	Holman Creek	2.41
110100010608	Glade Creek	2.19
110100010610	Clifty Creek-War Eagle Creek	2.26
110100010611	Beaver Lake-War Eagle Creek	3.27
110100010701	Roberts Creek-Beaver Lake	2.23
110100010702	Brush Creek-Beaver Lake	2.73
110100010904	Spanker Branch-Kings River	2.19
110100011106	Clabber Creek-Kings River	2.33
110100011306	Braswell Branch-Yocum Creek	2.26

1.2 Identify Recommended Sub-watersheds for Protection

HUC12 sub-watersheds were ranked for water quality protection using the following information:

- Presence of protected areas,
- Presence of federally listed threatened or endangered aquatic species,
- Predicted instream flux of sediment and nutrients, and
- Presence of impaired waterbodies.

The methods used to develop scores for the HUC12 sub-watersheds using this information are described in the following subsections. The HUC12 sub-watersheds were then ranked based on a sum of the scores from all the information categories (see Section 1.2.5).

1.2.1 Presence of Protected Areas

HUC12 sub-watersheds were assigned a score of one if Extraordinary Resources Waters were present, if Ecologically Sensitive Waterways were present, and if Natural Areas were present. For example, if both an Ecologically Sensitive Waterway and a Natural Area were present in a HUC12, it would receive a score of 2, one for each element present.

HUC12 subwatersheds were assigned an additional score based on the number of Wildlife Management Areas present. One subwatershed had three Wildlife Management Areas, but most had only one or two. The score for Wildlife Management Areas was calculated by dividing the number of Wildlife Management Areas present by three (the maximum number of Wildlife Management Areas in a HUC12). Figure 6 presents a summary of HUC12 scores based on the presence of protected areas.

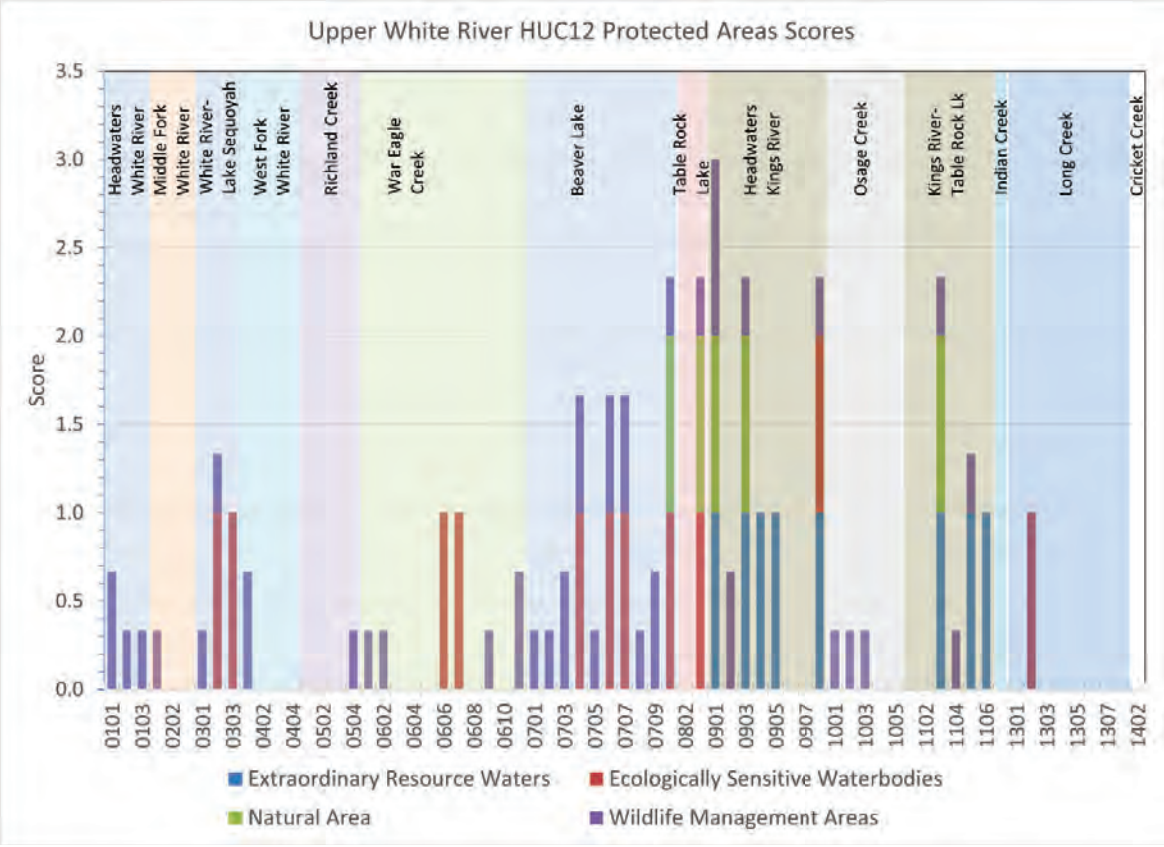


Figure 6. Upper White River HUC12 sub-watershed scores based on the presence of protected areas.

1.2.2 Presence of Threatened or Endangered Aquatic Species

The US Fish and Wildlife Service Information for Planning and Consultation (IPaC) online tool reports that between one and four federally listed threatened or endangered aquatic species are present in the HUC12 sub-watersheds of the Upper White River watershed. HUC12 scores for the presence of threatened or endangered aquatic species were calculated by dividing the reported number of threatened or endangered aquatic species by four (the maximum reported number of threatened or endangered aquatic species). Figure 7 shows a summary of HUC12 scores based on the presence of threatened or endangered aquatic species.

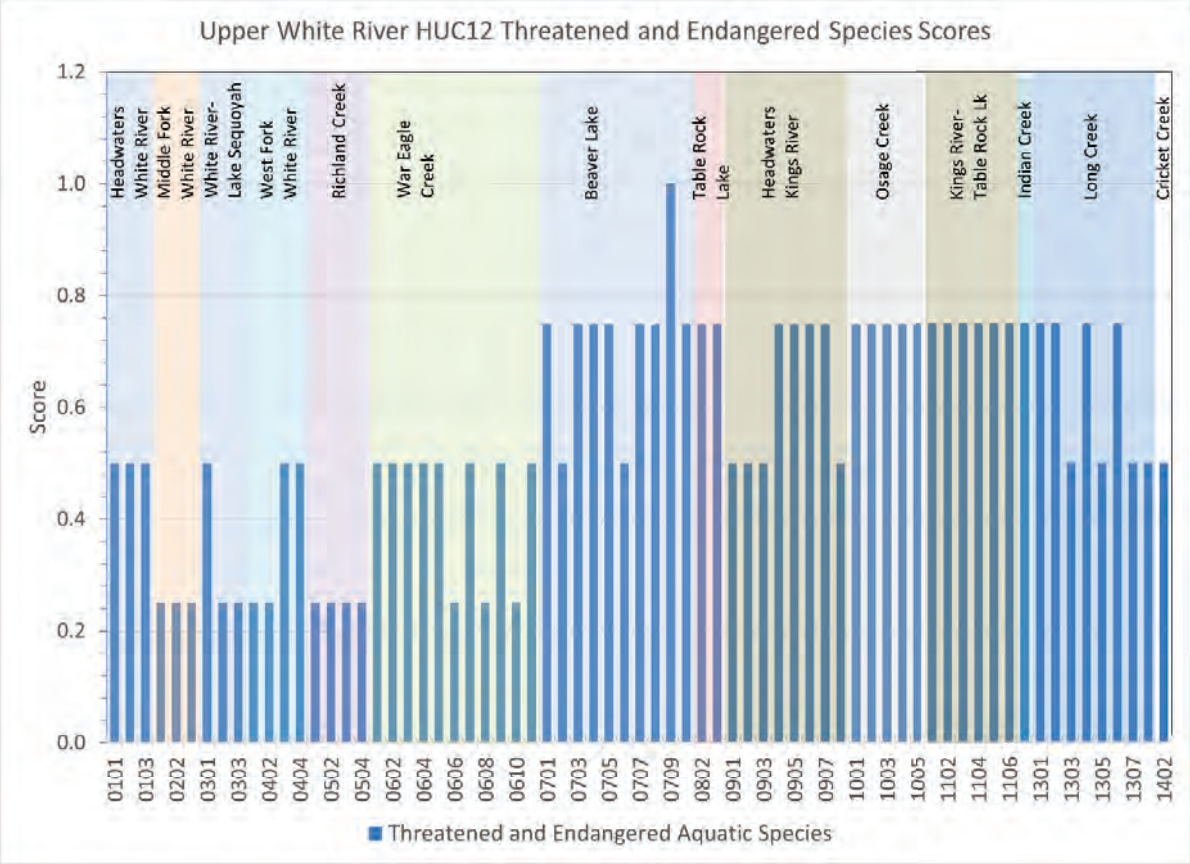


Figure 7. Upper White River HUC12 sub-watershed scores based on the presence of protected aquatic species.

1.2.3 Modeled Nonpoint Source Pollutant Flux

We used the same SWAT model results used to rank HUC12 sub-watersheds for NPS management, to rank the sub-watersheds for protection. For the protection ranking the score for each sub-watershed was calculated by subtracting the NPS management score (see Section 1.1.2) from one. As a result, sub-watersheds with lower nonpoint source pollutant flux have higher score values. Figure 8 shows the HUC12 sub-watershed scores based on predicted nonpoint source pollutant flux.

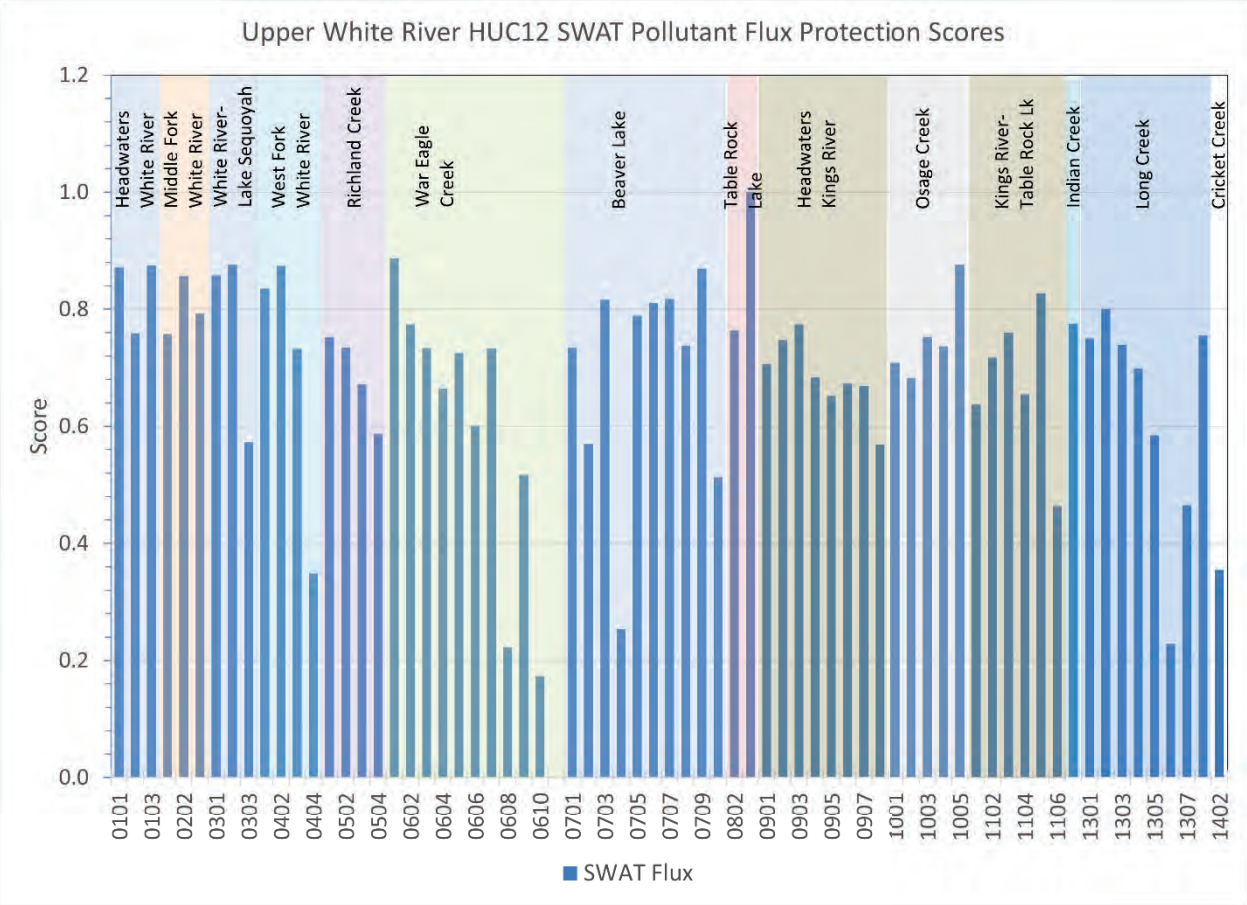


Figure 8. Upper White River HUC12 sub-watershed scores based on SWAT predicted nonpoint source pollutant flux.

1.2.4 Impaired Waterbodies

HUC12 sub-watersheds were assigned a score of -1 if impaired waterbodies were present. The purpose of this ranking is to identify locations with high quality water for protection, which impaired waterbodies are not. An impaired waterbody is considered lower quality water in this assessment. HUC12 sub-watersheds are not scored based on the lack of impaired waterbodies, because the lack of impairments may be because of a lack of water quality data, rather than data showing good water quality. See Figure 1 for a summary of HUC12 sub-watersheds with impaired waterbodies.

1.2.5 Ranking of HUC12 Sub-watersheds for Protection

Seven scores were summed to calculate an overall score. Sub-watersheds with the highest scores have the greatest number of elements indicating sensitive or high-quality water resources. Figure 9 shows a graph of the overall scores for all of the HUC12 sub-watersheds ranked. Figure 10 is a map of these total scores. The three HUC12 sub-watersheds with the highest overall score (i.e., scores greater than 3.5) are Beaver Dam-Beaver Lake (110100010710), Cedar Creek-Table Rock Lake (110100010803), Rockhouse Creek-Kings River (110100011103) (Figure 9). The scoring values for these sub-watersheds are listed in Table 2. Scoring values for all sub-watersheds are listed in Attachment 4.

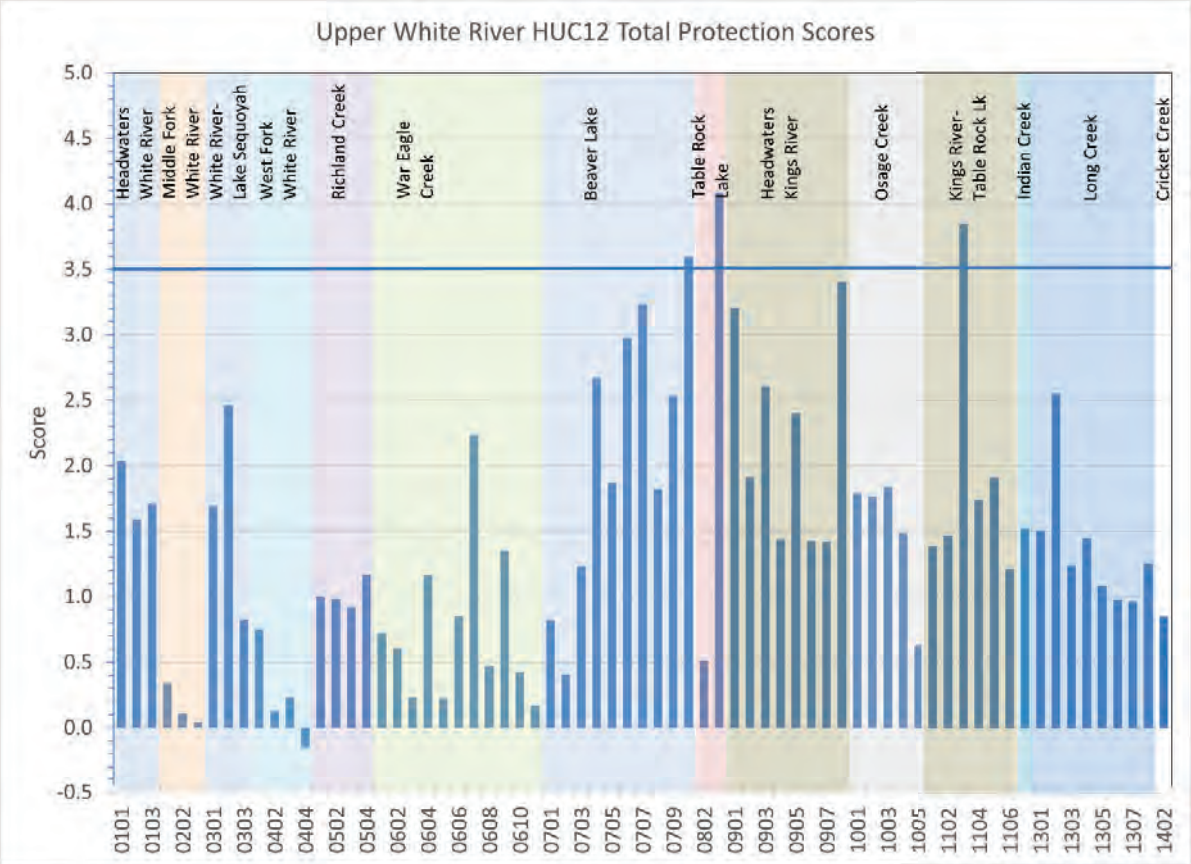


Figure 9. Upper White River HUC12 total ranking scores for protection.

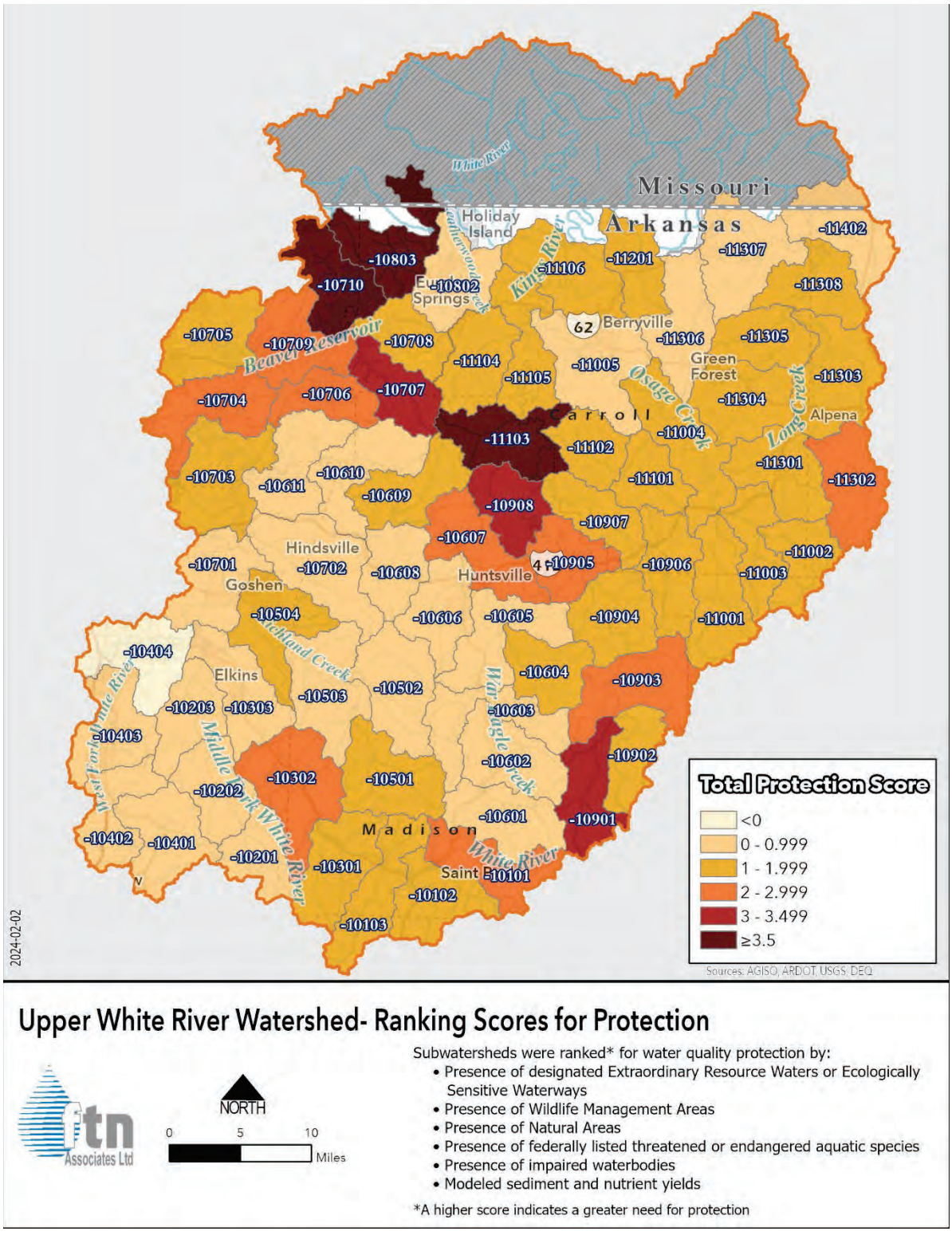


Figure 10. Map of Upper White River HUC12 total ranking scores for protection.

Table 2. Scoring values for sub-watersheds recommended for protection.

	Beaver Dam-Beaver Lake Scores (110100010710)	**Cedar Creek-Table Rock Lake (110100010803)**	**Rockhouse Creek-Kings River (110100011103)**
Ecologically Sensitive Waterbody	1	1	0
Extraordinary Resource Waters	0	0	1
Natural Areas	1	1	1
Wildlife Management Areas	0.33	0.33	0.33
Threatened or Endangered Aquatic Species	0.75	0.75	0.75
SWAT Flux	0.51	1	0.76
Impaired Waterbodies	0	0	0
Overall Score	3.59	4.08	3.84

2.0 REFERENCES

DEQ. 2021. "2020 Draft 303(d) List." *Arkansas Division of Environmental Quality.* Accessed January 2022. https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2020/2020CombineCat4_&_5.pdf.

—. 2020. "Final 2018 303(d) List." *Arkansas Department of Energy and Environment Division of Environmental Quality.* Accessed September 2020. https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/2018 303(d) list.pdf.

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NRCS. 2016. *State Resource Assessement.* Accessed January 2021. https://www.nrcs.usda.gov/wps/portal/nrcs/ar/technical/dma/NRCSEPRD1140008/.

APPENDIX H

Data Used for Calculation of Sediment Yield Target for Category 1 Sub-watersheds

C12s ith turbidit data	Turbidit i air ent	Categor 1 C12	With turbidit T DL	SWAT land sedi ent ield, ton/ha/ ear	SWAT sedi ent instrea flu ield, ton/ha/ ear	SWAT ban sedi ent ield, ton/ha/ ear	ercent develo ed	ercent asture/ha	ercent forest	ercent asture develo ed
110100010611	impaired			0.14	-8.43	7,453	6%	28%	62%	34%
110100010403	impaired			0.32	0.09	17,076	14%	28%	54%	42%
110100010703	impaired			0.11	-0.79	789	12%	31%	55%	43%
110100010303	impaired			0.08	3.11	4,031	9%	39%	49%	48%
110100010404	impaired			0.21	2.82	11,175	30%	21%	47%	51%
110100010606	impaired			0.19	0.55	8,479	12%	39%	45%	51%
110100010701	impaired			0.20	-5.33	1,492	11%	45%	42%	56%
110100010902	not impaired			0.06	0.28	2,280	3%	7%	89%	10%
110100010803	not impaired			0.10	-31.09	7,963	6%	5%	87%	11%
110100010802	not impaired			0.06	2.16	1,830	11%	2%	86%	13%
110100010101	not impaired			0.10	0.75	4,724	4%	10%	83%	15%
110100011001	not impaired			0.10	0.77	5,658	5%	13%	79%	19%
110100010501	not impaired			0.07	1.11	4,231	3%	17%	79%	20%
110100010602	not impaired			0.05	1.12	97,907	4%	18%	76%	22%
110100010603	not impaired			0.04	0.84	22,280	4%	21%	70%	25%
110100011302	not impaired			0.17	0.6	8,543	4%	23%	70%	27%
110100010502	not impaired			0.14	1.35	8,594	5%	25%	68%	30%
110100010704	not impaired			0.07	32.2	3,576	14%	16%	68%	31%
110100010908	not impaired			0.08	3.55	3,129	5%	27%	65%	32%
110100010203	not impaired			0.17	0.8	7,267	5%	29%	64%	34%
110100010604	not impaired			0.07	1.62	81,164	4%	30%	60%	34%

C12s ith turbidit data	Turbidit i air ent	Categor 1 C12	With turbidit T DL	SWAT land sedi ent ield, ton/ha/ ear	SWAT sedi ent instrea flu ield, ton/ha/ ear	SWAT ban sedi ent ield, ton/ha/ ear	ercent develo ed	ercent asture/ha	ercent forest	ercent asture develo ed
110100011004	not impaired			0.07	-0.01	4,334	4%	33%	60%	37%
110100010904	not impaired			0.04	2.81	2,036	5%	38%	54%	43%
110100010607	not impaired			0.04	0.23	14,831	6%	40%	51%	46%
110100010504	not impaired			0.15	0.08	8,356	7%	46%	45%	53%
110100010609	not impaired			0.07	1.98	54,402	5%	50%	41%	55%
110100011005	not impaired			0.07	0.66	5,130	10%	49%	37%	60%
110100011106	not impaired			0.04	-0.45	2,500	7%	55%	36%	62%

Median of land loads from monitored HUC12s without turbidity impairments and 34% or more of land area in pasture and/or developed land covers 0.07

Range of percent pasture developed in Category 1 HUC12s 34% - 62%

otes SW T yields evaluated are only those from HUC12s where active 2018-2022 monitoring stations are located.

Target is set using yields only from HUC12s where percent of pasture developed is at least 34% rows colored gray in the table above . Thus, the target value represents a yield that is predicted as possible for HUC12s with ranges of developed and pasture land use similar to those in the Category 1 HUC12s.

APPENDIX I

Development of Nutrient Load Targets for Category 1 Sub-watersheds

1.1 E aluation of Relationships etween DO and Nutrient oncentrations

box and whisker graph comparison of reported total nitrogen and total phosphorus concentrations from stations on stream segments listed as impaired because of low DO on the 2018 and/or 2020 303 d Lists, to concentrations from stations on stream segments not listed as impaired because of low DO did show a statistically significant difference in the median values. However, this analysis showed that median total nitrogen and total phosphorus concentrations are statistically significantly lower at stations listed as impaired because of low DO, rather than higher, as expected Figure 1 .

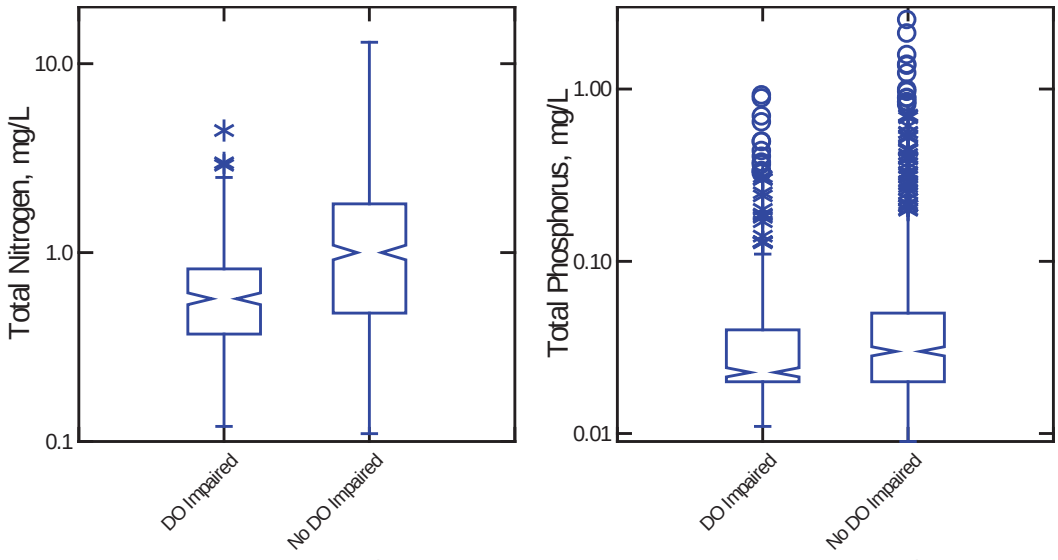


Figure 1. Box and whisker graph comparison of 2018-2022 total nitrogen T and total phosphorus TP concentrations reported from stations on DO impaired stream segments to concentrations from stations not on DO impaired stream segments.

ormality tests were performed on DO, total nitrogen, and total phosphorus concentrations from stations on DO impaired assessment units. t some stations these tests indicated the data sets were normally distributed. Linear regression analysis was performed for DO versus nutrient concentrations from the stations where data was normally distributed ttachment 1 . However, there were no statistically significant linear relationships between DO and nutrient concentrations in these data sets ttachment 2 .

1.2 DO Impairment and Simulated Nutrient Loads

Modeled nutrient yields from land and instream flux for monitored HUC12 sub-watersheds with and without DO impaired waterbodies were compared. The data used for this comparison is listed in Table 1. Figures 2 and 3 show box plots comparing simulated yields from HUC12 sub-watersheds with and without DO impaired waterbodies. There was no statistically significant difference in median land yields nor median instream flux estimates for sub-watersheds with and without DO impaired waterbodies.

Table 1. Data used to evaluate relationships between modeled loads and DO impairment.

C12s ith D data	D i air ent	SWAT land nitrogen ield, g/ha/ ear	SWAT land hos horus ield, g/ha/ ear	SWAT instrea nitrogen flu , g/ha/ ear	SWAT instrea hos horus flu , g/ha/ ear	ercent develo ed	ercent asture/ha	ercent forest	ercent develo ed asture
110100010802	impaired	0.25	0.01	4.71	0.4	11%	2%	86%	13%
110100010602	impaired	0.48	0.02	4.32	0.56	4%	18%	76%	22%
110100010603	impaired	0.56	0.02	5.41	0.65	4%	21%	70%	25%
110100010203	impaired	0.79	0.03	3.35	0.69	5%	29%	64%	34%
110100010611	impaired	1.11	0.19	13.61	4.46	6%	28%	62%	34%
110100010403	impaired	1.49	0.01	7.07	0.37	14%	28%	54%	42%
110100010904	impaired	0.80	0.03	5.56	0.72	5%	38%	54%	43%
110100010404	impaired	1.47	0.10	8.88	2.51	30%	21%	47%	51%
110100010701	impaired	1.57	0.04	5.66	0.7	11%	45%	42%	56%
110100010902	not impaired	0.34	0.04	3.89	0.98	3%	7%	89%	10%
110100010803	not impaired	0.41	0.01	-62.64	-11.05	6%	5%	87%	11%
110100010101	not impaired	0.33	0.01	2.43	0.31	4%	10%	83%	15%
110100010710	not impaired	0.18	0.01	2.8	0.24	11%	4%	83%	15%
110100011001	not impaired	0.59	0.02	7.07	0.46	5%	13%	79%	19%
110100010501	not impaired	0.48	0.03	3.92	0.82	3%	17%	79%	20%
110100011302	not impaired	0.55	0.00	5.65	0.11	4%	23%	70%	27%
110100010705	not impaired	0.46	0.02	4.59	0.37	17%	11%	69%	28%
110100010502	not impaired	0.65	0.03	5.08	0.65	5%	25%	68%	30%
110100010704	not impaired	0.58	0.02	3.51	0.44	14%	16%	68%	31%
110100010908	not impaired	0.61	0.07	5.28	1.57	5%	27%	65%	32%
110100010604	not impaired	0.68	0.03	6.44	0.83	4%	30%	60%	34%
110100011004	not impaired	0.96	0.03	5.14	0.81	4%	33%	60%	37%
110100010703	not impaired	0.68	0.03	3.68	0.54	12%	31%	55%	43%

Table 1. Data used to evaluate relationships between modeled loads and DO impairment continued .

C12s ith D data	D i air ent	SWAT land nitrogen ield, g/ha/ ear	SWAT land hos horus ield, g/ha/ ear	SWAT instrea nitrogen flu , g/ha/ ear	SWAT instrea hos horus flu , g/ha/ ear	ercent develo ed	ercent asture/ha	ercent forest	ercent develo ed asture
110100010607	not impaired	0.64	0.04	4.09	1.05	6%	40%	51%	46%
110100010303	not impaired	0.92	0.09	2.08	2.35	9%	39%	49%	48%
110100010606	not impaired	1.18	0.04	8.63	0.95	12%	39%	45%	51%
110100010504	not impaired	1.29	0.06	6.38	1.65	7%	46%	45%	53%
110100010609	not impaired	1.50	0.05	5.68	2.09	5%	50%	41%	55%
110100011005	not impaired	2.10	0.12	0.85	0.66	10%	49%	37%	60%
110100011106	not impaired	0.25	0.01	5.31	2.8	7%	55%	36%	62%

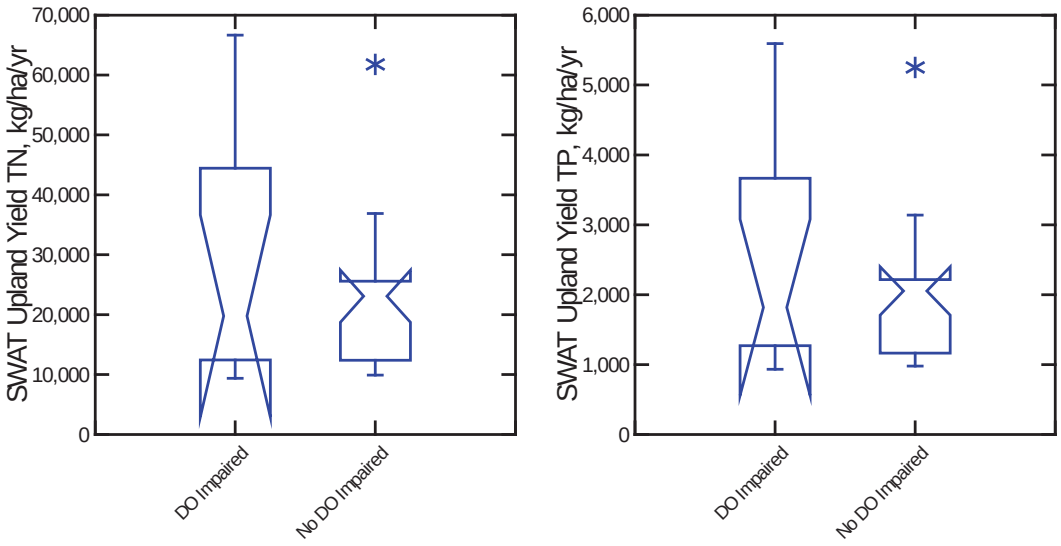


Figure 2. Box plot comparison of modeled nitrogen yields from land and instream for selected monitored HUC12 sub-watersheds with and without waterbodies impaired because of low DO. The notches represent the median value, with a 95% confidence interval. If notches do not overlap, the median values are statistically significantly different with 95% confidence.

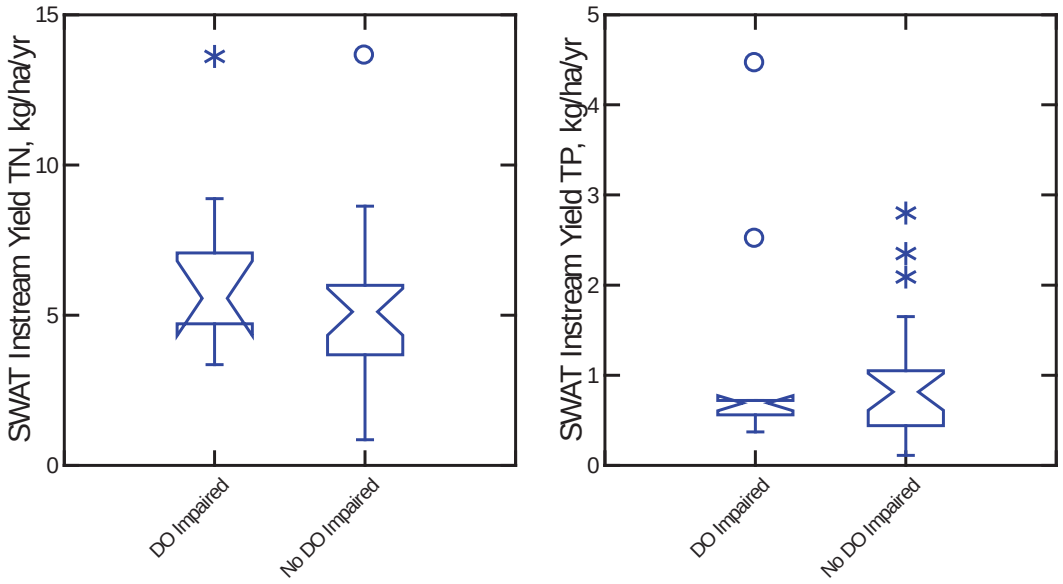


Figure 3. Box plot comparison of modeled phosphorus yields from land and instream for selected monitored HUC12 sub-watersheds with and without waterbodies impaired because of low DO. The notches represent the median value, with a 95% confidence interval. If notches do not overlap, the median values are statistically significantly different with 95% confidence.

1.3 De elopment of Nutrient Yield Targets

We looked at modeled nutrient upland yields from all sub-watersheds, yields from ust monitored sub-watersheds without a DO impairment, and yields from all sub-watersheds with similar percentages of developed land and pasture/hayland in the HUC12 and in the riparian buffer. Statistics calculated from these data sets are listed in Tables 2 and 3.

Table 2. Statistics for modeled total nitrogen upland yield kg/ha/year .

	All sub-atersheds	**onitored sub-atersheds ithout D i air ent**	**onitored sub-atersheds ithout D i air ent and develo ed asture in C12 34%**	**All sub atersheds ith develo ed asture in C12 34% - 65%**	**All sub atersheds ith develo ed asture in ri arian buffer 22% - 57%**
umber of values	74	21	10	30	41
75th percentile	1.02	0.93	1.26	1.18	1.13
Median	0.66	0.64	0.94	1.03	0.80
25th percentile	0.47	0.48	0.74	0.83	0.60

Table 3. Statistics for modeled total phosphorus upland yield kg/ha/year .

	All sub-atersheds	**onitored sub-atersheds ithout D i air ent**	**onitored sub-atersheds ithout D i air ent and develo ed asture in C12 34%**	**Sub atersheds ith develo ed asture in C12 34% - 62%**	**Sub atersheds ith develo ed asture in ri arian buffer 22% - 57%**
umber of values	74	21	10	30	41
75th percentile	0.04	0.05	0.08	0.06	0.05
Median	0.03	0.03	0.04	0.04	0.03
25th percentile	0.01	0.02	0.03	0.03	0.02

We also looked at graphs of simulated land yields versus percentage of the HUC12 land in developed and pasture uses. These graphs are provided as Figures 4 and 5. The total nitrogen graph does exhibit an increasing trend in simulated land yields with increasing percentage of land in pasture and development. Based on these graphs, 75th percentile values appear to be a

reasonable guide for potential targets. Taking all this information together, we set the total nitrogen land yield target to 1.04 kg/ha/year, and the total phosphorus land yield target to 0.04 kg/ha/year.

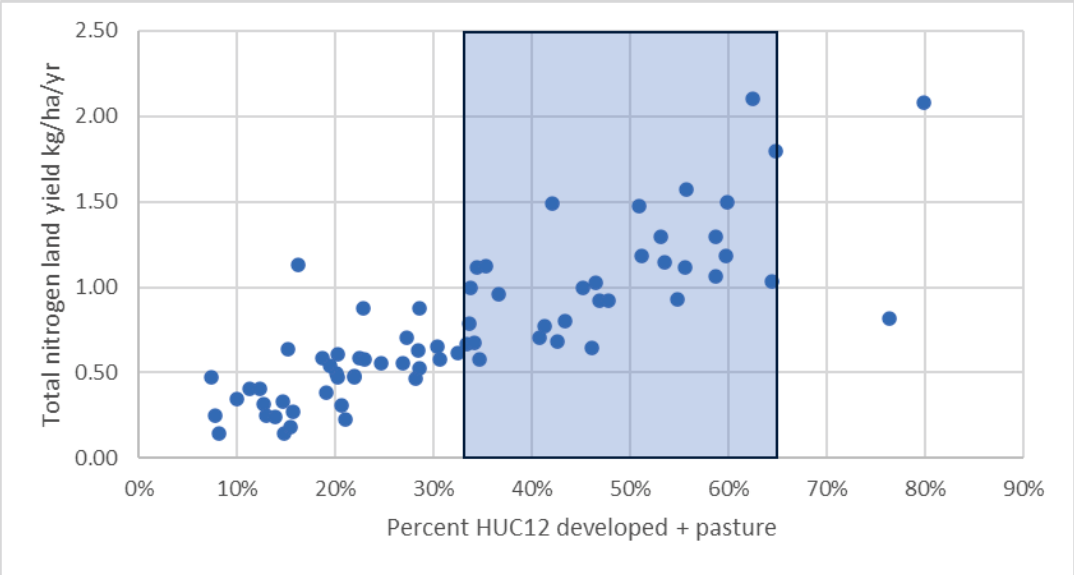


Figure 4. Modeled total nitrogen land yield versus percentage of HUC12 sub-watershed land in developed or pasture/hayland land uses. The blue box highlights yields for the range of developed pasture percentages present in Category 1 sub-watersheds 34% to 62% .

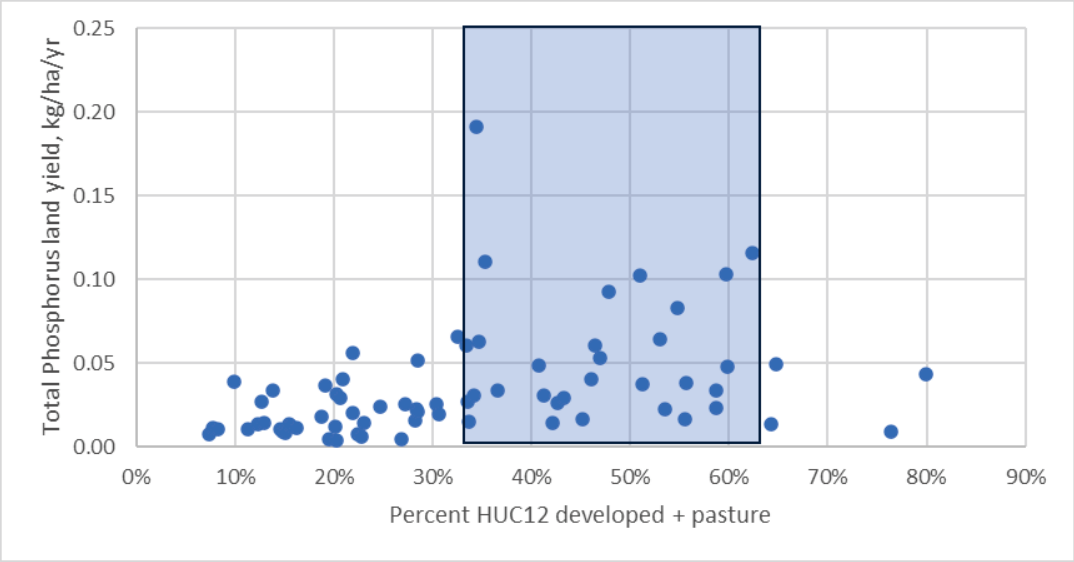


Figure 5. Modeled total phosphorus land yield versus percentage of HUC12 sub-watershed land in developed or pasture/hayland land uses. The blue box highlights yields for the range of developed pasture percentages present in Category 1 sub-watersheds 34% to 62% .

APPENDIX J

Calculation of Sulfate Load Reduction Targets for Category 1 Sub-watersheds

Reduced sulfate concentrations in Table 1 are calculated by multiplying measured concentrations by the multiplier in Table 2. The reduction factor in Table 2 is one minus the multiplier. Table 3 shows calculation of a reduction factor for Base Flow turbidity at station WHI0106. The resulting reduction factor is provided in Table 4.

Table 1. Measured and reduced 2018-2022 sulfate concentrations from stations WHI0100 and WFWR.

	easured Sulfate Concentrations		**educed Sulfate Concentrations**	
Sa ling Date	**Station W 0100**	**Station W W**	**Station W 0100**	**Station W W**
1/3/2018	--	35.31	--	20.83
1/10/2018	--	44.81	--	26.44
1/18/2018	--	42.41	--	25.02
1/22/2018	--	30.69	--	18.11
1/30/2018	22.90	--	14.89	--
2/8/2018	--	27.34	--	16.13
2/14/2018	--	32.46	--	19.15
2/20/2018	--	7.95	--	4.69
2/24/2018	--	7.52	--	4.44
2/27/2018	19.00	--	12.35	--
3/6/2018	24.70	--	16.06	--
3/8/2018	--	0.32	--	0.19
3/19/2018	--	30.92	--	18.24
3/27/2018	--	7.30	--	4.31
4/9/2018	--	21.13	--	12.47
4/10/2018	22.00	--	14.30	--
4/26/2018	--	18.00	--	10.62
5/1/2018	16.90	--	10.99	--
5/3/2018	--	9.99	--	5.90
5/9/2018	--	17.31	--	10.21
5/15/2018	--	25.60	--	15.10
5/22/2018	--	21.23	--	12.53
5/30/2018	--	20.10	--	11.86
6/12/2018	35.60	--	23.14	--
6/13/2018	--	33.94	--	20.03
6/18/2018	--	34.43	--	20.31
6/25/2018	--	38.38	--	22.64
7/2/2018	--	35.94	--	21.20
7/9/2018	--	38.25	--	22.57
7/19/2018	--	26.51	--	15.64
7/24/2018	37.90	--	24.64	--
7/25/2018	--	34.21	--	20.19
7/30/2018	--	30.68	--	18.10
8/8/2018	--	35.73	--	21.08
8/14/2018	--	31.94	--	18.84
8/17/2018	--	17.21	--	10.15
8/22/2018	--	26.62	--	15.71
8/28/2018	--	33.85	--	19.97
9/11/2018	41.90	42.57	27.24	25.12
9/18/2018	--	39.49	--	23.30

Table 1. Measured and reduced 2018-2022 sulfate concentrations from stations WHI0100 and WFWR continued .

	easured Sulfate Concentrations		educed Sulfate Concentrations	
Sa ling Date	Station W 0100	Station W W	Station W 0100	Station W W
10/9/2018	41.70	--	27.11	--
11/27/2018	35.70	--	23.21	--
2/26/2019	19.00	--	12.35	--
3/19/2019	18.00	--	11.70	--
4/9/2019	20.60	--	13.39	--
5/28/2019	18.10	--	11.77	--
7/30/2019	32.50	--	21.13	--
8/6/2019	31.70	--	20.61	--
9/10/2019	23.20	--	15.08	--
10/7/2019	--	10.80	--	6.37
10/15/2019	--	11.47	--	6.77
10/20/2019	--	28.81	--	17.00
10/22/2019	18.10	--	11.77	--
10/24/2019	--	8.78	--	5.18
11/7/2019	--	8.17	--	4.82
11/13/2019	--	19.14	--	11.29
11/18/2019	19.40	--	12.61	--
11/19/2019	--	22.10	--	13.04
12/5/2019	--	18.34	--	10.82
12/10/2019	19.80	--	12.87	--
12/17/2019	--	27.61	--	16.29
1/7/2020	18.00	--	11.70	--
1/11/2020	--	7.95	--	4.69
1/15/2020	--	8.09	--	4.78
1/30/2020	--	17.69	--	10.44
2/4/2020	--	9.13	--	5.38
2/11/2020	--	16.43	--	9.70
2/26/2020	--	23.70	--	13.98
3/3/2020	21.40	--	13.91	--
3/14/2020	--	9.20	--	5.43
3/17/2020	--	15.46	--	9.12
3/20/2020	--	7.00	--	4.13
4/6/2020	--	16.44	--	9.70
4/7/2020	16.40	--	10.66	--
4/15/2020	--	14.87	--	8.77
4/23/2020	--	20.88	--	12.32
5/11/2020	--	18.31	--	10.80
5/12/2020	16.90	--	10.99	--
5/16/2020	--	12.97	--	7.65
5/26/2020	--	7.05	--	4.16
6/1/2020	--	15.36	--	9.06
6/9/2020	20.00	--	13.00	--
6/16/2020	--	24.21	--	14.28
7/7/2020	22.70	--	14.76	--
7/9/2020	--	22.98	--	13.56
7/23/2020	--	25.27	--	14.91
8/4/2020	31.60	--	20.54	--
8/25/2020	--	35.80	--	21.12
9/2/2020	--	38.56	--	22.75
9/8/2020	19.90	--	12.94	--

Table 1. Measured and reduced 2018-2022 sulfate concentrations from stations WHI0100 and WFWR continued .

	easured Sulfate Concentrations		educed Sulfate Concentrations	
Sa ling Date	Station W 0100	Station W W	Station W 0100	Station W W
9/15/2020	--	24.41	--	14.40
9/22/2020	--	26.82	--	15.83
10/6/2020	--	32.95	--	19.44
10/13/2020	--	34.87	--	20.57
10/27/2020	26.70	28.33	17.36	16.71
10/29/2020	--	10.72	--	6.33
11/4/2020	--	26.88	--	15.86
11/16/2020	--	35.71	--	21.07
11/30/2020	--	28.81	--	17.00
12/1/2020	26.80	--	17.42	--
12/16/2020	--	10.79	--	6.37
1/1/2021	--	11.49	--	6.78
1/5/2021	16.40	--	10.66	--
1/13/2021	--	20.11	--	11.86
1/25/2021	--	28.29	--	16.69
2/2/2021	21.10	--	13.72	--
2/5/2021	--	23.49	--	13.86
2/22/2021	--	38.04	--	22.44
3/8/2021	--	22.23	--	13.11
3/13/2021	--	26.08	--	15.39
3/15/2021	--	15.43	--	9.11
3/26/2021	--	11.75	--	6.93
3/30/2021	14.60	--	9.49	--
4/5/2021	--	19.34	--	11.41
4/24/2021	--	11.60	--	6.84
4/26/2021	--	13.89	--	8.20
4/27/2021	14.10	--	9.17	--
4/28/2021	--	6.39	--	3.77
4/29/2021	--	3.62	--	2.13
5/11/2021	18.90	--	12.29	--
5/18/2021	--	24.87	--	14.68
5/26/2021	--	17.95	--	10.59
5/28/2021	--	6.88	--	4.06
6/10/2021	--	14.98	--	8.84
6/21/2021	--	22.91	--	13.52
6/22/2021	24.50	--	15.93	--
6/28/2021	--	35.42	--	20.90
7/13/2021	--	35.75	--	21.09
7/18/2021	--	8.13	--	4.80
7/19/2021	--	7.19	--	4.24
7/20/2021	18.60	--	12.09	--
8/6/2021	--	33.89	--	19.99
8/10/2021	36.80	--	23.92	--
8/16/2021	--	33.70	--	19.88
9/13/2021	--	40.55	--	23.93
9/28/2021	37.10	--	24.12	--
9/30/2021	--	42.24	--	24.92
10/5/2021	47.50	--	30.88	--
10/11/2021	--	40.81	--	24.08
10/14/2021	--	24.51	--	14.46

Table 1. Measured and reduced 2018-2022 sulfate concentrations from stations WHI0100 and WFWR continued .

	easured Sulfate Concentrations		educed Sulfate Concentrations	
Sa ling Date	**Station W 0100**	**Station W W**	**Station W 0100**	**Station W W**
11/2/2021	32.70	--	21.26	--
11/3/2021	--	42.14	--	24.86
11/10/2021	--	40.52	--	23.91
11/15/2021	--	18.36	--	10.84
12/1/2021	--	41.79	--	24.66
12/7/2021	39.90	--	25.94	--
12/17/2021	--	16.64	--	9.82
12/18/2021	--	8.99	--	5.30
1/17/2022	--	33.38	--	19.70
1/18/2022	31.30	--	20.35	--
1/31/2022	--	30.94	--	18.26
2/1/2022	29.40	--	19.11	--
2/17/2022	--	11.18	--	6.60
2/28/2022	--	17.97	--	10.60
3/8/2022	17.20	--	11.18	--
3/9/2022	--	20.99	--	12.39
3/21/2022	--	17.72	--	10.46
3/22/2022	--	13.68	--	8.07
3/30/2022	--	7.49	--	4.42
4/14/2022	--	6.20	--	3.66
4/19/2022	13.10	13.58	8.52	8.01
4/25/2022	--	6.75	--	3.98
5/3/2022	--	6.72	--	3.96
5/5/2022	--	4.84	--	2.86
5/10/2022	--	16.58	--	9.78
5/31/2022	16.60	--	10.79	--
6/8/2022	--	5.72	--	3.37
6/13/2022	--	12.34	--	7.28
6/14/2022	14.00	--	9.10	--
7/5/2022	29.50	--	19.18	--
7/18/2022	--	33.03	--	19.49
8/2/2022	27.30	--	17.75	--
8/15/2022	--	40.12	--	23.67
8/31/2022	--	14.63	--	8.63
9/12/2022	--	41.45	--	24.45
9/13/2022	35.80	--	23.27	--
9/19/2022	--	38.21	--	22.54
11/1/2022	41.30	--	26.85	--
12/6/2022	29.80	--	19.37	--
umber of measurements	53	129	53	129
umber exceeding 20	31	69	16	28
Maximum number of exceedances allowed for attainment DE 2022, Table 2	16	30	16	30

Table 2. Multipliers used to calculate reduced sulfate concentrations, with associated reduction factors.

	Station W 0100	Station W W
Multiplier	0.65	0.59
Reduction factor	0.35	0.41

Table 3. Measured and reduced 2018-2022 Base Flow turbidity concentrations from station WHI0106.

	W 0106 ase lo Turbidit , T	
Sa ling Date	easured	educed
6/12/2018	9.17	7.8
7/24/2018	2.98	2.5
9/11/2018	5.20	4.4
10/9/2018	23.00	19.6
7/30/2019	3.27	2.8
8/6/2019	2.58	2.2
9/10/2019	5.38	4.6
10/22/2019	21.10	17.9
6/9/2020	11.80	10.0
7/7/2020	17.90	15.2
8/4/2020	4.59	3.9
9/8/2020	7.20	6.1
10/27/2020	45.70	38.8
6/22/2021	3.72	3.2
7/20/2021	16.60	14.1
8/10/2021	3.36	2.9
9/28/2021	4.70	4.0
10/5/2021	4.40	3.7
6/14/2022	10.30	8.8
7/5/2022	4.10	3.5
8/2/2022	11.60	9.9
9/13/2022	11.50	9.8
umber of measurements	22	22
umber exceeding 10	9	6
Maximum number of exceedances allowed for attainment	7	7

Table 4. Multiplier used to calculate reduced turbidity, with associated reduction factor.

	Station W 0106
Multiplier	0.85
Reduction factor	0.15

APPENDIX K

Evaluation of historical TDS data at WHI0100 and WHI0009A

In the biennial water uality evaluation, data from five years preceding the listing year is used to evaluate attainment of water uality standards. Table 1 shows a summary of the number of TDS measurements from station WHI0009 on the Kings River that exceed the TDS water uality criterion, 150 mg/L, during recent impairment evaluation periods. The number of exceedances appears to be decreasing over time. Based on this evaluation, it appears that this assessment unit of the Kings River may be classified as meeting standards on the 2024 303 d impaired waters list. The draft 2024 303 d list is not currently published. Figure 1 shows a graph of the TDS data from this station over the same period. lthough a decline in the number of measurements greater than 150 mg/L shown as a solid blue line on the graph is not readily apparent, a decline in the maximum TDS concentrations measured is. s a result, a linear regression of the data indicates a decline in TDS concentration.

Table 1. Evaluation of TDS data from WHI0009 110100011106 Kings River U 11010001-037 .

303(d) List ear	Data eriod for i air ent deter ination	u ber of TDS easure ents	u ber of easure ents e ceeding 150 g/L	u ber of e ceedances for listing	valuation result	303(d) listing
2018	4/1/2012 to 3/31/2017	59	30	19	Impaired	Impaired
2020	4/1/2014 to 3/31/2019	59	25	19	Impaired	Impaired
2022	4/1/2016 to 3/31/2021	57	21	18	Impaired	Impaired
2024	4/1/2018 to 3/31/2023	49	16	16	Impaired	-
WMP	1/1/2018 to 12/31/2022	49	15	16	ot impaired	-

twenty-five percent exceedance rate from Table 1 of the 2022 ssessment Methodology Methodology for 305 b /303 d - 2002 ssessment state.ar.us

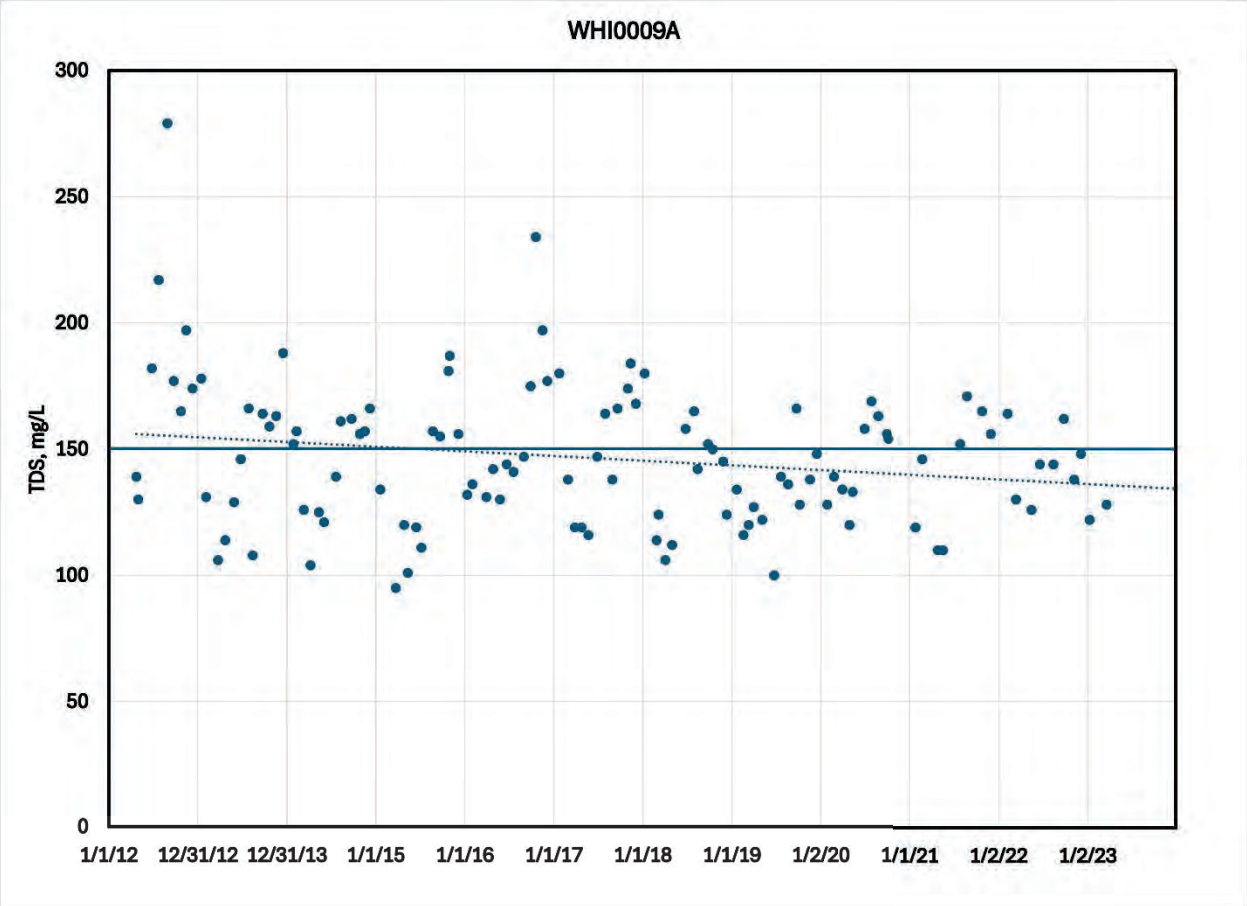


Figure 1. raph of TDS measurements from Kings River station WHI0009 , 2012-2022.

Table 2 shows a summary of the number of TDS measurements from station WHI0100 on the West Fork White River that exceed the TDS water uality criterion, 150 mg/L, during recent impairment evaluation periods. The number of exceedances appears to have decreased over time, though not as consistently as at station WHI0009 . However, as with the station WHI0009 data, this evaluation indicates that this unit of the West Fork White River may be classified as meeting standards on the 2024 303 d impaired waters list. Figure 2 shows a graph of the TDS data from this station over the same period.

Table 2. Evaluation of TDS data from WHI0100 110100010404 West Fork White River U 11010001-024 .

303(d) List ear	Data eriod for i air ent deter ination	u ber of TDS easure ents	u ber of easure ents e ceeding 150 g/L	u ber of e ceedances for listing	valuation result	303(d) listing
2018	4/1/2012 to 3/31/2017	47	20	16	Impaired	Impaired
2020	4/1/2014 to 3/31/2019	55	24	18	Impaired	Impaired
2022	4/1/2016 to 3/31/2021	54	19	18	Impaired	Impaired
2024	4/1/2018 to 3/31/2023	53	15	17	ot impaired	-
WMP	1/1/2018 to 12/31/2022	53	15	17	ot impaired	-

twenty-five percent exceedance rate from Table 1 of the 2022 ssessment Methodology Methodology for 305 b /303 d - 2002 ssessment state.ar.us

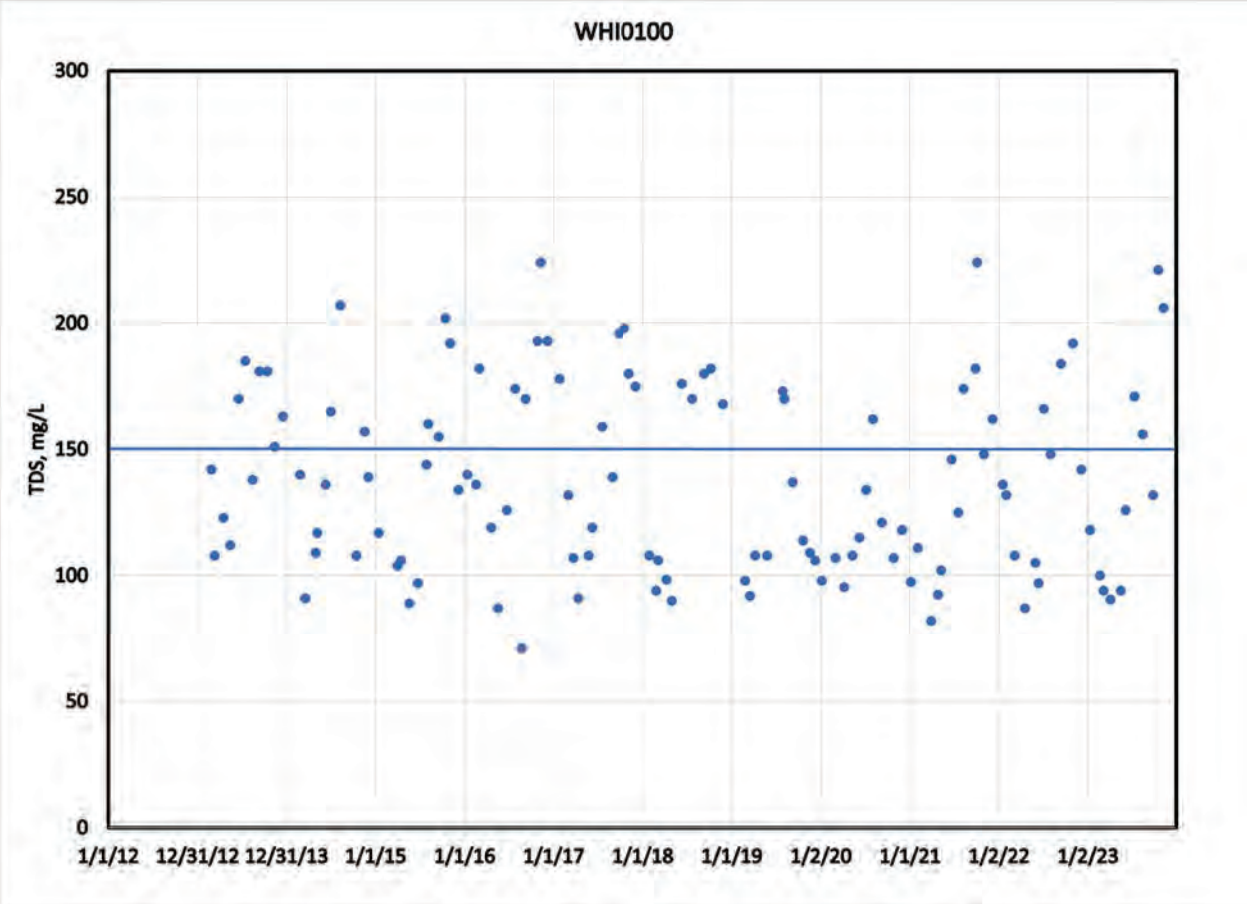


Figure 2. raph of TDS measurements from West Fork White River station WHI0100, 2012-2022.

APPENDIX L

SWAT Model Yield Output

Table 1. SW T estimated HUC12 instream yields for sub-watersheds with at least 50% of area in rkansas, with ranking.

C12 D 11010001	Total itrogen ield		Total Phos horus ield		Sedi ent ield		an rosion ield	
	g/ha/ r	an (highest ield 1)	g/ha/ r	an (highest ield 1)	ton/ha/ r	an (highest ield 1)	ton/ha/ r	an (highest ield 1)
-0101	2.43	63	0.31	56.5	0.75	34	4,724	36
-0102	6.46	16	0.21	63	0.81	30.5	11,098	11
-0103	2.26	66	0.31	56.5	0.83	29	8,148	18
-0201	6.95	14	0.16	65	0.43	45	6,543	26
-0202	4.18	43	0.11	67.5	-0.04	59	8,144	19
-0203	3.35	54	0.69	34.5	0.8	32	7,267	24
-0301	2.73	62	0.39	50	0.42	46	9,988	12
-0302	2.39	64	0.33	55	0.4	47	8,223	17
-0303	2.08	67	2.35	6	3.11	6	4,031	43
-0401	4.31	41	0.2	64	0.32	50	8,035	20
-0402	3.33	55	0.13	66	0.34	49	7,681	22
-0403	7.07	12.5	0.37	52	0.09	55	17,076	6
-0404	8.88	9	2.51	4	2.82	7	11,175	10
-0501	3.92	48	0.82	27.5	1.11	25.5	4,231	41
-0502	5.08	33	0.65	38.5	1.35	19	8,594	13
-0503	4.66	37	1.25	16	1.2	22.5	4,277	40
-0504	6.38	18	1.65	8	0.08	56	8,356	16
-0601	2.34	65	0.22	62	0.69	36	15,271	7
-0602	4.32	40	0.56	42.5	1.12	24	97,907	1
-0603	5.41	27	0.65	38.5	0.84	28	22,280	5
-0604	6.44	17	0.83	25.5	1.62	17.5	81,164	2
-0605	5.38	28	0.83	25.5	0.07	57	63,723	3
-0606	8.63	10	0.95	21	0.55	40.5	8,479	15

Table 1. SW T estimated HUC12 instream yields with ranking continued .

C12 D 11010001	Total itrogen ield		Total Phos horus ield		Sedi ent ield		an rosion ield	
	g/ha/ r	an (highest ield 1)	g/ha/ r	an (highest ield 1)	ton/ha/ r	an (highest ield 1)	ton/ha/ r	an (highest ield 1)
-0607	4.09	45	1.05	18	0.23	53	14,831	8
-0608	18.86	1	1.22	17	2.09	12	14,093	9
-0609	5.68	21	2.09	7	1.98	13	54,402	4
-0610	13.33	5	2.5	5	5.03	3	4,862	34
-0611	13.61	4	4.46	1	-8.43	68	7,453	23
-0701	5.66	22	0.7	33	-5.33	66	1,492	61
-0702	10.63	6	0.61	40.5	1.29	21	826	66
-0703	3.68	51	0.54	44	-0.79	63	789	67
-0704	3.51	52	0.44	46	32.2	1	3,576	46
-0705	4.59	38	0.37	52	1.2	22.5	5,121	33
-0706	2.77	61	0.29	59	3.65	4	369	69
-0707	3.83	50	0.34	54	1.11	25.5	2,261	56
-0708	4.87	35	0.68	36	1.3	20	2,897	50
-0709	3.01	59	0.29	59	-8.29	67	3,766	44
-0710	2.8	60	0.24	61	20.49	2	6,383	27
-0802	4.71	36	0.4	49	2.16	11	1,830	59
-0803	-62.64	69	-11.05	69	-31.09	69	7,963	21
-0901	4.16	44	0.93	23	2.46	10	597	68
-0902	3.89	49	0.98	20	0.28	51.5	2,280	55
-0903	3.41	53	0.72	31.5	-1.51	64	3,004	49
-0904	5.56	24	0.72	31.5	2.81	8	2,036	58
-0905	9.12	8	0.41	48	-0.78	62	870	65
-0906	4.24	42	1.28	15	1.63	16	4,128	42
-0907	4	47	1.47	11	0.91	27	1,455	62
-0908	5.28	30	1.57	10	3.55	5	3,129	48

Table 1. SW T estimated HUC12 instream yields with ranking continued .

C12 D 11010001	Total itrogen ield		Total Phos horus ield		Sedi ent ield		an rosion ield	
	g/ha/ r	an (highest ield 1)	g/ha/ r	an (highest ield 1)	ton/ha/ r	an (highest ield 1)	ton/ha/ r	an (highest ield 1)
-1001	7.07	12.5	0.46	45	0.77	33	5,658	30
-1002	7.47	11	0.56	42.5	0.81	30.5	6,730	25
-1003	6.15	19	0.37	52	0.54	42	4,752	35
-1004	5.14	32	0.81	29	-0.01	58	4,334	39
-1005	0.85	68	0.66	37	0.66	37	5,130	32
-1101	4.99	34	1.33	14	1.95	14	1,336	63
-1102	4.03	46	0.99	19	1.62	17.5	6,060	29
-1103	3.08	58	0.77	30	2.49	9	4,611	37
-1104	4.43	39	1.37	13	1.69	15	2,123	57
-1105	3.15	57	0.29	59	-2.11	65	3,715	45
-1106	5.31	29	2.8	2	-0.45	60	2,500	52
-1201	3.16	56	0.89	24	0.64	38	1,764	60
-1301	5.22	31	0.61	40.5	0.55	40.5	5,434	31
-1302	5.65	23	0.11	67.5	0.6	39	8,543	14
-1303	5.46	26	0.69	34.5	0.15	54	2,458	53
-1304	5.49	25	0.94	22	0.53	43	3,413	47
-1305	6.52	15	1.6	9	0.37	48	910	64
-1306	18.82	2	1.38	12	0.72	35	2,411	54
-1307	13.63	3	0.82	27.5	0.46	44	6,338	28
-1308	5.99	20	0.42	47	0.28	51.5	2,511	51
-1402	9.44	7	2.72	3	-0.46	61	4,515	38

Table 2. SW T estimated HUC12 upland yields for sub-watersheds with at least 50% of area in rkansas, with ranking.

C12 D 11010001	Sedi ent		Total nitrogen		Total hos horus	
	land ield, ton/ha/ ear	ield ran (highest ield 1)	land ield, g/ha/ ear	ield ran (highest ield 1)	land ield, g/ha/ ear	ield ran (highest ield 1)
-0101	0.10	26	0.33	61	0.011	61
-0102	0.23	3	0.47	54	0.007	67
-0103	0.16	15	0.25	65	0.011	59
-0201	0.18	7	0.88	28	0.006	68
-0202	0.18	10	0.61	41	0.004	71
-0203	0.17	12	0.79	30	0.027	36
-0301	0.18	9	0.40	58	0.014	54
-0302	0.12	23	0.50	51	0.012	58
-0303	0.08	40	0.92	25	0.093	7
-0401	0.15	18	0.59	42	0.008	66
-0402	0.18	8	0.54	49	0.005	69
-0403	0.32	2	1.49	8	0.015	51
-0404	0.21	4	1.47	9	0.103	6
-0501	0.07	43	0.48	53	0.032	31
-0502	0.14	20	0.65	38	0.025	40
-0503	0.07	45	0.71	33	0.049	18
-0504	0.15	16	1.29	11	0.064	10
-0601	5.37	1	1.13	15	0.011	60
-0602	0.05	56	0.48	52	0.020	45
-0603	0.04	66	0.56	47	0.024	41
-0604	0.07	41	0.68	36	0.030	33
-0605	0.09	29	0.77	31	0.031	32
-0606	0.19	6	1.18	13	0.037	25
-0607	0.04	61	0.64	39	0.040	22
-0608	0.09	33	1.79	4	0.049	17

Table 2. SW T estimated HUC12 upland yields with ranking continued .

C12 D 11010001	Sedi ent		Total nitrogen		Total hos horus	
	land ield, ton/ha/ ear	ield ran (highest ield 1)	land ield, g/ha/ ear	ield ran (highest ield 1)	land ield, g/ha/ ear	ield ran (highest ield 1)
-0609	0.07	48	0.93	24	0.083	8
-0610	0.09	32	1.19	12	0.103	5
-0611	0.14	19	1.11	18	0.191	1
-0701	0.20	5	1.57	6	0.038	24
-0702	0.05	58	1.06	19	0.023	42
-0703	0.11	24	0.68	35	0.026	38
-0704	0.07	46	0.58	44	0.019	46
-0705	0.09	30	0.46	56	0.016	49
-0706	0.06	55	0.14	70	0.011	62
-0707	0.06	54	0.27	64	0.013	57
-0708	0.08	37	0.32	62	0.027	37
-0709	0.07	44	0.14	71	0.009	64
-0710	0.12	22	0.18	69	0.013	56
-0802	0.06	50	0.25	66	0.014	53
-0803	0.10	27	0.41	57	0.010	63
-0901	0.06	52	0.39	59	0.037	26
-0902	0.06	49	0.34	60	0.039	23
-0903	0.05	59	0.31	63	0.029	34
-0904	0.04	63	0.80	29	0.029	35
-0905	0.02	70	1.12	17	0.017	48
-0906	0.09	34	0.52	50	0.051	16
-0907	0.04	67	0.67	37	0.061	12
-0908	0.08	38	0.61	40	0.066	9
-1001	0.10	28	0.59	43	0.018	47
-1002	0.18	11	0.88	27	0.021	44
-1003	0.12	21	0.58	46	0.014	52
-1004	0.07	47	0.96	23	0.033	29

Table 2. SW T estimated HUC12 upland yields with ranking continued .

C12 D 11010001	Sedi ent		Total nitrogen		Total hos horus	
	land ield, ton/ha/ ear	ield ran (highest ield 1)	land ield, g/ha/ ear	ield ran (highest ield 1)	land ield, g/ha/ ear	ield ran (highest ield 1)
-1005	0.07	42	1.50	7	0.048	19
-1101	0.04	64	0.92	26	0.053	15
-1102	0.17	13	0.23	68	0.041	21
-1103	0.08	35	0.24	67	0.033	30
-1104	0.04	60	0.47	55	0.056	14
-1105	0.03	68	1.00	22	0.015	50
-1106	0.04	62	2.10	1	0.115	2
-1201	0.01	71	1.29	10	0.034	27
-1202	0.15	17	1.13	16	0.111	3
-1203	0.09	31	0.58	45	0.063	11
-1301	0.10	25	0.70	34	0.025	39
-1302	0.17	14	0.55	48	0.004	70
-1303	0.04	65	1.03	20	0.014	55
-1304	0.06	53	1.15	14	0.022	43
-1305	0.02	69	2.08	2	0.043	20
-1306	0.06	51	1.92	3	0.056	13
-1307	0.08	39	1.64	5	0.034	28
-1308	0.05	57	1.03	21	0.009	65
-1402	0.08	36	0.71	32	0.105	4

Table 3. SW T estimated upland loads by HUC12 and land use.

C12 D 11010001	Land se	Area, ha	land Loads			Percent of land Load			
			Total nitrogen, g/ ear	Total hos horus, g/ ear	Sedi ent, ton/ ear	Total nitrogen	Total hos horus	Sedi ent	Percent of area
-0101	Total	188,907	63,026	2,006	19,312				
	Forest	168,402	12,335	1,095	14,592	20%	55%	76%	89%
	Pasture	20,505	50,691	911	4,720	80%	45%	24%	11%
-0102	Total	200,092	94,519	1,468	45,371				
	Forest	190,112	47,008	920	38,554	50%	63%	85%	95%
	Pasture	9,980	47,512	548	6,817	50%	37%	15%	5%
-0103	Total	213,544	53,034	2,361	33,310				
	Forest	202,798	15,522	1,553	25,148	29%	66%	75%	95%
	Pasture	10,746	37,512	807	8,162	71%	34%	25%	5%
-0201	Total	148,120	129,610	900	26,747				
	Forest	117,580	24,874	406	11,156	19%	45%	42%	79%
	Pasture	30,540	104,736	494	15,591	81%	55%	58%	21%
-0202	Total	186,819	113,299	756	33,293				
	Forest	153,226	19,821	284	19,706	17%	38%	59%	82%
	Pasture	33,593	93,479	472	13,587	83%	62%	41%	18%
-0203	Total	170,489	134,490	4,640	29,707				
	Forest	115,538	10,210	262	12,797	8%	6%	43%	68%
	Pasture	54,950	124,279	4,378	16,910	92%	94%	57%	32%
-0301	Total	228,912	92,623	3,137	40,832				
	Developed	6,245	7,964	452	1,013	9%	14%	2%	3%
	Forest	203,234	14,872	1,279	23,548	16%	41%	58%	89%
	Pasture	19,432	69,787	1,406	16,272	75%	45%	40%	8%

Table 3. SW T estimated upland loads by HUC12 and land use continued .

C12 D 11010001	Land se	Area, ha	land Loads			Percent of land Load			
			Total nitrogen, g/ ear	Total hos horus, g/ ear	Sedi ent, ton/ ear	Total nitrogen	Total hos horus	Sedi ent	Percent of area
-0302	Total	291,025	144,082	3,448	33,615				
	Forest	240,950	12,331	1,026	10,449	9%	30%	31%	83%
	Pasture	50,075	131,750	2,422	23,166	91%	70%	69%	17%
-0303	Total	216,900	199,401	20,169	16,481				
	Developed	10,193	15,667	3,401	901	8%	17%	5%	5%
	Forest	113,616	5,893	5,342	10,812	3%	26%	66%	52%
	Pasture	93,092	177,840	11,425	4,769	89%	57%	29%	43%
-0401	Total	226,237	132,953	1,753	32,848				
	Developed	7,958	10,016	457	980	8%	26%	3%	4%
	Forest	178,077	16,646	349	17,674	13%	20%	54%	79%
	Pasture	40,201	106,291	947	14,194	80%	54%	43%	18%
-0402	Total	174,730	94,129	818	31,400				
	Forest	149,485	11,077	271	16,525	12%	33%	53%	86%
	Pasture	25,244	83,051	548	14,876	88%	67%	47%	14%
-0403	Total	216,398	322,809	3,149	69,808				
	Developed	26,760	52,018	1,444	5,060	16%	46%	7%	12%
	Forest	122,489	9,538	434	15,856	3%	14%	23%	57%
	Pasture	67,149	261,254	1,271	48,892	81%	40%	70%	31%
-0404	Total	218,646	322,385	22,441	45,683				
	Developed	67,779	127,296	7,921	15,686	39%	35%	34%	31%
	Forest	102,139	9,203	1,000	7,307	3%	4%	16%	47%
	Pasture	48,727	185,886	13,520	22,690	58%	60%	50%	22%
-0501	Total	240,527	114,583	7,581	17,299				
	Forest	196,976	21,238	1,712	8,285	19%	23%	48%	82%
	Pasture	43,551	93,344	5,869	9,013	81%	77%	52%	18%

Table 3. SW T estimated upland loads by HUC12 and land use continued .

C12 D 11010001	Land se	Area, ha	land Loads			Percent of land Load			
			Total nitrogen, g/ ear	Total hos horus, g/ ear	Sedi ent, ton/ ear	Total nitrogen	Total hos horus	Sedi ent	Percent of area
-0502	Total	253,359	164,536	6,381	35,131				
	Developed	7,559	9,768	601	865	6%	9%	2%	3%
	Forest	178,401	22,507	1,204	17,890	14%	19%	51%	70%
	Pasture	67,400	132,261	4,576	16,376	80%	72%	47%	27%
-0503	Total	258,755	183,289	12,624	17,484				
	Developed	12,216	15,888	863	1,167	9%	7%	7%	5%
	Forest	152,152	16,996	1,315	12,767	9%	10%	73%	59%
	Pasture	94,387	150,405	10,445	3,550	82%	83%	20%	36%
-0504	Total	220,959	285,363	14,194	34,159				
	Developed	9,982	15,976	792	916	6%	6%	3%	5%
	Forest	102,588	9,478	729	3,468	3%	5%	10%	46%
	Pasture	108,389	259,909	12,674	29,775	91%	89%	87%	49%
-0601	Total	204,178	231,579	2,229	1,095,532				
	Forest	172,951	142,629	594	1,078,485	62%	27%	98%	85%
	Other undeveloped	4,255	1,801	52	434	1%	2%	0%	2%
	Pasture	26,973	87,149	1,583	16,613	38%	71%	2%	13%
-0602	Total	223,250	106,662	4,485	11,957				
	Forest	180,201	29,737	1,215	5,918	28%	27%	49%	81%
	Pasture	43,049	76,925	3,269	6,039	72%	73%	51%	19%
-0603	Total	210,993	117,850	4,990	7,707				
	Forest	160,008	24,764	1,023	5,288	21%	21%	69%	76%
	Pasture	50,985	93,086	3,967	2,419	79%	79%	31%	24%
-0604	Total	169,251	114,525	5,126	12,314				
	Developed	7,605	10,127	819	717	9%	16%	6%	4%
	Forest	107,030	19,218	794	10,073	17%	15%	82%	63%
	Pasture	54,616	85,180	3,514	1,524	74%	69%	12%	32%

Table 3. SW T estimated upland loads by HUC12 and land use continued .

C12 D 11010001	Land se	Area, ha	land Loads			Percent of land Load			
			Total nitrogen, g/ ear	Total hos horus, g/ ear	Sedi ent, ton/ ear	Total nitrogen	Total hos horus	Sedi ent	Percent of area
-0605	Total	230,518	177,913	7,094	21,263				
	Developed	3,252	5,483	374	327	3%	5%	2%	1%
	Forest	132,101	20,718	883	9,477	12%	12%	45%	57%
	Pasture	95,165	151,712	5,838	11,459	85%	82%	54%	41%
-0606	Total	183,681	217,119	6,795	35,219				
	Developed	19,109	29,336	1,389	2,676	14%	20%	8%	10%
	Forest	85,937	11,171	173	6,661	5%	3%	19%	47%
	Other undeveloped	1,476	188	10	52	0%	0%	0%	1%
	Pasture	77,158	176,425	5,223	25,829	81%	77%	73%	42%
-0607	Total	226,569	145,633	9,093	9,525				
	Developed	4,767	5,708	376	342	4%	4%	4%	2%
	Forest	119,933	10,328	640	5,162	7%	7%	54%	53%
	Pasture	101,868	129,597	8,076	4,021	89%	89%	42%	45%
-0608	Total	166,968	299,555	8,259	14,990				
	Developed	999	1,726	105	97	1%	1%	1%	1%
	Forest	53,698	19,285	137	1,250	6%	2%	8%	32%
	Other undeveloped	1,536	224	12	79	0%	0%	1%	1%
	Pasture	110,735	278,319	8,006	13,564	93%	97%	90%	66%
-0609	Total	194,955	180,696	16,207	12,983				
	Developed	1,463	2,632	615	122	1%	4%	1%	1%
	Forest	83,931	7,243	762	2,766	4%	5%	21%	43%
	Other undeveloped	1,195	391	91	110	0%	1%	1%	1%
	Pasture	108,366	170,430	14,740	9,986	94%	91%	77%	56%

Table 3. SW T estimated upland loads by HUC12 and land use continued .

C12 D 11010001	Land se	Area, ha	land Loads			Percent of land Load			
			Total nitrogen, g/ ear	Total hos horus, g/ ear	Sedi ent, ton/ ear	Total nitrogen	Total hos horus	Sedi ent	Percent of area
-0610	Total	220,556	261,414	22,803	19,876				
	Developed	4,385	6,316	1,590	268	2%	7%	1%	2%
	Forest	86,134	30,393	2,110	2,693	12%	9%	14%	39%
	Pasture	130,037	224,705	19,103	16,915	86%	84%	85%	59%
-0611	Total	217,694	242,452	41,668	30,470				
	Developed	10,137	20,735	5,246	1,236	9%	13%	4%	5%
	Forest	128,704	71,731	6,587	8,169	30%	16%	27%	59%
	Pasture	62,448	149,986	29,835	21,065	62%	72%	69%	29%
	Water	16,404	-	-	-	0%	0%	0%	8%
-0701	Total	219,291	343,990	8,320	43,727				
	Developed	13,738	27,677	1,218	1,935	8%	15%	4%	6%
	Forest	94,757	13,516	485	9,363	4%	6%	21%	43%
	Pasture	101,498	302,796	6,617	32,429	88%	80%	74%	46%
	Water	9,298	-	-	-	0%	0%	0%	4%
-0702	Total	299,199	318,022	6,868	15,523				
	Developed	6,061	15,871	861	532	5%	13%	3%	2%
	Forest	121,474	38,154	860	6,404	12%	13%	41%	41%
	Pasture	171,664	263,996	5,147	8,588	83%	75%	55%	57%
-0703	Total	282,307	192,765	7,428	29,795				
	Developed	19,214	26,029	1,713	3,066	14%	23%	10%	7%
	Forest	141,929	15,621	1,001	8,630	8%	13%	29%	50%
	Pasture	84,678	151,114	4,714	18,099	78%	63%	61%	30%
	Water	36,487	-	-	-	0%	0%	0%	13%

Table 3. SW T estimated upland loads by HUC12 and land use continued .

C12 D 11010001	Land se	Area, ha	land Loads			Percent of land Load			
			Total nitrogen, g/ ear	Total hos horus, g/ ear	Sedi ent, ton/ ear	Total nitrogen	Total hos horus	Sedi ent	Percent of area
-0704	Total	218,783	126,556	4,253	14,617				
	Developed	17,125	19,271	1,404	2,335	15%	33%	16%	8%
	Forest	133,603	13,570	946	6,683	11%	22%	46%	61%
	Pasture	35,478	93,715	1,903	5,598	74%	45%	38%	16%
	Water	32,577	-	-	-	0%	0%	0%	15%
-0705	Total	230,629	106,955	3,624	20,936				
	Developed	31,060	38,048	2,090	6,336	36%	58%	30%	13%
	Forest	145,441	15,544	389	8,876	15%	11%	42%	63%
	Pasture	24,125	53,362	1,146	5,724	50%	32%	27%	10%
	Water	30,004	-	-	-	0%	0%	0%	13%
-0706	Total	138,977	19,884	1,460	7,778				
	Developed	7,158	8,433	655	1,116	42%	45%	14%	5%
	Forest	116,194	11,452	805	6,663	58%	55%	86%	84%
	Water	15,625	-	-	-	0%	0%	0%	11%
-0707	Total	156,928	43,051	1,986	9,243				
	Developed	7,722	8,698	693	1,181	20%	35%	13%	5%
	Forest	122,862	12,857	882	7,513	30%	44%	81%	78%
	Pasture	15,424	21,496	411	550	50%	21%	6%	10%
	Water	10,921	-	-	-	0%	0%	0%	7%
-0708	Total	148,020	46,865	3,978	11,844				
	Developed	10,133	11,813	988	2,186	25%	25%	18%	7%
	Forest	120,082	19,057	927	8,919	41%	23%	75%	81%
	Pasture	6,331	15,996	2,063	739	34%	52%	6%	4%
	Water	11,474	-	-	-	0%	0%	0%	8%

Table 3. SW T estimated upland loads by HUC12 and land use continued .

C12 D 11010001	Land se	Area, ha	land Loads			Percent of land Load			
			Total nitrogen, g/ ear	Total hos horus, g/ ear	Sedi ent, ton/ ear	Total nitrogen	Total hos horus	Sedi ent	Percent of area
-0709	Total	225,817	31,890	2,085	15,395				
	Developed	11,978	15,670	1,174	2,452	49%	56%	16%	5%
	Forest	120,943	16,220	911	12,943	51%	44%	84%	54%
	Water	92,896	-	-	-	0%	0%	0%	41%
-0710	Total	213,071	38,304	2,843	26,092				
	Developed	13,040	16,962	1,730	5,434	44%	61%	21%	6%
	Forest	126,452	21,342	1,113	20,658	56%	39%	79%	59%
	Water	73,579	-	-	-	0%	0%	0%	35%
-0802	Total	201,267	49,850	2,846	13,047				
	Developed	13,603	18,504	1,400	2,822	37%	49%	22%	7%
	Forest	187,664	31,347	1,446	10,225	63%	51%	78%	93%
-0803	Total	233,294	95,013	2,378	23,176				
	Forest	220,514	44,133	1,799	17,597	46%	76%	76%	95%
	Pasture	12,780	50,880	580	5,579	54%	24%	24%	5%
-0901	Total	187,514	72,556	6,934	11,758				
	Forest	151,977	21,257	4,574	8,284	29%	66%	70%	81%
	Pasture	35,537	51,299	2,360	3,475	71%	34%	30%	19%
-0902	Total	143,558	49,234	5,626	9,323				
	Forest	132,520	18,290	3,970	7,052	37%	71%	76%	92%
	Pasture	11,039	30,944	1,656	2,271	63%	29%	24%	8%
-0903	Total	258,745	79,759	7,522	12,281				
	Forest	210,212	26,464	5,880	10,835	33%	78%	88%	81%
	Pasture	48,532	53,295	1,642	1,447	67%	22%	12%	19%

Table 3. SW T estimated upland loads by HUC12 and land use continued .

C12 D 11010001	Land se	Area, ha	land Loads			Percent of land Load			
			Total nitrogen, g/ ear	Total hos horus, g/ ear	Sedi ent, ton/ ear	Total nitrogen	Total hos horus	Sedi ent	Percent of area
-0904	Total	210,340	168,765	6,112	8,322				
	Developed	4,391	6,160	1,378	498	4%	23%	6%	2%
	Forest	117,942	16,022	831	3,066	9%	14%	37%	56%
	Pasture	88,007	146,583	3,903	4,759	87%	64%	57%	42%
-0905	Total	164,711	184,290	2,740	3,557				
	Developed	7,981	12,317	479	673	7%	17%	19%	5%
	Forest	66,247	12,599	135	1,724	7%	5%	48%	40%
	Pasture	90,483	159,374	2,126	1,160	86%	78%	33%	55%
-0906	Total	197,001	102,911	10,120	16,875				
	Forest	143,829	19,128	3,755	14,088	19%	37%	83%	73%
	Pasture	53,173	83,783	6,365	2,787	81%	63%	17%	27%
-0907	Total	166,624	111,755	10,084	5,950				
	Developed	7,391	9,826	2,981	930	9%	30%	16%	4%
	Forest	107,556	9,271	1,811	3,653	8%	18%	61%	65%
	Pasture	51,678	92,658	5,292	1,367	83%	52%	23%	31%
-0908	Total	160,513	98,257	10,540	12,792				
	Developed	6,522	7,929	2,394	766	8%	23%	6%	4%
	Forest	106,874	12,002	1,720	4,213	12%	16%	33%	67%
	Pasture	47,117	78,326	6,427	7,813	80%	61%	61%	29%
-1001	Total	236,107	138,537	4,288	23,130				
	Developed	11,059	17,843	926	1,554	13%	22%	7%	5%
	Forest	190,940	42,921	1,225	16,604	31%	29%	72%	81%
	Pasture	34,108	77,773	2,137	4,972	56%	50%	21%	14%
-1002	Total	155,091	136,029	3,294	27,514				
	Forest	113,674	29,603	754	12,173	22%	23%	44%	73%
	Pasture	41,416	106,426	2,539	15,341	78%	77%	56%	27%

Table 3. SW T estimated upland loads by HUC12 and land use continued .

C12 D 11010001	Land se	Area, ha	land Loads			Percent of land Load			
			Total nitrogen, g/ ear	Total hos horus, g/ ear	Sedi ent, ton/ ear	Total nitrogen	Total hos horus	Sedi ent	Percent of area
-1003	Total	158,097	91,081	2,279	19,424				
	Forest	126,044	29,131	768	14,585	32%	34%	75%	80%
	Pasture	32,052	61,950	1,511	4,839	68%	66%	25%	20%
-1004	Total	265,756	255,382	8,866	17,718				
	Forest	168,674	39,517	989	15,771	15%	11%	89%	63%
	Pasture	97,082	215,865	7,878	1,947	85%	89%	11%	37%
-1005	Total	290,843	435,775	13,846	20,971				
	Developed	15,681	43,233	1,450	1,769	10%	10%	8%	5%
	Forest	117,823	24,572	582	4,197	6%	4%	20%	41%
	Pasture	157,339	367,971	11,813	15,005	84%	85%	72%	54%
-1101	Total	142,059	130,398	7,511	5,461				
	Forest	73,723	7,944	1,608	4,970	6%	21%	91%	52%
	Pasture	68,335	122,453	5,904	490	94%	79%	9%	48%
-1102	Total	144,242	33,066	5,858	24,774				
	Forest	110,880	19,190	4,397	23,740	58%	75%	96%	77%
	Other undeveloped	7,465	1,358	307	919	4%	5%	4%	5%
	Pasture	25,897	12,518	1,155	115	38%	20%	0%	18%
-1103	Total	225,424	55,020	7,498	18,852				
	Forest	202,155	26,800	5,440	18,645	49%	73%	99%	90%
	Pasture	23,269	28,221	2,058	207	51%	27%	1%	10%
-1104	Total	200,180	94,099	11,169	8,680				
	Developed	8,602	13,045	4,446	1,305	14%	40%	15%	4%
	Forest	157,227	20,520	3,786	6,626	22%	34%	76%	79%
	Pasture	34,351	60,534	2,938	749	64%	26%	9%	17%

Table 3. SW T estimated upland loads by HUC12 and land use continued .

C12 D 11010001	Land se	Area, ha	land Loads			Percent of land Load			
			Total nitrogen, g/ ear	Total hos horus, g/ ear	Sedi ent, ton/ ear	Total nitrogen	Total hos horus	Sedi ent	Percent of area
-1105	Total	205,697	205,270	3,039	6,263				
	Forest	142,076	20,731	1,793	4,051	10%	59%	65%	69%
	Pasture	63,621	184,539	1,246	2,213	90%	41%	35%	31%
-1106	Total	253,281	531,603	29,247	10,219				
	Developed	1,991	4,670	1,027	213	1%	4%	2%	1%
	Forest	98,660	14,421	2,067	2,545	3%	7%	25%	39%
	Pasture	152,631	512,513	26,153	7,461	96%	89%	73%	60%
-1201	Total	158,645	205,070	5,385	1,967				
	Forest	57,803	7,390	1,054	1,334	4%	20%	68%	36%
	Other undeveloped	7,595	1,891	304	518	1%	6%	26%	5%
	Pasture	93,247	195,789	4,027	115	95%	75%	6%	59%
-1301	Total	216,350	152,282	5,469	22,214				
	Forest	159,523	27,716	211	18,284	18%	4%	82%	74%
	Pasture	56,827	124,566	5,258	3,930	82%	96%	18%	26%
-1302	Total	210,643	116,425	870	34,924				
	Forest	156,034	32,485	250	29,644	28%	29%	85%	74%
	Pasture	54,609	83,941	620	5,280	72%	71%	15%	26%
-1303	Total	269,281	277,993	3,640	10,047				
	Developed	13,676	21,784	944	1,617	8%	26%	16%	5%
	Forest	87,249	12,459	317	7,262	4%	9%	72%	32%
	Pasture	168,356	243,750	2,379	1,169	88%	65%	12%	63%
-1304	Total	228,246	261,753	5,057	13,954				
	Developed	11,271	19,244	717	1,039	7%	14%	7%	5%
	Forest	100,364	13,918	355	7,503	5%	7%	54%	44%
	Pasture	116,612	228,592	3,985	5,412	87%	79%	39%	51%

Table 3. SW T estimated upland loads by HUC12 and land use continued .

C12 D 11010001	Land se	Area, ha	land Loads			Percent of land Load			
			Total nitrogen, g/ ear	Total hos horus, g/ ear	Sedi ent, ton/ ear	Total nitrogen	Total hos horus	Sedi ent	Percent of area
-1305	Total	169,807	352,855	7,348	3,721				
	Developed	7,269	13,540	574	858	4%	8%	23%	4%
	Forest	29,798	4,280	103	1,995	1%	1%	54%	18%
	Pasture	132,739	335,034	6,672	867	95%	91%	23%	78%
-1306	Total	152,239	291,631	8,588	9,858				
	Developed	7,111	20,664	359	815	7%	4%	8%	5%
	Forest	30,452	10,431	7	653	4%	0%	7%	20%
	Other undeveloped	7,033	4,612	5	511	2%	0%	5%	5%
	Pasture	107,643	255,924	8,217	7,879	88%	96%	80%	71%
-1307	Total	335,088	550,028	11,305	25,908				
	Forest	66,526	16,736	1,323	1,852	3%	12%	7%	20%
	Pasture	268,562	533,292	9,982	24,057	97%	88%	93%	80%
-1308	Total	194,530	199,584	1,757	10,265				
	Forest	81,998	18,006	377	8,884	9%	21%	87%	42%
	Pasture	112,532	181,578	1,381	1,381	91%	79%	13%	58%
-1402	Total	224,586	159,342	23,538	18,459				
	Developed	12,150	21,806	8,376	2,374	14%	36%	13%	5%
	Forest	158,140	57,609	8,074	15,124	36%	34%	82%	70%
	Pasture	49,164	79,927	7,089	961	50%	30%	5%	22%
	Water	5,131	-	-	-	0%	0%	0%	2%
rand Total		14,395,814	11,693,424	514,176	2,480,672				

APPENDIX M

Erosion risks from 2015 State Resources Assessment for Upper White River HUC12s

C12 D 11010001	C12 a e	Concentrated flo erosion		an erosion		Sheet, rill, ind erosion	
		is	an (highest 1)	is	an (highest 1)	is	an (highest 1)
-0101	East Prong White River-White River	1.259689	61	0.487258	61.00	1.44	64
-0102	Fleming Creek-White River	0.626867	69	0.236025	68.00	0.66	69
-0103	Mill Creek-Headwaters White River	0.745629	67	0.249089	67.00	0.83	67
-0201	Dry Creek-Middle Fork White River	1.372052	57	0.740089	32.00	1.76	55
-0202	reasy Creek-Middle Fork White River	1.734974	31	0.863553	12.00	2.07	43
-0203	Koger Branch-Middle Fork White River	1.506823	53	0.784655	23.00	1.97	50
-0301	Delaney Creek-White River	1.006068	66	0.320199	66.00	1.17	66
-0302	Crosses Creek-White River	1.630378	45	0.656817	46.00	1.97	51
-0303	Lake Se uoyah	1.121372	65	0.728841	34.00	1.66	57
-0401	London Creek-West Fork White River	1.712347	35	0.964258	7.00	2.10	42
-0402	Winn Creek-West Fork White River	1.796461	23	0.911362	9.00	2.11	40
-0403	Rock Creek-West Fork White River	1.29673	59	0.803585	19.00	1.65	58
-0404	Town Branch-West Fork White River	1.195806	62	0.677007	42.00	1.49	61
-0501	Lollars Creek	1.670031	42	0.691496	40.00	2.06	44
-0502	Hock Creek-Richland Creek	1.572268	51	0.845126	15.00	2.11	41
-0503	Cherry Creek-Richland Creek	1.605099	48	0.585495	55.00	2.27	30
-0504	Dry Creek-Richland Creek	1.50226	54	0.823465	17.00	2.25	32

C12 D 11010001	C12 a e	Concentrated flo erosion		an erosion		Sheet, rill, ind erosion	
		is	an (highest 1)	is	an (highest 1)	is	an (highest 1)
-0601	Dry Fork-War Eagle Creek	1.72782	33	0.616596	51.00	1.98	47
-0602	Seals Creek-War Eagle Creek	1.674461	41	0.652486	47.00	1.97	48
-0603	ackson Creek-War Eagle Creek	1.734618	32	0.748711	31.00	2.19	35
-0604	Wharton Creek	1.650796	44	0.797379	21.00	2.13	38
-0605	Reed Creek-War Eagle Creek	1.570683	52	0.597872	54.00	2.16	36
-0606	Holman Creek	1.710794	36	0.880352	11.00	2.50	19
-0607	Berry Branch-War Eagle Creek	1.692177	40	0.798036	20.00	2.45	21
-0608	lade Creek-War Eagle Creek	1.697511	39	0.849783	14.00	2.78	15
-0609	Clear Creek-War Eagle Creek	1.791352	26	0.754688	28.00	2.85	12
-0610	Clifty Creek-War Eagle Creek	1.767625	27	0.749051	30.00	2.83	14
-0611	Beaver Lake-War Eagle Creek	2.192282	4	1.577389	3.00	3.15	3
-0701	Roberts Creek-Beaver Lake	2.234235	3	1.882923	1.00	3.33	2
-0702	Brush Creek-Beaver Lake	2.646673	1	1.771885	2.00	4.20	1
-0703	Beaver Lake	2.084966	5	1.4379	5.00	2.97	8
-0704	Phillips Creek-Beaver Lake	1.923965	8	1.157865	6.00	2.41	24
-0705	Bear Creek-Beaver Lake	2.482771	2	1.500137	4.00	2.92	9
-0706	West Fork Little Clifty Creek-Beaver Lake	0.651017	68	0.211299	69.00	0.70	68
-0707	Long Hollow-Beaver Lake	1.597277	50	0.414803	63.00	1.82	54
-0708	orth Fork orth Clifty Creek-Beaver Lake	1.603613	49	0.525976	57.00	1.75	56

C12 D 11010001	C12 a e	Concentrated flo erosion		an erosion		Sheet, rill, ind erosion	
		is	an (highest 1)	is	an (highest 1)	is	an (highest 1)
-0709	Fords Creek-Beaver Lake	1.431044	55	0.611412	52.00	1.51	60
-0710	Beaver Dam-Beaver Lake	1.314382	58	0.397154	64.00	1.44	63
-0802	Leatherwood Creek	1.94826	7	0.676548	43.00	2.04	45
-0803	Cedar Creek-Table Rock Lake	1.827528	20	0.703808	37.00	1.97	49
-0901	Headwaters Kings River	1.149586	63	0.49087	59.00	1.44	62
-0902	Felkins Creek	1.398274	56	0.467177	62.00	1.53	59
-0903	Sweden Creek-Kings River	1.605147	47	0.567748	56.00	1.87	52
-0904	Spanker Branch-Kings River	1.614689	46	0.750809	29.00	2.21	34
-0905	Big Onion Creek-Kings River	1.743737	29	0.884938	10.00	2.62	18
-0906	Upper Dry Fork	1.737089	30	0.659088	45.00	2.15	37
-0907	Lower Dry Fork	1.918514	9	0.941328	8.00	2.48	20
-0908	Pine Creek-Upper Kings River	1.294819	60	0.664189	44.00	1.86	53
-1001	Kenner Creek	1.80023	22	0.619594	50.00	2.02	46
-1002	Headwaters Osage Creek	1.724247	34	0.81075	18.00	2.21	33
-1003	Dog Branch-Osage Creek	1.794012	24	0.628707	49.00	2.12	39
-1004	ackson Lake-Osage Creek	1.752558	28	0.487501	60.00	2.28	29
-1005	Warden Branch-Osage Creek	1.792459	25	0.712988	36.00	2.69	16
-1101	Upper Piney Creek-Kings River	1.862322	11	0.781928	24.00	2.66	17
-1102	Lower Piney Creek	1.950212	6	0.770023	26.00	2.31	28
-1103	Rockhouse Creek-Kings River	1.127384	64	0.368981	65.00	1.33	65
-1104	Keels Creek	1.879959	10	0.69985	39.00	2.31	26

C12 D 11010001	C12 a e	Concentrated flo erosion		an erosion		Sheet, rill, ind erosion	
		is	an (highest 1)	is	an (highest 1)	is	an (highest 1)
-1105	Pine Creek-Kings River	1.817658	21	0.509742	58.00	2.39	25
-1106	Clabber Creek-Kings River	1.857756	12	0.837532	16.00	2.87	11
-1201	Headwaters Indian Creek	1.847332	15	0.759158	27.00	2.85	13
-1301	Bobo Creek-Long Creek	1.828788	19	0.606736	53.00	2.26	31
-1302	Terrapin Creek	1.832563	17	0.722468	35.00	2.41	22
-1303	Lick Branch-Long Creek	1.8557	13	0.857432	13.00	3.01	5
-1304	South Fork Dry Creek-Dry Creek	1.661292	43	0.678487	41.00	2.41	23
-1305	Callens Branch-Dry Creek	1.702745	38	0.700706	38.00	2.98	6
-1306	Braswell Branch- ucum Creek	1.710113	37	0.794118	22.00	2.97	7
-1307	ocum Creek-Table Rock Lake	1.845497	16	0.729003	33.00	3.13	4
-1308	Long Creek-Table Rock Lake	1.8539	14	0.643242	48.00	2.87	10
-1402	Brush Creek-Table Rock Lake	0	70	0	70.00	0.00	70

APPENDIX N

Estimation of Potential Pollutant Load Reductions Through Use of BMPs

1.0 PRA TI ES AND T EIR REDU TION E I IEN IES

Information has been published on the effectiveness of many of the BMPs identified in Section 4.8 for reducing selected pollutants in surface waters, including *E. coli* sediment, and nutrients. s part of a ulf of Mexico Hypoxia Task Force pro ect, rkansas experts identified expected large-scale nutrient reduction efficiencies for selected individual and suites of agricultural BMPs often implemented in rkansas FT ssociates, Ltd. 2019 . Load reduction efficiencies for nutrients and sediment were also identified for selected BMPs in the Beaver Lake Watershed Protection Strategy RTI 2023 . Literature reduction efficiencies for selected BMPs identified in Section 4.8 are listed in tables 1 through 7 below by pollutant source Literature values . Reduction efficiencies for fecal coliforms are also listed in these tables to provide guidance for *E. coli* reduction assumptions when *E. coli* reduction efficiencies are not reported in literature. ote that BMPs must be properly installed, operated, and maintained to achieve reported pollutant reduction efficiencies.

alues used to estimate load reductions from implementation of BMPs through this plan are also shown in Tables 1-7 Calculation values . Calculation values are set only for practices that are used to estimate load reductions for Category 1 sub-watersheds. For those practices for which rkansas nutrient reduction efficiencies have been set, the nutrient reduction calculation values were set to the values reported in FT ssociates, Ltd 2019 . These values are highlighted in yellow in Tables 1 and 2. Most of the remaining calculation values are based on literature values. Exceptions are

- Sediment and nutrient calculation values for prescribed gra ing are also used for pasture/hay planting, based on the assumption that these two practices have similar impacts on pasture condition, and pasture/hay planting would not reduce loads more than prescribed gra ing.
- The *E. coli* calculation value for filter strips is also used for pasture/hay planting and riparian buffers.

We did not find information about the effectiveness of BMPs for reducing sulfate in runoff. We did find some information about the influence of urban stormwater BMPs on TDS, but the available information indicates that these practices don t reduce TDS, and sometimes

increase it Clary, ones, Leisenring, Hobson, Strecker, 2020 . Therefore, there are no calculations of the potential for reducing sulfate or TDS levels by implementing BMPs. It is expected that practices that filter runoff or reduce the amount of stormwater runoff would also reduce the sulfate loads from stormwater runoff.

Table 1. Literature pollutant reduction efficiency values reported for selected pasture management practices.

Practice	fficiencies	Sedi ent reduction	Total itrogen reduction	Total Phos horus reduction	*E. coli* reduction	ecal colifor reduction
Prescribed gra ing and gra ing management	Literature values	60%[a], 8%[b], 30%[c], 33%[d], 25%[e]	34%[b], 9%-11%[c], 40.8[d], 10%[f], 25%[e]	24%[c], 22.7[d], 15%[f], 25%[e]	66% - 72%[b]	90-96%[b]
	Calculation values	30%	10%	15%	60%	--
Heavy use area protection	Literature values	75-98%[g], 33%[d]	86%[g], 10%[f], 18.3%[d]	50%[g], 19.3%[d], 15%[f]	o information found	92-99%[g]
Pasture/hay planting	Literature values	59%[a]	66%[a], 18.1%[d]	67%[a], 15%[d]	o information found	o information found
	Calculation values	30%	10%	15%	60%	--
Critical area planting	Literature values	42%[d]	17.5%[d]	20%[d]	o information found	o information found
Pasture aeration	Literature values	o information found	49%[h], 72%-80%[l]	37%[h], 76%-85%[l]	o information found	o information found
	Calculation values	0	45%	35%	0	--
Riparian forest buffer	Literature values	55%-95%[a], 55-95%[c], 40-60%[c], 60-90%[i], 53%-57%[d], 59%[h]	47-59%[a], 19-65%[c], 68-89%[i], 45%-48%[d], 35%[f], 49%[h]	53%-56%[a], 30-45%[c], 30-80%[i], 40%-46%[d], 35%[f], 47%[h]	o information found	o information found
	Calculation values	60%	35%	35%	60%	--

Table 1. Literature pollutant reduction efficiency values reported for selected pasture management practices continued .

Practice	fficiencies	Sedi ent reduction	Total itrogen reduction	Total Phos horus reduction	*E. coli* reduction	ecal colifor reduction
Riparian herbaceous buffer	Literature values	40-60%[c], 66-84%[i], 53%-65%[d], 10%-20%[h]	13-46%[c], 50-76%[i], 34%-87%[d], 35%[f],8%-20%[h]	50-70%[c], 50-89%[i], 44%-77%[d], 35%[f], 36%[k], 36%-60%[m], 7%-15%[h]	o information found	21-100%[i], 70-95%
	Calculation values	60%	35%	35%	60%	--
Headwater ponds retention ponds	Literature values	60%[h], 76%[n], 77%[a], 80%[e]	35%[h], 26%[n], 30%-40%[o], 30%[e]	45%[h], 51%[n], 72%[a], 50%-75%[o], 50%[e]	83%[n]	60%[n]
	Calculation values	60%	35%	45%	65%	--

ote ellow-highlighted values are rkansas set nutrient reduction efficiencies see page -1 .

a Merriman, itau, Chauby, 2009
b Petersen, Redmon, McFarland, 2011a
c Chesapeake Bay Program, 2022
d TetraTech Inc., 2018
e Pennsylvania Department of Environmental Protection, 2013
f FT ssociates, Ltd., 2019
g Peterson, Redmon, McFarland, ESP-412, 2011e
h RTI, 2023
i Klapproth ohnson, 2009
Koelsch, Lorimer, Mankin, 2006
k shworth, et al., 2021
l de Koff, Moore, Formica, an Eps, DeLaune, 2011
m nderson, et al., 2020
n Clary, ones, Leisenring, Hobson, Strecker, 2020 , calculated from reported median inflow and outflow values for urban retention ponds inflow-outflow /inflow
o irginia Department of Environmental uality, 2013

Table 2. Literature pollutant reduction efficiency values reported for selected management practices used to control livestock access to streams and/or riparian areas.

Practice	fficiencies	Sedi ent reduction	Total itrogen reduction	Total Phos horus reduction	*E. coli* reduction	ecal colifor reduction
Controlled stream access	Literature values	82%-84%[a], 8%-82%[b], 60%[c], 40%[d]	34%[b], 10%[e]	75%[a], 76%[b], 15%[e], 60%[f]	37%-46%, 46%[h]	30%-94%, 44-52%[h]
	Calculation values	50%	10%	15%	40%	--
Watering facility	Literature values	38%-96%[a], 10%[g], 19%[c]	-27%-56%[a], 5%[g], 10%[e]	-10%-97%[a], 8%[g], 15%[e]	85%[i]	51-94%[i]
	Calculation values	30%	10%	15%	70%	

ote ellow-highlighted values are rkansas set nutrient reduction efficiencies see page -1

Controlled stream access may be complete exclusion, or development of a stream crossing.

a Merriman, itau, Chauby, 2009
b Peterson, Redmon, McFarland, 2011b
c TetraTech Inc., 2018
d Owens, Edwards, Keuren, 1996
e FT ssociates, Ltd., 2019
f nderson, et al., 2020
g Chesapeake Bay Program, 2022
h Peterson, Redmon, McFarland, ESP-416, 2011d
i Peterson, Redmon, McFarland, ESP-412, 2011e
Peterson, Redmon, McFarland, ESP-411, 2011c

Table 3. Literature pollutant reduction efficiency values reported for selected practices applicable to poultry operations.

Practice	fficiencies	Sedi ent reduction	Total itrogen reduction	Total Phos horus reduction	*E. coli* reduction	ecal colifor reduction
Filter strip	Literature values	0-99%[a], 56%[b], 41-100%[c], 52%[d]	1-93%[a], 20%[b], 14%[d]	2-93%[a], 54%[b], 27-96%[c], increase[d]	58-99%[c]	30-100%[c]
	Calculation values	50%	15%	50%	60%	--
rassed waterway	Literature values	17%[a], 52%[d]	28%-36%[e], 11%[d]	24%-32%[e], increase[d]	0[d]	
	Calculation values	30%	25%	25%	0	--
egetated treatment area	Literature values	70-90% of solids[f]	85%, average 70%[f]	12-97%, average 70%[f]	o information found	64%-87%[f]
	Calculation values	80%	70%	70%	50%	
Manure stacking shed poultry	Literature values	one expected	52%[a], 14%[g], 35%[h]	58%[a], 14%[g], 54%[h]	97%-99%[h]	44%-99%[h]
	Calculation values	0	15%	15%	90%	--

Table 3. Literature pollutant reduction efficiency values reported for selected practices applicable to poultry operations continued .

Practice	fficiencies	Sedi ent reduction	Total itrogen reduction	Total Phos horus reduction	*E. coli* reduction	ecal colifor reduction
Roof runoff structure	Literature values	40%[b], 40%[g]	20%[b], 10%-20%[g]	20%[b], 10%-20%[g]	o information found	o information found
	Calculation values	40%	15%	15%	0	--
nimal mortality facility	Literature values	one expected	14%[g]	14%[g]	o information found	o information found
Composting facility	Literature values	one expected	10%-33%[b]	o information found	o information found	o information found

a Merriman, itau, Chauby, 2009
b Chesapeake Bay Program, 2022
c Peterson, Redmon, McFarland, ESP-405, 2011f
d Clary, ones, Leisenring, Hobson, Strecker, 2020 , calculated from reported median inflow and outflow concentrations
e irginia Department of Environmental uality, 2013
f Koelsch, Lorimer, Mankin, 2006
g Pennsylvania Department of Environmental Protection, 2013
h Peterson, Redmon, McFarland, ESP-404, 2011g

Table 4. Literature pollutant reduction efficiency values reported for Environmentally Sensitive Road Maintenance practices.

Practice		Sedi ent reduction	itrogen reduction	Phos horus reduction	*E. coli* reduction	ecal colifor reduction
Environmentally sensitive road maintenance ESRM	Literature values	80-94%[a], 31-94%[a]	one expected	one expected	one expected	one expected
	Calculation value	80%	0	0	0	--

a The ature Concservancy, 2017
b Sheet Bloser, 2008

Table 5. Literature pollutant reduction efficiency values reported for properly functioning septic systems.

Practice		Sedi ent reduction	itrogen reduction	Phos horus reduction	*E. coli* reduction	ecal colifor reduction
Fix failing septic systems	Literature values	one expected	10%-40%[a]	85%-95%[a]	73.915% 99.99%[b]	99%-99.9%[a]
	Calculation values	0	25%	90%	90%	--

a Otis, et al., 2002

b Wang, hu, Mao, 2021

Table 6. Literature pollutant reduction efficiency values reported for selected low impact development and urban stormwater treatment practices.

Practice		Sedi ent reduction	itrogen reduction	Phos horus reduction	*E. coli* reduction	ecal colifor reduction
Bioretention basin/rain garden	Literature values	55-90%[a], 90%[c], 77%[d], 87%[e]	64-90%[b], 25-80%[a], 75%[c], 24%[d], 96%[e]	55-90%[b], 45-85%[a], 75%[c], increase[d], 95%[e]	43%[d]	90%[c]
	Calculation values	75%	25%	0	40%	--
Constructed wetland	Literature values	60%[a], 7%-60%[d], 80%	20%[a], 25%-55%[b], 4%-18%[d], 30%	45%[a], 50%-75%[b], 8%-28%[d], 71%[i], 50%	86%[d]	7%-95%[d]
	Calculation values	60%	20%	40%	85%	--
Permeable pavement	Literature values	55%-85%[a], 71%[d]	59%-81%[b], 10%-80%[a], increase[f]	59%-81%[b], 20%-80%[a], 41%[d]	o information found	o information found
	Calculation values	60%	60%	60%	0	--
reen streets	Literature values	o information found	o information found	53%-90%[g]	o information found	o information found
Stormwater detention basin	Literature values	10%-60%[a], 66%[d]	5%-20%[a], 10%-24%[b], 2%[d],	10%-20%[a], 15%-31%[b], 26%[d],	44%[d]	71%[d]
	Calculation values	60%	15%	25%	40%	--
Stormwater retention basin	Literature values	60%[a], 76%[d], 77%[i], 80%	20%[a], 30%-40%[b], 26%[d], 30%	45%[a], 50%-75%[b], 51%[d], 72%[i], 50%	83%[d]	60%[d]

Table 6. Literature pollutant reduction efficiency values reported for selected low impact development and urban stormwater treatment practices continued .

Practice		Sedi ent reduction	itrogen reduction	Phos horus reduction	*E. coli* reduction	ecal colifor reduction
	Calculation values	60%	35%	45%	65%	--
Hydrodynamic separation devices	Literature values	10%[a], 40%[d]	5%[a], 2%[d]	10%[a], 23%[d], 20%[b]	29%[d]	increase[d]
Media filters	Literature values	84%[d]	16%[d]	45%[d]	62%[d]	50%[d]

a Simpson Weammert, 2009
b irginia Department of Environmental uality, 2013
c Un, 2016
d Clary, ones, Leisenring, Hobson, Strecker, 2020
e Roark, 2014
f The Water Research Foundation, merican Society of Civil Engineers, US Environmental Protection gency, US Department of Transportation, eosyntec, Wright Water Engineers, Inc., 2024
g Wood, 2018
i Merriman, itau, Chauby, 2009
Pennsylvania Department of Environmental Protection, 2013

Table 7. Literature pollutant reduction efficiency values reported for practices to address streambank erosion.

Practice	fficiencies	Sedi ent reduction	itrogen reduction	Phos horus reduction	*E. coli* reduction	ecal colifor reduction
Streambank stabili ation	Literature values	58%-75%[a]	15%-75%[a]	22%-75%[a]	ot expected	ot expected
	Calculation values	60%	15%	20%	0	--
Stream restoration	Literature values	ear 100%[b], 58%-95%[c]	ear 100%[b], 15%-95%[c]	ear 100%[b], 22%-95%[c]	ot expected	ot expected
	Calculation values	75%	55%	60%	0	--

a TetraTech Inc., 2018
b an Eps, 2014
c RTI, 2023

2.0 LOAD REDU TION ESTIMATES

In the following subsections potential pollutant reductions from implementation of selected practices are estimated for Category 1 sub-watersheds. These estimates use the calculation reduction efficiency values from Tables 1-7. Percent load reductions are calculated by multiplying the calculation reduction efficiency by the assumed portion of the pollutant load from the treated source, and the portion of the source being treated. Table 8 lists the portion of upland loads from the Category 1 sub-watersheds modeled as coming from pastures. Table 9 lists the portion of upland loads from the Category 1 sub-watersheds modeled as coming from developed land.

Table 8. Percentages of modeled upland load from pasture see ppendix K .

C12 D nu ber	C12 na e	Total nitrogen	Total hos horus	Sedi ent
110100010303	Lake Se uoyah	50%	43%	60%
110100010404	Town Branch-West Fork White River	17%	15%	22%
110100010606	Holman Creek	38%	35%	48%
110100010608	lade Creek	66%	67%	69%
110100010610	Clifty Creek-War Eagle Creek	66%	66%	75%
110100010611	Beaver Lake-War Eagle Creek	29%	35%	60%
110100010701	Roberts Creek-Beaver Lake	18%	12%	22%
110100010702	Brush Creek-Beaver Lake	48%	47%	37%
110100010904	Spanker Branch-Kings River	40%	39%	43%
110100011106	Clabber Creek-Kings River	63%	64%	66%
110100011306	Braswell Branch-ocum Creek	44%	28%	60%

Table 9. Percentages of modeled upland load from developed land see ppendix K .

C12 D nu ber	C12 na e	Total nitrogen	Total hos horus	Sedi ent
110100010303	Lake Se uoyah	6%	5%	3%
110100010404	Town Branch-West Fork White River	57%	69%	60%
110100010606	Holman Creek	11%	9%	7%
110100010608	lade Creek	1%	1%	1%
110100010610	Clifty Creek-War Eagle Creek	2%	2%	1%
110100010611	Beaver Lake-War Eagle Creek	5%	6%	4%
110100010701	Roberts Creek-Beaver Lake	8%	12%	6%
110100010702	Brush Creek-Beaver Lake	3%	3%	2%
110100010904	Spanker Branch-Kings River	2%	2%	2%
110100011106	Clabber Creek-Kings River	1%	1%	1%
110100011306	Braswell Branch-ocum Creek	10%	14%	6%

When a practice reduction efficiency is higher than the target load reduction, the portion of the source that needs to be treated to achieve the target load reduction is calculated by dividing the load reduction target value by the product of the portion of the pollutant load from the source and the practice reduction efficiency. When a practice reduction efficiency is lower than the target load reduction, the estimate of the load reduction from implementing the practice is calculated assuming 100% of the source is treated. The results of the analysis of potential pollutant load reductions from implementation of selected practices indicate that it will not be possible to achieve the target load reductions using a single practice or approach.

2.1 La e Se uoyah

iven the nonpoint sources present in Lake Se uoyah sub-watershed, the potential for meeting the proposed load reduction targets was evaluated using agricultural practices and streambank erosion practices. Because turbidity and sediment are the primary concerns in this sub-watershed, the potential for meeting this target was evaluated first. Load reduction calculations are shown in Table 10. Table 10 also shows potential reductions in nitrogen,

phosphorus, and *E. coli* loads associated with practices that could be implemented to reach the sediment load reduction target. Table 11 shows nutrient and *E. coli* load reduction potential when practices are applied to meet the phosphorus load reduction target for this sub-watershed.

ssumptions used in these calculations are

- Pasture, livestock, and poultry operation sources treated using conservation practices, and streambank erosion, contribute 60% of sediment, 43% of phosphorus, and 50% of nitrogen loads Table 8 .
- Failing septic systems remediated contribute 5% of phosphorus and 6% of nitrogen loads developed area contribution from Table 9 .
- Reduction efficiencies of practices are the calculation values from Tables 1-7.

2.2 Town ranch West or White Ri er

iven the nonpoint sources present in Town Branch-West Fork White River sub-watershed, the potential for meeting the proposed load reduction targets was evaluated using streambank and riparian restoration practices, low impact development practices, and pasture management practices. Because the largest load reduction target is for nitrogen, the potential for meeting this target was evaluated first. Load reduction calculations are shown in Table 12. Table 12 also shows potential reductions in phosphorus, sediment, and *E. coli* loads associated with practices that could be implemented to reduce nitrogen load. ssumptions used in these calculations are

- Pasture and livestock sources treated using conservation practices contribute 17% of nitrogen, 15% of phosphorus, and 22% of sediment loads Table 8 .
- Development sources, including failing septic systems, treated using conservation practices contribute 57% of nitrogen, 69% of phosphorus, and 66% of sediment loads Table 9 .
- Streambank erosion contributes 14% of nitrogen load, 22% of phosphorus load, and 66% of sediment load ttachment .
- Reduction efficiencies of practices are the calculation values from Tables 1-7.

Table 10. Lake Se uoyah sub-watershed potential load reductions from implementation of management practices to achieve sediment load reduction target.

	Sedi ent eduction (Target 25%)				Associated eductions								
					Phos horus (Target 50%)			itrogen			*E. coli*		
Practices	Assu ed ortion of sedi ent load fro treated source	Assu ed sedi ent reduction efficienc	Portion of source to treat to eet target sedi ent reduction	Potential sedi ent load reduction	Assu ed ortion hos horus load	Assu ed hos horus reduction efficienc	Potential hos horus load reduction	Assu ed ortion nitrogen load	Assu ed nitrogen reduction efficienc	Potential nitrogen load reduction	Assu ed ortion .coli load	Assu ed .coli reduction	Potential .coli reduction
Prescribed gra ing	0.60	0.30	1.00	18%	0.43	0.15	6%	0.5	0.10	5%	1	0.60	60%
Watering facility	0.60	0.30	1.00	18%	0.43	0.15	6%	0.5	0.10	5%	1	0.70	70%
ccess control	0.60	0.50	0.83	25%	0.43	0.15	5%	0.5	0.10	4%	1	0.40	33%
Restore riparian buffer	0.60	0.60	0.69	25%	0.43	0.35	10%	0.5	0.35	12%	1	0.55	38%
Pasture/hay planting	0.60	0.60	0.69	25%	0.43	0.15	4%	0.5	0.10	3%	1	0.30	21%
Roof runoff structure	0.60	0.40	1.00	24%	0.43	0.15	6%	0.5	0.15	8%	1	0.00	0%
rassed waterway	0.60	0.30	1.00	18%	0.43	0.25	11%	0.5	0.25	13%	1	0.00	0%
Filter strip	0.60	0.50	0.83	25%	0.43	0.50	18%	0.5	0.15	6%	1	0.60	50%
Bank stabili ation	0.60	0.60	0.69	25%	0.43	0.15	4%	0.5	0.15	5%	1	0.00	0%
Stream restoration	0.60	0.75	0.56	25%	0.43	0.60	14%	0.5	0.55	15%	1	0.00	0%

Table 11. Lake Se uoyah sub-watershed potential load reductions from implementation of management practices to achieve phosphorus load reduction target.

	Phos horus eduction (Target 50%)				Associated eductions								
					itrogen			Sedi ent (Target 25%)			*E. coli*		
Practices	Assu ed ortion hos horus load fro treated source	Assu ed hos horus reduction efficienc	Portion of source to treat to eet target hos horus reduction	Potential hos horus load reduction	Assu ed ortion nitrogen load	Assu ed nitrogen reduction efficienc	Potential nitrogen load reduction	Assu ed ortion sedi ent load	Assu ed sedi ent reduction efficienc	Potential sedi ent load reduction	Assu ed ortion .coli load	Assu ed .coli reduction	Potential .coli reduction
Prescribed gra ing	0.43	0.15	1.00	6%	0.86	0.10	9%	0.88	0.30	26%	1	0.60	60%
Watering facility	0.43	0.15	1.00	6%	0.86	0.10	9%	0.88	0.30	26%	1	0.70	70%
ccess control	0.43	0.15	1.00	6%	0.86	0.10	9%	0.88	0.50	44%	1	0.40	40%
Pasture aeration	0.43	0.35	1.00	15%	0.86	0.45	39%	0.88	0.00	0%	1	0.00	0%
Restore riparian buffer	0.43	0.35	1.00	15%	0.86	0.35	30%	0.88	0.60	53%	1	0.55	55%
Pasture/hay planting	0.43	0.15	1.00	6%	0.86	0.10	9%	0.88	0.60	53%	1	0.30	30%
Headwater ponds	0.43	0.45	1.00	19%	0.86	0.35	30%	0.88	0.60	53%	1	0.75	75%
Waste storage	0.43	0.15	1.00	6%	0.86	0.15	13%	0.00	0.00	0%	1	0.90	90%
Roof runoff structure	0.43	0.15	1.00	6%	0.86	0.15	13%	0.88	0.40	35%	1	0.00	0%
rassed waterway	0.43	0.25	1.00	11%	0.86	0.25	22%	0.88	0.30	26%	1	0.00	0%
Filter strip	0.43	0.50	1.00	22%	0.86	0.15	13%	0.88	0.50	44%	1	0.60	60%
Remediate failing septic systems	0.05	0.90	1.00	5%	0.02	0.25	1%	0.01	0.00	0%	1	0.90	90%
Bank stabili ation	0.43	0.15	1.00	6%	0.05	0.15	1%	0.40	0.60	24%	0	0.00	--
Stream restoration	0.43	0.60	1.00	26%	0.05	0.55	3%	0.40	0.75	30%	0	0.00	--

Table 12. Town Branch-West Fork White River sub-watershed potential load reductions from implementation of management practices.

	itrogen eduction (Target 60%)				Associated eductions								
					Phos horus (Target 60%)			Sedi ent (Target 55%)			*E. coli*		
Practices	Assu ed ortion nitrogen load	Assu ed nitrogen reduction efficienc	Portion of source to treat to eet target nitrogen reduction	Potential nitrogen load reduction	Assu ed ortion hos horus load fro treated source	Assu ed hos horus reduction efficienc	Potential hos horus load reduction	Assu ed ortion sedi ent load	Assu ed sedi ent reduction efficienc	Potential sedi ent load reduction	Assu ed ortion .coli load	Assu ed .coli reduction	Potential .coli reduction
Restore riparian buffer	0.14	0.35	1.00	5%	0.22	0.35	8%	0.66	0.60	40%	1	0.55	55%
Bank stabili ation	0.14	0.15	1.00	2%	0.22	0.15	3%	0.66	0.60	40%	1	0.00	0%
Stream restoration	0.14	0.55	1.00	8%	0.22	0.60	13%	0.66	0.75	50%	1	0.00	0%
Remediate failing septic systems	0.57	0.25	1.00	14%	0.69	0.90	62%	0.60	0.00	0%	1	0.90	90%
Rain garden	0.57	0.25	1.00	14%	0.69	0.00	0%	0.60	0.75	45%	1	0.40	40%
Permeable pavement	0.57	0.60	1.00	34%	0.69	0.60	41%	0.60	0.60	36%	1	0.00	0%
Media filters	0.57	0.15	1.00	9%	0.69	0.45	31%	0.60	0.80	48%	1	0.60	60%
Hydrodynamic separation devices	0.57	0.02	1.00	1%	0.69	0.20	14%	0.60	0.40	24%	1	0.25	25%
Constructed wetland	0.57	0.20	1.00	11%	0.69	0.40	28%	0.60	0.60	36%	1	0.85	85%
Retention basin	0.57	0.35	1.00	20%	0.69	0.45	31%	0.60	0.60	36%	1	0.75	75%
Detention basin	0.57	0.15	1.00	9%	0.69	0.25	17%	0.60	0.60	36%	1	0.40	40%
Prescribed gra ing	0.17	0.10	1.00	2%	0.15	0.15	2%	0.22	0.30	7%	1	0.60	60%
Watering facility	0.17	0.10	1.00	2%	0.15	0.15	2%	0.22	0.30	7%	1	0.70	70%
ccess control	0.17	0.10	1.00	2%	0.15	0.15	2%	0.22	0.50	11%	1	0.40	40%
Pasture aeration	0.17	0.45	1.00	8%	0.15	0.35	5%	0.22	0.00	0%	1	0.00	0%
Headwater ponds	0.17	0.35	1.00	6%	0.15	0.45	7%	0.22	0.60	13%	1	0.75	75%

2.3 olman ree

iven the nonpoint sources present in Holman Creek sub-watershed, the potential for meeting the proposed load reduction targets was evaluated using agricultural practices, streambank erosion practices, environmentally sensitive road maintenance, and low impact development practices. Because the largest load reduction target is for nitrogen, the potential for meeting this target was evaluated first. Load reduction calculations are shown in Table 13. Table 13 also shows potential reductions in phosphorus, sediment, and *E. coli* loads associated with practices that could be implemented to reduce nitrogen load. ssumptions used in these calculations are

- Pasture, livestock, and poultry operation sources treated using conservation practices contribute 38% of nitrogen, 35% of phosphorus, and 48% of sediment loads Table 8 .
- Development sources, including failing septic systems and unpaved roads, to be treated using conservation practices contribute 11% of nitrogen, 9% of phosphorus, and 7% of sediment loads Table 9 .
- Streambank erosion contributes 38% of nitrogen load, 35% of phosphorus load, and 48% of sediment load pasture area contribution from Table 8 .
- Reduction efficiencies of practices are the calculation values from Tables 1-7.

2.4 Glade ree

iven the nonpoint sources present in the lade Creek sub-watershed, the potential for meeting the proposed load reduction targets was evaluated using agricultural practices, streambank erosion practices, and environmentally sensitive road maintenance. Because the largest load reduction target is for nitrogen, the potential for meeting this target was evaluated first. Load reduction calculations are shown in Table 14. Table 14 also shows potential reductions in phosphorus, sediment, and *E. coli* loads associated with practices that could be implemented to reduce sediment load. ssumptions used in these calculations are

- Pasture, livestock, and poultry operation sources treated using conservation practices contribute 66% of nitrogen, 67% of phosphorus, and 69% of sediment loads Table 8 .

- Streambank erosion contributes 66% of sediment load, 67% of nitrogen load, and 69% of phosphorus load pasture area contribution from Table 8．
- Failing septic systems remediated contribute 1% of phosphorus and nitrogen loads developed area contribution from Table 9．
- Reduction efficiencies of practices are the calculation values from Tables 1-7.

Table 13. Holman Creek sub-watershed potential load reductions from implementation of management practices.

Practices	itrogen eduction (Target 60%)				Associated eductions								
					Phos horus (Target 50%)			Sedi ent (Target 60%)			*E. coli*		
	Assu ed ortion nitrogen load	Assu ed nitrogen reduction efficienc	Portion of source to treat to eet target nitrogen reduction	Potential nitrogen load reduction	Assu ed ortion hos horus load	Assu ed hos horus reduction efficienc	Potential hos horus load reduction	Assu ed ortion of sedi ent load fro treated source	Assu ed sedi ent reduction efficienc	Potential sedi ent load reduction	Assu ed ortion .coli load	Assu ed .coli reduction	Potential .coli reduction
Prescribed gra ing	0.38	0.10	1.00	4%	0.35	0.15	5%	0.48	0.30	14%	1	0.60	60%
Watering facility	0.38	0.10	1.00	4%	0.35	0.15	5%	0.48	0.30	14%	1	0.70	70%
ccess control	0.38	0.10	1.00	4%	0.35	0.15	5%	0.48	0.50	24%	1	0.40	40%
Restore riparian buffer	0.38	0.35	1.00	13%	0.35	0.35	12%	0.48	0.60	29%	1	0.55	55%
Pasture/hay planting	0.38	0.10	1.00	4%	0.35	0.15	5%	0.48	0.60	29%	1	0.30	30%
Pasture aeration	0.38	0.45	1.00	17%	0.35	0.35	12%	0.48	0.00	0%	1	0.00	0%
Headwater ponds	0.38	0.35	1.00	13%	0.35	0.45	16%	0.48	0.60	29%	1	0.75	75%
Roof runoff structure	0.38	0.15	1.00	6%	0.35	0.15	5%	0.48	0.40	19%	1	0.00	0%
rassed waterway	0.38	0.25	1.00	10%	0.35	0.25	9%	0.48	0.30	14%	1	0.00	0%
Filter strip	0.38	0.15	1.00	6%	0.35	0.50	18%	0.48	0.50	24%	1	0.60	60%
Waste storage	0.38	0.15	1.00	6%	0.35	0.15	5%	0.00	0.00	0%	1	0.90	90%
Bank stabili ation	0.38	0.15	1.00	6%	0.35	0.15	5%	0.48	0.60	29%	1	0.00	0%
Stream restoration	0.38	0.55	1.00	21%	0.35	0.60	21%	0.48	0.75	36%	1	0.00	0%
Remediate failing septic systems	0.11	0.25	1.00	3%	0.09	0.90	8%	0.07	0.00	0%	1	0.90	90%
ESM	0.11	0.00	1.00	0%	0.09	0.00	0%	0.07	0.80	6%	1	0.00	0%
Restore riparian buffer	0.11	0.35	1.00	4%	0.09	0.35	3%	0.07	0.60	4%	1	0.55	55%
Bank stabili ation	0.11	0.15	1.00	2%	0.09	0.15	1%	0.07	0.60	4%	1	0.00	0%
Stream restoration	0.11	0.55	1.00	6%	0.09	0.60	5%	0.07	0.75	5%	1	0.00	0%
Remediate failing septic systems	0.11	0.25	1.00	3%	0.09	0.90	8%	0.00	0.00	0%	1	0.90	90%
Rain garden	0.11	0.25	1.00	3%	0.09	0.00	0%	0.07	0.75	5%	1	0.40	40%
Permeable pavement	0.11	0.60	1.00	7%	0.09	0.60	5%	0.07	0.60	4%	1	0.00	0%
Media filters	0.11	0.15	1.00	2%	0.09	0.45	4%	0.07	0.80	6%	1	0.60	60%
Hydrodynamic separation devices	0.11	0.02	1.00	0%	0.09	0.20	2%	0.07	0.40	3%	1	0.25	25%
Constructed wetland	0.11	0.20	1.00	2%	0.09	0.40	4%	0.07	0.60	4%	1	0.85	85%
Retention basin	0.11	0.35	1.00	4%	0.09	0.45	4%	0.07	0.60	4%	1	0.75	75%
Detention basin	0.11	0.15	1.00	2%	0.09	0.25	2%	0.07	0.60	4%	1	0.40	40%

Table 14. lade Creek sub-watershed potential load reductions from implementation of management practices to reduce nitrogen load.

	itrogen eduction (Target 40%)				Associated eductions								
					Phos horus (Target 5%)			Sedi ent (Target 5%)			*E. coli*		
Practices	Assu ed ortion nitrogen load	Assu ed nitrogen reduction efficienc	Portion of source to treat to eet target nitrogen reduction	Potential nitrogen load reduction	Assu ed ortion hos horus load	Assu ed hos horus reduction efficienc	Potential hos horus load reduction	Assu ed ortion of sedi ent load fro treated source	Assu ed sedi ent reduction efficienc	Potential sedi ent load reduction	Assu ed ortion .coli load	Assu ed .coli reduction	Potential .coli reduction
Prescribed gra ing	0.66	0.10	1.00	7%	0.67	0.15	10%	0.69	0.30	21%	1	0.60	60%
Watering facility	0.66	0.10	1.00	7%	0.67	0.15	10%	0.69	0.30	21%	1	0.70	70%
ccess control	0.66	0.10	1.00	7%	0.67	0.15	10%	0.69	0.50	35%	1	0.40	40%
Pasture/hay planting	0.66	0.10	1.00	7%	0.67	0.15	10%	0.69	0.60	41%	1	0.30	30%
Waste storage	0.66	0.15	1.00	10%	0.67	0.15	10%	0.69	0.00	0%	1	0.90	90%
Pasture aeration	0.66	0.45	1.00	30%	0.67	0.35	23%	0.69	0.00	0%	1	0.00	0%
Headwater ponds	0.66	0.35	1.00	23%	0.67	0.45	30%	0.69	0.60	41%	1	0.75	75%
Roof runoff structure	0.66	0.15	1.00	10%	0.67	0.15	10%	0.69	0.40	28%	1	0.00	0%
rassed waterway	0.66	0.25	1.00	17%	0.67	0.25	17%	0.69	0.30	21%	1	0.00	0%
Filter strip	0.66	0.15	1.00	10%	0.67	0.50	34%	0.69	0.50	35%	1	0.60	60%
Restore riparian buffer	0.66	0.35	1.00	23%	0.67	0.35	23%	0.69	0.60	41%	1	0.55	55%
Bank stabili ation	0.66	0.15	1.00	10%	0.67	0.15	10%	0.69	0.60	41%	1	0.00	0%
Stream restoration	0.66	0.55	1.00	36%	0.67	0.60	40%	0.69	0.75	52%	1	0.00	0%
Remediate failing septic systems	0.01	0.25	1.00	0%	0.01	0.90	1%	0.01	0.00	0%	1	0.90	90%
ESM	0.01	0.00	1.00	0%	0.01	0.00	0%	0.01	0.80	1%	1	0.00	0%

2.5 lifty ree War Eagle ree

iven the nonpoint sources present in Clifty Creek-War Eagle Creek sub-watershed, the potential for meeting the proposed load reduction targets was evaluated using agricultural practices and streambank erosion practices. The only plan load reduction target for this sub-watershed is for nitrogen. Load reduction calculations are shown in Table 15. Table 15 also shows potential reductions in phosphorus, sediment, and *E. coli* loads associated with practices that could be implemented to reduce nitrogen load. ssumptions used in these calculations are

- Pasture, livestock, and poultry operation sources treated using conservation practices, and streambank erosion, contribute 66% of nitrogen and phosphorus, and 75% of sediment loads Table 8 .
- Failing septic systems remediated contribute 2% of nitrogen and phosphorus loads developed area contribution from Table 9 .
- Reduction efficiencies of practices are the calculation values from Tables 1-7.

2.6 ea er La e War Eagle ree

iven the nonpoint sources present in the Beaver Lake-War Eagle Creek sub-watershed, the potential for meeting the proposed load reduction targets was evaluated using agricultural practices and streambank erosion practices. Because the largest load reduction target is for sediment, the potential for meeting this target was evaluated first. These load reduction calculations are shown in Table 16. Table 16 also shows potential reductions in nitrogen, phosphorus, and *E. coli* loads associated with practices that could be implemented to reduce sediment load. ssumptions used in these calculations are

- Pasture, livestock, and poultry operation sources treated using conservation practices, and streambank erosion, contribute 60% of sediment, 29% of nitrogen, and 35% of phosphorus loads Table 8 .
- Failing septic systems remediated contribute 6% of phosphorus and 5% of nitrogen loads developed area contribution from Table 9 .
- Reduction efficiencies of practices are the calculation values from Tables 1-7.

Table 15. Clifty Creek-War Eagle Creek sub-watershed potential load reductions from implementation of management practices to reduce nitrogen load.

Practices	itrogen eduction (Target 40%)				Associated eductions								
					Phos horus			Sedi ent			*E. coli*		
	Assu ed ortion nitrogen load	Assu ed nitrogen reduction efficienc	Portion of source to treat to eet target nitrogen reduction	Potential nitrogen load reduction	Assu ed ortion hos horus load	Assu ed hos horus reduction efficienc	Potential hos horus load reduction	Assu ed ortion of sedi ent load fro treated source	Assu ed sedi ent reduction efficienc	Potential sedi ent load reduction	Assu ed ortion .coli load	Assu ed .coli reduction	Potential .coli reduction
Prescribed gra ing	0.66	0.10	1.00	7%	0.66	0.15	10%	0.75	0.30	23%	1	0.60	60%
Watering facility	0.66	0.10	1.00	7%	0.66	0.15	10%	0.75	0.30	23%	1	0.70	70%
ccess control	0.66	0.10	1.00	7%	0.66	0.15	10%	0.75	0.50	38%	1	0.40	40%
Restore riparian buffer	0.66	0.35	1.00	23%	0.66	0.35	23%	0.75	0.60	45%	1	0.55	55%
Pasture/hay planting	0.66	0.10	1.00	7%	0.66	0.15	10%	0.75	0.60	45%	1	0.30	30%
Pasture aeration	0.66	0.45	1.00	30%	0.66	0.35	23%	0.75	0.00	0%	1	0.00	0%
Headwater ponds	0.66	0.35	1.00	23%	0.66	0.45	30%	0.75	0.60	45%	1	0.75	75%
Roof runoff structure	0.66	0.15	1.00	10%	0.66	0.15	10%	0.75	0.40	30%	1	0.00	0%
rassed waterway	0.66	0.25	1.00	17%	0.66	0.25	17%	0.75	0.30	23%	1	0.00	0%
Filter strip	0.66	0.15	1.00	10%	0.66	0.50	33%	0.75	0.50	38%	1	0.60	60%
Waste storage	0.66	0.15	1.00	10%	0.66	0.15	10%	0.75	0.00	0%	1	0.90	90%
Bank stabili ation	0.66	0.15	1.00	10%	0.66	0.15	10%	0.75	0.60	45%	1	0.00	0%
Stream restoration	0.66	0.55	1.00	36%	0.66	0.60	40%	0.75	0.75	56%	1	0.00	0%
Remediate failing septic systems	0.02	0.25	1.00	1%	0.02	0.90	2%	0.01	0.00	0%	1	0.90	90%

Table 16. Beaver Lake-War Eagle Creek sub-watershed potential load reductions from implementation of management practices to reduce sediment load.

Practices	Sedi ent eduction (Target 50%)				Associated eductions								
					Phos horus (Target 25%)			itrogen (Target 25%)			*E. coli*		
	Assu ed ortion of sedi ent load fro treated source	Assu ed sedi ent reduction efficienc	Portion of source to treat to eet target sedi ent reduction	Potential sedi ent load reduction	Assu ed ortion hos horus load	Assu ed hos horus reduction efficienc	Potential hos horus load reduction	Assu ed ortion nitrogen load	Assu ed nitrogen reduction efficienc	Potential nitrogen load reduction	Assu ed ortion .coli load	Assu ed .coli reduction	Potential .coli reduction
Prescribed gra ing	0.60	0.30	1.00	18%	0.35	0.15	5%	0.29	0.10	3%	1	0.60	60%
Watering facility	0.60	0.30	1.00	18%	0.35	0.15	5%	0.29	0.10	3%	1	0.70	70%
ccess control	0.60	0.50	1.00	30%	0.35	0.15	5%	0.29	0.10	3%	1	0.40	40%
Headwater ponds	0.60	0.50	1.00	30%	0.35	0.15	5%	0.29	0.10	3%	1	0.40	40%
Restore riparian buffer	0.60	0.60	1.00	36%	0.35	0.35	12%	0.29	0.35	10%	1	0.55	55%
Pasture/hay planting	0.60	0.60	1.00	36%	0.35	0.15	5%	0.29	0.10	3%	1	0.30	30%
Roof runoff structure	0.60	0.40	1.00	24%	0.35	0.15	5%	0.29	0.15	4%	1	0.00	0%
rassed waterway	0.60	0.30	1.00	18%	0.35	0.25	9%	0.29	0.25	7%	1	0.00	0%
Filter strip	0.60	0.50	1.00	30%	0.35	0.50	18%	0.29	0.15	4%	1	0.60	60%
Bank stabili ation	0.60	0.60	1.00	36%	0.35	0.15	5%	0.29	0.15	4%	1	0.00	0%
Stream restoration	0.60	0.75	1.00	45%	0.35	0.60	21%	0.29	0.55	16%	1	0.00	0%

Table 17. Beaver Lake-War Eagle Creek sub-watershed potential load reductions from implementation of management practices to reduce nutrient and pathogen loads.

Practices	Phos horus eduction (Target 25%)				Associated eductions					
					itrogen (Target 25%)			*E. coli*		
	Assu ed ortion hos horus load fro treated source	Assu ed hos horus reduction efficienc	Portion of source to treat to eet target hos horus reduction	Potential hos horus load reduction	Assu ed ortion nitrogen load	Assu ed nitrogen reduction efficienc	Potential nitrogen load reduction	Assu ed ortion .coli load	Assu ed .coli reduction	Potential .coli reduction
Pasture aeration	0.35	0.35	1.00	12%	0.29	0.45	13%	1	0.00	0%
Waste storage	0.35	0.15	1.00	5%	0.29	0.15	4%	1	0.90	90%
Remediate failing septic systems	0.06	0.90	1.00	5%	0.05	0.25	1%	1	0.90	90%

2.7 Roberts Creek-Beaver Lake

Given the nonpoint sources present in the Roberts Creek-Beaver Lake sub-watershed, the potential for meeting the proposed load reduction targets was evaluated using agricultural practices and streambank erosion practices. Because the largest load reduction target is for sediment, the potential for meeting this target was evaluated first. These load reduction calculations are shown in Table 18. Table 18 also shows potential reductions in nitrogen, phosphorus, and *E. coli* loads associated with practices that could be implemented to reduce sediment load. Table 19 shows potential reductions from additional practices that address only nutrients and pathogens. Assumptions used in these calculations are

- Pasture, livestock, and poultry operation sources treated using conservation practices, and streambank erosion, contribute 22% of sediment, 18% of nitrogen, and 12% of phosphorus loads (Table 8).
- Failing septic systems remediated contribute 12% of phosphorus and 8% of nitrogen loads (developed area contribution from Table 9).
- Reduction efficiencies of practices are the calculation values from Tables 1-7.

2. Brush Creek-Beaver Lake

Given the nonpoint sources present in the Brush Creek-Beaver Lake sub-watershed, the potential for meeting the proposed load reduction targets was evaluated using agricultural practices and streambank erosion practices. Because the largest load reduction target is for nitrogen, the potential for meeting this target was evaluated first. These load reduction calculations are shown in Table 20. Table 20 also shows potential reductions in phosphorus, sediment, and *E. coli* loads associated with practices that could be implemented to reduce nitrogen load. Assumptions used in these calculations are

- Pasture, livestock, and poultry operation sources treated using conservation practices, and streambank erosion, contribute, 48% of nitrogen, 47% of phosphorus, and 37% of sediment loads (Table 8).
- Failing septic systems remediated contribute 3% of nitrogen and phosphorus loads (developed area contribution from Table 9).
- Reduction efficiencies of practices are the calculation values from Tables 1-7.

Table 18. Roberts Creek-Beaver Lake sub-watershed potential load reductions from implementation of management practices to reduce sediment load.

Practices	Sedi ent eduction (Target 40%)				Associated eductions								
					Phos horus (Target 25%)			itrogen (Target 30%)			*E. coli*		
	Assu ed ortion of sedi ent load fro treated source	Assu ed sedi ent reduction efficienc	Portion of source to treat to eet target sedi ent reduction	Potential sedi ent load reduction	Assu ed ortion hos horus load	Assu ed hos horus reduction efficienc	Potential hos horus load reduction	Assu ed ortion nitrogen load	Assu ed nitrogen reduction efficienc	Potential nitrogen load reduction	Assu ed ortion .coli load	Assu ed .coli reduction	Potential .coli reduction
Prescribed gra ing	0.22	0.30	1.00	7%	0.12	0.15	2%	0.18	0.10	2%	1	0.60	60%
Watering facility	0.22	0.30	1.00	7%	0.12	0.15	2%	0.18	0.10	2%	1	0.70	70%
ccess control	0.22	0.50	1.00	11%	0.12	0.15	2%	0.18	0.10	2%	1	0.40	40%
Headwater ponds	0.22	0.60	1.00	13%	0.12	0.45	5%	0.18	0.35	6%	1	0.75	75%
Restore riparian buffer	0.22	0.60	1.00	13%	0.12	0.35	4%	0.18	0.35	6%	1	0.55	55%
Pasture/hay planting	0.22	0.60	1.00	13%	0.12	0.15	2%	0.18	0.10	2%	1	0.30	30%
Roof runoff structure	0.22	0.40	1.00	9%	0.12	0.15	2%	0.18	0.15	3%	1	0.00	0%
rassed waterway	0.22	0.30	1.00	7%	0.12	0.25	3%	0.18	0.25	5%	1	0.00	0%
Filter strip	0.22	0.50	1.00	11%	0.12	0.50	6%	0.18	0.15	3%	1	0.60	60%
Bank stabili ation	0.22	0.60	1.00	13%	0.12	0.15	2%	0.18	0.15	3%	1	0.00	0%
Stream restoration	0.22	0.75	1.00	17%	0.12	0.60	7%	0.18	0.55	10%	1	0.00	0%
Rain garden	0.06	0.75	1.00	5%	0.12	0.00	0%	0.08	0.25	2%	1	0.40	40%
Permeable pavement	0.06	0.60	1.00	4%	0.12	0.60	7%	0.08	0.60	5%	1	0.00	0%
Media filters	0.06	0.80	1.00	5%	0.12	0.45	5%	0.08	0.15	1%	1	0.60	60%
Hydrodynamic separation devices	0.06	0.40	1.00	2%	0.12	0.20	2%	0.08	0.02	0%	1	0.25	25%
Constructed wetland	0.06	0.60	1.00	4%	0.12	0.40	5%	0.08	0.20	2%	1	0.85	85%
Retention basin	0.06	0.60	1.00	4%	0.12	0.45	5%	0.08	0.35	3%	1	0.75	75%
Detention basin	0.06	0.60	1.00	4%	0.12	0.25	3%	0.08	0.15	1%	1	0.40	40%

Table 19. Roberts Creek-Beaver Lake sub-watershed potential load reductions from implementation of management practices to reduce nutrient and pathogen loads.

Practices	Phos horus eduction (Target 25%)				Associated eductions					
					itrogen (Target 30%)			*E. coli*		
	Assu ed ortion hos horus load fro treated source	Assu ed hos horus reduction efficienc	Portion of source to treat to eet target nitrogen reduction	Potential hos horus load reduction	Assu ed ortion nitrogen load	Assu ed nitrogen reduction efficienc	Potential nitrogen load reduction	Assu ed ortion .coli load	Assu ed .coli reduction	Potential .coli reduction
Pasture aeration	0.12	0.35	1.00	4%	0.18	0.45	8%	1	0.00	0%
Waste storage	0.12	0.15	1.00	2%	0.18	0.15	3%	1	0.90	90%
Remediate failing septic systems	0.12	0.90	1.00	11%	0.08	0.25	2%	1	0.90	90%

Table 20. Brush Creek-Beaver Lake sub-watershed potential load reductions from implementation of management practices to reduce nitrogen load.

	itrogen eduction (Target 25%)				Associated eductions								
					Phos horus (Target 5%)			Sedi ent (Target 20%)			*E. coli*		
Practices	Assu ed ortion nitrogen load	Assu ed nitrogen reduction efficienc	Portion of source to treat to eet target nitrogen reduction	Potential nitrogen load reduction	Assu ed ortion hos horus load	Assu ed hos horus reduction efficienc	Potential hos horus load reduction	Assu ed ortion of sedi ent load fro treated source	Assu ed sedi ent reduction efficienc	Potential sedi ent load reduction	Assu ed ortion .coli load	Assu ed .coli reduction	Potential .coli reduction
Prescribed gra ing	0.48	0.10	1.00	5%	0.47	0.15	7%	0.37	0.30	11%	1	0.60	60%
Watering facility	0.48	0.10	1.00	5%	0.47	0.15	7%	0.37	0.30	11%	1	0.70	70%
ccess control	0.48	0.10	1.00	5%	0.47	0.15	7%	0.37	0.50	19%	1	0.40	40%
Restore riparian buffer	0.48	0.35	1.00	17%	0.47	0.35	16%	0.37	0.60	22%	1	0.55	55%
Pasture/hay planting	0.48	0.10	1.00	5%	0.47	0.15	7%	0.37	0.60	22%	1	0.30	30%
Pasture aeration	0.48	0.45	1.00	22%	0.47	0.35	16%	0.37	0.00	0%	1	0.00	0%
Headwater ponds	0.48	0.35	1.00	17%	0.47	0.45	21%	0.37	0.60	22%	1	0.75	75%
Waste storage	0.48	0.15	1.00	7%	0.47	0.15	7%	0.37	0.00	0%	1	0.90	90%
Roof runoff structure	0.48	0.15	1.00	7%	0.47	0.15	7%	0.37	0.40	15%	1	0.00	0%
rassed waterway	0.48	0.25	1.00	12%	0.47	0.25	12%	0.37	0.30	11%	1	0.00	0%
Filter strip	0.48	0.15	1.00	7%	0.47	0.50	24%	0.37	0.50	19%	1	0.60	60%
Bank stabili ation	0.48	0.15	1.00	7%	0.47	0.15	7%	0.37	0.60	22%	1	0.00	0%
Stream restoration	0.48	0.55	0.95	25%	0.47	0.60	27%	0.37	0.75	26%	1	0.00	0%
Remediate failing septic systems	0.03	0.25	1.00	1%	0.03	0.90	3%	0.00	0.00	0%	1	0.90	90%

2. Span er ranch ings Ri er

iven the nonpoint sources present in the Spanker Branch-Kings River sub-watershed, the potential for load reduction for target pollutants was evaluated using agricultural practices and streambank erosion practices. Load reduction calculations are shown in Table 21. Reductions in sediment and *E. coli* loads are recommended in this sub-watershed, but load reduction targets were not able to be determined. ssumptions used in the load reduction calculations are

- Pasture, livestock, and poultry operation sources treated using conservation practices, and streambank erosion, contribute, 43% of sediment, 39% of phosphorus, and 40% of nitrogen loads Table 8 .
- Streambank erosion contributes approximately 45% of the HUC12 sediment load FT ssociates, Ltd., 2005 .
- Failing septic systems contribute 2% of nitrogen and phosphorus loads developed area percentages from Table 9 .
- Reduction efficiencies of practices are the calculation values from Tables 1-7.

2.10 la er ree ings Ri er

iven the nonpoint sources present in the Clabber Creek-Kings River sub-watershed, potential for load reduction target was evaluated using agricultural practices and low impact development. Load reduction calculations are shown in Table 22. Reductions in *E. coli* and TDS loads are recommended in this sub-watershed, but load reduction targets were not able to be determined. ssumptions used in these calculations are

- Pasture, livestock, and poultry operation sources treated using conservation practices, and streambank erosion, contribute, 63% of nitrogen, 64% of phosphorus, and 66% of sediment loads Table 8 .
- Failing septic systems contribute 1% of nitrogen and phosphorus loads developed area percentages from Table 9 .
- Reduction efficiencies of practices are the calculation values from Tables 1-7.

2.11 raswell ranch Yocum ree

iven the nonpoint sources present in the Braswell Branch- ocum Creek sub-watershed, the potential for meeting the proposed load reduction targets was evaluated using agricultural practices, streambank erosion practices, and low impact development practices. Because the largest load reduction target is for sediment, the potential for meeting this target was evaluated first. These load reduction calculations are shown in Table 23. Table 23 also shows potential reductions in nitrogen, phosphorus, and *E. coli* loads associated with practices that could be implemented to reduce sediment load. Table 24 shows nutrient and *E. coli* load reduction potential when practices are applied to meet the phosphorus load reduction target for this sub-watershed. ssumptions used in these calculations are

- Pasture, livestock, and poultry operation sources treated using conservation practices, and streambank erosion, contribute, 44% of nitrogen, 28% of phosphorus, and 60% of sediment loads Table 8 .
- Development sources, including failing septic systems and unpaved roads, contribute 10% of nitrogen, 14% of phosphorus, and 6% of sediment loads Table 9 .
- Reduction efficiencies of practices are the calculation values from Tables 1-7.

Table 21. Spanker Branch-Kings River sub-watershed potential load reductions from implementation of management practices.

	Sedi ent eduction				Associated eductions								
					Phos horus			itrogen			*E. coli*		
Practices	Assu ed ortion of sedi ent load fro treated source	Assu ed sedi ent reduction efficienc	Portion of source to treat to eet target sedi ent reduction	Potential sedi ent load reduction	Assu ed ortion hos horus load	Assu ed hos horus reduction efficienc	Potential hos horus load reduction	Assu ed ortion nitrogen load	Assu ed nitrogen reduction efficienc	Potential nitrogen load reduction	Assu ed ortion .coli load	Assu ed .coli reduction	Potential .coli reduction
Prescribed gra ing	0.43	0.30	1.00	13%	0.39	0.15	6%	0.40	0.10	4%	1	0.60	60%
Watering facility	0.43	0.30	1.00	13%	0.39	0.15	6%	0.40	0.10	4%	1	0.70	70%
ccess control	0.43	0.50	1.00	22%	0.39	0.15	6%	0.40	0.10	4%	1	0.40	40%
Restore riparian buffer	0.43	0.60	1.00	26%	0.39	0.35	14%	0.40	0.35	14%	1	0.55	55%
Pasture/hay planting	0.43	0.60	1.00	26%	0.39	0.15	6%	0.40	0.10	4%	1	0.30	30%
Pasture aeration	0.43	0.00	1.00	0%	0.39	0.35	14%	0.40	0.45	18%	1	0.00	0%
Waste storage	0.00	0.00	1.00	0%	0.39	0.15	6%	0.40	0.15	6%	1	0.90	90%
Roof runoff structure	0.43	0.40	1.00	17%	0.39	0.15	6%	0.40	0.15	6%	1	0.00	0%
rassed waterway	0.43	0.30	1.00	13%	0.39	0.25	10%	0.40	0.25	10%	1	0.00	0%
Filter strip	0.43	0.50	1.00	22%	0.39	0.50	20%	0.40	0.15	6%	1	0.60	60%
Bank stabili ation	0.43	0.60	1.00	26%	0.39	0.15	6%	0.40	0.15	6%	1	0.00	0%
Stream restoration	0.43	0.75	1.00	32%	0.39	0.60	23%	0.40	0.55	22%	1	0.00	0%
Remediate failing septic systems	0	0.25	1.00	0%	0.02	0.90	2%	0.02	0.25	1%	1	0.90	90%

Table 22. Clabber Creek-Kings River sub-watershed potential load reductions from implementation of management practices.

	E. coli eduction				Associated eductions								
					Phos horus			Sedi ent			itrogen		
Practices	Assu ed ortion *E.coli* load	Assu ed .coli reduction	Portion of source to treat	Potential .coli reduction	Assu ed ortion hos horus load fro treated source	Assu ed hos horus reduction efficienc	Potential hos horus load reduction	Assu ed ortion sedi ent load	Assu ed sedi ent reduction efficienc	Potential sedi ent load reduction	Assu ed ortion nitrogen load	Assu ed nitrogen reduction efficienc	Potential nitrogen reduction
Restore riparian buffer	1	0.55	1.00	55%	0.64	0.35	22%	0.66	0.60	40%	0.63	0.35	22%
Remediate failing septic systems	1	0.90	1.00	90%	0.01	0.90	1%	0.01	0.00	0%	0.01	0.25	0%
Rain garden	1	0.40	1.00	40%	0.01	0.00	0%	0.01	0.75	1%	0.01	0.25	0%
Media filters	1	0.60	1.00	60%	0.01	0.45	0%	0.01	0.80	1%	0.01	0.15	0%
Hydrodynamic separation devices	1	0.25	1.00	25%	0.01	0.20	0%	0.01	0.40	0%	0.01	0.02	0%
Constructed wetland	1	0.85	1.00	85%	0.01	0.40	0%	0.01	0.60	1%	0.01	0.20	0%
Retention basin	1	0.75	1.00	75%	0.01	0.45	0%	0.01	0.60	1%	0.01	0.35	0%
Detention basin	1	0.40	1.00	40%	0.01	0.25	0%	0.01	0.60	1%	0.01	0.15	0%
Prescribed gra ing	1	0.60	1.00	60%	0.64	0.15	10%	0.66	0.30	20%	0.63	0.10	6%
Watering facility	1	0.70	1.00	70%	0.64	0.15	10%	0.66	0.30	20%	0.63	0.10	6%
ccess control	1	0.40	1.00	40%	0.64	0.15	10%	0.66	0.50	33%	0.63	0.10	6%
Waste storage	1	0.90	1.00	90%	0.64	0.15	10%	0.66	0.00	0%	0.63	0.15	9%
Filter strip	1	0.60	1.00	60%	0.64	0.50	32%	0.66	0.50	33%	0.63	0.15	9%

Table 23. Braswell Branch- ocum Creek sub-watershed potential load reductions from implementation of management practices to reduce sediment load.

	Sedi ent eduction (Target 35%)				Associated eductions								
					Phos horus (Target 2%)			itrogen (Target 5%)			*E. coli*		
Practices	Assu ed ortion sedi ent load	Assu ed sedi ent reduction efficienc	Portion of source to treat to eet target sedi ent reduction	Potential sedi ent load reduction	Assu ed ortion hos horus load fro treated source	Assu ed hos horus reduction efficienc	Potential hos horus load reduction	Assu ed ortion nitrogen load	Assu ed nitrogen reduction efficienc	Potential nitrogen load reduction	Assu ed ortion .coli load	Assu ed .coli reduction	Potential .coli reduction
Restore riparian buffer	0.95	0.35	1.00	33%	0.99	0.35	35%	0.88	0.60	53%	1	0.55	55%
Stream restoration	0.60	0.55	1.00	33%	0.99	0.60	59%	0.88	0.75	66%	1	0.00	--
Rain garden	0.07	0.25	1.00	2%	0.04	0.00	--	0.08	0.75	6%	1	0.40	40%
Permeable pavement	0.07	0.60	1.00	4%	0.04	0.60	2%	0.08	0.60	5%	1	0.00	--
Media filters	0.07	0.15	1.00	1%	0.04	0.45	2%	0.08	0.80	6%	1	0.60	60%
Hydrodynamic separation devices	0.07	0.02	1.00	0%	0.04	0.20	1%	0.08	0.40	3%	1	0.25	25%
Constructed wetland	0.07	0.20	1.00	1%	0.04	0.40	2%	0.08	0.60	5%	1	0.85	85%
Retention basin	0.07	0.35	1.00	2%	0.04	0.45	2%	0.08	0.60	5%	1	0.75	75%
Detention basin	0.07	0.15	1.00	1%	0.04	0.25	1%	0.08	0.60	5%	1	0.40	40%
Prescribed gra ing	0.88	0.10	1.00	9%	0.96	0.15	14%	0.8	0.30	24%	1	0.60	60%
Watering facility	0.88	0.10	1.00	9%	0.96	0.15	14%	0.8	0.30	24%	1	0.70	70%
ccess control	0.88	0.10	1.00	9%	0.96	0.15	14%	0.8	0.50	40%	1	0.40	40%
Pasture aeration	0.88	0.45	1.00	40%	0.96	0.35	34%	0.8	0.00	--	1	0.00	--
Waste storage	0.88	0.15	1.00	13%	0.96	0.15	14%	0.8	0.00	--	1	0.90	90%
Remediate failing septic systems	0.07	0.25	1.00	2%	0.04	0.90	4%	0.08	0.00	--	1	0.90	90%
Roof runoff structure	0.88	0.15	1.00	13%	0.96	0.15	14%	0.8	0.40	32%	1	0.00	--
egetated treatment area	0.88	0.70	0.65	40%	0.96	0.70	44%	0.8	0.80	42%	1	0.50	32%
rassed waterway	0.95	0.25	1.00	24%	0.99	0.25	25%	0.88	0.30	26%	1	0.00	--
Filter strip	0.95	0.15	1.00	14%	0.99	0.50	50%	0.88	0.50	44%	1	0.60	60%

Table 24. Braswell Branch- ocum Creek sub-watershed potential load reductions from implementation of management practices to reduce nutrient and pathogen loads.

	Phos horus eduction (Target 2%)				Associated eductions					
					itrogen (Target 5%)			*E. coli*		
Practices	Assu ed ortion hos horus load fro treated source	Assu ed hos horus reduction efficienc	Portion of source to treat to eet target nitrogen reduction	Potential hos horus load reduction	Assu ed ortion nitrogen load	Assu ed nitrogen reduction efficienc	Potential nitrogen load reduction	Assu ed ortion *E.coli* load	Assu ed *E.coli* reduction	Potential *E.coli* reduction
Pasture aeration	0.28	0.35	1.00	10%	0.44	0.45	20%	1	0.00	0%
Waste storage	0.28	0.15	1.00	4%	0.44	0.15	7%	1	0.90	90%
Remediate failing septic systems	0.14	0.90	1.00	13%	0.1	0.25	3%	1	0.90	90%

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ATTA MENT A

Pounds of phosphorus and nitrogen per ton of sediment from streambank erosion were calculated from values reported by an Eps for West Fork White River restoration pro ect at Fayetteville executive airport see Table 1 an Eps, 2013 . These ratios were multiplied by the total sediment load from streambank erosion in West Fork White River watershed reported in DE 2004 see Table 2 . The resulting nutrient values were added to estimated West Fork watershed nutrient loads to calculate revised total watershed nutrient loads, and then the portion from streambank erosion calculated see Table 3 .

Table 1. Estimation of pounds of nitrogen and phosphorus per ton of sediment from streambank erosion.

nfor ation	**Average annual sedi ent load, tons/ ear**	**Average annual nitrogen load, ounds/ ear**	**Average annual hos horus load, ounds/ ear**
Reported values from an Eps 2013	4,318	5,583	1,933
Ratio of nutrients to sediment, pounds/ton annual nutrient load/annual sediment load	--	1.29	0.45

Table 2. Estimated nutrient load from streambank erosion in West Fork White River sub-watershed.

e orted value (D , 2004)	**Calculated values**	
verage annual sediment from streambank erosion in West Fork White River sub-watershed, tons/year	verage annual nitrogen load, pounds/year	verage annual phosphorus load, pounds/year
Main branch 18,532 Tributaries 5,118 Total 23,650	30,508	10,642

Table 3. Summary of potential sources and estimated loads of sediment and nutrients in West Fork White River sub-watershed from DE 2004 .

Source	Sedi ent, tons	Total hos horus, tons	Total nitrogen, tons
Pasture	1,709	11.3	45.6
Forest	Forest 391 Harvested 8 Total 399	0.8	7.8
Urban	Urban 1,104 Construction 2,787 Total 3,891	Urban 3.8 olf courses 0.05 Total 3.85	Urban 25.3 olf courses 0.2 Total 25.5
Point sources	WWTP 0.5 uarry 7.5 Total 8.0	0.9	3.2
Septic tanks	0	0.5	1.2
Roadways and ditches	Unpaved 4,500 Paved highways 122 Residential 34 I-540 272 I-540 gullies 1,210 Total 6,138	--	--
Streambanks	Main branch 18,532 Tributaries 5,118 Total 23,650	4.8	13.9
Total	35,795	22.2	97.2
Percentage from streambank erosion	66%	22%	14%

APPENDIX O

Examples of Education and Outreach Activities in the Upper White River Watershed

1.1 US Army orps of Engineers

Information about natural resources on US CE lands in the Upper White River watershed, and their management, is available on the US CE Beaver Lake website https //www.swl.usace.army.mil/Missions/Recreation/Lakes/Beaver-Lake/ . US CE Little Rock District also provides information on several social media platforms, including Facebook, Twitter, ouTube, and Instagram.

1.2 US ish and Wildlife Ser ice

USFWS provides information about rkansas wildlife and habitat issues and management, including endangered species, through their website https //www.fws.gov/office/arkansas-ecological-services , and a variety of social media platforms, including Facebook, Instagram, Twitter, Flickr, and ouTube.

1.3 Natural Resources onser ation Ser ice

Information and education activities of the RCS include participation in field days and farm demonstrations, soil and water stewardship materials, and informational and training programs at county offices, in addition to information posted on their website https //www.nrcs.usda.gov/wps/portal/nrcs/ar/home/ , Twitter, and ouTube. Education and outreach are often part of Regional Conservation Partnership Program RCPP pro ects. Through these activities, RCS provides information and education on a wide range of topics related to agriculture and natural resources management in the state, including benefits, implementation, and maintenance of agricultural practices to protect or improve water uality so water uality standards are met.

1.4 Uni ersity of Ar ansas Di ision of Agriculture

The Uof Division of griculture is a research and information support agency for the agricultural sector in rkansas. The Division of griculture provides information and education through the Cooperative Extension Service. Information and education activities of the Cooperative Extension Service include the rkansas Watershed Steward program, displays and

presentations at fairs and festivals, participation in field days and farm demonstrations, informational and training programs at county offices, newsletters, publications on a variety of topics including feral hog management, and short and long-term agricultural methods that protect water uality, so water uality standards are met. website https //www.uaex.edu/ , and Facebook, Twitter, Instagram, and ouTube accounts provide access to information about programs and resources, and copies of informational publications and videos. The Division of griculture also sponsors the annual Most Crop per Drop Irrigation contest.

The rkansas Cooperative Extension Service also provides information on protecting water uality for non-agricultural landowners and residents in developed areas, through their website and social media. rkansas Cooperative Extension Service is a partner in the orthwest rkansas Urban Stormwater Education Program. Education and outreach through this program includes storm drain art, car care clinics, clean up events, and information on a wide variety of topics related to urban stormwater. In addition, rkansas Cooperative Extension Service is working with atural Resources Division to offer the rkansas Watershed Steward Program.

1.5 ounty onser ation Districts

Information and education activities of the County Conservation Districts include displays and presentations at fairs and festivals, participation in field days and farm demonstrations, soil and water stewardship materials, informational and training programs at county offices, and support of rkansas Envirothon, in addition to social media like Facebook and Twitter. Through these activities, County Conservation Districts provide information and education on a wide range of topics related to agriculture and rural life, including benefits, implementation, and maintenance of agricultural practices to protect water uality so water uality standards are met.

1.6 Ar ansas Natural Resource Agencies

rkansas natural resource agencies, including FC, rkansas atural Heritage Commission, rkansas Department of griculture Forestry Division, DE and the atural Resources Division, all have information and education programs aimed at increasing public

interest, understanding, and stewardship of the natural resources of our state, including protecting water uality to achieve water uality standards. FC s O ark Highlands ature Center in Springdale offers educational programs and exhibits, and nature trails for citi ens to learn about the natural world and outdoor recreation in orthwest rkansas. Other examples of agency programs that are relevant to targeting nonpoint pollution sources in the Category 1 sub-watersheds include the atural Resources Division Unpaved Roads Program and nonpoint source pollution program, FC Stream Habitat and Trout Habitat Programs, and DE Watershed Outreach and Education Program. rkansas natural resources agencies use a variety of methods to reach rkansans, including websites https //www.agfc.com/en/**,** https //www.arkansasheritage.com/arkansas-natural-heritage/anhc-home, https //www.agriculture.arkansas.gov/natural-resources/, https //www.ade .state.ar.us/poa/watershed/ social media e.g., https //www.youtube.com/c/ rkansas ameandFishCommission, https //www.facebook.com/arnaturalheritage/, https //twitter.com/ RDeptof gricul newsletters presentations and displays at meetings, fairs, festivals, and schools news media stories and hosting volunteer and training events.

1.7 The Nature onser ancy

The ature Conservancy T C assists with outreach and education through a variety of programs. T C conducts education and outreach through their website, social media, and member periodicals, and through articles in local newspapers and maga ines. T C also helped establish the Walton ature Preserve to prevent development and protect water uality in Beaver Lake and the Upper White River watershed. T C established the Kings River Preserve to protect and improve the health and water uality of Kings River.

1. Northwest Ar ansas Land Trust

The orthwest rkansas Land Trust provides outreach and education about land conservation activities and benefits through their website LE R W Land Trust , their

collaboration on the Kessler Mountain ature Center and Outdoor Classroom, and development of nature preserves with public access.

1. Other Nonprofit Interest Groups

There are several other nonprofit groups with interests in the Upper White River watershed. These include the rkansas Cattlemen s ssociation, rkansas Farm Bureau, udubon rkansas, Beaver Lake Foundation, Trout Unlimited, uail Forever, and Tourism ssociation. These organi ations provide information and education to their members and the public through a variety of methods including, websites social media newsletters visitor guides presentations and displays at schools, meetings, conferences, fairs, and festivals teacher resources river and lake clean up events workshops mailings and news media stories. Many of these organi ations already provide information and education about how to protect and improve water uality so that state water uality standards are met. Some of these organi ations, e.g., rkansas Cattlemen s ssociation, Trout Unlimited, and uail Forever, focus their efforts only in select areas of the Upper White River watershed.

APPENDIX P

Estimation of Costs for Implementing BMPs in Category 1 Sub-watersheds

1.0 INTRODU TION

This appendix describes how costs were estimated for implementing BMPs to achieve target nutrient and sediment loads. Cost estimates were calculated by multiplying an assumed unit cost for a practice by the number of units of the practice to be implemented. Unit costs used in these calculations are discussed in Section 2. The units of practices to be implemented in the Category 1 sub-watersheds are derived in Section 3. Section 4 presents the cost estimate calculations for the Category 1 sub-watersheds.

2.0 ASSUMED OST PER UNIT

The cost of implementing BMPs to reduce nonpoint source pollution can be variable, depending on materials markets and site conditions e.g., slope, soil type . Table 1 lists available cost information for selected BMPs identified in Section 4.8. While RCS E IP reimbursement allocations do not reflect the actual cost of implementing the practice, they provide an idea of relative costs of the shown BMPs. H2O arks reports that they have completed 61 septic remediation pro ects totaling over 800,000 E. Scott, H2O arks, personal communication 9/23/2024 . This suggests an average cost of around 13,000 per pro ect.

Table 1. E IP reimbursements and reported implementation costs for selected nonpoint source pollution BMPs applicable in the Upper White River watershed.

Practice (CS D u ber)	nit	2024 P (non-) 75% rei burse ent er unit[a]	nit Costs fro ther Sources	Assu ed Cost for Calculations
Fence 382	Feet	1.47- 3.49	2.15- 2.60[b], 0.23- 2.54	4.00
Watering facility 5,000 gallons 614	allons	1.62- 4.62	--	1,200
Watering facility, fountain 614	Each	1,184.17	2,000- 10,000[b]	
Watering facility 614	Each	-	134.20- 1,335.69	
Livestock pipeline 516	Feet	1.97- 4.72	--	
Stream crossing 578	S uare feet	5.75- 58.16	243- 7,545 each	3,000
Riparian forest buffer plants 391	Each	0.91- 2.01	--	800
Hardwood riparian forest buffer with forgone pasture income 391	cres	367.02- 432.45	--	
Riparian forest buffer establishment maintenance 391	cres	--	218- 7,112[b-e], 286.20 - 442.8[t]	
Riparian herbaceous buffer 390	cres	219.54- 280.62	168- 400[b], 286.20 - 442.8[t]	280
Prescribed gra ing, medium intensity 528	cres	31.60	30- 70[f], 14.27- 56.78	40
ra ing management, design implementation, 501 ac 159	Each	1,254.51 - 1,568.14	--	
egetated treatment area 635	cre	1,678.45 - 10,618.12	--	8,500
mendment of waste 591	Ton	340.73 - 408.88	--	--
Filter strip 393	cres	165.42- 209.74	305.81 , 4 per foot[m]	250

Table 1. E IP reimbursements and reported implementation costs for selected nonpoint source pollution BMPs applicable in the Upper White River watershed continued.

Practice (CS D u ber)	nit	2024 P (non-) 75% rei burse ent er unit[a]	nit Costs fro ther Sources	Assu ed Cost for Calculations
Filter strip with forgone income 393	cres	519.95- 564.27	--	
rassed waterway 412	cres	1,505.50	17- 2,879	2,000
Bioretention basins rain gardens	S uare foot	--	3- 15[g], up to 14 75% reimbursement [l], 14[m], 1.39- 607.46[n], 197.28- 10,000 each per year[n]	20
Streambank and shoreline protection 580	Linear foot	12.66- 254.48	32.42- 209.79	160
Streambank/channel restoration	Linear foot	--	30,000 for 100 feet[i], 286.20 - 442.8[t]	500
Waste storage facility, dry stack 313	S uare foot	2.77- 6.98	231.84- 38,052.91 each	19,000 each
nimal mortality facility 316	umber	44,835.28 - 50,483.37	--	60,000
Composting facility 317	S uare foot	14.35- 50.64	--	--
Pasture and hay planting 512	cres	254.87- 408.86	40.18- 343.64	400
Pasture aeration	cres	--	0.01 - 2.49[r]	2.00
Ponds	Cubic yards	2.73 - 4.71	--	5,000/pond ssuming 1,000 cu yd excavated[s]
Roof runoff structure 558	feet	10.85- 18.75	2,306.40- 31,950 each	7,000 per house
Septic tank repair/replacement	umber	--	13,000[k]	13,000

Table 1. E IP reimbursements and reported implementation costs for selected nonpoint source pollution BMPs applicable in the Upper White River watershed continued.

Practice (CS D u ber)	nit	2024 P (non-) 75% rei burse ent er unit[a]	nit Costs fro ther Sources	Assu ed Cost for Calculations
Permeable pavement	S uare feet	--	13[m], 2.07- 40.28 capital cost [n], 200- 21,300 each per year[n]	--
Detention basin	umber	--	10,000- 50,000[o]	30,000
Media filter	umber	--	0.02- 3,392.28 capital cost [n], 1,800- 60,000 each per year[n]	3,000
Hydrodynamic separator	umber	--	1,000- 4,250 each per year[n], 10,000- 40,000[p]	20,000

HU historically underserved producers
a RCS, 2024 ,
b Lynch T aden 2000
c Butler Long 2005
d Whitescarver 2013
e Washington State University 2006
f Undersander, et al. 2002
g http //raingardenalliance.org/what/fa s
h Myers, Weber and Tellatin 2019
i E. Powers, FC, personal communication, 9/20/2022 Christianson 2020
k E. Scott, H2O arks, personal communication 9/23/2024
l IRWP, 2014
m Center for eighborhood Technology, 2020
n Municipal Water Infrastructure Council of EWRI Water Research Foundation, 2022
o Pennsylvania Environmental Council, 2012
p US Environmental Protection gency, 1999 RTI, 2023
r Popp, et al., 2021
s Scott Haggard, 2015
t BW , 2012 , multiplied by 1.35 to convert to 2024 dollars

3.0 UNITS O PRA TI ES TO IMPLEMENT

The units of a practice to be implemented are based on the extent of the targeted source, and the amount of that source to treat to meet the load reduction targets for a sub-watershed. Estimates of pollutant sources and the approaches used to derive them are described in the following subsections.

3.1 Prescri ed Gra ing

Pasture accounts for 21% to 68% of the land area of Category 1 sub-watersheds. Table 2 lists information about pasture area and cattle operations Benton, Carroll, Madison, and Washington Counties from the 2022 Census of griculture. s shown in Table 3, this information was used to calculate the average pasture area associated with each cattle operation in these counties pasture divided by number of cattle farms , and the percentage of cattle operations in these counties using prescribed rotational gra ing or gra ing management number of farms using rotational gra ing divided by number of farms with cattle . In Table 3, these values are used to estimate the area of pasture in Category 1 sub-watersheds where prescribed gra ing is not yet in use.

Table 2. Information about pasture and cattle operations in Benton, Carroll, Madison, and Washington Counties from the 2022 US Census of griculture. Census tables from which the information is taken are indicated in the Information column.

nfor ation (Census Table nu ber)	**enton Count**	**Carroll Count**	**adison Count**	**Washington Count**
cres pasture, all types Table 8	120,032	161,133	123,787	148,660
umber of farms with cattle Table 11	1,091	657	692	1,226
verage acres pasture with cattle farms	110	245	179	121
umber of farms using rotational gra ing Table 43	269	170	173	367
Percent of cattle farms using rotational gra ing	25%	26%	25%	30%

Table 3. Estimated pasture in Category 1 sub-watersheds without prescribed gra ing.

Sub- atershed	Total Pasture area, acres	Average acres/ cattle o eration	sti ated o. cattle o erations	Percent o erations ith rescribed gra ing	sti ated nu ber o erations ithout rescribed gra ing	sti ated asture area ithout rescribed gra ing, acres
Lake Se uoyah 110100010303	7,783	121	64	30%	45	5,445
Town Branch-West Fork White River 110100010404	4,321	121	36	30%	25	3,025
Holman Creek 110100010606	6,878	179	38	25%	28	5,012
lade Creek 110100010608	9,139	179	51	25%	38	6,802
Clifty Creek-War Eagle Creek 110100010610	11,226	179	63	25%	47	8,413
Beaver Lake-War Eagle Creek 110100010611	5,340	116[a]	46	28%[a]	33	3,828
Roberts Creek-Beaver Lake 110100010701	8,905	121	74	30%	52	6,292
Brush Creek-Beaver Lake 110100010702	14,604	150[b]	97	28%[b]	70	10,500
Spanker Branch-Kings River 110100010904	7,568	179	42	25%	32	5,728
Clabber Creek-Kings River 110100011106	13,238	245	54	26%	40	9,800
Braswell Branch-ocum Creek 110100011306	14,562	245	59	26%	44	10,780

a average of Benton and Washington County values
b average of Madison and Washington County values

Load reduction calculations for prescribed gra ing in ppendix suggest that all the pasture without prescribed gra ing be converted to prescribed gra ing. Therefore, cost estimates will be calculated based on converting all pasture to prescribed gra ing. The areas used to calculate cost estimates are the areas without prescribed gra ing from Table 3.

3.2 Pasture Aeration

survey that included uestions about use of pasture aeration was conducted in the Beaver Lake watershed in 2018 and 2019 Popp, et al., 2021 . Based on the results of this survey we estimate that around 40% of pasture in the Beaver Lake watershed was not being aerated.[1]

For the cost estimate calculations, we assume that 40% of the pasture in each of the Category 1 sub-watersheds is not being aerated. Load reduction calculations for pasture aeration in ppendix suggest that pasture aeration be applied to all pastures not currently being aerated. Therefore, cost estimates will be calculated based on applying aeration to 40% of pasture in each Category 1 sub-watershed. Pasture areas in need of aeration are calculated for the Category 1 sub-watersheds in Table 4.

Table 4. Estimates of pasture area in need of aeration within Category 1 sub-watersheds.

Sub- atershed	Total Pasture area, acres	Pasture area for aeration (40% of total asture), acres
Lake Se uoyah 110100010303	7,783	3,113
Town Branch-West Fork White River 110100010404	4,321	1,728
Holman Creek 110100010606	6,878	2,751
lade Creek 110100010608	9,139	3,656
Clifty Creek-War Eagle Creek 110100010610	11,226	4,490
Beaver Lake-War Eagle Creek 110100010611	5,340	2,136
Roberts Creek-Beaver Lake 110100010701	8,905	3,562
Brush Creek-Beaver Lake 110100010702	14,604	5,842
Spanker Branch-Kings River 110100010904	7,568	3,027
Clabber Creek-Kings River 110100011106	13,238	5,295
Braswell Branch- ocum Creek 110100011306	14,562	5,825

[1] Popp et al 2021 report the percentage of survey respondents that aerate ero to over 76% of their pasture, in 25% increments. n estimate of the percentage of pasture that is not aerated was calculated by multiplying the reported percentage of respondents by the top value of the range they reported aerating, e.g., 0, 25%, 50%, 75%, or 100%. The result of this calculation is 38%.

3.3 Li estoc Access ontrol

StreamCat reports the percentage of the area within a 100-meter buffer around mapped streams that is in agriculture Hill, Weber, Leibowit , Olsen, Thornbrugh, 2016 . For the Upper White River Category 1 sub-watersheds we assume agriculture means pasture. Miles of streambank associated with riparian pasture were estimated by dividing the area of riparian agriculture land cover reported in StreamCat by 100 meters Table 5 . These estimated lengths of streambanks are assumed to be suitable places for implementation of access control.

Table 5. Riparian pasture and associated streambank lengths in Upper White River Category 1 sub-watersheds.

Sub- atershed	Pasture ithin 100 eter buffer, s uare eters	Associated strea ban (area/100 eters), eters	Associated strea ban , ilo eters	Associated strea ban , feet
Lake Se uoyah 110100010303	5,839,717	58,397	58	191,592
Town Branch-West Fork White River 110100010404	3,900,411	39,004	39	127,966
Holman Creek 110100010606	4,538,951	45,390	45	148,916
lade Creek 110100010608	5,474,828	54,748	55	179,620
Clifty Creek-War Eagle Creek 110100010610	7,341,513	73,415	73	240,863
Beaver Lake-War Eagle Creek 110100010611	3,021,630	30,216	30	99,135
Roberts Creek-Beaver Lake 110100010701	4,733,608	47,336	47	155,302
Brush Creek-Beaver Lake 110100010702	7,769,306	77,693	78	254,899
Spanker Branch-Kings River 110100010904	4,882,804	48,828	49	160,197
Clabber Creek-Kings River 110100011106	7,194,999	71,950	72	236,056
Braswell Branch- ocum Creek 110100011306	9,673,817	96,738	97	317,382

Table 6 shows the calculations of units of practices to reduce livestock access to streams. Load reduction calculations for stream access control in ppendix suggest that access control be applied to all streambanks with riparian pasture. In estimating the extents of practices to implement it was assumed that one stream crossing and two watering facilities will be installed for every km of streambank fenced Mississippi State University Extension 2022 Reynolds 2022 .

Table 6. Units of livestock access control practices estimated for Upper White River Category 1 sub-watersheds.

Sub- atershed	ence, feet	Strea crossings	Watering facilities
Lake Se uoyah 110100010303	191,592	58	116
Town Branch-West Fork White River 110100010404	127,966	39	78
Holman Creek 110100010606	148,916	45	90
lade Creek 110100010608	179,620	55	110
Clifty Creek-War Eagle Creek 110100010610	240,863	73	146
Beaver Lake-War Eagle Creek 110100010611	99,135	30	60
Roberts Creek-Beaver Lake 110100010701	155,302	47	94
Brush Creek-Beaver Lake 110100010702	254,899	78	156
Spanker Branch-Kings River 110100010904	160,197	49	98
Clabber Creek-Kings River 110100011106	236,056	72	144
Braswell Branch- ocum Creek 110100011306	317,382	97	194

3.4 Pasture eadwater Ponds

RTI estimated the number of headwater ponds present in the Beaver Lake subbasin potentially suitable for stormwater retrofit, identifying those ponds located in catchments with a classified severe hydrologic risk based on hydrologic curve numbers as priorities for retrofit. Table 7 lists the number of priority headwater ponds identified in Category 1 sub-watersheds of the Upper White River, from Figure 4-8 of the Beaver Lake Watershed Protection Strategy. Estimates of headwater ponds are not available in the Kings River subbasin.

Table 7. umber of priority headwater ponds estimated by RTI in Category 1 sub-watersheds of the Beaver Lake subbasin RTI, 2023 .

Sub- atershed	u ber of head ater onds in severe ris areas
Lake Se uoyah 110100010303	11
Town Branch-West Fork White River 110100010404	9
Holman Creek 110100010606	5
lade Creek 110100010608	10
Clifty Creek-War Eagle Creek 110100010610	2
Beaver Lake-War Eagle Creek 110100010611	0
Roberts Creek-Beaver Lake 110100010701	7
Brush Creek-Beaver Lake 110100010702	1
Spanker Branch-Kings River 110100010904	--
Clabber Creek-Kings River 110100011106	--
Braswell Branch- ocum Creek 110100011306	--

3.5 Other Pasture Management Practices

The extent of the need for pasture management practices that address more locali ed issues, such as heavy use area protection, grassed waterways, and vegetated treatment areas and the need for pasture planting, is not known at the HUC12 sub-watershed scale. Therefore, implementation extent estimates are not calculated for the use of these practices to reduce pasture pollutant loss.

3.6 Poultry Operations

For estimating BMP costs, the number of poultry houses reported to the atural Resources Division for 2019 were used to calculate the units of poultry operation practices needed T. Went , atural Resources Division, personal communication, 5/12/2022 . ote that poultry house numbers by HUC12 sub-watershed were not provided for Madison County, so it is not possible to estimate practice extents for Category 1 sub-watersheds in Madison County. The following assumptions were used in estimating cost of implementing practices to reduce pollutant loads from poultry operations

- one of the evaluated practices are currently in use at the poultry houses in the Category 1 sub-watersheds.
- One of the following practices would be needed for every four poultry houses
  - waste storage facility,
  - filter strip or vegetated treatment area 0.3 acres ,

- One roof runoff structure would be needed for each poultry house.
- Based on load reduction estimates in ppendix all poultry houses will need to be treated.

ssumed filter strip si e is based on si e of this practice funded through E IP and CSP in rkansas 2008-2020 R. Christianson, University of Illinois, personal communication 12/7/2021 . egetated treatment area is assumed to be the same si e none were funded through E IP or CSP 2008-2020 . Table 8 shows the estimated practice units for poultry operations.

Table 8. Units of poultry operation practices estimated for Upper White River Category 1 sub-watersheds.

Sub- atershed	u ber of oultr houses re orted 2019	oof runoff structure	Waste storage facilities	ilter stri or vegetated treat ent area, acres
Lake Se uoyah 110100010303	20	20	5	1.5
Town Branch-West Fork White River 110100010404	0	0	0	0
Holman Creek 110100010606	Unknown	Unknown	Unknown	Unknown
lade Creek 110100010608	Unknown	Unknown	Unknown	Unknown
Clifty Creek-War Eagle Creek 110100010610	Unknown	Unknown	Unknown	Unknown
Beaver Lake-War Eagle Creek 110100010611	18	18	5	1.5
Roberts Creek-Beaver Lake 110100010701	19	19	5	1.5
Brush Creek-Beaver Lake 110100010702	32	32	8	2.4
Spanker Branch-Kings River 110100010904	Unknown	Unknown	Unknown	Unknown
Clabber Creek-Kings River 110100011106	79	79	20	6.0
Braswell Branch- ocum Creek 110100011306	129	129	32	9.6

3.7 Restore Riparian uffers

Riparian buffers in need of restoration are assumed to be represented by the length of streambank associated with riparian areas in agricultural or development land covers as reported in StreamCat Hill, Weber, Leibowit , Olsen, Thornbrugh, 2016 . The length of streambank associated with riparian areas in agricultural land cover is calculated in Table 5. Table 9 shows the calculation of streambank length associated with riparian areas in development land cover. To estimate the units of riparian buffer restoration, we assumed that restored riparian buffers would be 30 meters wide. The estimated units of riparian buffer restoration were calculated by multiplying the sum of the lengths of streambank associated with agricultural land cover and with development land cover by 30 meters Table 10 . The portion of riparian buffer needing to be restored in the Category 1 sub-watersheds is 100%.

Table 9. Riparian development and associated streambank lengths in Upper White River Category 1 sub-watersheds.

Sub- atershed	**Develo ent ithin 100 eter buffer, s uare eters**	**Associated strea ban (area/100 eters), eters**
Lake Se uoyah 110100010303	803,792	8,038
Town Branch-West Fork White River 110100010404	3,792,822	37,928
Holman Creek 110100010606	1,381,136	13,811
lade Creek 110100010608	721,631	7,216
Clifty Creek-War Eagle Creek 110100010610	1,131,967	11,320
Beaver Lake-War Eagle Creek 110100010611	566,863	5,669
Roberts Creek-Beaver Lake 110100010701	754,018	7,540
Brush Creek-Beaver Lake 110100010702	1,162,101	11,621
Spanker Branch-Kings River 110100010904	797,189	7,972
Clabber Creek-Kings River 110100011106	923,895	9,239
Braswell Branch- ocum Creek 110100011306	892,645	8,926

Table 10. Units of riparian buffer restoration estimated for Upper White River Category 1 sub-watersheds.

Sub- atershed	Strea ban ith asture in ri arian area, eters	Strea ban ith develo ent in ri arian area, eters	Total ri arian length for restoration, eters	Area for ri arian restoration (total length 30 eters), s uare eters	Area for ri arian restoration, acres
Lake Se uoyah 110100010303	58,397	8,038	66,435	1,993,050	492
Town Branch-West Fork White River 110100010404	39,004	37,928	76,932	2,307,960	570
Holman Creek 110100010606	45,390	13,811	59,201	1,776,030	439
lade Creek 110100010608	54,748	7,216	61,964	1,858,920	459
Clifty Creek-War Eagle Creek 110100010610	73,415	11,320	84,735	2,542,050	628
Beaver Lake-War Eagle Creek 110100010611	30,216	5,669	35,885	1,076,550	266
Roberts Creek-Beaver Lake 110100010701	47,336	7,540	54,876	1,646,280	407
Brush Creek-Beaver Lake 110100010702	77,693	11,621	89,314	2,679,420	662
Spanker Branch-Kings River 110100010904	48,828	7,972	56,800	1,704,000	421
Clabber Creek-Kings River 110100011106	71,950	9,239	81,189	2,435,670	602
Braswell Branch- ocum Creek 110100011306	96,738	8,926	105,664	3,169,920	783

3. Stream an or Stream Restoration

WCRC has identified 15 priority streambank restoration sites in the Town Branch-West Fork White River sub-watershed, 11 sites on the West Fork White River, three sites on Town Branch, and one site on Cato Springs Branch RTI, 2023 . Based on information about previous restoration pro ects in the West Fork White River watershed, we estimate that each of the priority sites in the Town Branch-West Fork White River sub-watershed are 1,000 feet long. Therefore, we estimate 15,000 feet of streambank in this sub-watershed has been prioriti ed for restoration.

t this point, information about other locations needing streambank restoration is not available. However, it is expected that additional sites will be identified in other areas of the watershed, in the future.

3. Remediate ailing Septic Systems

The number of septic systems in use in the Category 1 sub-watersheds has been estimated and is listed in Table 11. We assume 3% of septic systems are failing and will need to be remediated. H2O arks provided information that was used to determine how many failing septic systems in the Category 1 sub-watersheds have already been remediated through their Septic Tank Remediation Program. The units of septic tank remediations still needed was estimated by multiplying the number of septic systems by 0.03 and subtracting the number that have already been remediated see Table 11 .

Table 11. Estimated number of septic systems needing remediation in the Upper White River Category 1 sub-watersheds.

Sub- atershed	sti ated nu ber of active se tic s ste s	sti ated nu ber of failing s ste s (3%)	u ber of s ste s re ediated	sti ated nu ber of s ste s needing re ediation
Lake Se uoyah 110100010303	370	11	2	9
Town Branch-West Fork White River 110100010404	349	10	4	6
Holman Creek 110100010606	158	5	1	4
lade Creek 110100010608	167	5	1	4
Clifty Creek-War Eagle Creek 110100010610	177	5	0	5
Beaver Lake-War Eagle Creek 110100010611	267	8	1	7
Roberts Creek-Beaver Lake 110100010701	911	27	4	23
Brush Creek-Beaver Lake 110100010702	370	11	0	11
Spanker Branch-Kings River 110100010904	199	6	0	6
Clabber Creek-Kings River 110100011106	347	10	2	8
Braswell Branch- ocum Creek 110100011306	212	6	2	4

4.0 OST ESTIMATES

Cost estimate calculations are discussed in the following sub-sections. Low impact development cost estimates were calculated using an online tool. Cost estimates for other BMPs were calculated by multiplying the estimated source extent by the estimated cost per unit of practice.

4.1 Low Impact De elopment

The C T reen alues Stormwater Management Calculator was used to estimate example costs for implementing green infrastructure in the three sub-watersheds with the largest percentages of developed land, and the largest percentage of pollutant loads from developed land Town Branch-West Fork White River, Holman Creek, and Roberts Creek-Beaver Lake. Table 12 lists the 2019 LCD developed area for these three sub-watersheds. The impervious area was estimated by summing the different developed area classes by an assumed percentage impervious area. The percent impervious area for each developed area class was set to a value close to the midrange of the range of impervious area percentages for each class 10% of the developed open space class, 35% of the low intensity developed class, 65% of the medium intensity developed class, and 90% of the high intensity developed class Multi-resolution Land Characteristics Consortium, n.d. .

Table 12. Developed land cover areas for selected Category 1 sub-watersheds.

Land cover class	To n ranch-West or White iver (110100010404)	ol an Cree (110100010606)	oberts Cree - eaver La e (110100010701)
Developed, open space, acres	1,849	1,057	1,206
Developed, low intensity, acres	1,964	664	659
Developed, medium intensity, acres	1,636	308	236
Developed, high intensity, acres	710	94	19
Total developed, acres	6,159	2,123	2,120
Estimated impervious area, acres	2,504	613	520

4.1.1 Town ranch West or White Ri er

Inputs to the C T reen alues Stormwater Management Calculator for the Town Branch-West Fork White River sub-watershed were as follows. The location for rainfall data was set to Fayetteville, R average annual rainfall of 35.63 inches . The default volume capacity goal of 0.5 inches of rainfall 4,542,945 cubic feet was used to determine units of practices. Units of practices were selected that either achieved 100% of the volume capacity goal or were the maximum possible. Based on aerial imagery, the following assumptions were made about the developed areas of the Town Branch-West Fork White River sub-watershed in setting up the calculator

- One-third of the impervious area is streets,
- One-third of the impervious area is parking,
- One-sixth of the impervious area is flat-roofed buildings,
- One-sixth of the impervious area is pitched roof buildings,
- Sixty percent of the developed area is lawn, and
- round 19% of the developed area is shrubs or trees.

Table 13 summari es results from the C T reen alues Stormwater Management Calculator for the Town Branch-West Fork White River sub-watershed. Print outs of the calculator results for this sub-watershed are provided as ttachment 1.

Table 13. Example estimated costs for implementing green infrastructure practices in developed areas of Town Branch-West Fork White River sub-watershed.

Practice	nits of ractice	Portion of target volu e reduced	nitial cost	Annual aintenance cost	Life cost
Permeable pavement parking	21,800,000 s uare feet	100%	189,224,000	436,000	273,206,890
Bioswales	8,015,000 feet	100%	140,903,700	2,083,900	256,609,913
Rain garden	5,380,000 s uare feet	100%	32,656,600	2,205,800	75,337,701
reen roofs	18,164,520 s uare feet	76.6%	217,610,949.60	13,623,390	481,216,573

This is the entire assumed area of flat roofs in the sub-watershed.

4.1.2 olman ree

Inputs to the C T reen alues Stormwater Management Calculator for the Holman Creek sub-watershed were as follows. The location for rainfall data was set to Huntsville, R average annual rainfall of 36.88 inches . The default volume capacity goal of 0.5 inches of rainfall 1,112,595 cubic feet was used to determine units of practices. Units of practices were selected that either achieved 100% of the volume capacity goal or were the maximum possible. Based on aerial imagery, the following assumptions were made about the developed areas of the Holman Creek sub-watershed in setting up the calculator

- One-third of the impervious area is streets,
- One-third of the impervious area is parking,
- One- uarter of the impervious area is flat-roofed buildings,
- round 8% of the impervious area is pitched roof buildings,
- Forty percent of the developed area is lawn, and
- round 31% of the developed area is shrubs or trees.

Table 14 summari es results from the C T reen alues Stormwater Management Calculator for the Holman creek sub-watershed. Print outs of the calculator results for this sub-watershed are provided as ttachment 2.

Table 14. Example estimated costs for implementing green infrastructure practices in developed areas of Holman Creek sub-watershed.

Practice	nits of ractice	Portion of target volu e reduced	nitial cost	Annual aintenance cost	Life cost
Permeable pavement parking	5,340,000 s uare feet	100%	46,351,200	106,800	66,923,156
Bioswales	1,963,000 feet	100%	34,509,540	510,380	62,847,818
Rain garden	1,317,000 s uare feet	100%	7,994,190	539,970	18,442,333
reen roofs	5,805,000 s uare feet	100%	69,543,900	4,353,750	153,786,734

4.1.3 Ro erts ree ea er La e

Inputs to the C T reen alues Stormwater Management Calculator for Roberts Creek-Beaver Lake sub-watershed were as follows. The location for rainfall data was set to Fayetteville, R average annual rainfall of 35.62 inches . The default volume capacity goal of 0.5 inches of rainfall 941,985 cubic feet was used to determine units of practices. Units of practices were selected that either achieved 100% of the volume capacity goal or were the maximum possible. Based on aerial imagery, the following assumptions were made about the developed areas of the Roberts Creek-Beaver Lake sub-watershed in setting up the calculator

- Forty percent of the impervious area is streets,
- ineteen percent of the impervious area is parking,
- One percent of the impervious area is flat-roofed buildings,
- Forty percent of the impervious area is pitched roof buildings,
- Sixty percent of the developed area is lawn, and
- round 15% of the developed area is shrubs or trees.

Table 15 summari es results from the C T reen alues Stormwater Management Calculator for the Roberts Creek-Beaver Lake sub-watershed. Print outs of the calculator results for this sub-watershed are provided as ttachment 3.

Table 15. Example estimated costs for implementing green infrastructure practices in developed areas of Roberts Creek-Beaver Lake sub-watershed.

Practice	nits of ractice	Portion of target volu e reduced	nitial cost	Annual aintenance cost	Life cost
Permeable pavement parking	4,312,440 s uare feet	95.4%	37,431,979.20	86,248.80	54,045,336
Bioswales	1,662,000 feet	100%	29,217,960	432,120	53,210,939
Rain garden	1,115,000 s uare feet	100%	6,768,050	457,150	15,613,669

This is the total estimated parking area for the sub-watershed

4.2 Other Practices

Tables 16 through 26 show cost estimate calculations for each of the Category 1 sub-watersheds for BMP practice implementation. Maintenance costs are not included. The costs presented represent a potential maximum cost, based on assuming that all the target pollutants come from the treated source, and all the available source is treated using a single BMP. variety of BMPs is likely to be implemented. The information presented here is most useful for comparing the cost of using different practices to improve water uality. Implementation costs are affected by a wide range of factors. ctual implementation costs may be different from what is presented here. Estimated costs are rounded to two significant digits.

Table 16. Estimated costs for implementing practices in the Lake Se uoyah sub-watershed.

Practices	nits	nits to i le ent	Cost er unit	sti ated cost
ccess control Fence	foot	191,592	4.00	770,000
ccess control Stream crossing	crossing	58	3,000.00	170,000
Headwater ponds	pond	11	5,000.00	55,000
Pasture aeration	acre	3,113	2.00	6,200
Prescribed gra ing	acre	5,445	40.00	220,000
Remediate failing septic systems	system	9	13,000.00	120,000
Restore forested riparian buffer	acre	493	800.00	390,000
Restore herbaceous riparian buffer	acre	493	280.00	140,000
Roof runoff structure	house	20	7,000.00	140,000
Waste storage	each	5	19,000.00	95,000
Watering facility	facility	116	1,200.00	140,000

Table 17. Estimated costs for implementing practices in the Town Branch-West Fork White River sub-watershed.

Practices	nits	nits to i le ent	Cost er unit	sti ated cost
ccess control Fence	foot	127,966	4.00	510,000
ccess control Stream crossing	crossing	39	3,000.00	120,000
Bank stabili ation	foot	15,000	160.00	2,400,000
Headwater ponds	pond	9	5,000.00	45,000
Pasture aeration	acre	1,728	2.00	3,000
Prescribed gra ing	acre	3,025	40.00	120,000
Remediate failing septic systems	system	6	13,000.00	78,000
Restore forested riparian buffer	acre	570	800.00	460,000
Restore herbaceous riparian buffer	acre	570	280.00	160,000
Stream restoration	foot	15,000	500.00	7,500,000
Watering facility	facility	78	1,200.00	94,000

Table 17. Estimated costs for implementing practices in the Town Branch-West Fork White River sub-watershed continued .

Table 18. Estimated costs for implementing practices in the Holman Creek sub-watershed.

Practices	nits	nits to i le ent	Cost er unit	sti ated cost
ccess control Fence	foot	148916	4.00	600,000
ccess control Stream crossing	crossing	45	3,000.00	140,000
Headwater ponds	pond	5	5,000.00	25,000
Pasture aeration	acre	2,751	2.00	5,500
Prescribed gra ing	acre	5,191	40.00	210,000
Remediate failing septic systems	system	4	13,000.00	52,000
Restore forested riparian buffer	acre	439	800.00	350,000
Restore herbaceous riparian buffer	acre	439	280.00	120,000
Watering facility	facility	90	1,200.00	110,000

Table 19. Estimated costs for implementing practices in the lade Creek sub-watershed.

Practices	nits	nits to i le ent	Cost er unit	sti ated cost
ccess control Fence	foot	179,620	4.00	720,000
ccess control Stream crossing	crossing	55	3,000.00	160,000
Headwater ponds	pond	10	5,000.00	50,000
Pasture aeration	acre	3,656	2.00	7,300
Prescribed gra ing	acre	6,802	40.00	270,000
Remediate failing septic systems	system	4	13,000.00	52,000
Restore forested riparian buffer	acre	459	800.00	370,000
Restore herbaceous riparian buffer	acre	459	280.00	130,000
Watering facility	facility	110	1,200.00	130,000

Table 20. Estimated costs for implementing practices in the Clifty Creek-War Eagle Creek sub-watershed.

Practices	nits	nits to i le ent	Cost er unit	sti ated cost
ccess control Fence	foot	240,863	4.00	960,000
ccess control Stream crossing	crossing	73	3,000.00	220,000
Headwater ponds	pond	2	5,000.00	10,000
Pasture aeration	acre	4,490	2.00	9,000
Prescribed gra ing	acre	8,413	40.00	340,000
Remediate failing septic systems	system	5	13,000.00	65,000
Restore forested riparian buffer	acre	628	800.00	500,000
Restore herbaceous riparian buffer	acre	628	280.00	180,000
Watering facility	facility	146	1,200.00	180,000

Table 21. Estimated costs for implementing practices in the Beaver Lake-War Eagle Creek sub-watershed.

Practices	nits	nits to i le ent	Cost er unit	sti ated cost
ccess control Fence	foot	99,135	4.00	400,000
ccess control Stream crossing	crossing	30	3,000.00	90,000
Pasture aeration	acre	2,136	2.00	4,300
Prescribed gra ing	acre	3,828	40.00	150,000
Remediate failing septic systems	system	7	13,000.00	91,000
Restore forested riparian buffer	acre	266	800.00	210,000
Restore herbaceous riparian buffer	acre	266	280.00	74,000
Roof runoff structure	house	18	7,000.00	130,000
Waste storage	each	5	19,000.00	95,000
Watering facility	facility	60	1,200.00	72,000

Table 22. Estimated costs for implementing practices in the Roberts Creek-Beaver Lake sub-watershed.

Practices	nits	nits to i le ent	Cost er unit	sti ated cost
ccess control Fence	foot	155,302	4.00	620,000
ccess control Stream crossing	crossing	47	3,000.00	140,000
Headwater ponds	pond	7	5,000.00	35,000
Pasture aeration	acre	407	2.00	810
Prescribed gra ing	acre	6,292	40.00	250,000
Remediate failing septic systems	system	7	13,000.00	91,000
Restore forested riparian buffer	acre	407	800.00	330,000
Restore herbaceous riparian buffer	acre	407	280.00	110,000
Roof runoff structure	house	19	7,000.00	130,000
Waste storage	each	5	19,000.00	95,000
Watering facility	facility	94	1,200.00	110,000

Table 23. Estimated costs for implementing practices in the Brush Creek-Beaver Lake sub-watershed.

Practices	nits	nits to i le ent	Cost er unit	sti ated cost
ccess control Fence	foot	254,899	4.00	1,000,000
ccess control Stream crossing	crossing	78	3,000.00	230,000
Headwater ponds	pond	1	5,000.00	5,000
Pasture aeration	acre	5,842	2.00	12,000
Prescribed gra ing	acre	10,500	40.00	420,000
Remediate failing septic systems	system	11	13,000.00	140,000
Restore forested riparian buffer	acre	662	800.00	530,000
Restore herbaceous riparian buffer	acre	662	280.00	190,000
Roof runoff structure	house	32	7,000.00	220,000
Waste storage	each	8	19,000.00	150,000
Watering facility	facility	156	1,200.00	190,000

Table 24. Estimated costs for implementing practices in the Spanker Branch-Kings River sub-watershed.

Practices	nits	nits to i le ent	Cost er unit	sti ated cost
ccess control Fence	foot	160,197	4.00	640,000
ccess control Stream crossing	crossing	49	3,000.00	150,000
Prescribed gra ing	acre	5,728	40.00	230,000
Remediate failing septic systems	system	6	13,000.00	78,000
Restore forested riparian buffer	acre	421	800.00	340,000
Restore herbaceous riparian buffer	acre	421	280.00	120,000
Watering facility	facility	98	1,200.00	120,000

Table 25. Estimated costs for implementing practices in the Clabber Creek-Kings River sub-watershed.

Practices	nits	nits to i le ent	Cost er unit	sti ated cost
ccess control Fence	foot	236,056	4.00	940,000
ccess control Stream crossing	crossing	72	3,000.00	220,000
Prescribed gra ing	acre	9,800	40.00	390,000
Remediate failing septic systems	system	8	13,000.00	100,000
Restore forested riparian buffer	acre	602	800.00	480,000
Restore herbaceous riparian buffer	acre	602	280.00	170,000
Waste storage	each	20	19,000.00	380,000
Watering facility	facility	144	1,200.00	170,000

Table 26. Estimated costs for implementing practices in the Braswell Branch- ocum Creek sub-watershed.

Practices	nits	nits to i le ent	Cost er unit	sti ated cost
ccess control Fence	foot	317,382	4.00	1,300,000
ccess control Stream crossing	crossing	97	3,000.00	290,000
Pasture aeration	acre	5,825	2.00	12,000
Prescribed gra ing	acre	10,780	40.00	430,000
Remediate failing septic systems	system	4	13,000.00	52,000
Restore forested riparian buffer	acre	783	800.00	630,000
Restore herbaceous riparian buffer	acre	783	280.00	220,000
Waste storage	each	32	19,000.00	610,000
Watering facility	facility	194	1,200.00	230,000

APPENDIX Q

Assistance Contact Information

Organization	Website	Office	Phone Number	Local Contact Information
Arkansas Department of Agriculture Natural Resources Division	agriculture.arkansas.gov/natural-resources/divisions/water-management/nonpoint-source-management	Nonpoint Source Program	(501) 682-3902	1 Natural Resources Drive, Little Rock, AR 72205
Arkansas Game and Fish Commission	agfc.com	Northwest Regional Office	(833) 345-0325	455 Dam Site Road, Eureka Springs, AR 72631
Cooperative Extension Service	uaex.uada.edu	Little Rock	(501) 671-2000	2301 S. University Ave, Little Rock, AR 72204
		Benton County	(479) 271-1060	1204 SW 14th St, Bentonville, AR 72712
		Washington County	(479) 444-1755	2536 N. McConnell Ave, Fayetteville, AR 72704
		Madison County	(479) 738-6000	100 E. Main St, Huntsville, AR 72740
		Carroll County	(870) 423-2958	909 W. Trimble Ave, Berryville, AR 72616
County Conservation Districts	conservation.ok.gov	Benton County	(479) 271-1060	1204 SW 14th St, Bentonville, AR 72712
		Washington County	(479) 444-1755	2536 N. McConnell Ave, Fayetteville, AR 72704
		Madison County	(479)0738-6000	100 E. Main St, Huntsville, AR 72740
		Carroll County	((870) 423-2958	909 W. Trimble Ave, Berryville, AR 72616
EPA	epa.gov	Region 6 Office	(202) 564-4700	1201 Elm Street, Dallas, TX 75270
Farm Services Agency	fsa.usda.gov	Benton County	(479) 273-2622	2504 SE 14th St, Bentonville, AR 72712
		Washington County	(479) 442-4160	2536 N. McConnell Ave, Fayetteville, AR 72704
		Madison County	(479) 738-6000	100 E. Main St, Huntsville, AR 72740
		Carroll County	(870) 423-2958	909 W. Trimble Ave, Berryville, AR 72616
NRCS	nrcs.usda.gov	Benton County	(479) 273-2622	2504 SE 14th St, Bentonville, AR 72712
		Washington County	(479) 442-4160	2536 N. McConnell Ave, Fayetteville, AR 72704
		Madison County	(479) 738-6000	100 E. Main St, Huntsville, AR 72740
		Carroll County	(870) 423-2958	909 W. Trimble Ave, Berryville, AR 72616
National Center for Appropriate Technology	attra.ncat.org	Southeast Office	(479) 442-9824	20 E. Spring St., Fayetteville, AR 72701
Sustainable Agriculture Research and Education	southern.sare.org	State Coordinator	(501) 671-2229	University of Arkansas, Fayetteville, AR 72701
US Fish and Wildlife Service	fws.gov	Arkansas Ecological Services Field Office	(800) 344-9453	110 S. Amity Road, Suite 300, Conway, AR 72032
USDA Wildlife Services	aphis.usda.gov	Arkansas Office	(202) 720-2791	2301 S. University Ave, Little Rock, AR 72204
The Nature Conservancy	nature.org	Arkansas Field Office	(703) 841-5300	601 N. University Ave, Little Rock, AR 72205
H2Ozarks	h2ozarks.org	Main Office	(417) 739-5001	1800 S. 8th St, Rogers, AR 72756
Northwest Arkansas Land Trust	nwalandtrust.org	Main Office	(479) 966-4666	1725 S. Smokehouse Trail, Fayetteville, AR 72701
Beaver Water District	bwdh2o.org	Main Office	(479) 756-3651	301 N. Primrose Road, Lowell, AR 72745
Beaver Watershed Alliance	beaverwatershedalliance.org	Main Office	(479) 750-8007	162 Doolin Drive, Elkins, AR 72727
Watershed Conservation Resource Center	watershedconservation.org	Main Office	(479) 444-1916	380 W. Rock St, Fayetteville, AR 72701

Note: This information is valid as of October 2024