KINGS RIVER
WATERSHED PARTNERSHIP

Watershed Management Plan

For the

Kings River Watershed
Northwest Arkansas & Southwest Missouri
HUC: 1101001



Photos courtesy of Sam Davis

August 2006

Kings River Watershed Partnership

An Arkansas Non-Profit Organization

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The Kings River Watershed Partnership and watershed planner Shawna Miller sincerely thank the many local citizens that took part in the Roundtable planning meetings. The patience, open-mindedness, and forward vision of these individuals will be the basis for the success of this watershed plan.

Executive Summary

The Kings River Watershed is located in northwestern Arkansas and southwestern Missouri and makes up a portion of the Upper White River Basin. The Kings River is the third largest tributary to Table Rock Lake in Missouri. This river drains approximately 591 square miles of a predominantly rural land area. There is only one incorporated city located entirely within the watershed boundaries, that being Berryville, Arkansas.

The lower reach of Osage Creek, the largest tributary of the Kings River, has been placed on the final 2002 Arkansas 303(d) list for not supporting its aquatic life designated use with the primary cause being total phosphorus. The draft TMDL written for this reach found that the primary source of elevated phosphorus concentrations is the City of Berryville wastewater treatment plant. The Kings River and all of its other tributaries are considered to be supporting their designated uses. However, the Kings River flows into Table Rock Lake, which is considered to be impaired due to excessive levels of nutrients (primarily phosphorus). The Arkansas Unified Watershed Assessment selected the Beaver Reservoir watershed, which includes the Kings River watershed, as the top priority for the implementation of watershed restoration practices.

The Kings River Watershed Partnership (KRWP), a nonprofit group committed to protecting the environmental and economic components of the watershed through a locally based effort, is striving to further scientific study, education, and the cooperation of all users of the Kings River and its tributaries. In 2004, the KRWP partnered with the Upper White River Basin Foundation to write a watershed plan for the Kings River Watershed. The KRWP held a series of 15 planning meetings and involved over 60 people in a two year process to determine water quality concerns, recommend restoration action strategies, and pin-point funding and partnering possibilities.

This watershed plan is meant to outline recommended educational curriculum, monitoring programs, and voluntary land use management measures coupled with the necessary scientific/technical analyses and cost estimates. This plan will primarily be used by the KRWP to direct and prioritize its activities to improve water quality in the most economically efficient and environmentally effective way possible. It is hoped that other partners and stakeholder groups within the watershed will implement the plan's recommended actions and take part in the activities of the KRWP as outlined in the plan.

Identified concerns include (listed in no particular order):

1. Sediment
2. Nutrients (primarily phosphorus)
3. Pesticides, Herbicides, and other Toxic Substances
4. Bacteria and other Pathogens
5. Habitat alterations
6. Illegal dumping
7. Education
8. Property Rights

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A. Introduction

1. Kings River Watershed Partnership

The Kings River Watershed Partnership (KRWP) had its beginnings in 2001 when a group of concerned local citizens met to discuss the water resources of the Kings River Watershed. This group, committed to protecting the environmental and economic components of the watershed through a locally based effort, is striving to further scientific study, education, and the cooperation of all users of the Kings River and its tributaries. To this end, the group adopted their name, developed by-laws, and annually elects a Board of Directors who represent a wide array of interests. The Partnership became a certified IRS 501 (c)(3) non-profit organization in November of 2004 and is entirely funded through membership subscriptions, donations, and grants. The KRWP has not and will not lobby for policy changes, promote watershed regulations, or promote mandatory land use practices for the Kings River Watershed (KRW).

In 2003 the focus of the KRWP shifted towards the creation of a Kings River Watershed Plan. The KRWP believes that a locally prepared watershed plan will improve and protect water quality through the encouragement and support of self-implementation of better management practices from all stakeholder groups in the watershed. This watershed plan is meant to outline recommended educational curriculum, monitoring programs, and voluntary land use management measures coupled with supporting scientific/technical analyses and cost estimates. This plan will primarily be used by the KRWP to direct and prioritize its activities to improve water quality in the most economically efficient and environmentally effective way possible. It is hoped that other partners and stakeholder groups within the watershed will implement the plan's recommended actions and take part in the activities of the KRWP as outlined in the plan.

The Kings River Watershed Partnership is a cooperative effort, organized exclusively for charitable, scientific, and educational purposes; more specifically to protect the health, purity, and economic viability of the Kings River Watershed, now and for future generations.

Mission Statement of the KRWP

The funding for the creation of this watershed plan was provided primarily by the Upper White River Basin Foundation, a watershed group established to improve the quality of surface water in the Upper White River Basin by using a process of education for decision-makers, public awareness, and research. The Upper White River Basin Foundation received an EPA Watershed Initiative grant for this and other projects. The Kings River Watershed is part of the greater Upper White River Basin and its water flows directly into Table Rock Lake in Missouri. The Watershed Planner worked under the direct supervision of the Kings River Watershed Partnership Board of Directors.

The Kings River Watershed Partnership reached beyond its own membership into the community at large to gain input for the watershed plan. After a full year of newspaper

articles, one on one phone calls, and community presentations, the Partnership facilitated the creation of the "Kings Roundtable" in June 2005. This Roundtable involved more than sixty people and a total of fifteen planning meetings centered around the topics of Agriculture & Rural Land Issues, Onsite Waste Treatment, Education, and Urbanizing Issues. The participants represented six counties, city and county government, landowners, educators, Farm Bureau members, utility providers, recreationists, academia, real estate agents, state agencies, property rights representatives, and many more.

2. Current Regulatory Status

The 303(d) list, otherwise known as the impaired waterbodies list, is derived from Section 303 of the Clean Water Act, which directs the Environmental Protection Agency to list all the waters within the United States that are impaired by point and/or non-point source pollution. Once a waterbody segment is added to the 303(d) list, the State has 13 years to either complete a Total Maximum Daily Load (TMDL) for the listed parameter, or develop additional data or revise the water quality standards that will result in the de-listing of the waterbody segment. A TMDL is a determination of the total amount of a substance that can be present in a waterbody without adversely affecting the designated uses of the waterbody. For example, a stream that is designated as impaired because of excessive mercury would necessitate a TMDL which specifies the stream's total mercury load, allowable mercury load, sources of mercury, and reductions needed from both point and non-point sources to reach the water quality standards for mercury.

2.1 Arkansas Rules and Regulations

The Arkansas Department of Environmental Quality (ADEQ) is responsible for generating a list of impaired waterbodies on a biennial basis. The state of Arkansas considers a stream reach to be impaired if it is not meeting the water quality standards for its designated uses. The Environmental Protection Agency (EPA) is charged with evaluating the list for compliance with federal regulations. The EPA has the authority to approve or disapprove the list and make additions or other changes. Arkansas' most recent impaired waterbodies list, the proposed 2004 303(d) list, has 192 stream segments listed. Category 5a (truly impaired; requires a TMDL for the listed parameter) of the proposed list has a total of 59 stream segments, totaling approximately 1009.9 stream miles. In addition, ten lakes are listed, totaling approximately 5530 lake acres.

Refer to Section B.7. in Appendix for complete Arkansas 2004 303(d) list.

The designated uses for the Arkansas portion of the Kings River Watershed are primary contact recreation, secondary contact recreation, domestic, industrial, agricultural water supply, perennial fishery (for streams with a drainage areas of at least 10 square miles), extraordinary resource waters, and natural and scenic waterway [Madison County portion only]. (AP&EC 2004a)

ADEQ does not consider any stream reaches in the Arkansas portion of the Kings River Watershed to be truly impaired (i.e. they consider all stream reaches to be supporting their designated uses), but it has acknowledged that phosphorus levels are elevated downstream of Berryville during low flow conditions (ADEQ 2002). Arkansas' proposed 2004 303(d) list includes Reach 037, a 19.1 mile stretch of the main stem of the Kings River, The proposed list states that this reach is not supporting the designated uses for agriculture and industry water use because of Total Dissolved Solids with the source being the municipal wastewater treatment plant in Berryville, Arkansas. However, this reach was placed in category 5b – waters not attaining standards, but ones that will be de-listed with the adoption of current Regulation 2 revisions. Expected revisions include changes in the testing methods for Total Dissolved Solids.

Although ADEQ's proposed 2002 303(d) list did not include any reaches within the Kings River Watershed, EPA Region 6 overruled ADEQ and added Reach 045L, the lower portion of Osage Creek (downstream of Berryville), to the Final Arkansas 2002 303(d) list as impaired due to total phosphorus (EPA 2003). EPA Region 6 is currently in the process of approving a TMDL for this portion of Osage Creek.

Extraordinary Resource Waters Designation

The entire main stem of the Kings River is designated as an Extraordinary Resource Waterway under ADEQ Regulation No. 2 (Approved April 2004). The Extraordinary Resource Waterways Designation is a special use designation made by the Arkansas Pollution Control and Ecology Commission. About 16% of Arkansas' total stream miles have been designated as ERWs.

Restrictions on ERWs include:

- No significant physical alterations of in-stream habitat
- Bacteria concentrations must meet swimmable (primary contact) standards year-round
- No commercial gravel mining is allowed below the high water mark
- All point source discharges must meet "advanced treatment" technology
- The highest level of pollution prevention is required for new road and bridge construction, major pipeline construction, and solid waste disposal sites.

Refer to Section B.2. in Appendix for complete rules concerning gravel mining.

ON THE WEB: For more information about ERWs, visit www.adeq.state.ar.us/water/branch_planning/pdfs/wqs_erw_fact_sheet_010928.pdf

The Madison County portion of the Kings River is also a designated Natural and Scenic Riverway.

Nutrient Surplus Area

Eight watersheds in Arkansas, including the Upper White River Basin, have been designated as nutrient surplus areas by the Arkansas Natural Resources Commission (ANRC), formerly the Arkansas Soil and Water Conservation Commission. These areas have been so designated because the application of more phosphorus or nitrogen could harm water quality due to already high levels of nutrients. The primary goal of Acts 1059, 1060, and 1061 of 2003 is to maintain the benefits derived from the wise use of poultry litter, commercial fertilizers, and other soil nutrients while avoiding unwanted effects from excess nutrient applications on the waters within the State. The rules in these Acts went into effect on January 1, 2006. These Acts give ANRC the authority to impose penalties for violations.

Refer to Section B.5. of the Appendix for complete rules governing this program.

ON THE WEB: A detailed description of these Acts can be found at the following websites.

http://www.arkleg.state.ar.us/ftproot/acts/2003/public/act1059.pdf
http://www.arkleg.state.ar.us/ftproot/acts/2003/public/act1060.pdf
http://www.arkleg.state.ar.us/ftproot/acts/2003/public/act1061.pdf

2.2 Missouri Rules and Regulations

The Missouri Department of Natural Resources (MDNR) considers the portion of the Kings River in Missouri to be a part of Table Rock Lake, which has designated uses of livestock and wildlife watering, protection of warm water aquatic life and human health/fish consumption, whole body contact recreation, and boating and canoeing (MDNR 2004). MDNR has determined Table Rock Lake (including the Kings River arm of the lake) to be impaired for nutrients (primarily phosphorus) and therefore included the whole lake on the Missouri 2002 303(d) list (MDNR 2005). Missouri has not yet written a TMDL for Table Rock Lake. MDNR has expressed concerns about the loading of phosphorus to Table Rock Lake from the Kings River (EPA 2003).

Refer to Section B.10. in Appendix for Missouri Water Quality Standards.

3. Subject Watershed Description

The Kings River Watershed (HUC code 11010001) is located in northwestern Arkansas and southwestern Missouri and makes up a portion of the Upper White River Basin Watershed, which is itself a sub-basin of the Mississippi River Watershed. The Kings River Watershed drainage area totals 591 square miles (378,240 acres). 96% of the Kings River Watershed lies within Arkansas, while the remaining 4% lies in Missouri. Arkansas counties located in the watershed are Carroll, Madison, Newton, and Boone. Missouri counties located in the watershed are Barry and Stone.

This watershed has only one incorporated city located entirely within its boundaries, that being Berryville, Arkansas. A small portion of the southeastern corner of Eureka Springs is also located within the watershed boundaries. Other communities include Marble, Kingston, Osage, Rudd, Metalton, and Grandview.

The Kings River is the main stream that flows through this watershed, flowing generally northward for nearly ninety miles from the Boston Mountains in Arkansas to the White River arm of Table Rock Lake on the Missouri-Arkansas border. It is the last undamned major tributary of the White River and as such represents a unique eco-system. The largest tributary of the Kings River is Osage Creek, which is the receiving waterbody for effluent from the Berryville wastewater treatment facility. Other tributaries of the Kings include Piney Creek, Keels Creek, Dry Fork Creek, Warmfork Creek, Pine Creek, Felkins Creek, and Sweden Creek.

The Kings River drains two very different subsections of the Ozark Ecoregion. Headwaters of the Kings River drain the Boston Mountain subregion, which is characterized by rugged topography, narrow divides separating steep-sided valleys, and high stream gradients. Topographic relief is as much as 1,000 feet in some areas of the Boston Mountains. The middle and lower segments of the Kings drain portions of the Springfield Plateau. This subregion is characterized by gently rolling hills with localized ridges and steep slopes. Topographic relief in this area rarely exceeds 300 feet. (USGS 1995 & White 2001).

The Kings River is in a predominantly rural watershed and has only experienced heightened land use change over the past five to seven years. Current land use is approximately 69.4% forested, 29.1% pasture/hay/grass, and 0.6% urban. (FTN 2005)

4. Primary Areas of Concern within the Kings River Watershed

The lower reach of Osage Creek, the largest tributary of the Kings River, has been placed on the final 2002 Arkansas 303(d) list for not supporting its aquatic life designated use with the primary cause being total phosphorus. The draft TMDL written for this reach found that the primary source of elevated phosphorus concentrations is the City of Berryville wastewater treatment plant.

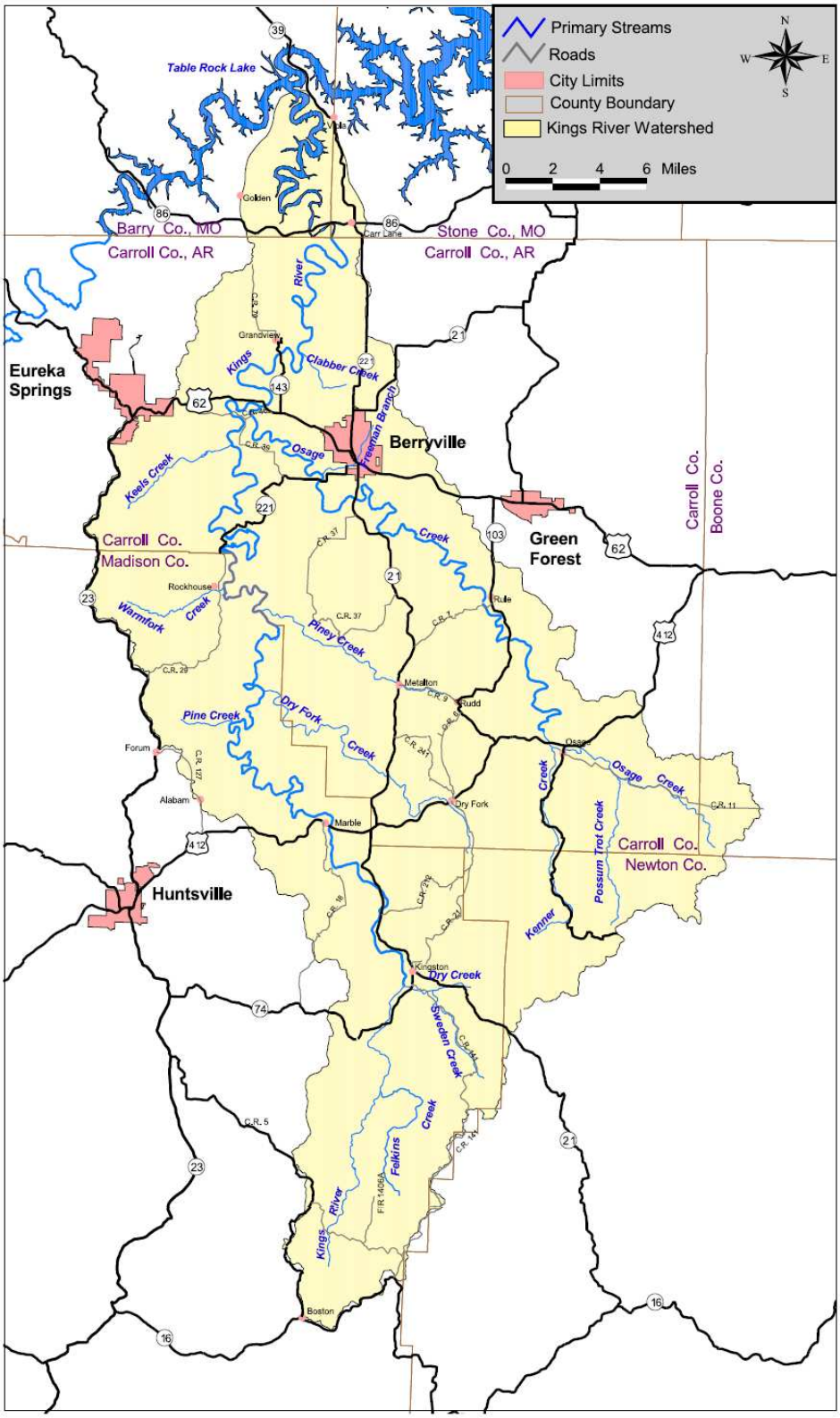
The Kings River and all of its other tributaries are considered to be supporting their designated uses. However, the Kings River flows into Table Rock Lake, which is considered to be impaired due to excessive levels of nutrients (primarily phosphorus). The Arkansas Unified Watershed Assessment selected the Beaver Reservoir watershed, which includes the Kings River watershed, as the top priority for the implementation of watershed restoration practices. Local stakeholders expressed concern over decreasing water quality at a series of public meetings. Identified concerns include (listed in no particular order):

1. Sediment
2. Nutrients (primarily phosphorus)
3. Pesticides, Herbicides, and other Toxic Substances
4. Bacteria and other Pathogens
5. Habitat alterations
6. Illegal dumping
7. Education
8. Property Rights

5. Purpose of this Document

The purpose of this document is to outline locally endorsed measures to improve and protect water quality through the encouragement and support of self-implementation of better management practices from all stakeholder groups in the watershed. This watershed plan recommends educational curriculae, monitoring programs, and voluntary land use management measures and provides scientific/technical analyses and cost estimates. This plan will primarily be used by the KRWP to direct and prioritize its activities to improve water quality in the most economically efficient and environmentally effective way possible. It is hoped that other partners and stakeholder groups within the watershed will implement the plan's recommended actions and take part in the activities of the KRWP as outlined in the plan. This watershed plan is intended to be ongoing and continually modified, evolving to balance restoration/conservation activities with changing conditions in the watershed.

Figure 1. Map of the Kings River Watershed



B. Kings River Watershed Characteristics

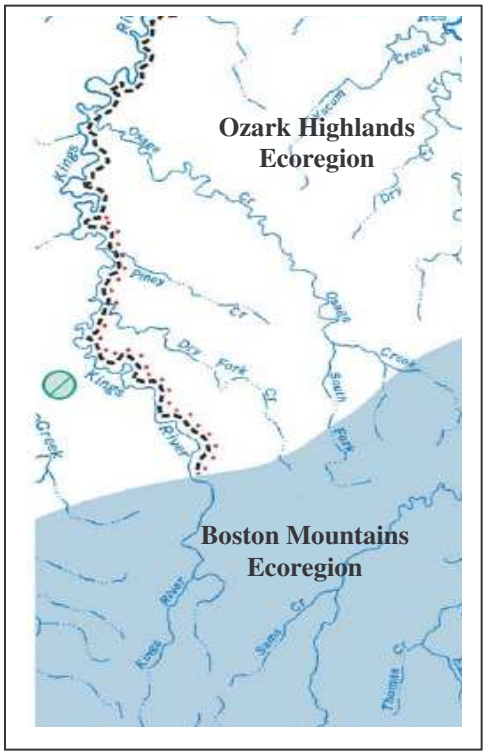
1. Location and Physical Setting

The Kings River Watershed is located in northwestern Arkansas and southwestern Missouri and makes up a portion of the Upper White River Basin, which is itself a sub-basin of the Mississippi River Watershed. 96% of the Kings River watershed lies within Arkansas, while the remaining 4% lies in Missouri. The watershed drainage area totals 591 square miles (378,240 acres). (FTN 2005)

The Kings River is the main stream that flows through this watershed, flowing generally northward for nearly ninety miles from the Boston Mountains in Arkansas to the White River Arm of Table Rock Lake on the Missouri-Arkansas border. The Kings River headwaters lie east of Boston in Madison County, Arkansas. It is from this same region the headwaters of the Buffalo River, the White River, and the Mulberry River originate The Kings continues through Madison County, passing through the communities of Kingston and Marble before skirting the eastern edge of the Madison County Wildlife Management Area. As it flows northward into Carroll County the Kings meets up with its largest tributary, Osage Creek, below the town of Berryville. The combined streams flow for approximately thirty miles into Missouri and a confluence with Table Rock Lake.

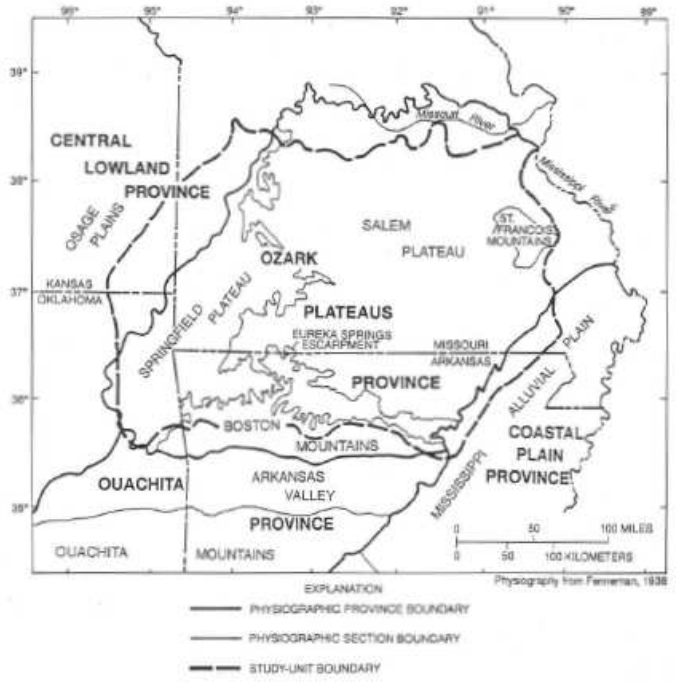
The Arkansas Pollution and Ecology Commission has divided the state into six ecoregions, each with its own regional water quality standards. Ecoregions are distinct areas defined by physical features such as geology and topography physiography, vegetation, climate, soils, land use, wildlife, and hydrology. According to this delineation of ecoregions, the Kings River Watershed is located in both the Boston Mountains Ecoregion and the Ozark Highlands Ecoregion.

Figure 2: Ecoregions of Kings River Watershed



2. Physiographic Setting

Figure 3. Ozark Mountains Physiographic Province



The Kings River Watershed is located entirely within the Ozark Mountains physiographic province. This province is characterized by rugged, flat-topped mountains; long, deep valleys; steep cliffs and ledges; and clear, spring-fed streams. This province is actually a series of plateaus, originally uplifted as a single unit with few folds and faults and severely dissected by many swift rivers, thus enhancing the ruggedness of the region. Local relief of more than 750 feet is not uncommon. Most of the area has been above sea level continuously for the nearly 300 million years since the Pennsylvanian Period. Elevations range from 250-2,450 feet (76-747 m) above sea level.

3. Landscape and Topography

Within Arkansas, the Ozark Mountains province is made of three distinct topographic subdivisions; the Salem Plateau, the Springfield Plateau, and the Boston Mountains. The Kings River is unique in that it drains portions of all three plateaus. The Salem Plateau lies primarily in the northeastern portion of the province, the Boston Mountains occupy the southern portion, and the Springfield Plateau extends in a narrow band between them. The Boston Mountains have the highest elevation, are the youngest geologically (Pennsylvanian Period of Paleozoic Era), and are the most extensively eroded (dissected), and therefore include the most rugged terrain of the Ozark Mountains in Arkansas. Gorges and ravines 500 to 1200 feet deep are common. The elevations of the Springfield Plateau are intermediate between those of other subdivisions and create gently rolling hills ranging from 1,000 – 1,500 feet above sea level. Solution valleys and caves are common. The Salem Plateau is the largest as well as the lowest of the Ozark Plateaus, ranging from 250 to 1,250 feet in elevation throughout its rolling landscape. It is situated mainly east and north of the Springfield Plateau. Because this plateau is relatively level or gently rolling, much of this area is being converted to pastures and residential building lots. The rugged terrain and steep slopes in the Boston Mountains results in streams with gradients of 20 feet per mile, whereas streams in shallower relief areas of the Springfield Plateau may only have average gradients of 3-5 feet per mile. (Robison 1988)

4. Geology

The Ozark Plateaus Province is underlain by a structural dome formed by a series of uplifts that have occurred since Precambrian time. Total uplift is approximately 5,000 ft . The dome is asymmetrical; the dip of sedimentary rocks is greater to the east-southeast than it is to the south, west, or north. For example, regional dip in southwestern Missouri is about 10 ft/mi whereas the dip to the south increases to 200 ft/mi on the southern flank of the Boston Mountains as a result of faulting in the area. (USGS 1995)

The different sub-regions through which the Kings River passes vary in age, geology, and parent material. The watershed consists of four major lithology types: sandstone (14%), shale (23%), limestone (39%), and dolomite (24%). The Boston Mountains, the southern portion of the watershed, is the youngest region and is primarily composed of Upper Mississippian and Pennsylvanian age sandstones, shales, and limestones. The areas with the most relief are composed mostly of the Pennsylvanian age Atoka Formation. This formation consists of sandstone parent material with alternating sandy shale and clay shale layers that cap the Boston Mountain bluff lines high above narrow stream valleys. The clean and very friable sands found in streambed outcroppings, such as the Everton Formation, are thought to be the source of the sandy river sediments found throughout the entire watershed. (White 2001)

Many of the rock formations of the Salem and Springfield Plateaus are carbonate rocks, sedimentary rocks formed by precipitation of calcium and magnesium and deposited in marine environments where they became compacted and cemented into limestone and dolomite. The northern half of the watershed is primarily composed of Mississippian age limestone and dolomite with random sandstone bluff caps and outcrops. The Boone Formation, found in the middle reaches of the watershed, consists primarily of limestone/chert parent material and can be found in the valley bottoms as the base on which most other formations sit. This formation makes up the largest percentage of geology in the watershed. Nearer Table Rock Lake, the Cotter and Jefferson City formations are abundant and are composed of dolomitic parent material. Limestone and dolomite are very similar in composition and are subject to solution by slightly acidic groundwater. Over millions of years the movement of rainwater through cracks and crevices in the rock has caused large amounts of the rock to dissolve, resulting in solution channels, caves, springs, and the development of sinkholes at the surface. These features are collectively known as karst rock units and are responsible for increased surface water and groundwater interaction. Consequently, karst areas are more vulnerable to groundwater contamination. (White 2001)

See Geology Map of Kings River Watershed in Appendix A Figure 4.

5. Climate

The Kings River Watershed has a temperate climate because of its mid-latitude, interior-continent location. (USGS 1995) The climate is characterized by mild winters, warm or hot summers, and fairly abundant rainfall. In winter the average temperature is 40 degrees F, and the average daily minimum temperature is 29 degrees F. In summer the average daily temperature is 77 degrees F and the average daily maximum temperature is 88 degrees. (USDA 1984) The seasonal variation in mean temperatures is closely related to seasonal solar radiation with greater regional contrasts in winter than in summer. Also, the polar front and jet stream normally pass through the study unit in winter causing increased temperature contrasts within the watershed. (USGS 1995)

The total annual rainfall is about 44 inches in the northern portion and 48 inches in the southern portion. (USGS 1995) Most rainfall usually occurs during the months of March through June although rainfall occurs throughout the year. Major weather systems normally move from west to east during the fall, winter, and spring seasons. In early spring, the watershed receives moisture-laden air from the Gulf of Mexico, which often results in thunderstorms, tornadoes, and intense rainfall. Thunderstorms are responsible for most of the severe weather in the study unit. The severe weather season extends from March through June, although thunderstorms can occur throughout the year and occasionally cause flash floods. (USGS 1995)

6. Hydrology

6.1. Surface water

Climate and precipitation have a direct effect on runoff and stream discharge within watersheds. Runoff can be defined as the water that drains from the land into stream or river channels after precipitation and is a function of precipitation amounts, topography, geology, soil moisture, and other factors. Mean annual runoff for a watershed is calculated by dividing the mean annual volume of water leaving the basin by the drainage area. Annual runoff for the Springfield Plateau physiographic unit ranges from 10-15 inches and slightly higher (14-20 inches) for the Boston Mountain unit. (White 2001) Magnitude, frequency, and duration of floods and high streamflows are affected by many factors, including drainage area, basin and channel slope, channel length, precipitation amount and intensity, vegetation, season, and flow-regulation activities or structures. (USGS 1995)

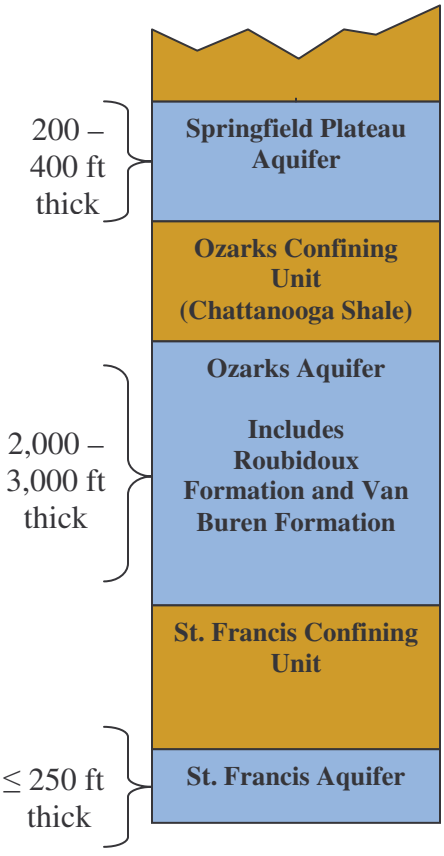
Duration of high streamflow, or discharge, and the time lag between onset of precipitation and the peak flow, generally will be shortest in small, steep watersheds. Therefore, the Boston Mountain tributaries remain at flood stage for shorter time intervals than the shallower Springfield Plateau tributaries. Streamflow can vary yearly and seasonally dependent upon the amount of precipitation. Minimum monthly streamflows typically occur in summer and fall, July through October and maximum monthly streamflows typically occur in spring, March through May.

These seasonal variations in streamflow are primarily the result of seasonal differences in evapotranspiration and precipitation. Potential evapotranspiration is much lower during October through March (about 6 to 10 in.) than in April through September (about 37 to 42 in.; Dugan and Peckenpaugh, 1985). Evapotranspiration probably has a greater effect than precipitation on low flow. For example, in northwestern Arkansas, January and February generally are the driest months, but streamflows generally are lowest in August and September when evapotranspiration rates are higher. (USGS 1995)

The only USGS fixed stream gauge (USGS Station #07050500) on the Kings River is just downstream of Berryville and the mean daily flow for the last 38 years at this station ranges from 242-6,390 cubic feet per second (cfs) with an average of 1,250 cfs. (White 2001)

6.2. Groundwater

Figure 4. Ozark Plateaus Aquifer System



Underlying most of northern Arkansas, including the Springfield and Salem Plateaus, is the Ozark Plateaus Aquifer System. This system is composed of three regional aquifers separated by two regional confining units. From shallowest to deepest the system includes the Springfield Plateau aquifer, the Ozarks confining unit, the Ozark aquifer, the St. Francois confining unit and the St. Francois aquifer. The majority of the ground water withdrawn in this region comes from either the Springfield Plateau aquifer or the Ozark aquifer because it is not economically feasible to drill wells into the extremely deep St. Francois aquifer. The Springfield aquifer is relatively thin (between 200 and 400 feet thick), has been highly dissected by erosion, and generally yields only small volumes of water (average yield of 5 gallons per minute). The principal source of groundwater in northern Arkansas is the thick, extensive, and productive Ozark aquifer. Within the Kings River Watershed this aquifer is between 2,000 to 3,000 feet thick. It is separated from the Springfield Plateau aquifer by the Ozarks confining unit, which consists of Chattanooga Shale. The Ozark aquifer is mainly composed of limestone and dolomite, but the most water-yielding strata in the aquifer are sandstones of the Roubidoux Formation and the Gunter Sandstone Member of the Van Buren Formation. These two productive sandstone beds are separated by the Gasconade Dolomite, a cherty dolomite that is about 100 feet thick. The Roubidoux Formation thickens eastward from 180 to 260 feet and its wells yield an average of 60 gallons per minute, with some wells yielding as much as 600 gallons per

minute. The Gunter Sandstone Member generally yields from 150 to 300 gallons per minute, with some wells yielding as much as 730 gallons per minute. (USGS HA 730-F)

The source of water that recharges the Ozark Plateaus aquifer system is precipitation that falls on the aquifer system where it is exposed at the land surface. As precipitation falls through the atmosphere, it absorbs small amounts of carbon dioxide to form a weak carbonic acid. Much more carbon dioxide is absorbed from plant roots and decaying organic matter in the soil as the precipitation infiltrates through the soil cover and percolates downward to underlying limestone and dolomite bedrock. Water that enters fractures dissolves parts of the adjoining bedrock, which slowly enlarges the fractures. As the fractures widen to form conduits, more water is funneled to the conduits that grow even larger. This dissolution of carbonate rocks results in a network of subsurface openings and an irregular rock surface characterized by sinkholes, caves, springs, and other types of openings, which are karst topography. Water that recharges an aquifer with a karstified surface either enters as direct runoff through sinkholes and sinking streams or enters by downward diffuse infiltration through shallow soil cover in the upland, interstream areas. (USGS HA 730-F)

Karst Topography - A network of subsurface openings and an irregular rock surface characterized by sinkholes, caves, springs, and other types of openings caused by the dissolution of carbonate rocks.

6.3. Interaction between surface 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. In general, interaction is less in the Boston Mountains and greater in the Springfield Plateau, and Salem Plateau. The amount of interaction generally can be characterized by flow-duration curves, dye-tracing and seepage-run studies, and ground-water level information. Streams with sustained dry-season flow (base flow) have a large ground-water contribution to streamflow and streams with little or no dry-season flow receive relatively little ground water and in some instances lose water to the ground-water system. Interaction between the surface- and ground-water flow systems is limited 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 Salem and Springfield Plateaus have relatively flat slopes, indicating a well-sustained flow from surface or ground-water storage. Streams in the Salem Plateau north of the Osage River generally have less base flow than streams south of the Osage River. Seasonal ground-water level fluctuations typically are greater in the Springfield and Salem Plateaus than in the Osage Plains, indicating that solution openings are well developed and that recharge occurs locally. Freiwald (1987), in a study of streamflow gain and loss for several streams in northern Arkansas, determined that for

most of the length of the studied streams in the Springfield and Salem Plateaus, these streams were gaining streamflow through ground-water contributions. Short reaches where the streams recharge the ground-water system through losing stream channels also were identified. (USGS 1995)

7. Hydrography

Stream drainage patterns are radial, away from regional and local topographic highs. Drainage patterns can follow geologic features such as faults and joints in the rocks. Springs, which are common in some areas, contribute substantially to stream flow during summer and fall. The stream valleys are entrenched and are commonly less than one-half mile wide. Most flood plains in Carroll County are 100 to 1,000 feet wide. (USDA 1984)

The terrain in the Boston Mountains is exceptionally steep and rugged with local relief as much as 1,000 ft in places. Because of the rugged terrain and steep slopes, streams have high gradients, averaging about 20 ft/mi. Stream beds consist predominantly of bedrock and rubble with smaller amounts of boulders, gravel, and sand.

Relief in the Springfield and Salem Plateaus generally is less than that in the Boston Mountains. Valleys generally are deeper and narrower and the ridges sharper in the Salem Plateau than in the Springfield Plateau. Local relief along the major streams often exceeds 300 ft and is as much as 500 ft in some areas. Stream channels in the Springfield and Salem Plateaus consist of a series of well-defined riffles and pools, and channel beds consist predominantly of coarse gravel, rubble, boulders, and bedrock. Stream gradients generally exceed 3 ft/mi even in the larger streams and are as much as 50 ft/mi in some headwater areas. The water usually is quite clear. In some areas of the Springfield and Salem Plateaus, forests have been cleared to develop land for agricultural purposes resulting in a reduction in the tree canopy overhanging streams. This reduction allows more sunlight to reach the stream, which can increase water temperatures and promote the growth of aquatic vegetation. (USGS 1995)

8. Soils

There is a diversity of soil series ranging from very thick and fertile alluvial soils in the lower reaches of the watershed to thin and compacted soils on Boston Mountain slopes in the upper reaches of the watershed. The majority of the soils within the Kings River Watershed are categorized in the Ozark Highlands category, which consists of a mixture of alfisols and ultisols. The alfisols are thin loams with a clay component in the subsurface, and are generally thought to have formed under timber and some prairie vegetation types. Ultisols can in many ways be considered a more leached, weathered version of alfisols, with a much lower component of basic cations. Soil data is very site specific and the series can blend together making detailed classification difficult.

Soils in the headwater streams located in the Boston Mountains are predominately made of the Enders, Mountainberg, Leesburg, and Linker soil series. These series contain very stony, sandy and gravelly soil particles that are characteristic of moderately sloping terrain and are well drained. These soils formed in either residium or colluvium of cherty limestones or shales and possess low solubility characteristics, thus giving rise to very soft waters. Downstream in the middle reaches, Clarksville, Nixa, Noark, and Captina soil series predominate. This categorization includes series that consist of more cherty soils with some stony mixture. These soils are deep, fertile, and found in a range of topography. Closer to Table Rock Lake in the lower reaches of the Kings River Watershed, the soil series are a combination of Arkana, Eldon, and Moko. These series are chert-loam mixtures that were formed from dolomite or limestone residuum. These series are shallower and are characteristic of larger floodplain areas adjacent to lake confluences. The last group of soils is found on floodplains and lower stream terraces throughout the entire Kings River Watershed. Portia, Britwater, Razort, and Elsah soils are much younger than the other groups and they are very well drained because of their historical formation in old alluvial sediment. This group of soils is represented in local erosion from adjacent fields and stream banks that have been affected by stream processes for many years. As surface waters flow across this area they become harder and more alkaline. (White 2001)

Soil Formation

Alluvium *– material deposited by water*

Colluvium *– material moved by creep or slide deposited on slopes*

Residuum *– unconsolidated material that has been formed from rock mineral in its current location*

In general, most of the soils have a high potential for nutrients and other dissolved constituents to be leached to the ground water and have a high potential for runoff to surface water systems (USGS 1995). As a geomorphic agent, soil is a component of run-off processes and a source of erodible sediment from the landscape. Variables including topsoil and subsoil texture, organic matter content, and depth to bedrock are important when assessing the susceptibility of soil movement in a fluvial system. There are four general geologic units in the Kings River Watershed and each unit possesses varying characteristics that can play a factor in soil movement from the terrestrial to the aquatic environment. The table shows that the Boston Mountains unit contains very shallow soils, low organic matter content and the soil texture is hard gravel and stone. In contrast, the dolomite and limestone units have deeper soils, they have moderate organic matter content and soil texture consists of silt, loam, and clay particles. According to these characteristics, the Boston Mountains unit would be less susceptible to organic soil matter eroding into nearby streams than the dolomite and limestone units. (White 2001)

Figure 5. Soil Characteristics of different geologic types (White 2001)

Unit	Texture		Bedrock Depth	Organic Matter Content
	Topsoil	Subsoil		
Boston Mountains	stony, gravel	silty, clay	20	Low
Limestone	cherty	cherty, silt loam	75	Medium
Dolomite	cherty, silt loam	cherty, clay	50	Medium
Alluvial	gravelly, silt loam	silty, clay loam	70	Medium

See Soils Map of Kings River Watershed in Appendix A Figure 5.

9. Vegetation

Vegetation patterns have changed in the Kings River Watershed as development has increased during the last two hundred years. Journals from explorers such as Henry Schoolcraft in 1818, describe the Ozarks terrain and vegetation in great detail, affording us the opportunity to detect changing land uses. Native vegetation patterns in Carroll County included sparse to dense stands of hardwoods or mixed hardwoods and shortleaf pine. The vegetation of the savannas was eastern redcedar or mixed hardwoods and tall grasses, similar to those on the small prairies, in the open areas between the trees. The native vegetation on most of the other uplands was sparse to dense stands of upland old-growth oaks and hickory, some mixed with shortleaf pine. There were a few small, gently sloping tall-grass prairies scattered throughout the watershed. The native vegetation on the prairies was mostly tall grass, such as big bluestem, little bluestem, indiangrass, and switchgrass, and a variety of forbes. (USDA 1984) Trees were not well established in these prairies because Native Americans periodically burned the vegetation to drive game. Early settlers continued the practice of burning to provide pastureland; after the Civil War, however, many of the prairies were allowed to revert to forests (Rafferty, 1980). In the alluvial areas the native vegetation was mainly hardwoods, such as sycamore, cottonwoods, maple, butternut, poplar, hackberry, elm, black walnut, ash, oak, and hickory. (USDA 1984)

A majority of the woodlands of the Ozarks Plateaus study unit are now second or third growth due to intense logging through the years. However, tree species in the woodlands are similar to those of the old growth forests. Currently [1993] land use in the Ozark Plateaus study unit consists primarily of forest, pasture, and some cropland. Deciduous forestland, mostly oak and hickory trees, predominate in the Salem Plateau and Boston Mountains. Pastureland, which is mostly fescue (used as hay) is grown in the river bottoms and gentle to steep slopes of the uplands in the Springfield Plateau. (USGS 1995)

10. Fish and Wildlife Resources

Heron Rookery

Map Turtle

Copperhead

Photos courtesy of Sam Davis

The Ozarks region is extremely rich in biological diversity of both plant and animal life. The Ozarks is one of the oldest continuously exposed land masses in North America. The region escaped the reach of both glaciers and the rising oceans and has served as a refuge for organisms escaping from climate shifts and other geologic events. The region continuously habited since the late Paleozoic, some 230 million years ago. The diversity of available habitats, influx of organisms from different regions, and extreme antiquity of the landscape have combined to sustain both relictual populations and allow the development of new species, making the Ozarks a center of endemism in North America. (TNC 2004)

Mammals

Early settlers found the Ozarks inviting because of the abundance of fresh spring water and wild game in the area. Explorer Henry Schoolcraft describes the great quantity of buffalo, black bear, beaver, rabbit, wolf, white-tail deer, grey squirrel, wild turkey, mountain lion, elk, and duck in the Ozark countryside. The early pioneers and Native Americans depended heavily on wild game because productive agricultural lands were limited in the area. (Schoolcraft 1996) Some of these native species have flourished, while others have declined significantly. White-tail deer, beaver, and wild turkey were almost completely eliminated in the state of Arkansas by 1930. The populations have rebounded due to hunting regulations, nature reserves, and an initial restocking effort by the AR Game and Fish Commission. The black bear population seems stable in the Kings River Watershed, but its future is far from certain as the area becomes more developed. Wild populations of buffalo, wolf, elk, and mountain lion have all been completely eliminated from the watershed. Native populations of coyote, rabbit, squirrel, and many other small mammals still abound in the watershed. (AGFC 2006)

Fish

The Kings River is particular renowned for its population of Smallmouth bass. The Smallmouth evolved in clear, cool mountain creeks and rivers, so it is best suited to survive and flourish in Ozark streams. The smallmouth bass is sensitive to environmental factors, and can be greatly affected by polluted waters. Clean rivers and lakes are essential to smallmouth survival. Because of good water quality (high concentrations of calcium carbonates, moderate pH, high oxygen levels, etc.) fairly long growing season, cool water temperatures, good forage populations, and plentiful habitat, Smallmouth grow fast and live long the Kings River.

While game, commercial, and bait fishes are of great economic importance to Arkansas, most of the fishes of the Kings River Watershed are not directly used for food or recreation and have no immediate economic value. However, the ecological value of these native species is becoming increasingly apparent as we learn more about the structure and functioning of aquatic ecosystems. All native species have specific ecological roles and all contribute to the diversity and stability of aquatic environments. For example, many native species are highly sensitive to environmental disturbances and are, therefore, important indicators of environmental quality. (Robison 1988)

Species of fish sensitive to environmental change comprise about 50% of the community relative abundance in the Boston Mountains and over 66% within the Ozark Highlands. (Keith 1987) Unique and diversified fish assemblages typify Ozark Highland streams. These fish communities are characterized by a preponderance of sensitive species and are normally dominated by a diverse minnow community followed by sunfishes and darters. According to the Arkansas Pollution Control and Ecology Commission, key species of Ozark Highland streams include: Duckystripe shiner, Northern hogsucker, Slender madtom, "Rock" basses, Rainbow and/or Orangethroat darters, and Smallmouth bass. Indicator species include the Banded sculpin, Ozark madtom, Southern redbelly dace, Whitetail shiner, and Ozark minnow. The Boston Mountains streams support diverse communities of indigenous or adapted species of fish and other forms of aquatic life. Fish communities are characterized by a major proportion of sensitive species; a diverse, often darter-dominated community exists but with nearly equal proportions of minnows and sunfishes. Key species include the Bigeye shiner, Black redhorse, Slender madtom, Longear sunfish, Greenside darter, and Smallmouth bass. Indicator species include the Shadow bass, Wedgespot shiner, Longnose darter, and Fantail darter (APC&EC 2004a).

Fish assemblages are good indicators of long-term environmental effects and broad habitat conditions because they are relatively long-lived and mobile. Because fish assemblages generally include a range of species that represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores), they tend to integrate effects of lower trophic levels and are reflective of integrated environmental health. (Robison 1988)

Refer to Section D.1. in the Appendix for a list of fish found in the KRW.

Amphibians and Reptiles

The diverse assemblage of amphibians and reptiles found in Arkansas has resulted in part from the state's geographic position and its physical features. Arkansas has a number of species whose broad geographic ranges center in or near the state. Furthermore, due to its geographic position, western species reach their eastern limits in Arkansas, eastern species reach their western limits, coastal plain species reach their northern limits, remnant populations of northern species lie at their southern limits, and several endemic species are found nowhere else. (Trauth)

Refer to Section D.2. in the Appendix for a list of amphibians and reptiles found in the KRW.

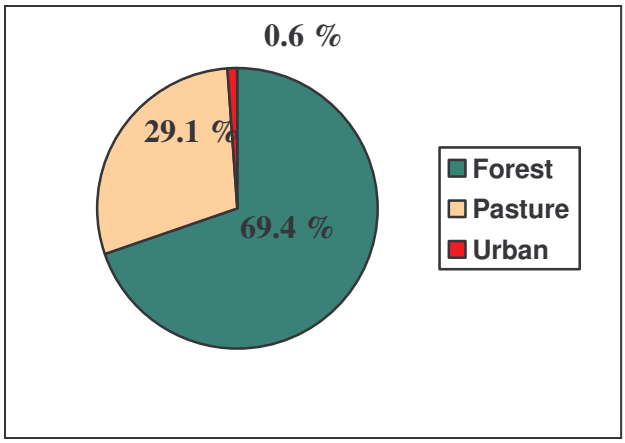
Birds

Refer to Section D.3. in the Appendix for a list of birds found in the region.

11. Demographic and Socioeconomic Characteristics

The watershed is characterized by large tracts of forest interspersed with pasture lands and rural communities. 69.4% of the watershed is forested, 29.1% is pasture, and 0.6% is urban. One incorporated city is located entirely within the watershed boundaries, that being Berryville, Arkansas (population: 4,745). (FTN 2005) A small portion of the southeastern corner of Eureka Springs (population 2,330) is also located within the watershed. Rural communities located within the watershed include Marble, Kingston, Osage, Rudd, Metalton, and Grandview. The rural population density for the region is 20 persons per square mile.

Figure 6. Land use in Kings River Watershed



The population within the Kings River Watershed has been steadily increasing during the last 10 to 15 years. Nearby cities in Northwest Arkansas, such as Fayetteville, Springdale, Bentonville, and Rogers, are experiencing population explosions which are impacting the entire region. Between 1990 and 2000, the population of Carroll County increased by 36% while that of Madison County increased by 23%. A growing Hispanic population is responsible for much of the growth in Carroll County, currently representing approximately 10% of the total population (U.S. Census 2000).

On average, 15% of individuals residing in the Kings River Watershed subsist on below poverty income levels. The median household income is approximately $27,000, well below the national median household income levels. The high school graduate percentage rate is about 70% while the percentage of individuals with a degree of higher education is between 10% and 13% within the watershed. (U.S. Census 2000)

The increase in population has also resulted in increased property values and some changing land uses. Intensified development around Berryville and Eureka Springs has increased the overall urban land use in the watershed. Between 1997 and 2002 there was a slight decrease in the number of farms in both Carroll and Madison Counties but there was a slight increase in total farm acreage. Studies in land use/land cover changes show that this is a result of the conversion of forest to pasture at the rate of about 420 acres per year. (Bottomley 2001) The real property assessments for Carroll County increased from 110.6 million dollars in 1990 to 228.8 million dollars in 2003, a 48% increase. The real property assessments for Madison County increased from 36.8 million dollars in 1990 to 77.3 million dollars in 2003, also a 48% increase.

Almost all of the 110,210 acres of cropland in the watershed are used for pasture and/or grazing. These pastures support approximately 25,000 beef cattle (not including calves) and 1,000 dairy cattle in the watershed. In addition, approximately 26.2 million broilers, 2.5 million turkeys, and 460,000 layers are raised in the watershed each year. Nearly all of the poultry litter from these operations is spread on pastures in the watershed, but no information is readily available concerning how much of the pasture acreage receives poultry litter. (FTN 2005) The majority of farmers who raise poultry in this area store and apply the litter according to nutrient management plans that are approved by the NRCS.

Photo courtesy of Sam Davis

Public lands in the Kings River Watershed

State land holdings within the Kings River Watershed include the Madison County Wildlife Management Area managed by the Arkansas Game and Fish Commission. The area consists of a total of 14,227 acres of state owned land and is managed primarily for hunting, with other outdoor activities such as hiking and horseback riding trails and camping available. Game and Fish Commission personnel also utilize forestry practices including planned timber harvests and controlled burns in order to maintain general forest diversity and maintain food plots with a grass/legume forage. There are numerous streams in the area that are all tributaries of the Kings River, which skirts the eastern edge of the WMA. Information for the Madison County WMA can be found at www.agfc.com/wma_lakes/wma_madison_county.html. The Arkansas Game and Fish Commission also maintains five access points to the Kings River. These include Marble/Big Onion Creek, Rockhouse, U.S. Hwy 62 Bridge, Stoney Point/Summers Point, and Romp Hole.

The Arkansas Natural Heritage Commission owns three areas within the Kings River Watershed. These areas are managed primarily to maintain their ecological character. Low impact activities such as hiking and bird-watching are promoted while activities such as camping, horses, and motorized vehicles are not allowed. Within Madison County the agency owns the Kings River Falls Natural Area, Bear Hollow Natural Area, and Sweden Creek Falls Natural Area. The Kings River Falls Natural Area includes 570 acres and the beautiful Kings River Falls. The Bear Hollow Natural Area is a 397 acre parcel that is bounded on the north and south by the Madison County WMA. This parcel includes a mile of the intermittent Bear Hollow Creek and the Ozark Natural Science Center, a center established in 1990 to provide environmental education opportunities for the people of the Ozark Mountains region. The Sweden Creek Falls Natural Area is a 136 acre parcel which includes an 80 foot waterfall and a Sandstone glade that is home to the rare small-headed pipewort. More information about these natural areas can be found at www.naturalheritage.org/areas/map.asp.

12. Watershed History

The Kings River Watershed, as part of the Upper White River basin, became part of the United States in 1803 through the Louisiana Purchase. The first settlers of the area were likely the Osage Indians. Documented archaeological evidence shows that the area was sparsely populated before the Osage arrived. Research by Dr. Jim Harlan of the University of Missouri on land use in the Ozarks during the early 1800s finds that there was slightly less forested area in the Ozarks during the early 1800's than there is now. During that time the Native Indians controlled the Ozarks, they would occasionally set fires that would burn large areas of land. These fires would suppress the growth of many types of trees, although other types of trees (such as oaks) would actually benefit from the fires due to reduced competition from other faster growing trees. The Ozarks region was far from being completely forested even before non-native American settlers arrived. (FTN 2005)

By 1835 there were virtually no Native Indians in residence in the watershed. Early settlers came to the Kings River valley via the larger and more traveled White and Arkansas River valleys, which were navigable year-round. The mountainous Boston and Ozark regions deterred large scale settlement until accessibility improved. Many of the earliest settlers of European ancestry were attracted by the abundance of game and fish rather than by agricultural productivity of the land. In 1833, Carroll County, Arkansas was designated to "include all the waters of King's River." Carroll County was subsequently reduced in 1836, 1842, and 1869 to create Madison, Newton, and Boone Counties respectively. The Kings River is responsible for the existence of two districts within Carroll County because spring rains would often make travel between Eureka Springs and Berryville impossible. (Goodspeed 1889)

From the early 1800's to around 1880, some of the forests and cane stands in valley bottoms were replaced with cultivated fields and pastures. In the upland areas, the suppression of wildfires during this period allowed an increase in under story growth and the loss of native grasslands and savannahs. Around 1870, timber harvest began on a large scale and continued until the 1920s. Between 1920 and 1960, known as the post-timber boom, there was annual burning and cutting of upland timber to open more grazing land. This played a large role in stream disturbances that are evident today. Changes in flow patterns during this period can probably be attributed to changes in upland and riparian zone vegetation that decreased storage and flow resistance in stream channels. From 1960 to 1993, the amount of farmland decreased, but cattle and poultry numbers increased significantly. (FTN 2005)

The only railroad to be built in the region was extended by the Missouri and North Arkansas railway from Joplin, Missouri to Helena, Arkansas, with a branch line serving Eureka Springs and Berryville. The line was officially complete in 1909 but it never prospered and the rails were finally taken up and sold as scrap in 1962. While in use, the line was primarily used to ship cotton, grain, and lumber products. (Rafferty 1980)

Minerals have never been of considerable importance in the history of Carroll County, but that is not to say that the county is totally devoid of precious rocks. Goodspeed records that as early as 1834, some silver was being extracted from Childer's Mountain by a Colonel Huff, who this historian equates as being a noted counterfeiter. The Goodspeed account goes on to state that this was in the "Varmint Lick" area of the county and that Huff was also engaged in the manufacture "of spurious currency" after he had smelted the silver. Other silver mines are also remembered from Carroll County's past. Namely the Jackson Mines, on Kings River, and the Clebin Mines. These are reported to have yielded some 315 ounces of high grade silver to a tone of ore. According to Goodspeed, iron was mined in the county in the early 1850's. Abraham Belcher is credited with the establishment of a forge on Kings River but Belcher died in 1853 and his iron works died with him. (Lair 1983)

13. Water Quality

13.1. Water Quality Impairments

The Arkansas Department of Environmental Quality has designated the following beneficial uses for the Kings River;
- Extraordinary Resource waters
- Natural and Scenic waterway [Madison County portion only]
- Primary contact recreation
- Secondary contact Recreation
- Domestic, Industrial and Agricultural water supply
- Perennial Boston Mountain fishery and Perennial Ozark Highlands fishery.

The portion of the Kings River in Missouri is considered by the Missouri Department of Natural Resources to be part of Table Rock Lake, which has the following designated uses:
- Livestock and wildlife watering
- Protection of warm water aquatic life
- Human health/fish consumption
- Whole body contact recreation
- Boating and canoeing

Water quality impairments as determined by state or federal agencies are based on whether or not streams support the above designated uses. All streams within the Arkansas portion of the Kings River Watershed meet their designated uses with the exception of Osage Creek downstream of Berryville. In an overruling by the Environmental Protection Agency, Reach 045-L, a five mile stretch of Osage Creek, was placed on the Final 2002 303(d) list for not supporting its aquatic life designated use with the cause listed as total phosphorus. According to ADEQ's water monitoring data for Osage Creek from 1983 to 2004, the average total phosphorus load above Berryville was 0.050 mg/L, while the average load below Berryville was 1.049 mg/L.

A draft TMDL for phosphorus in Osage Creek near Berryville is currently awaiting approval by the EPA. The TMDL uses a guideline of 0.1 mg/L total phosphorus as a target concentration, or endpoint, for the stream. This guideline was present in Arkansas' Regulation No. 2 in 2002 when Osage Creek was listed as an impaired waterway, although it has since been removed. The TMDL finds that Osage Creek can assimilate 96.64 lbs/day total phosphorus without exceeding the 0.1 mg/L target. The margin of safety equals 9.66 lbs/day. Average effluent phosphorus loads for the City of Berryville wastewater treatment plant are approximately 134 lbs/day. Reductions in total phosphorus from the plant were determined based on an already existing regulation. In Arkansas Regulation No. 6, Chapter 4, it is stated that "No permit for discharge of domestic wastewater to Osage Creek or its tributaries, by the City of Berryville, shall authorize more than 1.0 mg/L Total Phosphorus based on a monthly average." Compliance with this regulation is required by 2012. The TMDL calculations show that the City of Berryville will be allowed to release 20.02 lbs/day total phosphorus, which amounts to an 85% reduction from today's releases. At target effluent levels, the point sources plus the margin of safety only equal 32.1 lbs/day total phosphorus load. According to the report, the remaining phosphorus loads in the watershed can be attributed to non-point sources. The TMDL determines that no reductions of phosphorus from non-point sources in the watershed are needed at the present time to reach the target concentration. (FTN 2005, Draft TMDL)

Refer to Section B.4. in the Appendix for the complete Osage Creek Draft TMDL.

Arkansas' proposed 2004 303(d) list includes Reach 037, a 19.1 mile stretch of the main stem of the Kings River, in category 5b – waters not attaining standards, but ones that will be de-listed with the adoption of current Regulation 2 revisions. The proposed list states that this reach is not supporting the designated uses for agriculture and industry water use because of Total Dissolved Solids with the source being the municipal wastewater treatment plant in Berryville, Arkansas. (ADEQ 2005)

The Missouri Department of Natural Resources included Table Rock Lake, including the Kings River arm, on the 2002 303(d) list as being impaired due to nutrients (primarily phosphorus). The Missouri 2002 list was approved by EPA in December 2003. A TMDL for nutrients in Table Rock Lake has not yet been written and no schedule for its development is currently available.

13.2. Water Quality Monitoring Studies

Water quality monitoring and fish and invertebrate sampling have been collected for various locations in the watershed, primarily along the main stem of the Kings River. This data is important for characterizing long-term water quality trends in the watershed and is summarized in the following paragraphs.

A map of current water quality monitoring sites can be found in Appendix A Figure 11

Arkansas Water Resources Center

The Arkansas Water Resources Center has conducted flow-weighted sampling at the U.S. Geological Survey gauging station located on the Kings River just south of the town of Grandview (Station # 07050500) since 1999. This station utilizes an automatic sampler to collect continuous stage and discharge measurements as well as frequent water quality sampling. The greatest benefit of the automatic sampler is that it captures storm flow data, which can often be missed during regular grab sampling. The year with the lowest average phosphorus concentration (2003) was also the driest year, suggesting that nonpoint sources and stormwater runoff are having the greatest impact on average concentrations of phosphorus at this location. Also, these data show that the majority (54% to 75%) of the phosphorus load is from particulates (i.e. phosphorus attached to particles). Average sediment loads for 1999-2003 was 50,496 tons/yr. (AWRC 2005)

Figure 7. AWRC water quality data 1999 – 2003 (AWRC 2004)

Parameter	1999	2000	2001	2002	2003
Average flow (cfs)	535	320	372	653	239
Flow-weighted average concentrations (mg/L)					
Total phosphorus	0.32	0.36	0.33	0.31	0.19
Dissolved phos.	0.10	0.16	0.11	0.08	0.06
Nitrate (as N)	0.84	0.88	1.44	0.74	0.72
Ammonia (as N)	0.03	0.04	0.05	0.04	0.02
TKN	0.73	0.74	0.68	0.69	0.50
TSS	167	125	111	108	65
Annual loads (tons/yr)					
Total phosphorus	170	113	120	199	44
Dissolved phos.	53	52	39	49	15
Nitrate (as N)	443	276	528	476	170
Ammonia (as N)	14	12	19	23	4
TKN	384	232	250	443	118
TSS	87,757	39,299	40,592	69,619	15,259
Distribution of phosphorus load (%)					
Dissolved	31%	46%	33%	25%	34%
Particulate	69%	54%	67%	75%	66%

This sampling program has been instrumental in determining the total sediment load moving from the Kings River into Table Rock Lake. The program will continue as long as funding is available.

Refer to Section C.1. in the Appendix for the AWRC 2005 Monitoring Report.

Arkansas Department of Environmental Quality

The Arkansas Department of Environmental Quality tests the water quality (chemical parameters) at four sites within the KRW on a monthly basis. See below.

Station WHI0068 – Osage Creek above Berryville
Station WHI0069 – Osage Creek below Berryville
Station WHI0009A – Kings River north of Berryville
Station WHI0123 – Kings River near Alabam

ADEQ tests monthly for ammonia, nitrate + nitrate as nitrogen, ortho-phosphate, total phosphorus, total kjeldahl nitrogen, total organic carbon, biochemical oxygen demand, turbidity, total suspended solids, total dissolved solids, dissolved oxygen, pH, air temperature, and water temperature. ADEQ's monitoring does not differentiate between storm flow and base flow. This data is used to determine the status of rivers and streams in meeting Arkansas' water quality standards. Their program is expected to continue indefinitely.

Kings River Watershed Partnership

The Kings River Watershed Partnership tests the water quality (chemical parameters) at seven sites within the KRW on a monthly basis. Sites listed below.

Site 1 – Upper Osage Creek
Site 2 – Lower Osage Creek
Site 3 – Kings River above confluence with Osage Creek
Site 4 – Kings River – Hwy 74 bridge south of Kingston
Site 5 – Kings River, Stoney Point below Grandview
Site 10 – Keel's Creek, .5 miles above confluence with Kings
Site 11 – Kings River at Rockhouse Access

The KWRP also periodically tests at the sites listed below.

Site 6 – Kings River at Grandview Bridge
Site 7 – Piney Creek at CR 501
Site 8 – Dry Fork Creek at CR 543
Site 9 – Kings River at Marshall Ford/Madison County CR 1505

The KRWP uses a HACH testing kit to test the pH, dissolved oxygen, turbidity, nitrates, phosphorus, total dissolved solids, hardness, alkalinity, air and water temperature. The KRWP, in collaboration with the Arkansas Water Resources Center and Dr. Marc Nelson, received approval from the EPA for its Quality Assurance Project Plan. The KRWP continues to follow the QAPP procedures to ensure that its data is accurate and usable. This program is based on volunteers and donations and will continue as long as both are available.

Parson's and University of Arkansas

In 2003 and 2004, Parsons and the University of Arkansas at Fayetteville studied water quality, fish and benthic communities, and habitat and streambed characteristics at four sites in the Kings River Watershed.
The sites included:

Kings River upstream near Marble
Osage Creek above Berryville wastewater treatment plant (WTP)
Osage Creek below wastewater treatment plant
Kings River below confluence with Osage Creek

Overall the study shows that the ecological condition of the water bodies in the Kings River Watershed display minor water quality, biological, and habitat impacts in isolated locations. The water quality sampling showed increases of nitrite + nitrate, total nitrogen, orthophosphorus, and total phosphorus in Osage Creek downstream of the discharge from the City of Berryville WTP. Sampling at this site showed that Total Phosphorus exceeded the EPA guideline of 0.1 mg/L for all events. Only slight increases in orthophosphorus and total phosphorus occurred in the Kings River site downstream of the confluence with Osage Creek, and nitrite + nitrate and total nitrogen concentrations in the Kings River were lower below Osage Creek. The ADEQ numeric criterion for Total Dissolved Solids (TDS) at the lower Kings site is 150 mg/L, and all TDS values at this site exceeded the criterion. TDS for the two Osage Creek sites and the reference site is 240 mg/L. This value was exceeded for all three events at Osage Creek downstream of the WTP. All turbidity values on the Kings River were lower than the ADEQ numeric criterion of 10 NTUs. (Parsons 2004)

The stream habitat was characterized at the four sampling sites and none of the sites were characterized as impacted. The biological data collection showed some evidence of impacts during at least one sampling event at each of the four sampling sites. The water chemistry data, physical habitat data, and biological data were combined to classify each sampling site concerning the level of impacts to aquatic life. The site on Osage Creek downstream of Berryville was classified as severely impacted and the site on the Kings River downstream of Osage Creek was classified as slightly impacted. The other two sites were classified as unimpacted. (Parsons 2004)

Complete Parson's Report housed in KRWP office in Berryville, Arkansas.

Missouri Department of Natural Resources

Water quality data have been collected at 2 sites in the Kings River arm of Table Rock and are available on the Lakes of Missouri Volunteer Program web site (LMVP 2005). These measurements included Secchi depth, chlorophyll concentrations, nitrogen, and phosphorus. Secchi depth is the measurement of how deep a person can see a black and white disc in the water (looking from the surface); higher numbers indicate better water

clarity. Chlorophyll is an indirect measurement of the amount of algae in the water (not including algae attached to rocks or debris).

Nutrient and chlorophyll concentrations are higher and Secchi depths are lower at the upstream site (Site 7) than farther into the lake (Site 6.5). The improvement in water quality from Site 7 to Site 6.5 is a typical pattern where tributaries enter lakes and reservoirs. Sediment and nutrients that are flushed out of riverine reaches enter the lake and tend to accumulate in the tributary arm of the lake. The abundance of nutrients, the slow velocity of the water, and the lack of shading in the tributary arm of a lake often provide ideal conditions for algae in the water to grow and reach concentrations higher than either in the main stem of the lake or in the river upstream. (Thornton 1990, Kimmel et al. 1990) Both Sites 6.5 and 7 were classified as eutrophic every year through 2003 (i.e., high nutrient and chlorophyll concentrations and low Secchi depths). For the main stem of Table Rock Lake, water quality conditions were classified as mesotrophic (medium nutrient and chlorophyll concentrations and medium Secchi depths) for the majority of samples taken. (MDNR 2002)