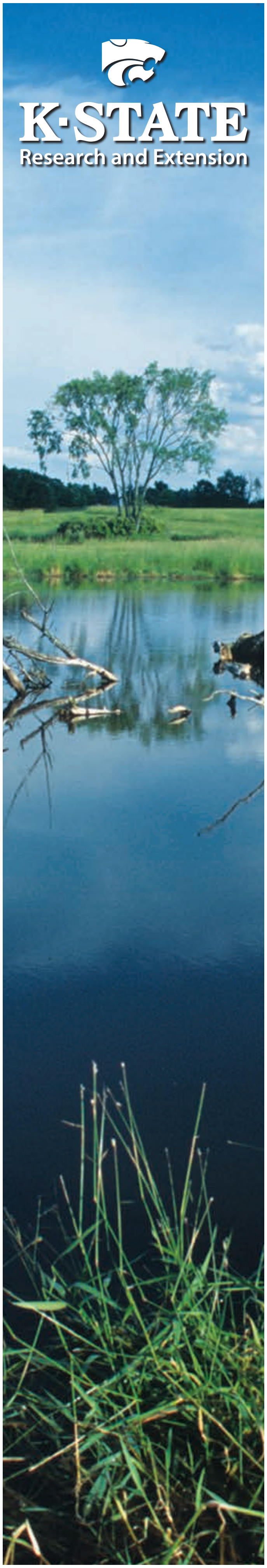

Water Primer: Part 4

Surface Water

Introduction

Rivers, tributary streams, lakes, reservoirs, and ponds are typically referred to as surface water. Water for surface supplies depends almost entirely on precipitation and the resulting runoff. Annual precipitation varies widely across Kansas, ranging from less than 16 inches in the west to more than 40 inches in the east (Figure 4, Part 2). There can be large deviations from the annual averages as well. Most precipitation in Kansas falls during the summer growing season, primarily from convection thunderstorms that produce isolated, intense rainfall. These conditions mean surface water supplies also vary seasonally and across the state.

Runoff

Runoff is strongly influenced by the amount and intensity of precipitation. Many other factors also influence the amount of runoff, such as soil type and soil conditions, including soil cover and soil water content, which affect the ability of the soil to absorb and hold water. The amount of impervious surfaces in an area also has an affect.

Because precipitation varies across the state, runoff to streams also varies, ranging from less than 0.1 inch in western Kansas to more than 10 inches in the east, a factor of more than 100. Figure 1 shows the average annual runoff across Kansas, clearly demonstrating why most of the larger rivers, lakes, and reservoirs are in the eastern part of Kansas.

When native grasses dominated the Kansas plains, streamflow rose and fell gradually because grass and wetlands slowed runoff. With the conversion of prairie to cropland using the farming practices of the time, more runoff occurred and streamflow would also rise and fall more rapidly. Increased flooding and streamflow variability are consequences of increased runoff. New farming practices were needed to help reduce both wind and water erosion potential from cropland; particularly highlighted by the drought years of the 1930s. As new conservation practices were developed and implemented, streamflows began to decline. The effect of conservation practices such as ponds, terraces, and conservation tillage are shown in Figure 2.

In some streams, alluvial groundwater depletion can play a role in streamflow reduction, if the base streamflow is diminished due to a decline in the groundwater table. Two common conservation techniques practiced in Kansas are terracing and conservation tillage. Terraces follow the contours of a slope in order to slow and retain runoff as it flows downslope in the field until it reaches the terrace channel. Once

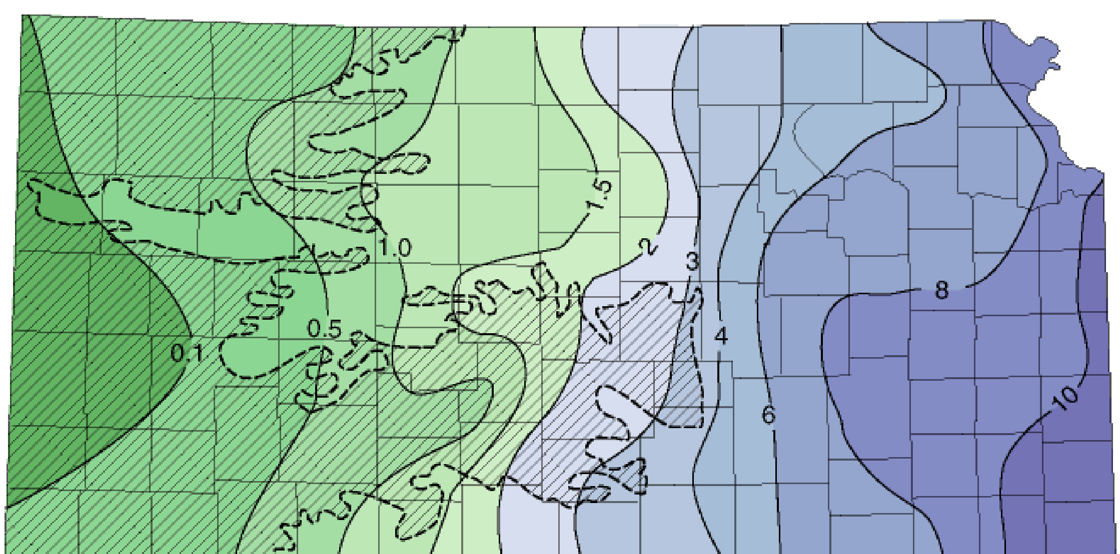

Figure 1. Average annual precipitation runoff in Kansas in inches. (Source: KWO)

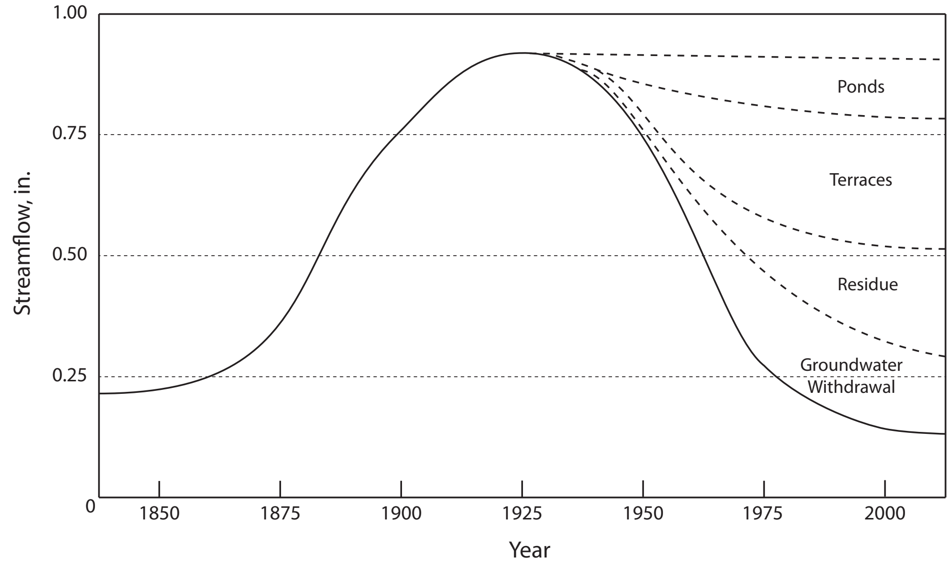

Figure 2. Predicted streamflow in northwest Kansas (1850–2000) and estimated depletions since 1930. (Source: Koelliker, 1984)

in the terrace channel, the slope of the terrace is designed to move the water along the terrace at a slow enough flow rate to prevent erosion as it moves toward the outlet of the terrace. At the outlet, the water is discharged into a defined waterway.

Various conservation tillage methods have been developed to help protect the soil surface. The adoption of these practices also increases infiltration, making more water available for the growing crop. Conservation tillage leaves more crop residue on the field's surface to increase infiltration and reduce surface runoff. In essence, the amount of runoff occurring from cropland fields may be more similar to the historic runoff levels before agricultural development.

Streamflow

As water moves across the land surface, it accumulates into flow paths that merge together into even larger and eventually well-defined and permanent channels. These channels can have various names, such as field waterway, stream, creek, or river. These terms are somewhat descriptive of the magnitude and frequency of flow.

Streamflow is proportional to precipitation and the runoff amount. In western Kansas, annual precipitation is 15 to 20 inches and runoff is as low as 0.1 to 0.5 inch, so the rivers and streams are small and often flow intermittently. In eastern Kansas, where annual precipitation and runoff is higher, rivers and streams are larger and flow continuously except during long periods of drought. Between periods of precipitation, base flows are sustained by bank storage (water held in the soil next to the stream or river) and groundwater. As described previously, human activities can influence streamflow characteristics as shown in Figure 3, indicating some streams classified in 1961 as perennial had become intermittent by 2009.

Just as streamflow on an annual basis is variable across the state, daily stream and river flows also can vary greatly. In western Kansas, some streams and rivers have periods when there is no flow. These are called intermittent streams. Streams and rivers that have permanent flow conditions under normal rainfall are called perennial streams. A third term used to describe streamflow conditions is "ephemeral." Ephemeral streams are normally dry and only flow for short periods following significant rainfall. They are often associated with desert conditions.

Since streamflows can be variable, three types of values are used to describe streamflow: average annual flow, median annual flow, and minimum annual flow. Sometimes a single large flow event can exceed the entire volume of water that is carried by a stream for the remainder of the year, therefore average annual flow values are greatly influenced by "big events." Median flow represents a more typical amount and means that half of the days in a year have a greater flow and half of the days have a smaller flow than the median. When the mini-

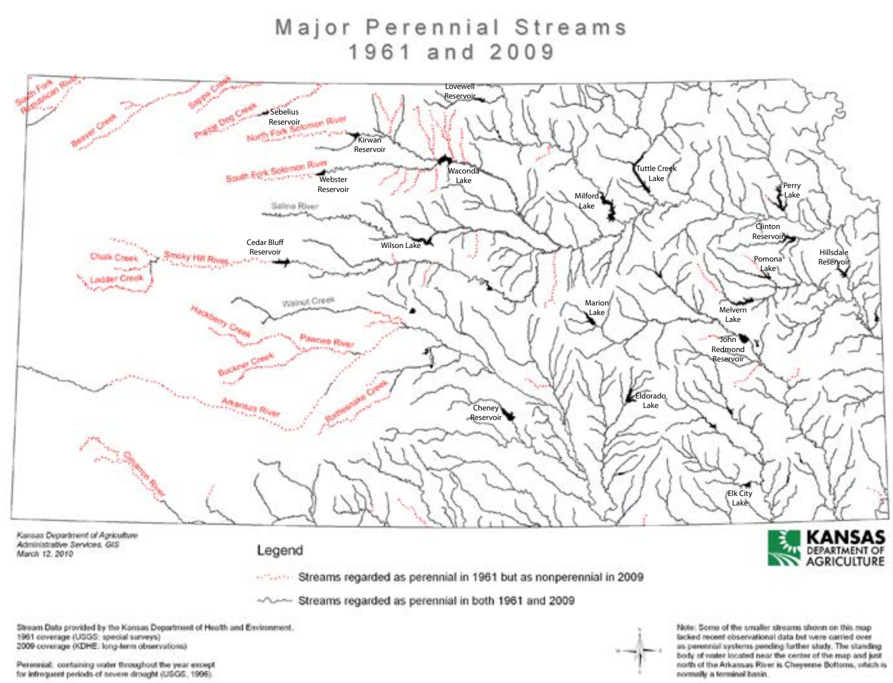

Figure 3. Changes in Kansas streams. (Source: KDA)

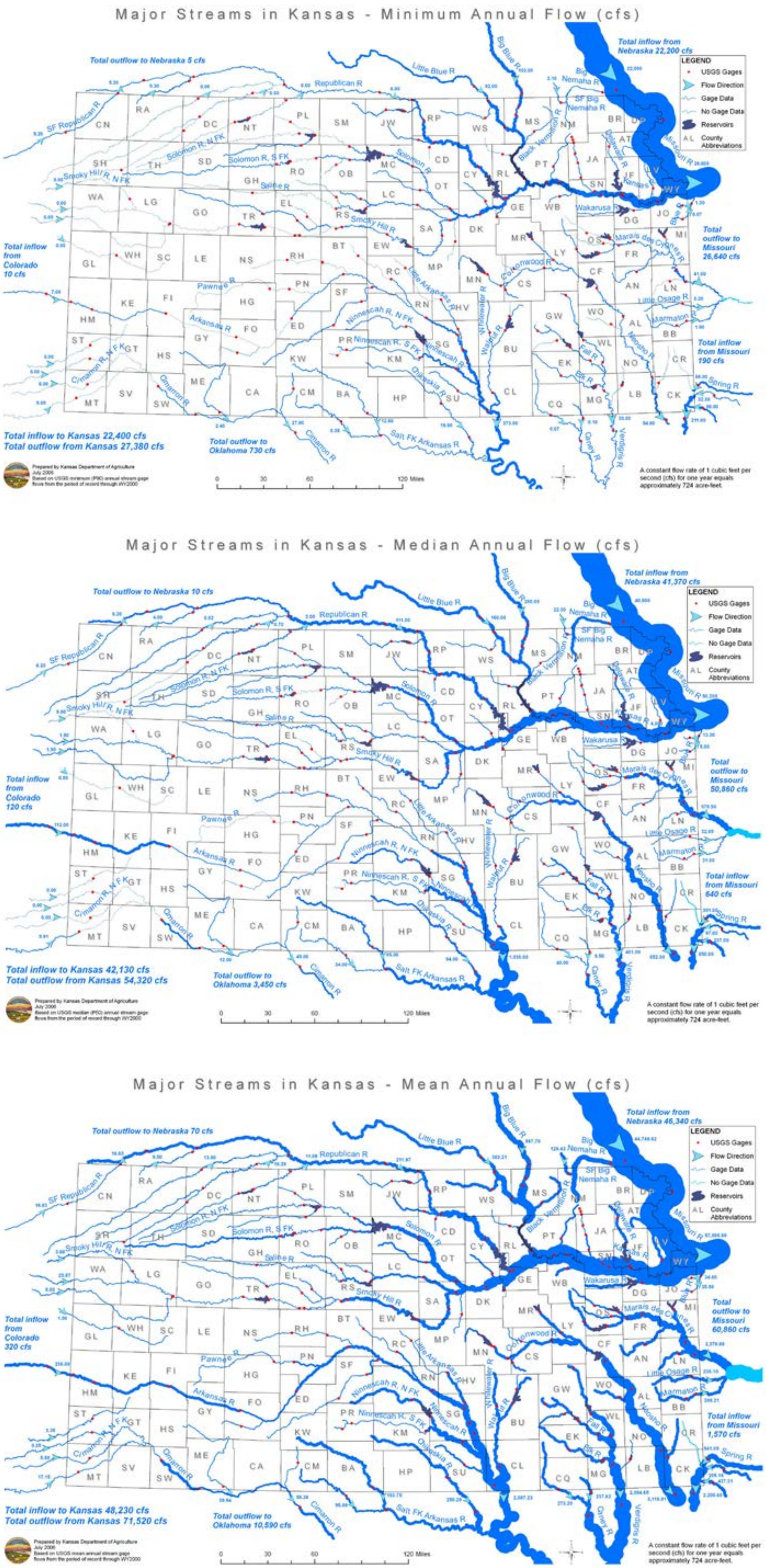

Figure 4. Levels of streamflow for Kansas. (Souce: KDA)

mum flow value for a stream is zero, the stream is an intermittent stream. Figure 4 illustrates the variability of Kansas streamflows and the effect that drought could have on municipal water supplies for eastern Kansas.

Watersheds

A watershed is the land area that drains to a common outlet or point, such as the outflow of a lake, the mouth of a river, or any point along a stream channel. Another common term for watershed is drainage basin or drainage area. A drop of water that is not evaporated, recharged into the aquifer, used by plants, or otherwise removed from the watershed eventually reaches this outlet. A watershed includes all surface areas that drain to the outlet, and the boundary of a watershed is the drainage divide between adjacent watersheds. Ridges, hills, or just the highest point in a relatively flat area form the watershed boundary. All of Kansas lies within the Mississippi Watershed (Figure 5). However this watershed is so large it can be divided into several other river watersheds, so northern Kansas is in the Missouri Watershed and southern Kansas is in the Arkansas Watershed.

The major rivers in the Missouri drainage area are the Marais des Cygnes River and the Kansas River and tributaries: Smoky Hill, Solomon, Saline, Republican, and Big Blue. The Arkansas Watershed includes the Arkansas River and tributaries: Cimarron, Medicine Lodge, Chikaskia, Walnut, Verdigris, and Neosho (Figure 6).

Kansas has few naturally occurring lakes, so reservoirs have been built to provide flood control and water storage for cities and industry and provide maintenance of minimum streamflow, irrigation, and power generation (Figure 6). The total storage volume of Kansas' 24 federal reservoirs at conservation pool is about 3 million acre-feet with a total surface area of nearly 160,000 acres (250 square miles). Each of the five largest reservoirs has a conservation pool storage volume greater

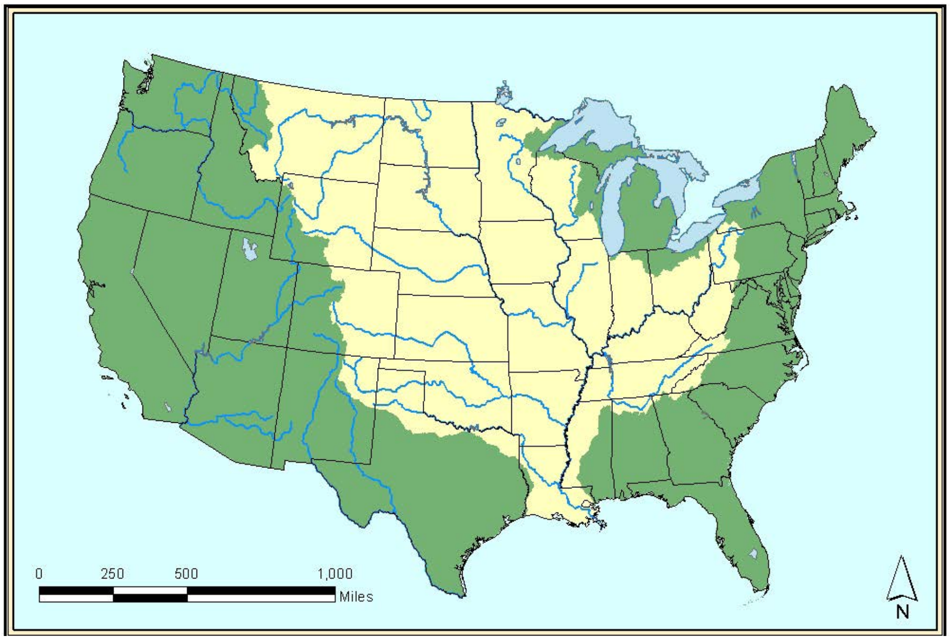

Figure 5. Kansas position in the Mississippi watershed or drainage basin.

than 200,000 acre feet. One acre-foot equals 325,851 gallons of water.

Because these reservoirs need substantial flow to support their water storage, they are primarily located in eastern Kansas where greater runoff occurs.

The watershed of lakes and rivers includes a network of intermittent drainages, manmade channels and storm drains, streams, wetlands, groundwater, and the surrounding upland. Some precipitation soaks into the ground, moves through soil materials, and reaches nearby surface water. Occasionally water percolates more deeply and replenishes groundwater supplies.

Managing Watersheds

Both natural and human activities affect the condition of a watershed. Natural variations are largely associated with seasonal and long-term climatic variations. Prolonged droughts, periods of excessive rainfall, or intense rainfall bursts can cause long-term changes in a watershed. Human activities also influence how surface waters drain from a watershed.

Impact of People: People affect the watershed environment and aquatic ecosystems by constructing impervious areas (roads, parking lots, buildings), by changing vegetation (harvesting trees, planting crops and lawns, grazing livestock), and altering water flow paths by building dikes and levees, straightening waterways, draining wetlands, and adding ponds and reservoirs. These activities change the pattern of water flow. (See Figures 7 through 10 on pages 5 and 6.) Sometimes the activities introduce additional pollutants. Other activities prevent filtering of pollutants that were once removed by water flowing along streams, through wetlands, or filtered through soil. Those pollutants can now accumulate and harm surface water and groundwater resources. Good planning for development in a watershed includes practices and structures that help maintain the watershed health and prevent pollution.

The Aquatic Ecosystem: The interrelationship between aquatic organisms and their environment are the components of the aquatic ecosystem. A watershed drainage network may allow pollutants to reach a water body located many miles from the source and affect the chemical and physical environment of plants, animals, and microorganisms. The watershed is part of this ecosystem.

Changes that affect the drainage area influence other parts of the ecosystem. For example, a housing development with impervious surfaces causes higher peak flow and volume from runoff, leading to channel erosion and increased chances of downstream flooding. As a remedy, many new developments use structures such as retention ponds (Figures 11 and 12 on page 7) and plant buffer strips to reduce the peak flow from the housing development and allow filtering of pollutants that might come from lawns, driveways, and roads. Artificial and restored wetlands also are used as a method to reduce the peak runoff rate to a stream and remove contaminants.

Wetlands: Wetlands include marshes, wooded swamps, and bogs. They have important hydrologic, water quality, and wildlife habitat value. Wetlands slow the flow of incoming water, temporarily storing it before slowly releasing it downstream, thus protect-

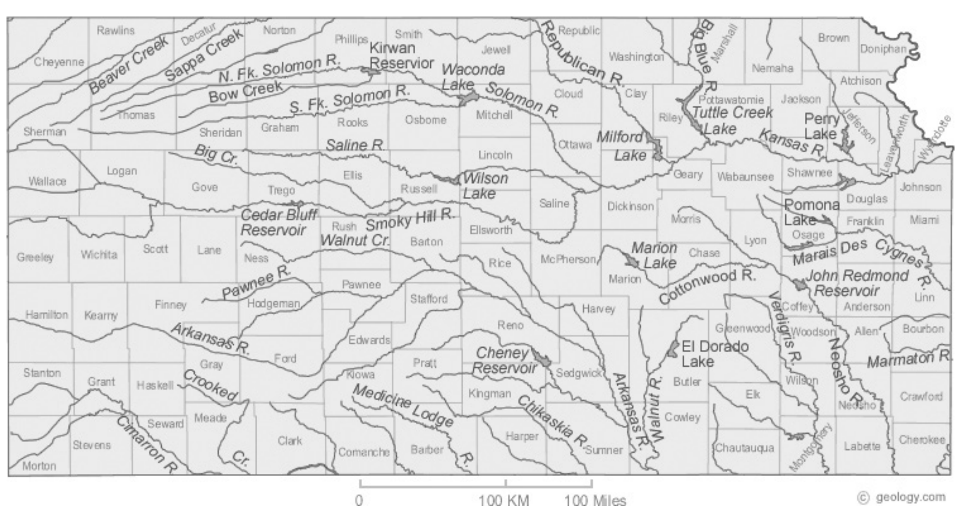

Figure 6. Reservoirs in Kansas.

ing downstream areas from flooding. The slow movement of water through wetland vegetation allows sediments to settle, and reduces nutrient and pesticide pollutants. When wetlands are filled, channeled, or drained, these natural protective functions are lost.

Nutrient Enrichment: Nutrient enrichment causes excessive aquatic growth, or eutrophocation, and has a major influence on aquatic ecosystems. In watersheds not affected by man, eutrophocation is a very slow, natural process. Often this process is greatly accelerated by human activities such as agricuture and urban development. The increase in nutrient supply from human activities usually results in an increase in the biological production that occurs in streams and lakes. Since eutrophication is increased nutrient input, any activity in the watershed of a lake that increases nutrient input causes eutrophication. Land-use changes can result in significant changes in nutrient runoff. Studies in Kansas have shown that both nitrogen and phosphorus export from agricultural lands is 10 to 20 times greater than from grass or forested lands, and urban areas may be even greater. Stormwater runoff from these developed land areas is the major source of nutrients for most lakes. The trophic state of a lake is a concept that measures the magnitude of these impairments.

Originally, the trophic state referred to the concentration of nutrients in water. Eutrophic water was water with high concentrations of nitrogen and phosphorus. Today the concept of trophic state is a characteristic of a lake rather than the water. Now trophic state applies the nutrient status of the water and includes the level of biological production occurring in the lake. A eutrophic lake may not only be a lake with high levels of nutrients, but also a very shallow pond, full of rooted aquatic plants, that may or may not have high levels of nutrients.

Water bodies are commonly classified into three trophic states: oligotrophic, mesotrophic, and eutrophic. An oligotrophic lake is a large deep lake with clear waters. Both planktonic and rooted plant growth are sparse, and the lake can support minimal aquatic populations. A eutrophic lake is typically shallow with a soft and mucky bottom. Rooted plant growth is abundant along the shore and out into the lake, and algal blooms are not unusual. Water clarity is not good and the water often has a tea color. If deep enough to

Figure 7. Spring Creek drains into the Fall River Watershed near Eureka. These are Flint Hills streams that show little impairment from human activities and are pristine. (Photo courtesy of Phil Barnes.)

Figure 8. Sharp meander bend near Lillis on Irish Creek draining into the Black Vermillion River. This region of Kansas is glacial till soil that is highly erodible and highly impaired by human activities in and along the creek. In this case, a riparian buffer strip of trees and deep-rooted shrubs and grasses are needed to stabilize the bank after it was reshaped to a stable bank slope. (Photo courtesy of Phil Barnes.)

Figure 9. North Branch of the Black Vermillion River near Frankfort. These streams have been channelized to prevent flooding. This man-made action has caused the water to accelerate down the stream, cutting into the bank and incising the stream. The banks are so high that they are currently collapsing into the stream and will eventually create a new flood plane at a lower elevation. In the meantime, millions of tons of sediment are washing out of the river into Tuttle Creek Reservoir, impairing its ability to store water. (Photo courtesy of Phil Barnes.)

Figure 10. Downstream side of a concrete road culvert with a steep slope chute that carries water from a watershed area developed with shopping malls, businesses and residential housing area and the accompanying impervious areas of streets, parking lots and roof tops. The small concrete pillars are to help dissipate water energy. However, stream bank erosion was still occurring, resulting in the construction of a fortified stream bank. Notice that the fortification is being undercut (see arrow), which will eventually result in the structure's failure. (Photo courtesy of Danny H. Rogers.)

thermally stratify, the bottom waters are devoid of oxygen. Mesotrophic is an intermediate trophic state with characteristics between the other two.

Management: Management of watershed systems can be difficult because river, wetland, and groundwater aquifer systems rarely follow political boundaries. In Kansas, the Kansas Water Office is a state agency with responsibility to coordinate the planning process to manage the state's water resources, which are protected through a combination of state regulations, local land-use controls, and individual actions. The state is divided in to 12 river basin units, and through these basin units, committees hold meetings and hearings to seek input on issues that affect the area and what actions might be needed. Many other units of government and quasi-governmental agencies, such as smaller watershed districts, water assurance districts, and rural water districts, also have responsibilities to represent and protect their stakeholders' water interests. Water resources are vulnerable and valuable. Everyone has a responsibility to protect water resources. This includes considering the effect individual decisions have on the watershed and balancing lifestyle choices with the needs of the aquatic environment within the watershed.

Figure 11. One of a series of water retention ponds that hold runoff water from roofs and parking lots of a business complex that was originally a wooded area. The inlet and outlet culverts control the rate of flow to the receiving downstream drainage area. The retention ponds are vegetated with wetland plants. (Photo courtesy of Danny H. Rogers.)

Figure 12. A nearly completed retention pond that receives water from a large apartment complex, sports facilities, and parking lots. The retention pond directs runoff water into a newly installed underground drainage pipe system and limits surface flow into the streets of a residential area. This pond has two outlets; one in the bottom of the pond and another that is located about halfway up the dam. The dam also has an emergency spillway to protect the structure in an extreme event. (Photo courtesy of Danny H. Rogers.)

References

Joubert, Lorraine and Arthur J. Gold. *What is a Watershed?* University of Rhode Island, Cooperative Extension Bulletin NRFS-9010.ri. 1990.

Koelliker, J.K. 1984. *Impact of improved agricultural water use efficiency on reservoir storage in sub-humid areas.* Contribution No. 242. Manhattan, Kansas: Water Resources Research Institute , Kansas State University.

Ratzlaff, J.R. "Variations in Runoff of the High Plains Section of the Smoky Hill Drainage." 1951-1980. *Transactions of the Kansas Academy of Science.* V. 90 No. 1-2. pp 25-34.

Authors:

Danny H. Rogers, professor, irrigation systems, biological and agricultural engineering

Phil Barnes, associate professor, water quality, biological and agricultural engineering

G. Morgan Powell, retired professor, biological and agricultural engineering

Kerri Ebert, extension assistant, biological and agricultural engineering

Brand names appearing in this publication are for product identification purposes only.
No endorsement is intended, nor is criticism implied of similar products not mentioned.

Publications from Kansas State University are available at: ***www.ksre.ksu.edu***

Publications are reviewed or revised annually by appropriate faculty to reflect current research and practice.
Date shown is that of publication or last revision. Contents of this publication may be freely reproduced for educational purposes. All other rights reserved. In each case, credit Danny H. Rogers, Phil Barnes, G. Morgan Powell, and Kerri Ebert, *Water Primer, Part 4: Surface Water*, Kansas State University, November 2012.

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

MF3023 **November 2012**

K-State Research and Extension is an equal opportunity provider and employer. Issued in furtherance of Cooperative Extension Work, Acts of May 8 and June 30, 1914, as amended. Kansas State University, County Extension Councils, Extension Districts, and United States Department of Agriculture Cooperating, John D. Floros, Director.