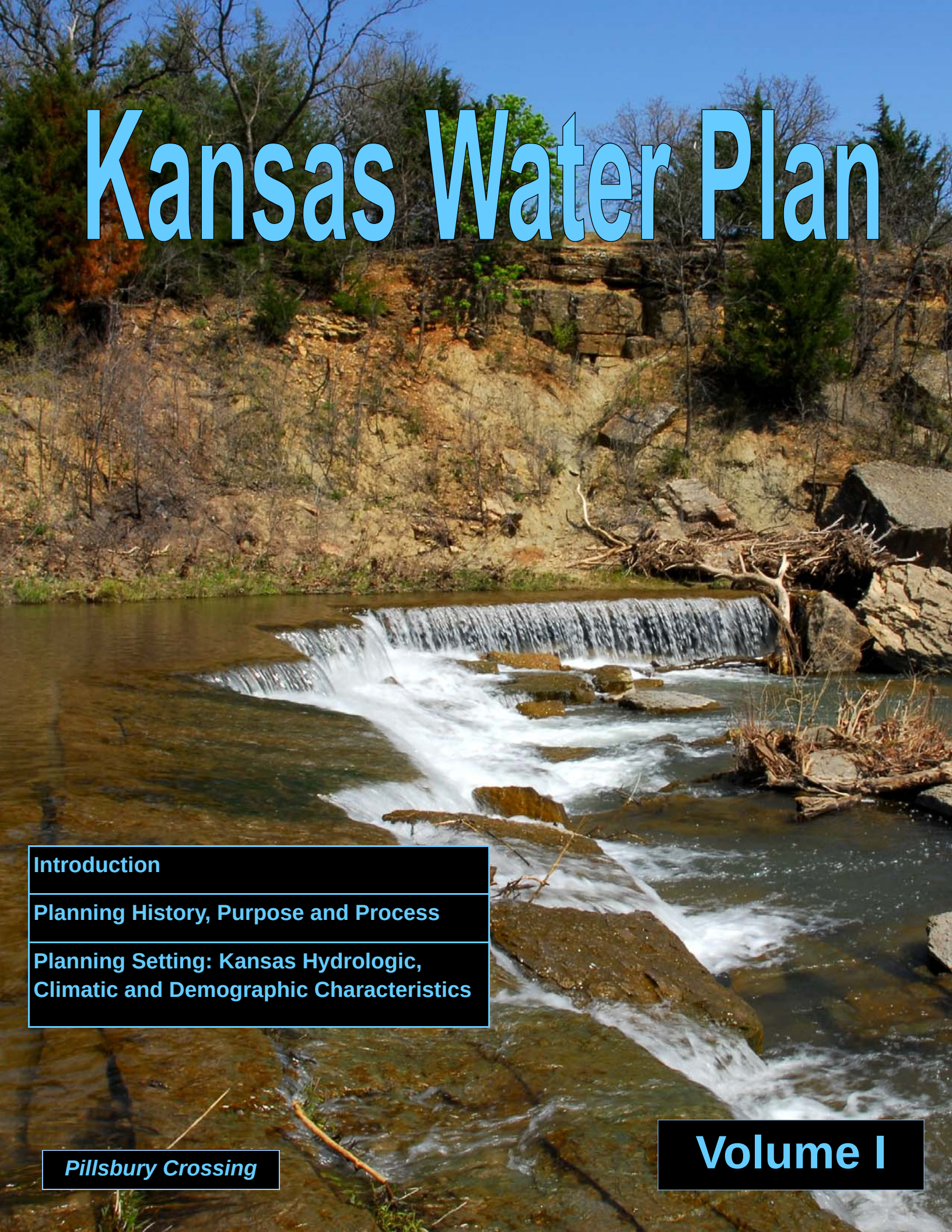
Kansas Water Plan



Introduction

Planning History, Purpose and Process

Planning Setting: Kansas Hydrologic, Climatic and Demographic Characteristics

Pillsbury Crossing

Volume I

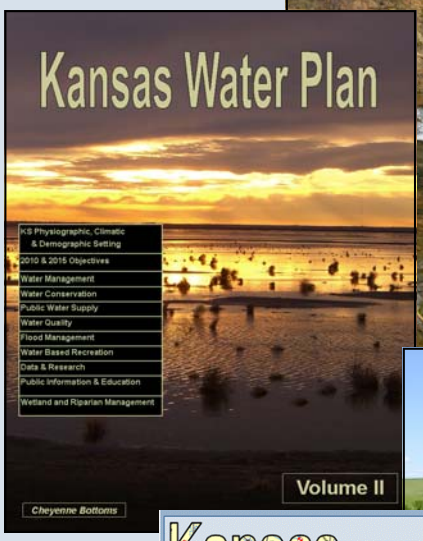
Kansas Water Plan - Volume I
Table of Contents

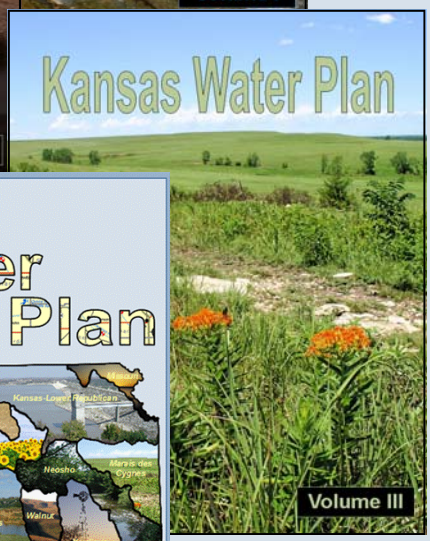
Kansas Water Plan
Introduction
January 2009

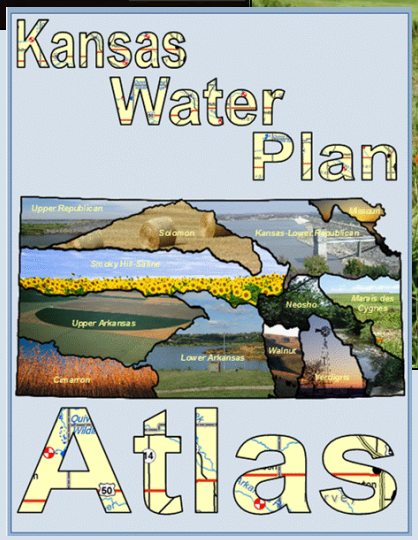
For 25 years, the *Kansas Water Plan* has been the tool that has allowed citizen groups and water professionals from state, federal and local levels to coordinate and identify the water problems and issues that Kansas must address. The Kansas Water Authority and Kansas Water Office are proud to release a comprehensive update of the *Kansas Water Plan* that has been in the works over the last year.

The *Kansas Water Plan* and supporting information is organized as follows:

- Volume one overviews the water planning process and purpose and highlights a history of water planning and the physiographic characterization of Kansas.
- Volume two covers statewide water management policies and objectives.
- Volume three covers the 12 basin sections and their priority issues.
- An atlas of maps and graphics depicts the resource conditions for each basin.
- A Program Manual (Redbook) describes various state and federal water resource programs.







The 2009 Kansas Water Plan is the product of a collaborative process that brought together the Kansas Water Authority, the basin advisory committees, representatives of the Governor's Natural Resources Subcabinet and other interested stakeholders. The result is a plan that includes the very best ideas for meeting the state's water challenges.

A major focus of the update has been on the water resource needs in each of the state's 12 river basins. The *Kansas Water Plan* provides a framework for water resource professionals and citizens to propose solutions that address statewide and regional issues. While work on all aspects of water resource management is ongoing, certain projects because of their urgency, move to the forefront. These projects are reflected as basin priority issues within the water plan.

These priority issues have been identified by members of the basin advisory committees. The various priorities reflect the basins' climatic, physiographic and demographic conditions. The basin priority issues and the complete plan are posted on the Kansas Water Office web site www.kwo.org.

The Kansas Water Plan and the priority issues contained within it, will help guide implementation efforts over the next 5 years, targeting resources to areas perceived to be the highest priority by local communities.

The conclusion of this water plan is clear: Kansans can meet their water demands into the future by making the right choices and investments. The Kansas Water Plan continues to provide the guidance state policymakers, local and regional entities and others need, to take actions to meet the state's water demands now and in the years to come.

Kansas Water Plan
Planning History, Purpose and Process
January 2009

Water Planning In Kansas

Water planning in Kansas has two main attributes - collaboration and citizen involvement. This *Kansas Water Plan (*KWP*)* section provides an overview of the KWP, including its purpose, structure and the process through which it is developed. The relationship of the KWP to other key water planning efforts also is described.

The *Kansas Water Plan* - The *Kansas Water Plan* is one of the primary tools used by the State of Kansas to address current water resources issues and to plan for future needs. The Plan also serves as a guide to coordinate local, state and federal actions. Statutory authority and basic guidance for formulating the *Kansas Water Plan* is contained in the State Water Resources Planning Act.[1]

State Water Resources Planning Act – Initially enacted in 1963, the Planning Act declares that ". . . the state can best achieve the proper utilization and control of the water resources of the state through comprehensive planning which coordinates and provides guidance for the management, conservation and development of the state's water resources. . ." The Kansas Water Office is directed to formulate a state water plan on a continuing basis and to include sections corresponding with water planning areas as determined by the KWO. Factors to be considered in formulating the state water plan are listed[2] as are long-range planning goals[3] and policies for achieving the long-range goals.[4]

The Planning Act directs that prior to submission of the state water plan for approval, advice from the general public and from committees within the 12 basin planning areas shall be sought and that public hearings be held. The Planning Act also states that the KWO, with KWA approval, shall annually submit to the Legislature and to the Governor an updated water plan containing recommendations needed to achieve the long-range planning goals as stated in the Act. [3]

Historical Overview

Comprehensive planning for water resources in Kansas began with an emphasis on use and development. Over the decades, the planning emphasis shifted to management and protection. The KWP is best understood with a basic knowledge of previous planning activities and the process through which it is developed.

1950s - 1970s

Comprehensive water resource planning at the state level in Kansas was spurred by the disastrous flooding of 1951 and the subsequent severe drought conditions from 1952 through 1956. A special meeting of the State Finance Council was held in 1954 to discuss the drought and to consider allocating money from the State Emergency Fund for a statewide water study. An appropriation for the study was unanimously approved.

The study was to provide the 1955 Kansas Legislature with a survey and other factual data needed for comprehensive statewide water planning and conservation programs. The Kansas Water Resources Fact Finding and Research Committee conducted the study. The resulting study, *Water in Kansas*, was presented to the Governor and members of the Kansas Legislature on January 2, 1955.[5]

Water in Kansas addressed the organizational structure needed for comprehensive planning, noting that closer working relationships among agencies were needed. A key recommendation was to ". . .Provide the necessary organizational structure, personnel and funds to prepare and maintain a state plan of water resources development." The Kansas Water Resources Board (KWRB) was established in 1955 to fulfill this recommendation.

Kansas Water Resources Board (KWRB) – For planning purposes, the KWRB divided the state into 12 units based on hydrological boundaries. Between 1955 and 1963, much of the planning effort concentrated on preliminary studies of these planning units which included an inventory of resources and identification of problems and needs.

The State Water Plan Act of 1963[1] expanded the role of the KRWB in planning, policy and coordination. The Act mandated preparation of a state water plan addressing all aspects of water resources, covering beneficial use, control and development. The Act also encouraged the Plan be prepared with cooperation of other agencies.

The State Water Plan Act was again expanded in 1965. A portion of the Act itself was identified as "the State Water Plan." The Plan identified reservoirs to be guilt and contained goals, policies and considerations for planning.

During this time the KWRB became an important partner with stakeholders and the federal government in the many water resources development projects. Among

these projects were federal dams and reservoirs constructed by the U.S. Army Corps of Engineers and the Bureau of Reclamation, watershed dams development by the USDA Soil Conservation Service and rural water districts developed with USDA Farmer's Home Administration financial assistance.

1970s

Governor's Task Force on Water Resources – By the 1970s, rising costs and public environmental concerns had altered the water resources management landscape. The era of intense water resources development had ended. The need for a more management-oriented approach to water resources was recognized. Drought gripped much of Kansas in 1976 and there was increasing concern about rapid depletion of ground water supplies in western Kansas. As a result, Governor Robert F. Bennett created the Governor's Task Force on Water Resources in 1977.


Governor Robert F. Bennett

Governor Bennett charged the Task Force with determining the key water supply problems facing Kansas, and examining their underlying causes. The Task Force was to identify options available to the state and to local units of government for resolving problems, including:

1. Ways to eliminate any duplication and inefficiencies in state and locally sponsored water resource programs;
2. Ways to achieve more effective coordination among state and local water resources programs;
3. Recommendations for any needed changes in existing water resources laws, policies and programs; and
4. New programs which should be undertaken at state or local levels.

The Task Force found that the State Water Plan, as identified in the Planning Act, had not been an effective mechanism for achieving interagency and state water resource policy coordination. The Task Force recommended:[6]

> *"...that increased attention be given to the use of the State Water Plan as the state's basic expression of policy on subjects relating to conservation, planning, development and management of the state's water resources, and the principal means of assuring continuous coordination of the research, regulatory, developmental and operational activities of the various state water agencies and local water entities. . . ."*

The task force further recommended that policy and objective statements be approved by the Legislature but that the State Water Plan itself not be incorporated into the statutes.

The Task Force Chairman, concerned about long term coordination proposed a reorganization of state water agencies that would have consolidated into one agency the functions of the Kansas Water Resources Board, the Division of Water Resources of the Kansas State Board of Agriculture and the water-related functions of the Division of Environment of the Kansas Department of Health and Environment. This proposed reorganization generated significant discussion. In the end, the Task Force concluded that reorganization was not justified. The Task Force reaffirmed the value of and need for interagency coordination and suggested physical co-location of the three major water agencies.

1980s

Creation of the Kansas Water Office and Kansas Water Authority - During the 1981 Legislative Session, water agency reorganization was again discussed. The Legislature reach a compromise that resulted in abolishment of the Kansas Water Resources Board and establishment of the Kansas Water Office (KWO), effective July 1, 1981.[7] The powers, duties and functions of the KWRB were transferred to the new KWO. The KWO was charged with development of a state plan of water resources management, conservation and development.

This Act also created the Kansas Water Authority (KWA). The KWA is statutorily within and a part of the KWO. Its membership is comprised of 13 appointed citizen members representing various water resources interests and 11 state agency representatives.

Duties of the KWA include:[8]

- Consulting with and advising the Governor, Legislature and Director of the KWO on water management issues;
- Reviewing plans of any state or local agency related

to the water resources of the state;

- Studying laws related to water resource management issues and recommending new or amendatory legislation;
- Recommending coordination of water resource management activities; and
- Approving amendments to the State Water Plan.

The current KWP took shape in the early 1980s. Public meetings were held by the KWO throughout the state during the summer of 1983. At these meetings drafts of proposed Water Plan sections were reviewed and public input was encouraged. After extensive revision and another round of public meetings, the KWP was approved by the KWA in December 1984. In February 1985, the Kansas Legislature endorsed the comprehensive, continuous coordinated planning process through which the Water Plan was formulated.[9]

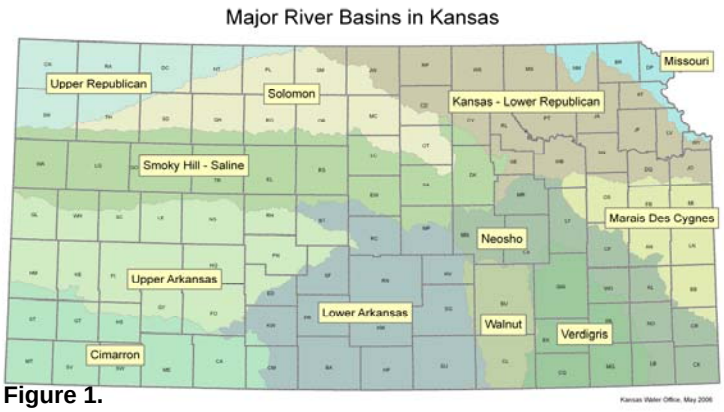


Figure 1.

An initial policy focus of the *Kansas Water Plan* was development of new programs or modification of existing programs needed to meet the water resource management challenges that had emerged by the 1980s.

In addition, twelve major river basins, nearly identical to the planning units utilized by the KWRB, were delineated and basin advisory committees (BAC) organized for each basin in 1985 (Figure 1). The BAC (then as now) provided significant citizen input on the development of the Plan. Targeting of program resources to areas of need and necessary interagency coordination was addressed through the *Kansas Water Plan* basin sections. Initial basin sections of the *Kansas Water Plan* were approved in 1986.

In 1989, under the leadership of then Governor Hayden another important step in current water planning was taken with the creation of the State Water Plan Fund (SWPF). The Fund is used for establishing and implementing water related programs or projects identified in the KWP.[10]

1990s

During the 1990s the KWP was updated regularly with guidelines to agencies and utilizing the SWPF. The KWP continued to address programs and projects but from a budgetary planning view point.

The 1997 Kansas Legislature directed that a report be prepared addressing the overall direction of programs and activities funded from the SWPF. A Vision Summit, attended by 275 Kansans, was held in Salina in November 1997 to gather advice prior to preparing the requested report. The resulting report, delivered to the 1998 Legislature, provided direction on the Water Plan with preliminary goals for the KWP to be achieved by 2010.[11] These 2010 Objectives were approved by the KWA and incorporated into the KWP in October 1998 following a series of public meetings to gather input. The objectives provided direction for planning, but despite this attempted reorientation of the KWP, its relevance and effectiveness continued to be less than desired.

The 21st Century

With the 2002 election of Governor Kathleen Sebelius, an extensive review of water resource agencies was undertaken. The Sebelius administration recommitted to the KWP and the Kansas water planning process as a tool to identify and coordinate implementation of water resource issues relevant to Kansas. An enhanced coordination process was established, including a Natural Resources Subcabinet comprised of agency executives named by the Governor.

Kansas Water Planning Process

The Kansas water planning process incorporates the three key state water plan characteristics mandated by the State Water Resources Planning Act,[1] comprehensive, coordinated and continuous adaptive planning approach. Adaptive planning is the cornerstone upon which the planning process and the *Kansas Water Plan* rest.

This process is based upon the assumptions that: 1) our ability to understand the interdependencies among natural and social systems is ever evolving; 2) water management decisions must be incremental adjustments from the status quo; and 3) water resource decisions must be made recognizing varying interests of public and private sectors. This view of water resource plan-

ning supports the ability of the decision-making process to be flexible in response to changing current and future conditions and promotes adjustments from the current situation which do not foreclose future resource use options.[12]

Guiding Principles – The Kansas water planning process emphasis is comprehensive, coordinated and continuous planning. The current KWP provides a comprehensive scope, organized around water management categories and the 12 river basin plans covering all aspects of water resources management, conservation and development. The river basin or watershed approach has been used in formulating the *Kansas Water Plan* wherever pertinent. Watersheds tend to integrate the effects of water management actions as they interact with the climatic, physiographic, land use and land cover characteristic of the watershed, making them an ideal spatial entity for planning purposes. Watersheds extend beyond state borders; some issues addressed must be from that perspective.

Coordination among local, federal, state and occasionally interstate partners is promoted for example, through the diverse membership on the KWA, agency representation at basin advisory committee meetings, membership on technical advisory committees and through public review and comment on the KWP. The State Water Resources Planning Act[1] also requires that plans, projects and recommendations of public corporations, the federal government and state agencies be considered, which may include: Kansas Hazard Mitigation Plan,[13] Total Maximum Daily Loads,[14] Kansas Surface Water Nutrient Reduction Plan,[15] Capacity Development Strategy[16] and State Comprehensive Outdoor Recreation Plan[17] to name a few.

Kansas Water Planning Process

The water process is not stagnant. Policy or basin issues are added or modified as needed, using the described planning process. Figures 2 and 3 illustrate the various steps in the Kansas water planning process.

Policy Issue Planning Process

Concept Paper – Preparation of a concept paper is the initial formal step in the policy issue planning process (see Figure 2). The concept paper defines the issue to be addressed, including a brief background discussion. A plan of study with an anticipated planning timeline is included. KWA approval authorizes the KWO to proceed with development of a Background Paper and Preliminary Draft Section of the KWP.

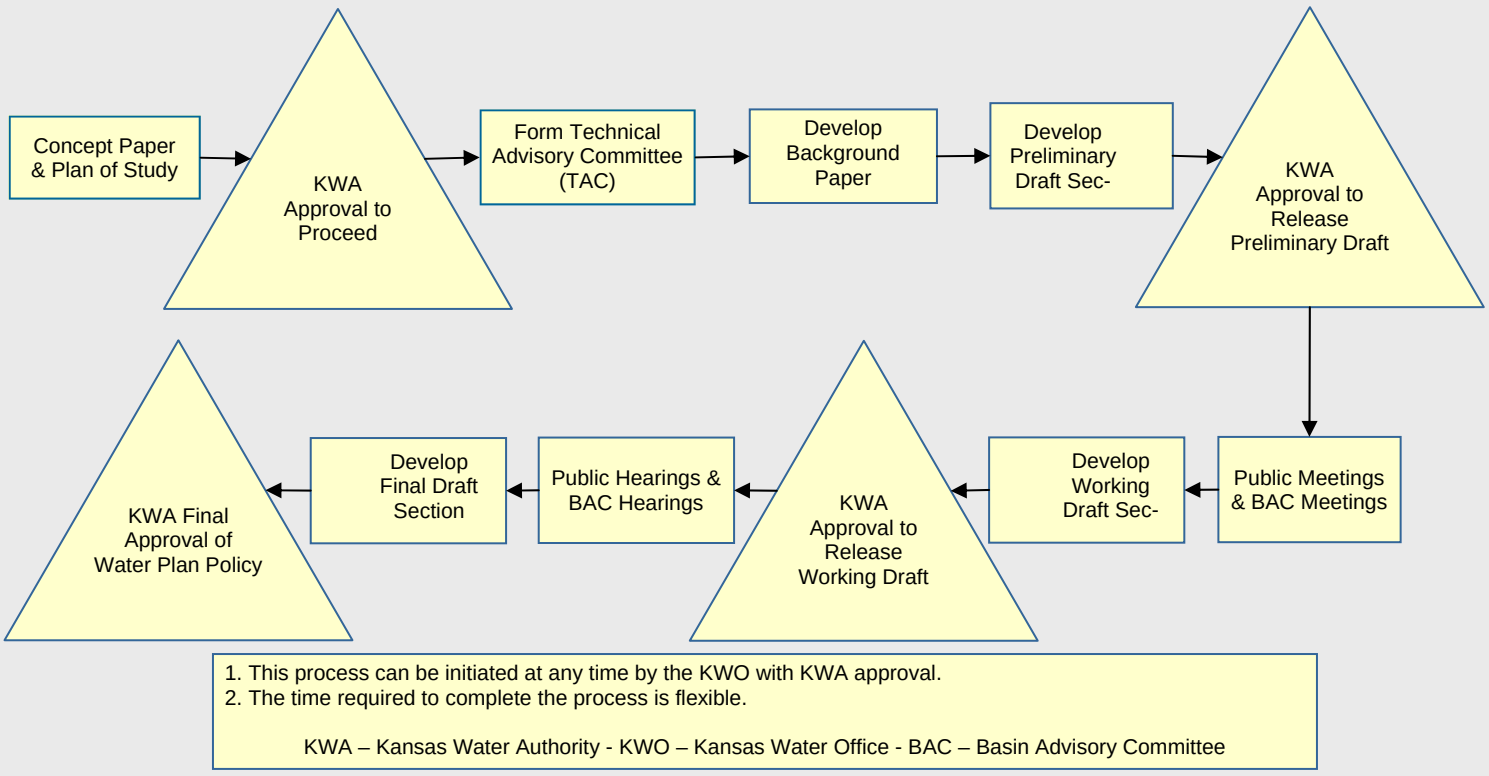


Figure 2. *Kansas Water Plan*—Policy Issue Planning Process (2004)

Background Paper – In the Policy Issue Planning Process, preparation of a Background Paper follows approval of the Concept Paper. The Background Paper expands on the Concept Paper, providing a comprehensive description of the issue, including its statutory and administrative context and possible alternative approaches. Associated federal authorities and programs are identified, if appropriate, as are approaches to the issue in peer states. The Background Paper is prepared in conjunction with development of a Preliminary Draft Policy Section (see following). A technical advisory committee is formed to provide input and review the paper.

Proposed Policy Section – Policy sections of the KWP present several options for addressing an issue and identify any recommended options. A detailed description of the issue being addressed and an overview regarding resource trends, statutory authority, applicable Kansas programs etc. are included. Legislative, administrative and fiscal requirements necessary for implementation are indentified. An implementation schedule is also developed. Proposed policy sections are developed through three drafts: Preliminary, Working and Final. Preliminary and Working drafts are released by the KWA for public comment prior to KWA action on the Final Draft (see Figure 2).

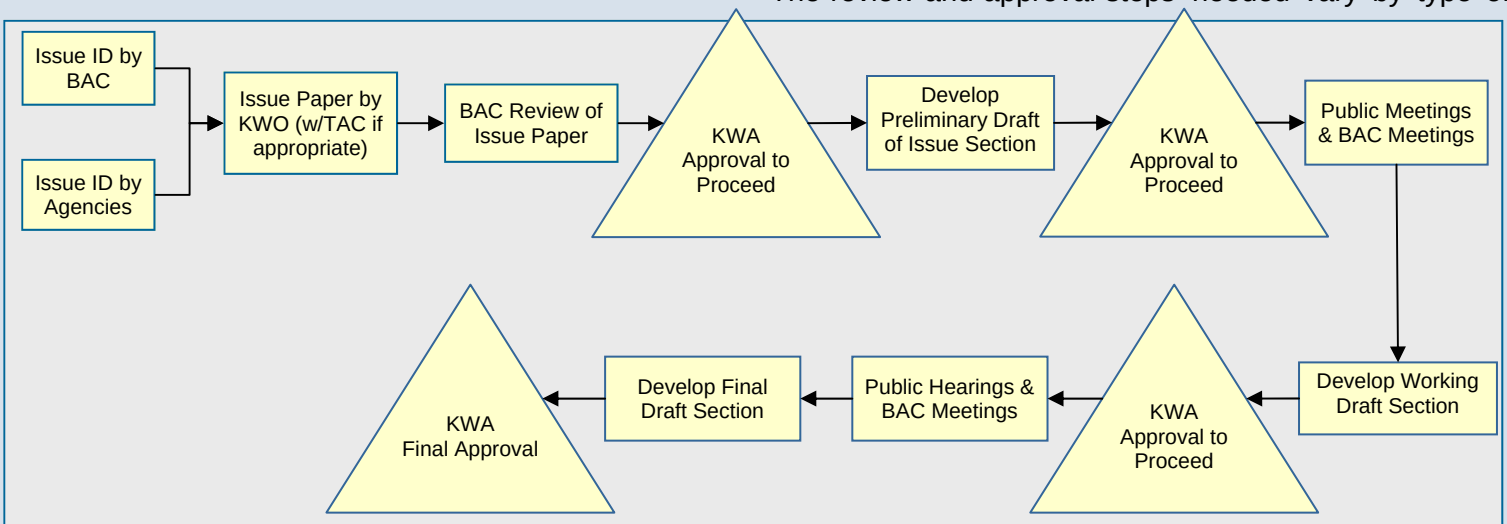
Basin Issue Planning Process

Issue Paper – The basin planning equivalent of the policy concept paper is the Issue Paper (see Figure 3). The KWP contains basin priority issues identified by a number of sources including a basin advisory committee, a member of the public or by a water resources agency. An issue paper is prepared that describes the issue, proposes revisions to the basin plan and a plan of study with proposed planning timeline. KWA approval authorizes the KWO to proceed with development of a preliminary draft basin issue section of the KWP.

Proposed Basin Plan Section – New priority issued identified in the issue paper step are developed through three draft stages: Preliminary, Working and Final. Preliminary and Working drafts are released by the KWA for public comment prior to KWA action on the Final Draft (see Figure 3). Basin issues may be introduced at any time. The entire basin section is reviewed at least every 5 years.

Kansas Water Plan Components and Products

The KWP references several related documents that describe existing policy and programs or make new recommendations regarding the management, conservation and development of the water resources of the state. The review and approval steps needed vary by type of



1. New issues can be submitted at any time by the BAC or any agency.
2. Time required to complete process is flexible depending on the specific issue being addressed.
3. When new issues are considered in the planning process, the entire basin plan will be subject to review.
4. The basin plan will be cycled through the planning process at least once every 5 years.

BAC - Basin Advisory Committee - KWA - Kansas Water Authority - KWO - Kansas Water Office - TAC Technical Advisory Committee

Figure 3. *Kansas Water Plan*—Basin Issue Planning Process (2004)

document. KWO and other agencies coordinate on several related documents that support SWP development and implementation. A brief description of each follows.

State and Federal Water Programs – The Programs Manual, compiled periodically by the KWO, is also referred to as the "Red Book." The Programs Manual describes state and federal water resources programs, including identification of relevant statutory authority and program contact information.

2010-2015 Objectives and Assessment[18] – Objectives were added to the *Kansas Water Plan* in 1998 and again in 2002. Objectives for each management category are located in in Volume II the Plan. An assessment of the Objectives was conducted to establish a baseline condition against which progress in achieving the objective could be measured. In several cases, the objective was too vague or data was not available to conduct an assessment. Summaries of assessment results were compiled in reports prepared by the Kansas Water Office in 2002 and 2006.[19, 20]

Kansas Water Plan Status Report – The annual Status Report, compiled by the KWO, provides an update on programs and projects receiving funding from the State Water Plan Fund (SWPF). The Status Report is organized by agency and program and provides summary information for the immediate past fiscal year and discusses planned activities for the current and next fiscal years. When possible, information is provided by river basin.

KWA Annual Report – The KWA makes recommendations to the Governor and the Kansas Legislature regarding implementation of the KWP through the annual report. The report contains recommendations on budget as well as new or amendatory legislation. The document plays a key role in defining the necessary budget to implement the KWP. The Report also highlights priority water issues around the state and how they are being addressed through agency actions supported by the Fund. The KWA Annual Report must be provided annually by December 1st.

The Future

No one knows what the future holds. What is known is that water and management, conservation and development of the states water resources, will continue to be critical to the state. Water planning for current and future needs will continue.

Resources

1. State Water Resources Planning Act. K.S.A. 82a-901 et seq. http://www.kslegislature.org/legsrv-statutes/getStatuteInfo.do

2. K.S.A. 82a-907. http://www.kslegislature.org/legsrv-statutes/getStatuteInfo.do

3. K.S.A. 82a-927. http://www.kslegislature.org/legsrv-statutes/getStatuteInfo.do

4. K.S.A. 82a-928. http://www.kslegislature.org/legsrv-statutes/getStatuteInfo.do

5. *Water in Kansas*. A Report to the 1955 Kansas State Legislature. Prepared by the Kansas Water Resources Fact Finding and Research Committee as directed by the State Finance Council.

6. State of Kansas. 1978. *Final Report of the Governor's Task Force on Water Resources*.

7. K.S.A. 74-2606 *et seq*. http://www.kslegislature.org/legsrv-statutes/getStatuteInfo.do

8. K.S.A. 74-2622. http://www.kslegislature.org/legsrv-statutes/getStatuteInfo.do

9. HCR No. 5010, February 18, 1985. A Concurrent Resolution commending the KWA and KWO in the preparation of the State Water Plan.

10. K.S.A. 82a-951. http://www.kslegislature.org/legsrv-statutes/getStatuteInfo.do

11. KWO/KWA. January 23, 1998. Report on Recommended Direction of Activities under the *Kansas Water Plan*.

12. Shabman, Leonard. April 1984. *Emerging Concepts for the Conduct of State Water Resources Planning*. American Water Resources Association. Water Resources Bulletin, Vol. 2, No.2.

13. Kansas Hazard Mitigation Plan

14. TMDLs

15. Kansas Surface Water Nutrient Reduction Plan

16. Capacity Development Strategy.

17. State Comprehensive Outdoor Recreation Plan

18. 2010/2015 Objectives Section of the *Kansas Water Plan*.

Kansas Water Plan
Planning Setting: Kansas Hydrologic, Climatic and Demographic Characteristics
January 2009

The physical Kansas that we experience today is the result of geologic and climatic factors interacting over eons of time. The resultant soils, topography and drainage pattern, along with the climate have helped influence where people live, work and play and the types of activities that they pursue.

Kansas, with a total area of 82,277 square miles, lies at the center of the contiguous United States and some 700 miles south of the geographic center of North America which is located in North Dakota. The land surface of Kansas slopes gently from west to east with extreme elevations ranging from 4,039 feet at Mt. Sunflower in Wallace County down to 679 feet at the point where the Verdigris River leaves the state in Montgomery County. The approximate mean elevation of the state is 2,000 feet.

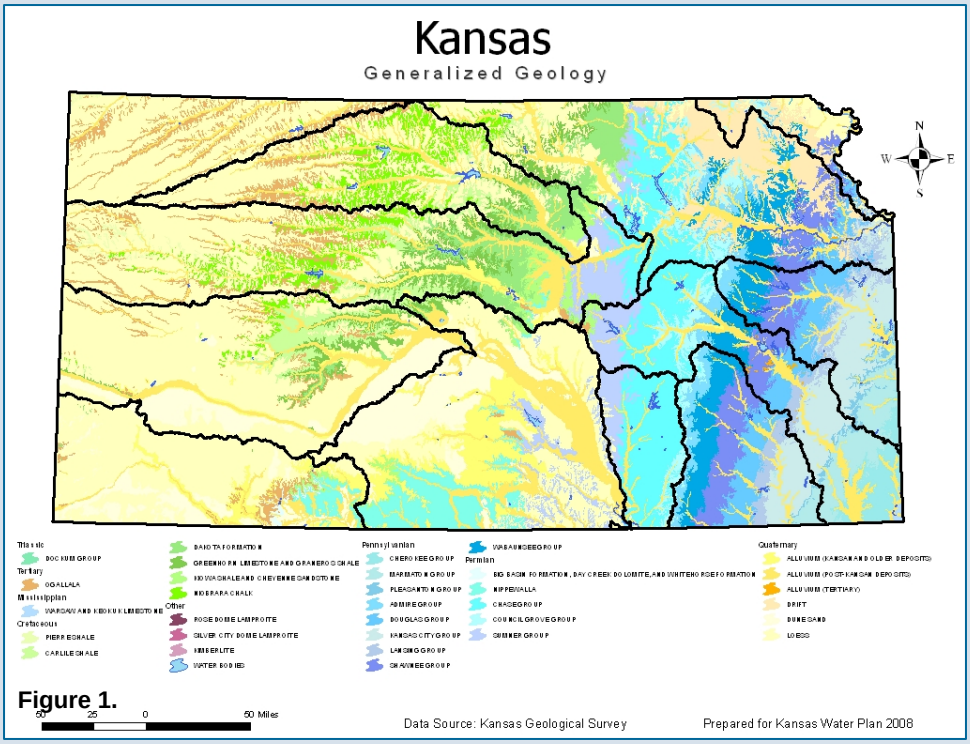


Figure 1.

Generalized bedrock formations or unconsolidated surface deposits are shown in Figure 1. These were formed by sediments deposited in ancient seas or by material deposited by wind, river currents or glaciers. The physical and chemical properties of these rock formations are critical to their suitability as aquifers and also influence surface water quality.

Figure 2 illustrates the general land cover and land use pattern across Kansas in 2005.

Kansas water resources are ground water dominated in the western half of the state and surface water dominated in the eastern half. Climate is a significant factor in this variability, with semi-arid conditions, low precipitation (typically 16 to 22 inches annually) and limited surface water in western Kansas. There are aquifers in eastern Kansas; however they are generally much more limited in extent and yield than the aquifers in western Kansas.

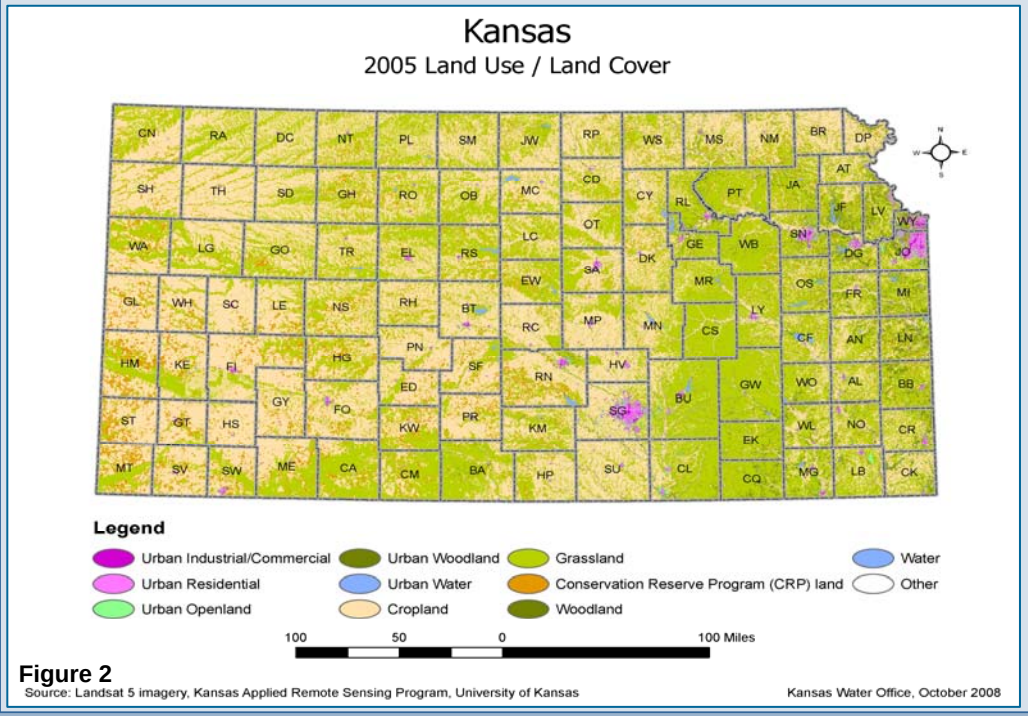


Figure 2

Surface Water Availability

Kansas has several major rivers and aquifers, but few natural lakes. Many reservoirs, large and small, have been constructed to control flooding and store water for beneficial use. Major rivers within Kansas include the Arkansas, the Kansas and the Neosho. The state's largest river, the Missouri, forms the northeast border.

Kansas Water Plan
Planning Setting: Kansas Hydrologic, Climatic and Demographic Characteristics
January 2009

Drainage Pattern and Streamflow Characteristics - The surface drainage pattern of Kansas reflects the general west to east slope of the land and the erosion characteristics of the bedrock formations. The entire state ultimately drains to the Gulf of Mexico by way of the Mississippi River as illustrated in Figure 3. In general, the northern half of the state is drained by the Missouri River and its tributaries, while the southern half is part of the Arkansas River drainage.

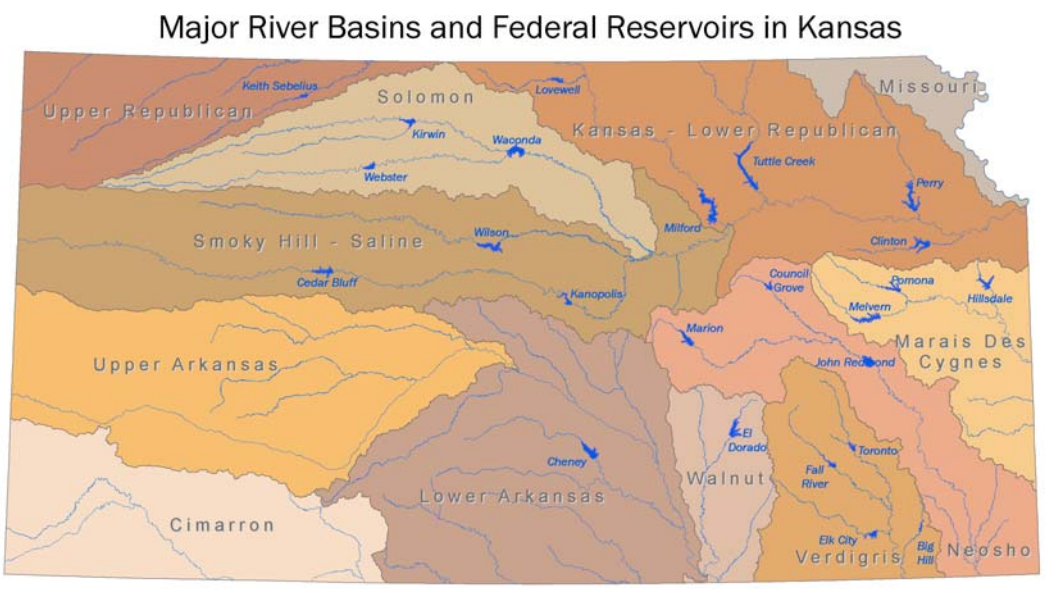


Figure 4.

Twelve major river basins are commonly recognized in Kansas for general planning purposes, including preparation of the *Kansas Water Plan.* These basins are shown in Figure 4. The Upper Republican, Solomon, Smoky Hill-Saline, Kansas-Lower Republican, Marais des Cygnes and Missouri basins are all part of the greater Missouri River basin, while the Cimarron, Upper Arkansas, Lower Arkansas, Walnut, Verdigris and Neosho basins are part of the greater Arkansas River basin.

Streamflow volume in eastern Kansas is much greater than it is in the west due to greater total precipitation and the fact that runoff rates increase greatly from west to east across the state. This is reflected in the summary streamflow statistics shown in Table 1.[2] Also worthy of note is the much greater annual volume of discharge generally experienced in streams located in the Missouri basin as compared with streams in the Arkansas basin.

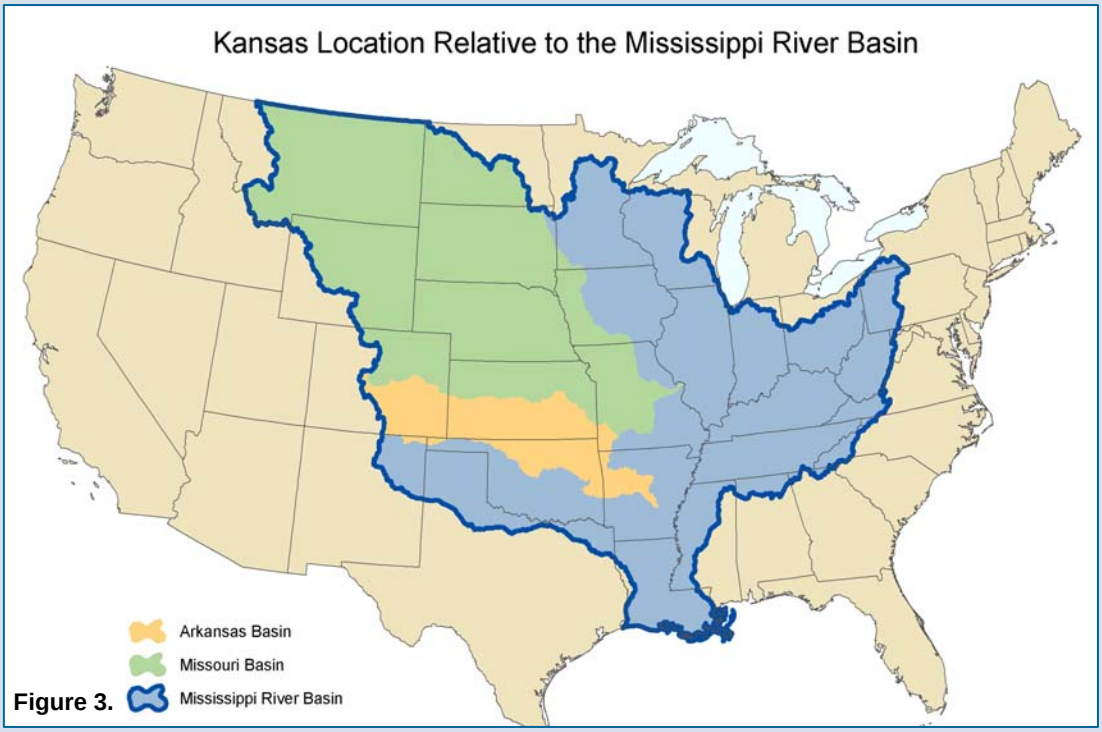


Figure 3.

Table 1
Summary Streamflow Statistics
Selected Kansas Rivers

Gaging Station	Period of Record (water year)	Annual Mean Flow (cfs)	Annual Mean Discharge (ac-ft)
Missouri Basin			
Prairie Dog Ck. near Woodruff	1929-2007	24.7	17,870
Saline R. at Tescott	1920-2007	214	155,000
NF Solomon R. at Portis	1946-2007	114	82,490
SF Solomon R. at Osborne	1947-2007	104	75,700
Solomon R. at Niles	1898-2007	550	398,400
Smoky Hill R. near Arnold	1951-2007	39.4	28,570
Smoky Hill R. at Enterprise	1935-2007	1,542	1,117,000
Republican R. at Junction City	1968-2007	844	611,500
Big Blue R. near Manhattan	1951-2007	2,320	1,681,000
Kansas R. at Wamego	1920-2007	5,055	3,662,000
Delaware R. at Perry	1970-2007	671	486,100
Wakarusa R. near Lawrence	1930-2007	216	456,400
Kansas R. at De Soto	1918-2007	7,295	5,285,000
Missouri R at Kansas City, MO	1958-2007	54,810	39,660,516
Marais des Cygnes R. near Pomona	1923-2007	604	437,300
Marais des Cygnes R. near KS-MO State Line	1959-2007	2,181	1,580,000
Marmaton R. near Marmaton	1972-2007	283	205,100
Arkansas Basin			
Arkansas R. at Syracuse	1903-2007	286	207,300
Arkansas R. at Dodge City	1903-2007	130	94,450
Pawnee R. at Rozel	1925-2007	58.8	42,580
Arkansas R. at Great Bend	1941-2007	250	181,300
Walnut Ck. at Albert	1959-2007	47.9	34,690
Rattlesnake Ck. near Macksville	1960-2007	23.3	16,870
Little Arkansas R. at Valley Center	1923-2007	315	228,100
Arkansas R. at Arkansas City	1903-2007	1944	1,409,000
Ninnescah R. near Peck	1938-2007	526	381,000
Walnut R. at Winfield	1922-2007	903	654,300
Cimarron R. near Elkhart	1972-2007	8.65	6,270
Cimarron R. near Forgan, OK	1966-2007	53.9	39,060
Fall R. at Fredonia	1939-2007	522	378,300
Verdigris R. at Independence	1968-2007	2186	1,583,000
Neosho R. near Americus	1964-2007	321	232,600
Cottonwood R. near Plymouth	1964-2007	868	628,600
Neosho R. at Burlington	1962-2007	1601	1,160,000
Neosho R. near Parsons	1922-2007	2733	1,980,000

cfs - cubic feet per second; ac-ft – acre feet
Source: U.S. Geological Survey

Wide seasonal and year-to-year variations in flow are experienced in Kansas streams. For example, while the 1918-2007 annual mean flow in the Kansas River at De Soto is 7,295 cubic feet per second (cfs), monthly mean flow varies from 2,840 cfs in January to 14,800 cfs in June. Annual mean flow has varied from 1,326 cfs in 1956 to 30,570 cfs in 1993.[2]

The year 1956 was the worst of the 1952-1957 drought period, which is considered the "drought-of-record" in Kansas. Four great floods, including that of 1993, have occurred on the Kansas River since the beginning of European settlement. The other great flood years were 1844, 1903 and 1951. The Flood Damage Mitigation and Small Dam Safety Management Section provides additional information about flooding.

Loss of Flow in Perennial Streams - Surface water and ground water are parts of a complex hydrologic system, and a change in one can impact the other. Areas in Kansas that have been intensely developed for ground water use have experienced water level declines. A consequence of these water level declines in some areas has been a decrease in baseflow in hydraulically connected streams. As a result, the flow in some western Kansas streams has become intermittent rather than perennial over time as depicted in Figure 5, causing a loss of water available to riparian vegetation and wetlands, and a detrimental impact to aquatic ecosystems.

Reservoirs - In an attempt to reduce the uncertainty produced by the state's variability in climate and associated surface water supplies, Kansans have built numerous ponds and reservoirs. As of 2005, nearly 6,000 small dams in the state were regulated by the Kansas Department of Agriculture-Division of Water Resources. More than 1,500 of these dams have been constructed by organized watershed districts. Based on information on 4,000 of these regulated dams, their average age is now approximately 40 years.

The federal government has constructed 24 major reservoirs in Kansas.[1] The primary authorized use for reservoirs built by the U.S. Army Corps of Engineers at the time of their construction was flood control. Irrigation water supply was a primary use for those reservoirs constructed by the U.S. Bureau of Reclamation (Bureau), along with flood control. Other authorized uses, which vary by reservoir include municipal and industrial water supply, water quality, recreation and navigation support.

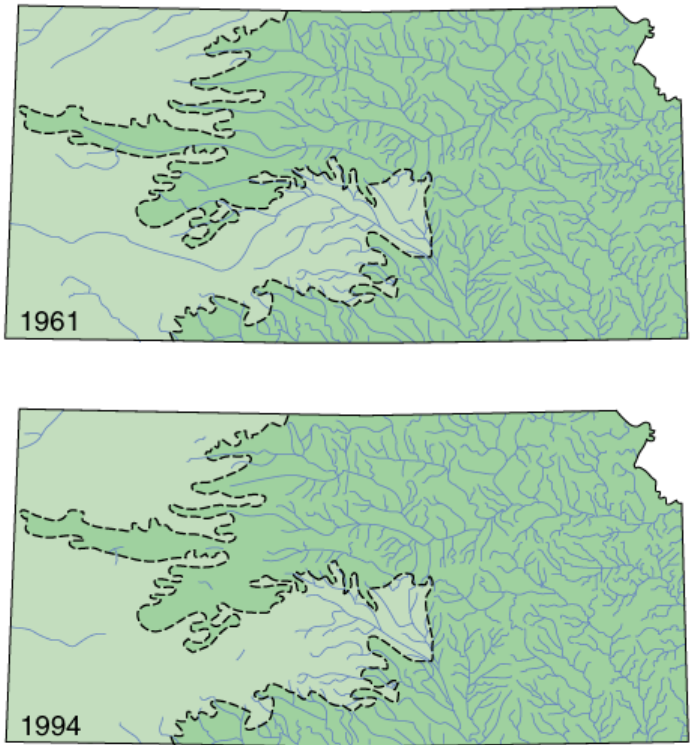


Figure 5. Major perennial streams in Kansas in 1961 and 1994. The area west of the dashed line show the extend of the High Plains aquifer in Kansas (adapted from Angelo, 1994).

The Public Water Supply Management Section provides additional information about the use of these reservoirs for municipal and industrial water supply.

Table 2 provides summary information for the major federal reservoirs in Kansas.

Ground Water Availability

Figure 6 illustrates the general availability of ground water across Kansas in terms of typical well yield. The greater yields present in much of western and south central Kansas contrast with lesser yields in the east except for alluvial aquifers adjacent to the Kansas River.

The water resources of Kansas, including ground water, are becoming fully allocated. As demands increase and treatment technology improves, brackish ground water sources are being evaluated to meet a portion of the growing demand in areas where fresh water supplies are limited.

Kansas has seven primary freshwater aquifer sources as shown in Figure 7. The most developed sources are in

Table 2
Major Federal Reservoirs in Kansas

Reservoir	Operating Agency	Year Storage Began	Drainage Area (sq. mil)	At Top of Conservation/Multi-Purpose Pool			
				Elevation (feet)	Surface Area (acres)	Storage Capacity (acre-ft)	Shoreline Perimeter (miles)
Big Hill	Corps	1981	37	858.0	1,192	26,650	20
Cedar Bluff	Bureau	1950	5,530	2144.0	6,689	170,658	50
Cheney	Bureau	1964	933	1421.6	9,540	143,427	67
Clinton	Corps	1977	367	875.5	7,120	120,643	82
Council Grove	Corps	1964	246	1274.5	3,314	43,176	40
El Dorado	Corps	1981	234	1339.0	7,911	157,973	98
Elk City	Corps	1966	634	795.0	4,188	38,385	50
Fall River	Corps	1949	585	949.5	2,329	19,433	40
Hillsdale	Corps	1981	144	917.0	5,476	71,950	51
John Redmond	Corps	1964	3,015	1039.0	8,084	44,385	59
Kanopolis	Corps	1948	2,327	1,463.0	3,252	43,121	30
Kirwin	Bureau	1955	1,373	1729.3	4,937	99,435	37
Lovewell	Bureau	1957	364	1582.6	2,986	41,690	44
Marion	Corps	1968	200	1350.5	6,220	75,133	60
Melvern	Corps	1970	349	1036.0	6,885	147,973	101
Milford	Corps	1964	3,796	1,144.4	15,314	351,577	163
Norton	Bureau	1964	712	2,304.4	2,180	34,330	32
Perry	Corps	1966	1,117	891.5	10,447	199,824	160
Pomona	Corps	1962	322	974.0	3,865	59,642	52
Toronto	Corps	1960	730	902.2	2,580	15,734	51
Tuttle Creek	Corps	1963	9,628	1,075.0	12,617	253,265	112
Waconda	Bureau	1967	5,076	1455.6	12,602	217,426	100
Webster	Bureau	1956	1,125	1,892.5	3,445	77.370	27
Wilson	Corps	1965	1,917	1,516.0	9,000	243,000	100

Source: U.S. Army Corps of Engineers and U. S. Bureau of Reclamation

unconsolidated sediments: the High Plains aquifer, the alluvial aquifers, and, to a lesser extent, the Glacial Drift aquifers. There are also several bedrock aquifers: the Dakota, the Ozark, the Osage and Flint Hills, along with a few more minor aquifers. A description of the basic characteristics of each primary aquifer follows.[4]

Alluvial Aquifers - Alluvial aquifers occur in the sand, gravel, silts and clays deposited by the major rivers and many of the smaller streams in Kansas. The thickness of the deposits varies considerably, with the deepest deposits up to 300 feet occurring in the major river valleys. The water in these aquifers tends to be shallow (10–30 feet), recharges relatively quickly, and is often directly

connected to the stream. In parts of eastern Kansas, the alluvial aquifers are the only significant source of ground water. In the Arkansas, Republican, Kansas and Pawnee river valleys, alluvial wells often yield 500 gallons per minute (GPM).

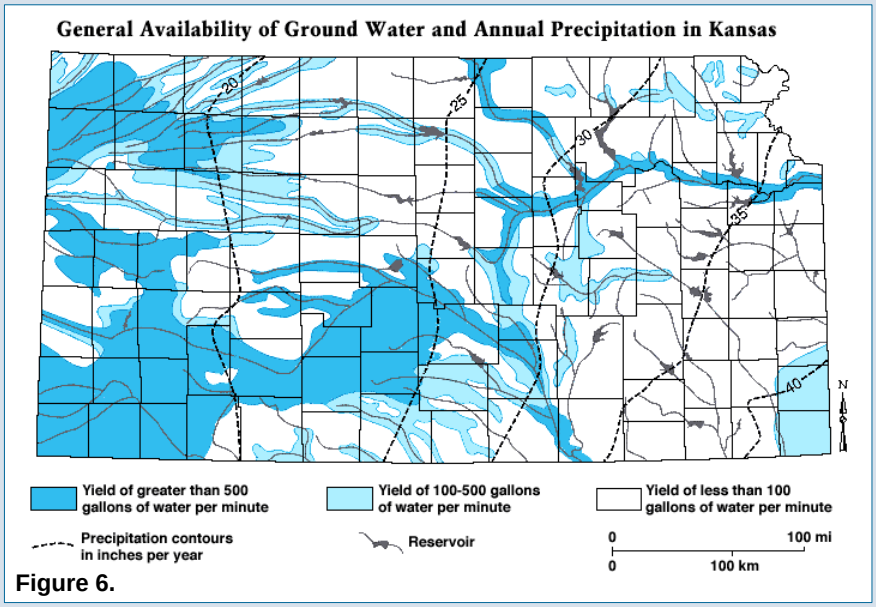


Figure 6.

The water in the alluvial aquifers generally flows towards or sub-parallel to the streams. High stream flows can enhance aquifer recharge from the rivers. During periods of low streamflow, water flows out of the alluvial aquifers and back into the streams; this contribution to streamflow is referred to as baseflow.

Baseflow helps maintain streamflow even when there is little precipitation and surface runoff. However, heavy withdrawals from an alluvial aquifer can lower the water table to the point where it no longer replenishes the stream. This has occurred in a number of streams in western and central Kansas including the Solomon, Smoky Hill, Arkansas, Pawnee and Walnut rivers.

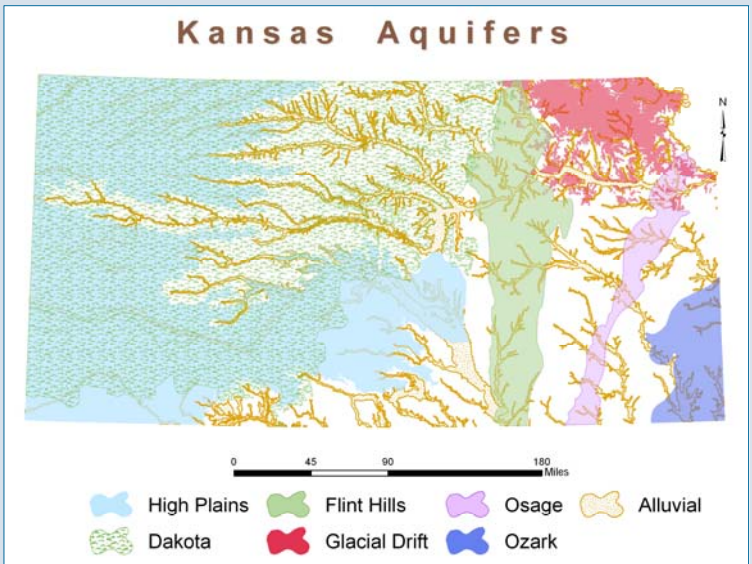


Figure 7.

Water quality in alluvial aquifers is generally acceptable for most purposes. Saltwater from Permian deposits has seeped into the Solomon and Smoky Hill River alluvial aquifers in Saline and Dickinson counties. Salinity problems have also occurred in parts of the Cimarron River valley of southwest Kansas, in the Ninnescah River in south central Kansas, and in portions of the Arkansas River valley. The Dakota aquifer also discharges saline water in Russell County and the Solomon River in Mitchell and Ottawa counties.

Glacial Drift Aquifers - Northeast Kansas was covered by continental glaciers roughly 750,000 years ago. The landforms and deposits left by the glaciers are common features in an area north of the Kansas River and east of Tuttle Creek Reservoir, extending to the Missouri River. Glacial deposits consist of a poorly sorted mix of sand, gravel and clay. In some cases these deposits have filled in ancient valleys that are now prolific water bearing sources. The buried valleys may be several miles wide, and 200 to 400 feet deep. Buried alluvial aquifers are not widespread nor are they well mapped. As a result, water in these aquifers can be difficult to locate.

Water-bearing zones can be as shallow as 5 to 50 feet in buried alluvial aquifers, but often exceed 100 feet. Well yields range from 10 to 500 gallons per minute (GPM). The water quality from shallow wells is generally good, although in some wells the nitrate concentrations exceed the safe drinking water level of 10 milligrams per liter (mg/L). The deeper wells often have more mineralized water, with total dissolved solids exceeding 500 mg/L.

High Plains Aquifer - The High Plains aquifer[7] underlies the western and south central portions of Kansas. It is one of the world's largest aquifers, and underlies portions of eight states, from South Dakota to Texas and New Mexico. About 27% of the irrigated cropland in the United States overlies the High Plains aquifer. In Kansas, the aquifer consists of the hydraulically intercon-

nected Ogallala aquifer in the west, the shallower and geologically younger Great Bend Prairie and the Equus Beds aquifers in south central Kansas, and associated alluvial and sand dune aquifers. Figure 8 shows the average saturated thickness of the High Plains aquifer in Kansas.

The Ogallala portion of the High Plains aquifer is the primary source of water in western Kansas for all uses, and is heavily developed, primarily for irrigation. Most of the Ogallala-High Plains aquifer is closed to or restricted from additional development. The aquifer is threatened by continued over-use and, in localized areas, deteriorating water quality.

The Ogallala-High Plains aquifer is up to several hundred feet thick in places, with the thickest deposits in southwestern Kansas. The saturated thickness is also highly variable, with some locations having more than 300 feet of water. Recharge from precipitation to the Ogallala may be as high as 1 inch per year, but may vary depending on local precipitation, soil type, land use, vegetation, and other factors. Ground water flow in general is in a west-northwest to east-southeast direction.

The Great Bend Prairie aquifer in south central Kansas is similar in composition to the Ogallala. It ranges in thickness from 350 feet in portions of Kiowa and Edwards counties, to thin deposits in Kingman and Reno counties. Recharge to the Great Bend Prairie may be up to three inches per year.

The Equus Beds, to the east, is an alluvial deposit of an ancestral river that flowed into the Arkansas River. The deposits filled an abandoned river channel in Harvey and McPherson counties, as well as areas of subsidence from salt dissolution. The deposits range up to 270 feet in thickness, with water depths typically fairly shallow, from 5 or 10 feet to 60 or 70 feet below ground surface. In the Equus Beds recharge may be up to four inches per year.

The water quality is generally good for most purposes, except in areas where salt has seeped in, either from natural sources or oil field brine disposal. The aquifer is a primary source of water for the Wichita metropolitan area. Protection from contamination is a high concern, due to the aquifer's shallow, vulnerable location.

Dakota Aquifer - The Dakota aquifer occurs within the sandstones of the Dakota Formation, as well as the Kiowa Formation and Cheyenne Sandstone. The Dakota aquifer system consists of upper and lower units, separated in western and central Kansas by the shale units of the Kiowa.[5] This shale aquitard ranges up to 300 feet in parts of west central and southwestern Kansas. The shale aquitard is not present in much of central Kansas, and in those regions there may be direct hydraulic connection between the upper and lower Dakota aquifer.

In much of western Kansas, the aquifer is confined by younger Cretaceous bedrock units that overlie the aquifer. In central and a few areas of southwestern Kansas, the Dakota crops out at the surface and the aquifer is unconfined. In much of southwest Kansas, the Dakota

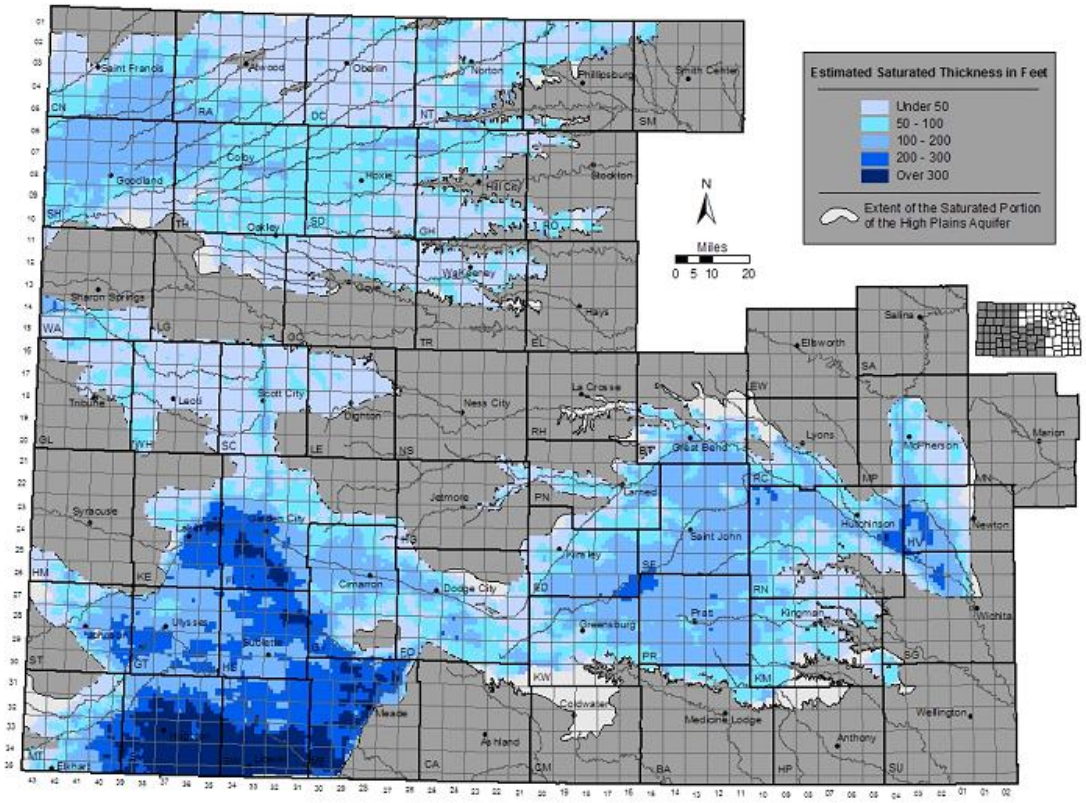


Figure 8. Average 2004 to 2006 Saturated Thickness for the High Plains Aquifer

underlies and is hydraulically connected to the High Plains aquifer.

The Dakota aquifer is used for municipal, industrial and irrigation uses in central and western Kansas. Ground water flow in the Dakota aquifer is from recharge areas in southwestern Kansas and southeastern Colorado northeastward towards discharge areas in central Kansas and Nebraska. Well yields range widely, but typically average between 50 and 100 gpm. In central Kansas, the Dakota overlies salt-bearing Permian deposits and is recharged, in part, by the saltwater, making the aquifer unusable. Some deeper portions of the Dakota aquifer become saline with total dissolved solids that exceed 10,000 mg/L.

There is growing interest in the Dakota aquifer as a water source. Unlike the High Plains aquifer, it is still open to new appropriations in many areas. However, it is deeper, so more expensive to pump, has more variable water quality, and wells typically have lower yields than do those utilizing the High Plains aquifer.

Flint Hills Aquifer - In the Flint Hills of eastern Kansas there are aquifers of limited extent in the Permian age limestones of the Chase and Council Grove Groups. These provide water for farmsteads and small communities. Well yields range from 10 to 100 gpm, typically, although some individual wells and springs discharge at considerably higher rates. The town of Florence in Marion County gets its water from a local spring. The quality of water from these aquifers is suitable for most purposes, although the sulfate concentrations can exceed 250 mg/L locally.[4]

Sandstone Outcrop. Photo courtesy Kansas Geological Survey

Osage Cuestas Aquifer System - Several of the sandstones and limestones of the Pennsylvanian age Douglas Group bear water utilized by small towns, rural water districts and domestic wells in eastern Kansas. The primary aquifer occurs in the Tonganoxie and Ireland sandstones. These deposits are in ancient river valleys that were cut into older bedrock. Recharge to the aquifers comes primarily from precipitation where the rock units crop-out or occurs in the shallow subsurface. These aquifers provide water to rural populations that do not have access to streams or reservoirs. Typical well yields are 5 to 50 gpm or less. The aquifers are typically unconfined. Some of the wells produce water with fluoride concentrations that exceed 1.4 mg/L. Water quality deteriorates to the west, where it becomes more saline. Lateral movement of the saline waters is a problem where well fields are close and are pumped too intensely.

Ozark Aquifer - The Ozark Plateau aquifer system is located in the southeastern corner of Kansas. It consists of two aquifer units separated by an impervious aquitard. The upper aquifer unit is the Springfield Plateau aquifer, the lower unit is the Ozark aquifer. In areas of southeast Kansas, where the Ozark aquifer is used as a water source, it is referred to as the Roubidoux. Elsewhere in Kansas, where not used as a drinking water source, it is often referred to as the Arbuckle.[4]

The Ozark aquifer is a confined aquifer, occurring in fractures and solution cavities within rock units consisting of soluble dolomite. It is a heterogeneous and high yielding aquifer, in which water levels are very responsive to withdrawals. Well yields typically range from 150 to more than 2,000 gpm. Recharge comes from precipitation falling on the Ozark region in southern Missouri, where the Cambro-Ordovician rocks crop-out at the surface.

The aquifer is an important source of water for the tri-state region of Missouri, Kansas and Oklahoma. Over the past two decades, water users in Cherokee and Crawford counties in Kansas have reported significant water level declines in wells, in some cases 50 to 100 feet in just a few years, as a result of increased withdrawals.

Declines in the Ozark aquifer can induce recharge from the overlying Springfield aquifer, the Arbuckle portion of the aquifer to the west or sources deeper within the Ozark, which could result in declines in water quality. The Springfield aquifer contains numerous mining and industrial contaminants, which could leak downward into the Ozark aquifer. Also, as water levels continue to decline in the freshwater part of the Ozark aquifer, brines from the Arbuckle could migrate eastward. The poor quality water, with high dissolved solids, chloride concentrations, and hardness, could cause treatment problems for some public water supplies and industries.

Water Use

Kansans divert approximately four million acre-feet of water annually for their use. Statewide, irrigation is the largest water user, accounting for 80-85 percent of all water diverted in most years. Municipal use is the second largest water use category. Figure 9 shows 2006 Kansas water use by category. About 90 percent of the water used is pumped from ground water sources.[11]

Figure 10 shows county water use by type and relative amount across Kansas in 2006. The large amount of water use in many western and south central counties, particularly for irrigation, stands out as does the very modest overall use of water in many non-metropolitan eastern and north central counties. Ground water is the major source of supply in western Kansas, while surface water supplies predominate in the east.

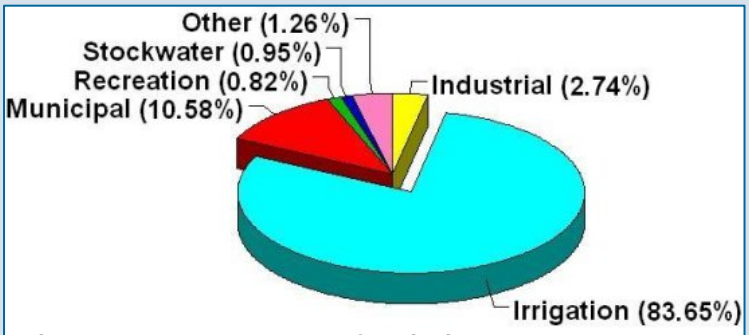


Figure 9. Source: KS Dept. of Agriculture, DWR

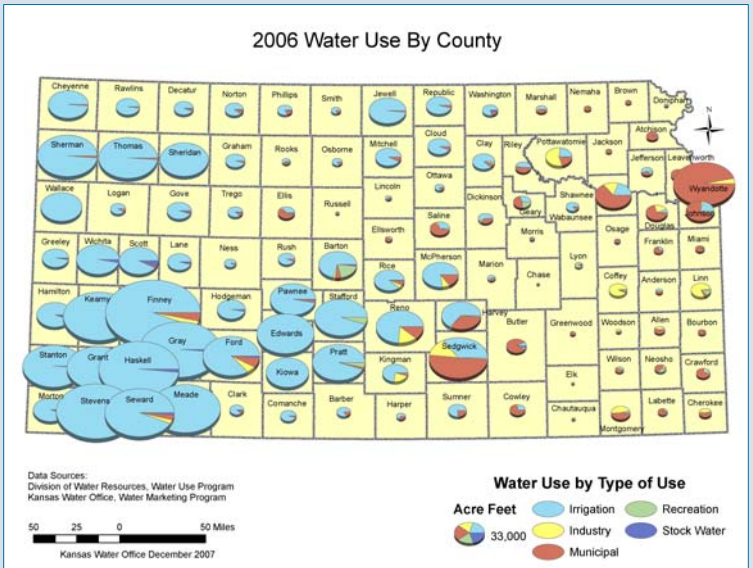


Figure 10.

All non-domestic Kansas water users must submit an annual water use report to the Kansas Department of Agriculture-Division of Water Resources (DWR). The DWR collaborates with the Kansas Water Office and the U.S. Geological Survey in publishing municipal and irrigation water use reports each year.[12]

Climate

Owing to its location, Kansas has a continental climate characterized by large variations in temperature, both seasonally and from day-to-day, and by concentration of precipitation during the growing season.

The oceans are the primary source of atmospheric moisture. In the case of moisture from the Pacific Ocean carried inland on prevailing westerly winds, much is lost as snow and rain over the Rocky Mountains and other western mountain ranges. Thus, western Kansas is in a so-called “rain shadow” downwind from the Rockies.

During summer, a semi-permanent area of high pressure, the Bermuda High, develops in the western Atlantic Ocean. The clockwise circulation around the Bermuda High brings warm, moist air northward from the Gulf of Mexico into the central United States. Here, this moist airmass often interacts with cold fronts associated with storms steered by the jet stream, bringing rain and thunderstorms to Kansas. During the winter there is a much greater frequency of dry continental air masses originating over northern Canada, which results in much less

precipitation during that season.

Figure 11 illustrates the main influences upon the state's climate.

Wide seasonal temperature variations are characteristic of Kansas. Far from the tempering influence of the ocean and without any mountain barrier to the north, Kansas is subject to occasional outbreaks of Arctic air during winter and hot, dry air masses from the desert southwest during summer.

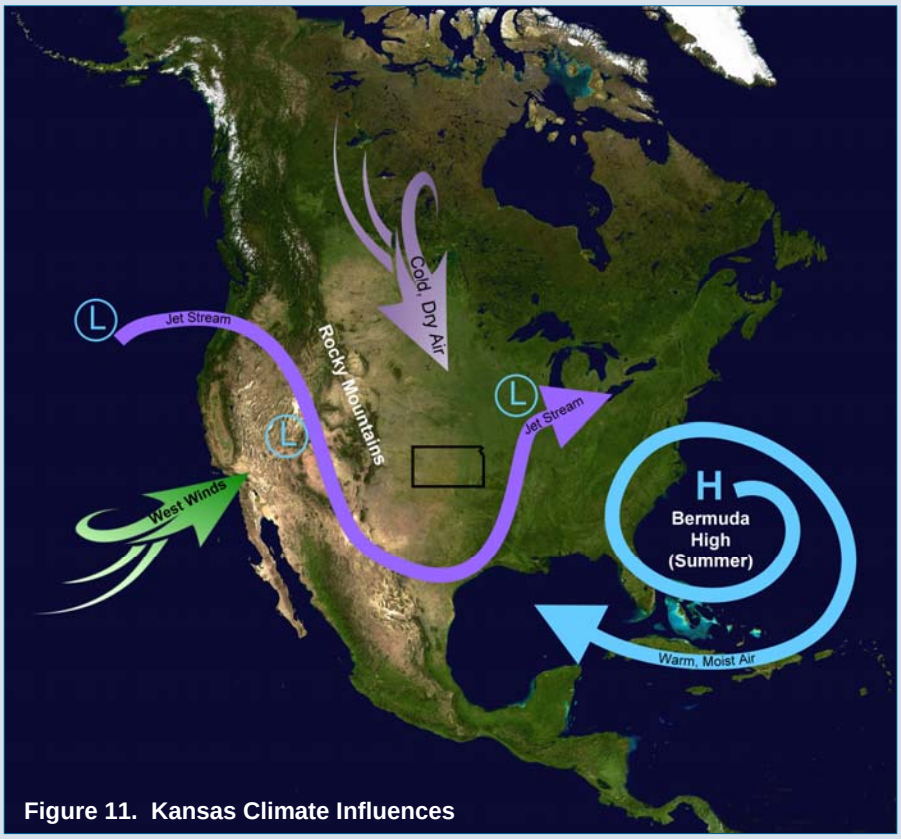


Figure 11. Kansas Climate Influences

Extreme temperatures recorded in the state have ranged from 121^{0}F at Alton and Fredonia in July 1936 down to -40^{0}F at Lebanon in February 1905. Total precipitation in a given year has ranged from 6.62 inches at Colby in 1910 to 71.99 inches at Hiawatha in 1973.[18]

Climate Normals - Normal values for precipitation, temperature and other variables are based upon a 30-year period of record, as recommended by the World Meteorological Organization. In the United States, these normals are established by the National Climatic Data Center,[20] an agency within the National Oceanic and Atmospheric Administration (NOAA). NOAA is also the parent agency for the National Weather Service.

The current climate normals are based upon the period 1971 through 2000. These normals are adjusted every 10 years. The next normal period will be 1981-2010. Normals may be established for individual weather stations, multi-county areas (climate divisions) within a state or for the state as a whole. In the case of individual stations, daily normals for maximum, minimum and average temperature and total precipitation are determined. Normal threshold dates for occurrences such as frost dates may also be determined. Monthly average temperature and total precipitation normals are established for individual stations, climate divisions and the state.

Figure 12 shows the multi-county climate divisions within Kansas. Figures 13, 14 and 15 show statewide patterns of normal annual total precipitation, normal annual temperature and the normal number of days between the last frost of spring and the first frost of autumn. Tables 3 and 4 following the maps provide current normal monthly total precipitation and average temperatures for each climate division.

Climate Variability and Drought - In describing the difference between weather and climate an old adage states "climate is what you expect and weather is what you get." Both weather and climate exhibit a great deal of variability in Kansas. This may be the case over several days, from year-to-year, or over a multi-year period. Precipitation variability is common throughout the year while temperatures tend to vary most during the winter.

Perhaps the most striking example of this variability is the periodic recurrence of drought conditions in Kansas. Drought differs from other natural disasters in that its onset is generally slow, but it may persist for a long period

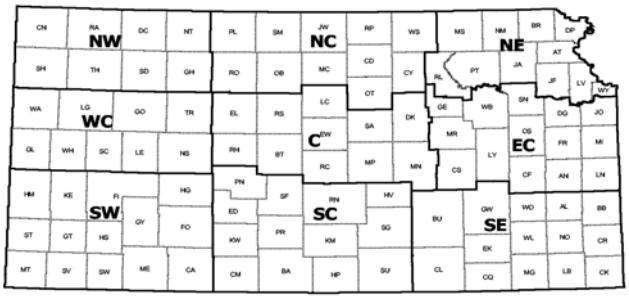


Figure 12

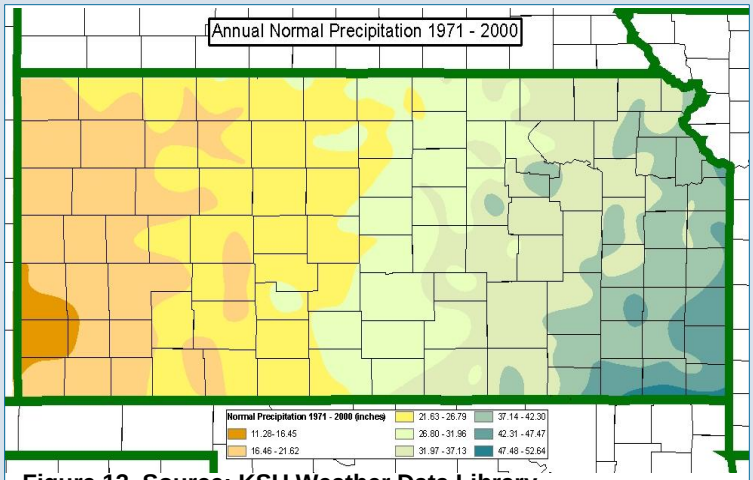


Figure 13. Source: KSU Weather Data Library

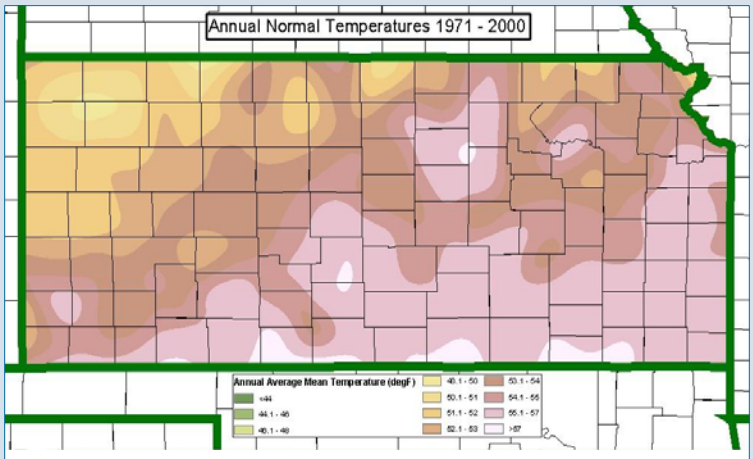


Figure 14. Source: KSU Weather Data Library

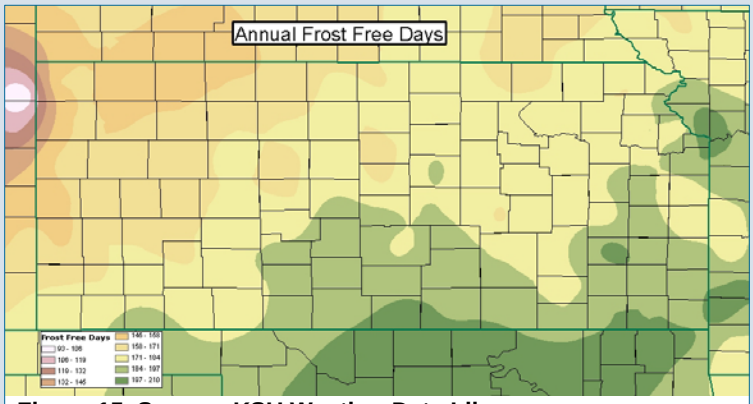


Figure 15. Source: KSU Weather Data Library

of time. Drought impacts are cumulative, first affecting soil moisture and agriculture, but ultimately affecting ground water levels, streamflow and reservoir storage if the drought is severe and persistent.[19]

Drought is commonly monitored through the use of indicators or indices and not by precipitation alone.[21] A common index used in the United States is the Palmer Drought Severity Index (PDSI). The PDSI is a soil moisture algorithm developed in the 1960s. It is based on the supply and demand concept of the water balance equation and is commonly calculated by climate division. The PDSI varies roughly between +/- 6.00 with values of 1.00 or above indicating wet conditions and values of -1.00 or below indicating drought of varying intensity.

Figure 16 shows the trend in the PDSI in the Southwest Kansas Climate Division between 1895 and 2007. The temporal variability of moisture conditions is evident with the drought periods in the 1930s and 1950s clearly indicated.[20]

Implications of Climate Change - Climate change or "global warming" has been a contentious issue in recent years. The degree to which human activity has been responsible for change is particularly controversial. Also, there is disagreement on how best to respond to climate change. Proposals to reduce greenhouse gas emissions to the atmosphere have received the most attention, but adaptation is another strategy being considered.

On March 21, 2008, Kansas Governor Kathleen Sebelius issued Executive Order 08-03 establishing the Kansas Energy and Environmental Policy Advisory Group (KEEP). The KEEP was directed to examine issues related to climate change and energy in Kansas and to make recommendations to the Governor for reducing greenhouse gas emissions in the state. A preliminary report is due in January 2009 with a final report to be submitted to the Governor on or before the first day of the 2010 legislative session.

Models used to predict the future impacts of climate change tend to provide very broad projections that are difficult to reduce to a local scale. Attempts have been made to model the effects of climate change at a regional scale in the United States, particularly in the Colorado River basin. Model results at this scale are not available for the Great Plains or the Midwest.

Due diligence in protecting water resources and adapting to future climate variability may be important to maintaining and improving the quality of life and the state's economy.

Table 3
Kansas Normal Total Precipitation (inches)

Month	Climate Division									
	NW	WC	SW	NC	C	SC	NE	EC	SE	State
Jan	0.51	0.52	0.49	0.65	0.74	0.76	0.90	1.09	1.26	0.77
Feb	0.55	0.59	0.53	0.72	0.91	0.96	1.04	1.21	1.63	0.91
Mar	1.51	1.57	1.49	2.21	2.43	2.48	2.53	2.75	3.22	2.25
Apr	2.05	1.76	1.69	2.50	2.61	2.57	3.23	3.42	3.62	2.59
May	3.71	3.25	3.10	4.19	4.39	4.05	4.95	5.07	5.23	4.18
Jun	3.08	2.73	2.92	3.47	3.80	4.03	4.82	5.08	5.17	3.88
Jul	3.43	3.37	2.86	3.85	3.83	3.37	4.38	3.94	3.92	3.61
Aug	2.65	2.63	2.51	3.25	3.43	2.97	3.79	3.73	3.72	3.16
Sep	1.45	1.54	1.61	2.50	2.54	2.59	4.15	3.95	4.14	2.68
Oct	1.27	1.17	1.25	1.85	2.18	2.23	2.94	3.14	3.70	2.18
Nov	1.00	1.04	0.88	1.50	1.62	1.64	2.29	2.64	3.11	1.73
Dec	0.45	0.49	0.51	0.79	0.92	1.01	1.25	1.52	1.89	0.98
Year	21.66	20.66	19.84	27.48	29.40	28.66	36.27	37.54	40.61	28.92

Normal period 1971-2000
Source: NOAA National Climatic Data Center

Table 4
Kansas Normal Average Temperature (^{0}F)

Month	Climate Division									
	NW	WC	SW	NC	C	SC	NE	EC	SE	State
Jan	27.4	28.6	30.7	26.4	28.3	30.4	25.9	28.0	30.8	28.8
Feb	32.6	34.1	36.3	32.1	34.1	36.4	32.0	34.0	36.7	34.5
Mar	40.6	42.1	44.5	42.1	43.9	45.5	42.7	44.4	46.6	43.8
Apr	50.1	51.4	53.6	52.5	53.9	55.1	53.5	54.5	56.3	53.6
May	59.9	61.1	63.2	62.4	63.7	64.8	63.6	64.2	65.4	63.3
Jun	70.7	71.9	73.6	73.0	74.2	75.1	73.1	73.4	74.4	73.4
Jul	76.5	77.4	78.7	78.7	79.8	80.5	78.1	78.6	79.7	78.8
Aug	74.3	75.3	76.8	76.4	77.8	78.9	76.0	76.9	78.3	76.9
Sep	64.9	66.2	68.0	67.2	68.7	70.0	67.3	68.3	69.7	68.0
Oct	52.7	54.2	56.2	55.1	56.8	58.1	55.9	56.9	58.5	56.2
Nov	38.0	39.5	41.9	40.0	42.1	43.4	41.4	43.1	45.1	41.8
Dec	29.6	31.2	33.1	29.7	31.9	33.4	29.9	32.1	34.5	31.9
Year	51.4	52.8	54.7	53.0	54.6	56.0	53.3	54.5	56.3	54.3

Normal period 1971-2000
Source: NOAA National Climatic Data Center

Population and Demographic Change

Kansas has experienced significant demographic changes since the end of World War II. As identified by Krider and Cliford,[23] these changes include 1) the concentration of population growth in the state's urban counties, 2) the aging of the population, and 3) rapid growth in minority populations.

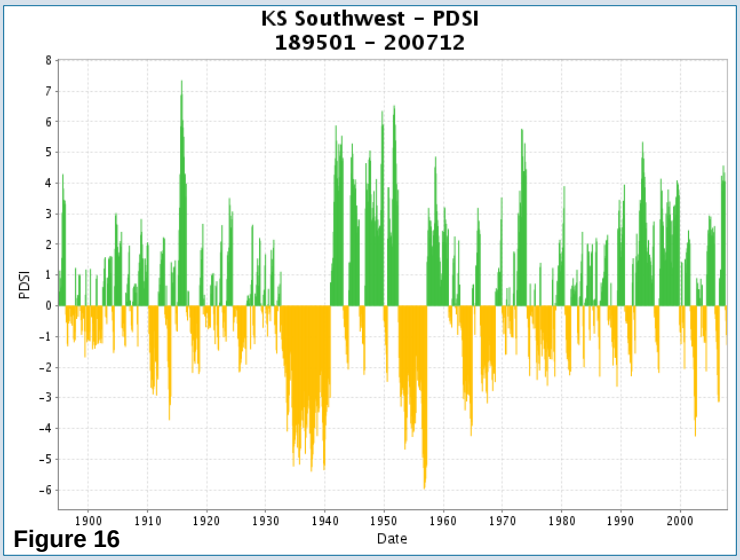


Figure 16

Population growth in Kansas has lagged behind the national average in recent decades. During the 1980s, the population of Kansas increased by 4.8%, compared to a national increase of 9.8%. During the 1990s, population growth in Kansas, 8.5%, was four percent below the national figure.[26] Table 5 shows the total population of Kansas by decade since 1950 compared with that of regional states.

Worthy of note is that Kansas had a greater population than Colorado as recently as 1970. Colorado's population now exceeds that of Kansas by more than 2 million people. Also of interest is the mega-state status of Texas, the second most populous state in the Union following California. With 23.9 million people, the total population of Texas is nearly that of the other seven regional states combined (24.7 million).

The most significant Kansas population trend has been the rapid movement of people from rural to urban areas.[23] Between 1950 and 2000, 44 Kansas counties experienced a population decline of 25 percent or more. Thirty-two counties grew during this time period. Growing counties were centered in the Kansas City and Wichita metropolitan areas, southwest Kansas and counties serving as regional commercial and medical hubs. Other growing counties benefitted from hosting a state university or military base, or in being served by an interstate highway.

As a result of this population shift, the state's population is increasingly being concentrated in its largest counties. By 2007, Johnson County had surpassed Sedgwick County as the state's most populous. The 10 largest counties in 2007 had a total population of 1,766,684. This was some 63% of the state total. In 1950, the 10 largest counties accounted for only 43% of the state's total population. Figure 17 illustrates the estimated 2007 population, by county, across Kansas.

Population Projections - In the 1990s, the Kansas Water Office made county and river basin population estimates and projections out to the year 2040. These projections were endorsed by the Kansas Department of Administration-Division of the Budget as the official Kansas projections.[22] These are available at Kansas Population 1990-2040. Water demands associated with these projections were made by county and by public water system.

More recently, some adjustments to county population projections based on 2000 U.S. Census figures have been made as part of the analyses supporting the Kansas Water Authority's Reservoir Sustainability Initiative.

Table 5
Total Population – Kansas and Regional States

State	Year						
	1950	1960	1970	1980	1990	2000	2007
Arkansas	1,909,511	1,786,272	1,923,295	2,286,435	2,350,725	2,673,400	2,834,797
Colorado	1,325,089	1,753,974	2,207,259	2,889,964	3,294,394	4,301,261	4,861,515
Iowa	2,621,073	2,757,537	2,824,376	2,913,808	2,776,755	2,926,324	2,988,046
Kansas	1,905,299	2,178,611	2,246,578	2,363,679	2,477,574	2,688,418	2,775,997
Missouri	3,954,653	4,319,813	4,676,501	4,916,686	5,117,073	5,595,211	5,878,415
Nebraska	1,325,510	1,411,330	1,483,493	1,569,825	1,578,385	1,711,263	1,774,571
Oklahoma	2,233,351	2,328,284	2,559,229	3,025,290	3,145,585	3,450,654	3,617,316
Texas	7,711,194	9,579,677	11,196,730	14,229,191	16,986,510	20,851,820	23,904,380

Resident total population on April 1 of year indicated; 2007 population estimated as of July 1.
Source: U.S. Census Bureau

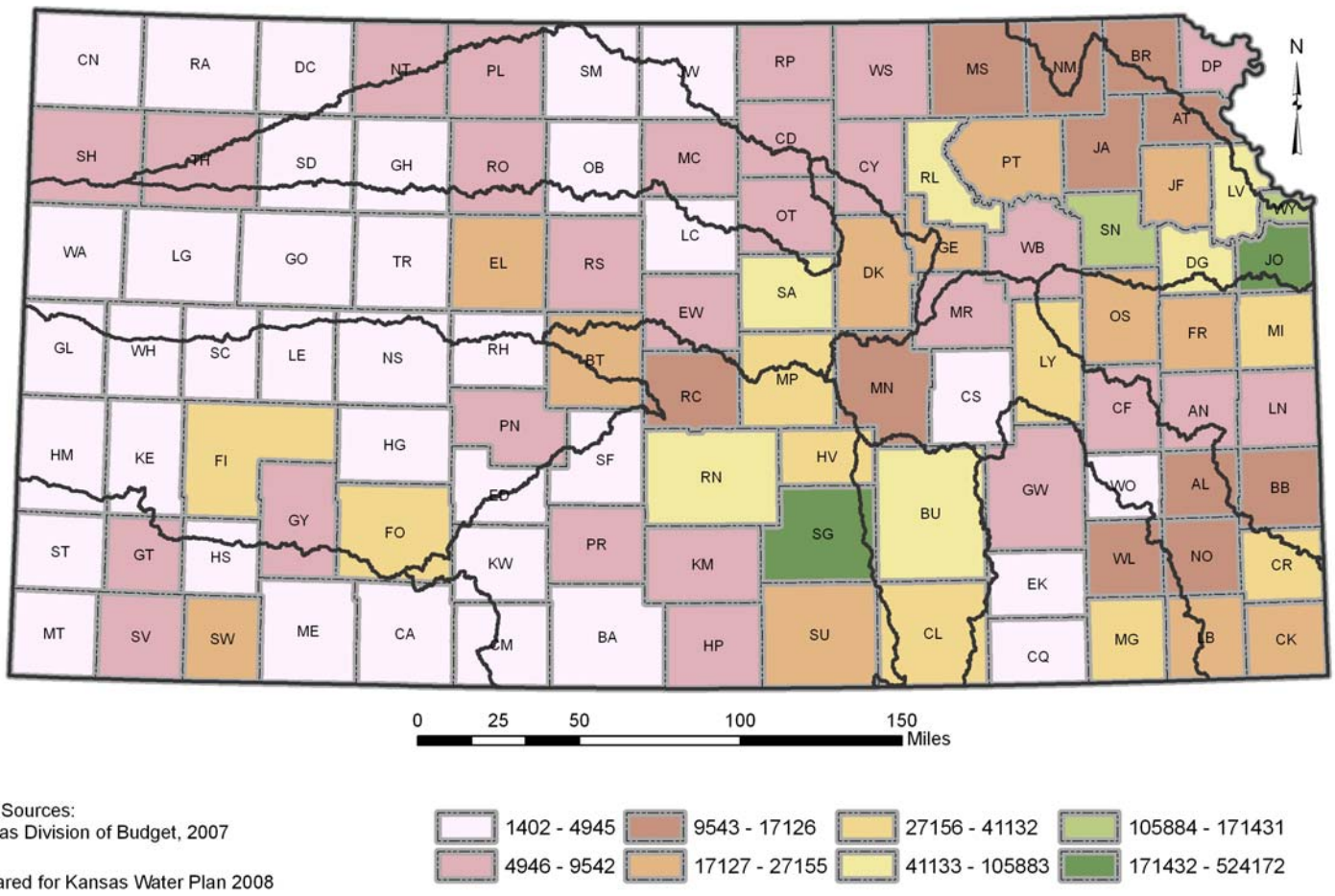


Figure 17.

Resources

Surface Water Availability

1. Kansas Water Office Reservoir Information. http://www.kwo.org/ReservoirInformation/Reservoir%20Information.htm.

2. U.S. Geological Survey Surface Water Data for Kansas. http://waterdata.usgs.gov/ks/nwis/sw/.

Ground Water Availability

3. Water Supply Paper 2275. Bevins, Hugh E., Spruill, Timothy B. and Kenny, Joan F. 1984. *Kansas Ground-Water Resources*. U.S. Geological Survey, National Water Summary.

4. *Buchanan, Rex and Buddemeier, Robert W. 1993. Kansas Ground Water: An Introduction to the State's Water Quantity, Quality, and Management Issues, Kansas Geological Survey, Educational Series 10.*

5. Macfarlane, P. A. 1997. *The Dakota Aquifer System in Kansas*. Kansas Geological Survey, Public Information Circular No. 7.

6. Rogers, Danny H. and Sothers, William M. October 1997. *Kansas Water Supplies.* Kansas State University. Agricultural Experiment Station and Cooperative Extension Service, L-910, revised.

7. Schloss, J. *et al*. 2000. *An Atlas of the Kansas High Plains Aquifer*, Kansas Geological Survey, Educational Series 14.

8. Kansas Geological Survey, Water Educational Resources. http://www.kgs.ku.edu/Hydro/hydroPubs.html.

9. U.S. Geological Survey Ground Water Data For Kansas. http://waterdata.usgs.gov/ks/nwis/gw/.

Water Use

10. Kenny, Joan F. and Hansen, Christi V. December 2004. *Water Use in Kansas, 1990-2000*. U.S. Geological Survey Fact Sheet 2004-3133.

11. Kansas Department of Agriculture, Division of Water Resources, Water Use in Kansas. http://www.ksda.gov/appropriation/?cid=321.

12. Kansas Water Office, Municipal and Irrigation Water Use Reports.

13. U.S. Geological Survey, Kansas Water Use in 2000. http://ks.water.usgs.gov/studies/wateruse/.

Climate

14. Brown, Merle J. and Bark, L. Dean. March 1971. *Drought in Kansas*. Kansas State University, Agricultural Experiment Station, Bulletin 547.

15. Flora, Snowden D. June 1948. *Climate of Kansas*. Report of the Kansas State Board of Agriculture, Vol. LXVII, No. 285.

16. Goodin, Douglas G., Mitchell, James E.. Knapp, Mary C., and Bivens, Raymond E. 1995, reprinted 2004. *Climate and Weather Atlas of Kansas*. Kansas Geological Survey, Educational Series 12.

17. High Plains Regional Climate Center. http://www.hprcc.unl.edu/.

18. Kansas State University, Weather Data Library. http://www.oznet.ksu.edu/wdl/.

19. National Drought Mitigation Center. http://www.drought.unl.edu/.

20. NOAA National Climatic Data Center. http://www.ncdc.noaa.gov/oa/ncdc.html.

21. National Integrated Drought Information System, U.S. Drought Portal.

Population and Demographic Change

22. Kansas Water Office. *Population Estimates and Projections, State of Kansas, 1990-2040.*

23. Krider, Charles and Clifford, Norman. June 2001. *Demographic Changes in Kansas: Implications for State Policy*. The University of Kansas, Kansas Center for Community Economic Development Policy Research Institute, Technical Report Series, Report No. 53.

24. Kansas Division of the Budget, Certified Population Data. http://budget.ks.gov/ecodemo.htm.

25. Kansas State University, Kansas Population Center. http://www.k-state.edu/sasw/kpc/.

26. U.S. Census Bureau, State and County QuickFacts. http://quickfacts.census.gov/qfd/states/20000.html.