IRRIGATION
MANAGEMENT
S E R I E S

Kansas Water Supplies

Danny H. Rogers
Extension Agricultural Engineer

William M. Sothers
Extension Assistant

Cooperative Extension Service
Manhattan, Kansas

Water is a vital natural resource and is an essential ingredient in sustaining life. With more than 70 percent of the Earth's surface covered with water, it would appear that there is sufficient water to sustain life indefinitely, but only 3 percent of it is fresh water (Figure 1). Most of this fresh water is frozen in polar icecaps and not readily available for human consumption. Although often considered a renewable resource because of the regenerative process called the hydrologic cycle, fresh water supplies in many areas are being depleted and/or contaminated.

Our lifestyles and industrial utilization are linked to the use of fresh water. Water requirements for production of various communities, for common foods and for other activities are shown in Figure 2. People indirectly consume large qualities of water. The typical water usage for one person is about 100–150 gallons per day. If the water used for agricultural and industrial purposes is added to the above value, the per capita water usage increases to approximately 1,700 gallons. This is equivalent to using 450 billion gallons of fresh water every day in the United

Figure 1. *The world's water supply. (Source: The Johnson Driller's Journal, Nov.–Dec. 1974.)*

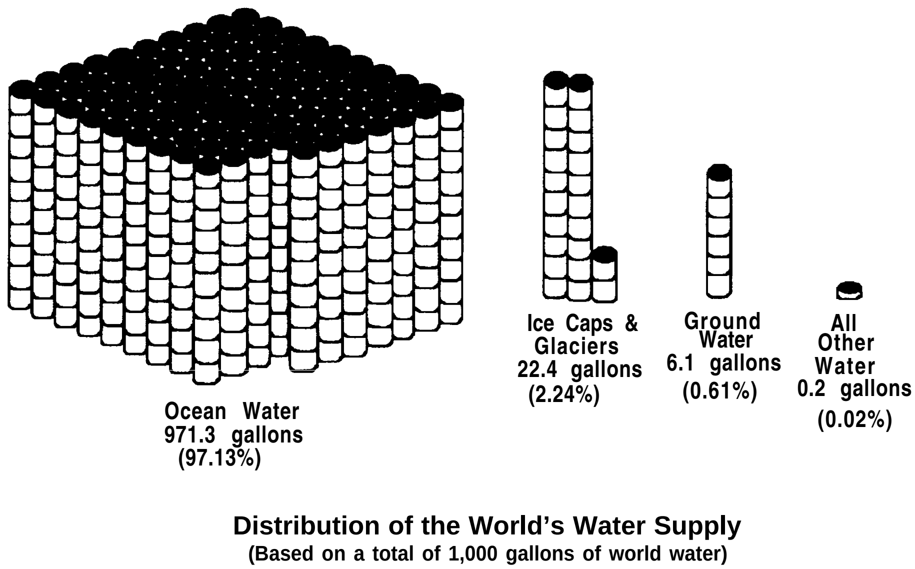


Figure 2. *Typical water use requirements for various activities.*

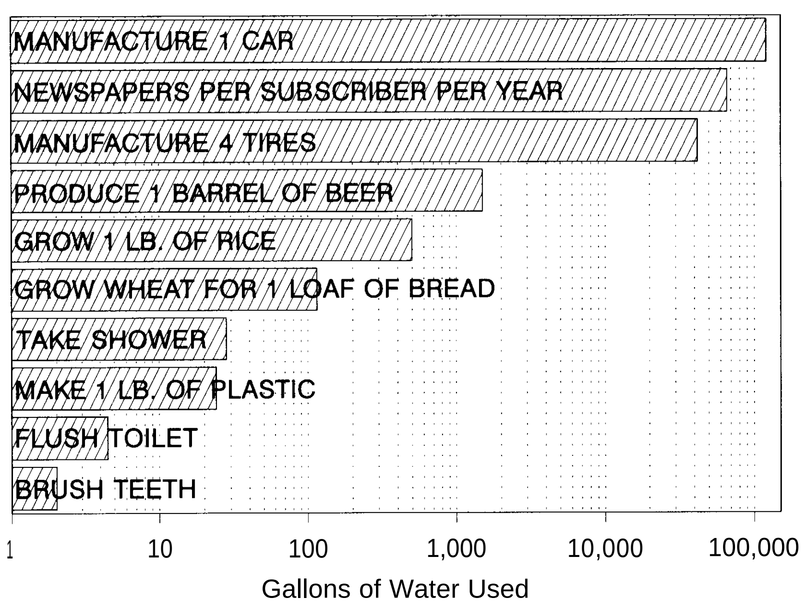
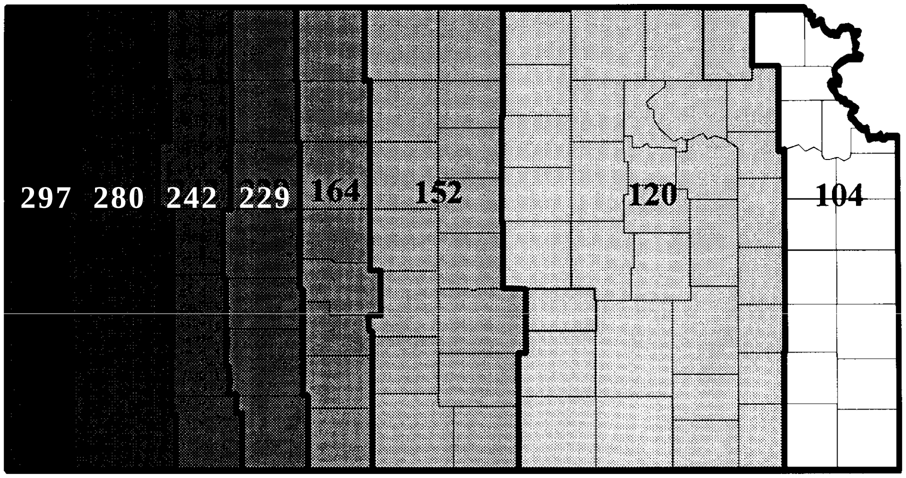


Figure 3. *Average Gallons Used Daily Per Capita by Public Water Users in Kansas by Region. The average for Kansas is 147 gallons per capita per day. (Source:* Kansas Municipalities Water *Use, Division of Water Resources, 1992)*



States alone. Kansas public water users currently average about 147 gallons per capita per day (Figure 3). The per capita use is higher in the west than the east, largely due to the drier climate, with summertime outdoor water demand much greater.

Kansas has an annual water budget of about 42 trillion gallons (128 million acre-feet). About 94 percent of this supply is from precipitation, with the other sources being stream flow into the state and withdrawals from stored groundwater reserves. Western Kansas groundwater withdrawals deplete around 3 million acre-feet of groundwater per year. One can easily see the need to conserve and protect our available fresh water resources.

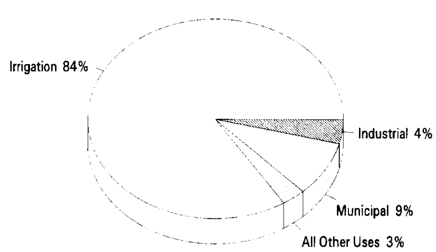
In Kansas, a permit must be obtained to divert surface and groundwater resources for non-domestic uses. In 1992, the reported total water usage by permit holders was approximately 2,710,555 acre-feet. Of this total usage, 84 percent (2,276,866 acre-feet) was irrigation usage, 9 percent (243,950 acre-feet) was municipal, 4 percent (108,422 acre-feet) industrial usage, and 3 percent (81,317 acre-feet) for all other uses (Figure 4). In drier years, the total value can be in excess of 5 million acre-feet.

Annual crop production requirements normally vary between 3 million and 5 million acre-feet of irrigation. In Kansas, approximately 3 million acres are irrigated. This is only about 14 percent of the total cropland acreage in Kansas, but is nearly one-third of the total crop value. Most irrigation usage is in western Kansas and not in direct conflict with the majority of municipal and industrial demands.

THE HYDROLOGIC CYCLE

The hydrologic cycle is the Earth's system for moving water from one location to another. Some of the processes involved in the hydrologic cycle include evaporation, transpiration, condensation, precipitation, interception, infiltration, percolation, storage, and runoff. The energy source for this process is solar energy from the sun. The processes in the hydrologic cycle occur continuously and simultaneously, so there is no real beginning or end to the cycle. Evaporation of large amounts of water from the Earth's oceans is the source of much of the atmospheric water vapor. It is estimated that 39 inches of water annually evaporate from each acre of ocean (Water of the World, USGS). This water vapor is moved around by wind

Figure 4. *Reported water use by type for 1992. (Source: Kansas State Board of Agriculture, Division of Water Resources)*



currents caused, in part, by the rotation of the Earth. When this air begins to cool, condensation occurs and clouds form. As the air continues to cool, saturation occurs and the result is precipitation. Precipitation can be in the form of rain, snow, sleet, or hail. As the precipitation falls, it can evaporate before it hits the ground, be intercepted by vegetation such as forests, trees, or fields of crops, or reach the ground. The intercepted water is temporarily held in storage and is later used by the vegetation or evaporated back into the atmosphere.

The precipitation that does reach the ground will follow one of several different paths back to the ocean or atmosphere. Approximately 70 to 90 percent of the water that falls to the Earth's surface will infiltrate into the soil. Most of this water will evaporate from the soil surface or be used by vegetation. Water that moves through the root zone, called percolation, may recharge groundwater systems. In Kansas, this recharge amount varies widely, from less than 0.5 inches in the west to over 6 inches in some areas of the central and east. The amount of rainfall and type of soil greatly influence the amount of movement. Water that moves through the root zone may take hours or years to reach groundwater, depending on the depth to the aquifer and the characteristics of the unsaturated zone.

Groundwater flows through the aquifer system towards natural discharge points such as wells, springs, streams or rivers, lakes, and the ocean. Groundwater moves slowly within the aquifer, often remaining in storage for years, decades and even centuries. Of course, groundwater can be pumped to the surface and used, eventually returning to the atmosphere as evaporation or transpiration. Transpiration is a plant's "respiratory" system which releases water vapor back into the atmosphere.

Water that does not infiltrate into the ground or evaporate from the soil surface becomes surface runoff. This water flows towards streams or rivers and ultimately back to the ocean where it can then again be evaporated. Surface runoff can also encounter storage systems such as depression storage, lakes, or reservoirs. This water is then returned to the atmosphere

Figure 5. *Regional diagram of the hydrologic cycle.*

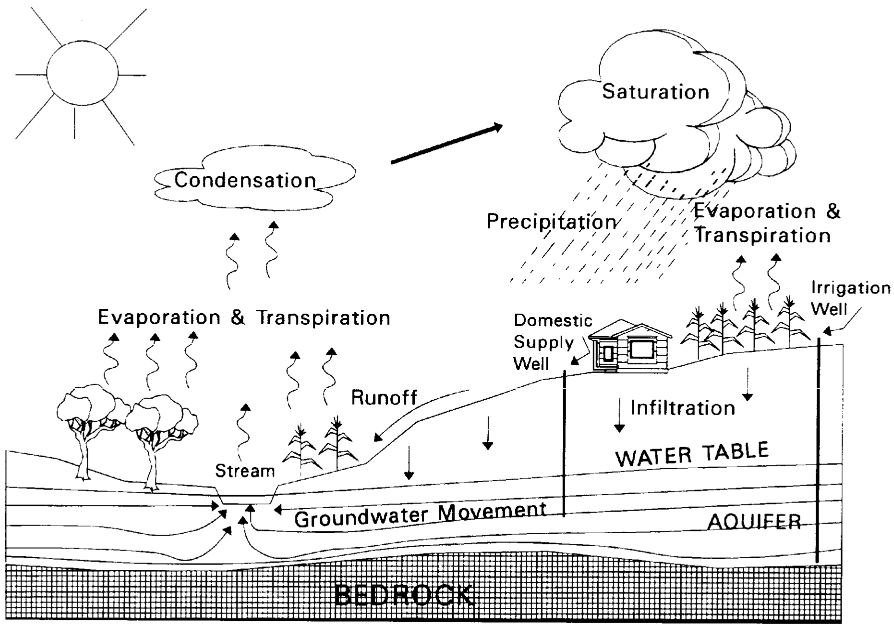


Figure 6. *Average annual precipitation in Kansas in inches.*

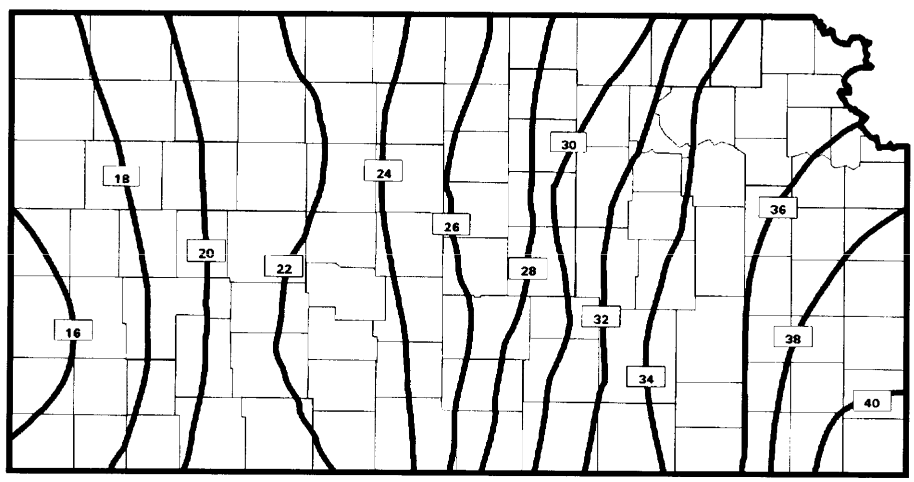
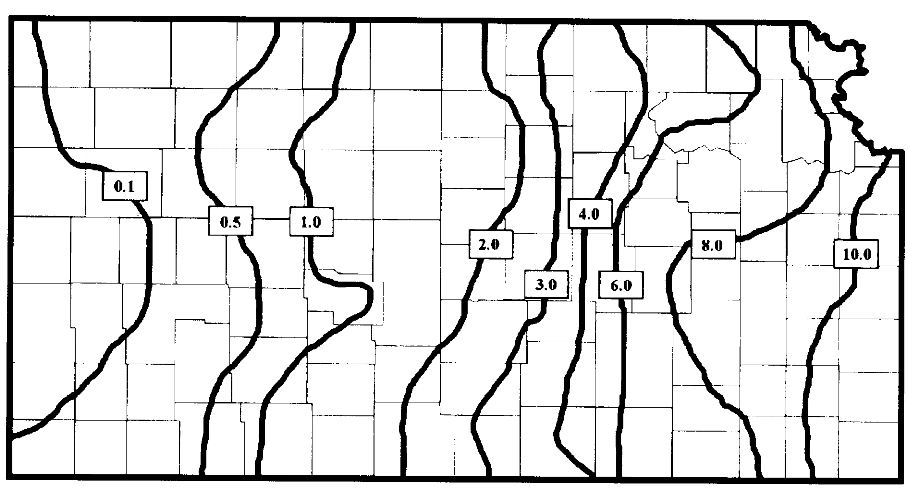


Figure 7. *Average annual runoff in Kansas in inches.*



through evaporation or is used for water supplies where it is eventually evaporated or released back into river systems and ultimately back to the ocean. A regional diagram of the hydrologic cycle is shown in Figure 5.

SURFACE WATER SUPPLIES

The surface water supplies of Kansas include rivers, tributaries, lakes and reservoirs. The amount of water available to these surface supplies depends almost entirely on precipitation.

Precipitation varies widely in time and space. The 1993 flooding in the upper Mississippi Valley occurred simultaneously with an extreme drought in southeast regions of the United States. This variability of precipitation is caused by complex global weather systems. Kansas has a continental type of precipitation pattern. This means most of the precipitation falls during the summer growing season and is largely from convection thunderstorms which often result in isolated, intense rainfall events.

Most Kansans are familiar with thunderstorms that produce rain at one site but none just a mile away. The average precipitation values over a longer period of time are shown in Figure 6. The extreme western parts of Kansas only receive an annual precipitation of 16 to 18 inches, whereas the extreme eastern parts of Kansas can receive an annual precipitation of up to 40 inches.

The amount of runoff associated with precipitation events is determined by such factors as type of ground cover, soil type, and whether the area is rural or urban, but is most heavily determined simply by the amount of precipitation. Figure 7 shows the average annual runoff for Kansas. Runoff in the east is one hundred times greater than runoff in the west. It is easy to see why most of the larger Kansas rivers, lakes and reservoirs occur in the eastern half of the state.

Another factor affecting runoff in Kansas in recent history is changing tillage and soil conservation methods. The adoption of conservation methods makes more water available for growing crops, but reduces runoff and increases infiltration and evaporation. Two of these conservation methods are terracing of long sloped areas and practicing low tillage methods.

Historically, stream flows were much lower when native grasses and woods were predominate in Kansas. With conversion to cropland, stream flow was increased. Measurement records largely correspond with periods of high stream flow. In recent years, as shown in Figure 8, stream flows may be declining due to conservation practices such as ponds, terraces and residue farming. In some cases, alluvial groundwater depletion plays a role as well.

RIVERS

The amount of flow in Kansas rivers is directly proportional to precipitation and runoff amounts. In western Kansas, where annual precipitation is 16 to 18 inches and runoff is as low as 0.1 inch per acre, the rivers and streams are small and often flow only intermittently. In eastern Kansas, where annual precipitation and runoff is much higher, the rivers and streams are much larger and may flow continuously. During periods of drought, these flows may be fed by groundwater systems. Figure 9 shows annual river flows for average, median and drought conditions.

Figure 8. *Predicted streamflow in northwest Kansas (1850–2000) and estimated depletions since 1930. (Source: James Koelliker KSU, 1984)*

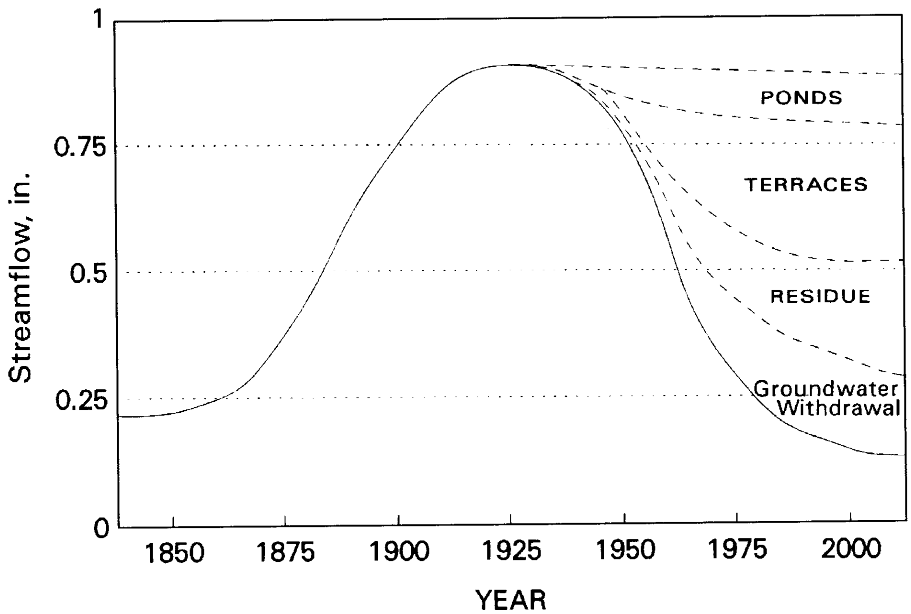
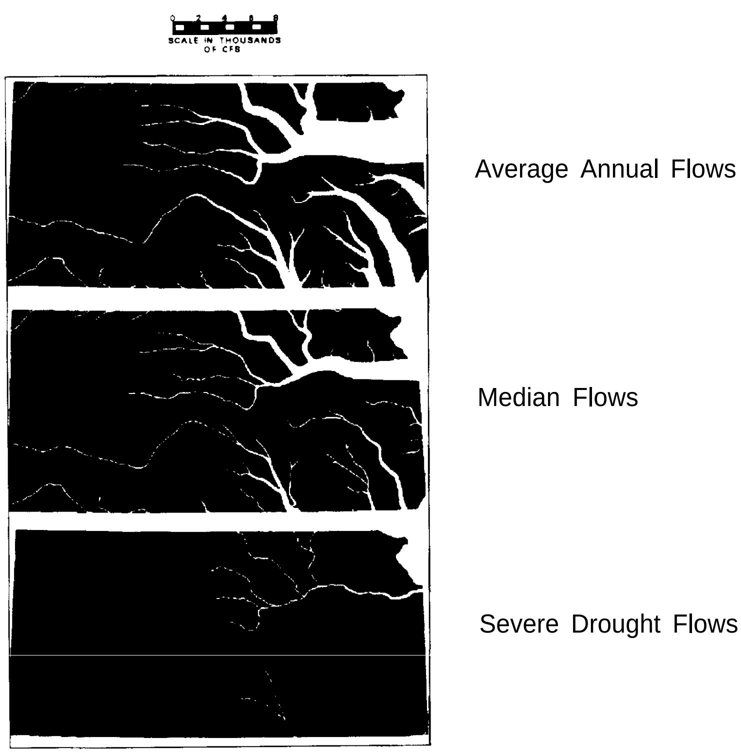


Figure 9. *Different levels of flow for Kansas. (Source: Kansas Water Atlas, The Kansas Water Resources Board, 1967)*



Average annual flows include the "big events." A large flood event may exceed the flow for the remainder of the year. The median flows, therefore, represent a more common flow. Median flow means half of the flow values are larger and half are smaller than the median. Kansas has two major drainage areas. The Missouri drainage area drains the northern part of Kansas, and the Arkansas drainage area drains the southern.

LAKES AND RESERVOIRS

Kansas has few naturally occurring lakes. Reservoirs have been built to provide water storage for use during periods of drought, to help control flood events, and to provide recreational areas for Kansas residents. The total storage volume of Kansas' twenty-four largest reservoirs at conservation pool is 2,929,200 acre-feet (954 billion gallons) with a total surface area of 158,500 acres (248 square miles). The five largest reservoirs have storage volumes greater than 200,000 acre-feet. Because of the need for higher runoff amounts to support these reservoirs, they are located mainly in the eastern half of the state.

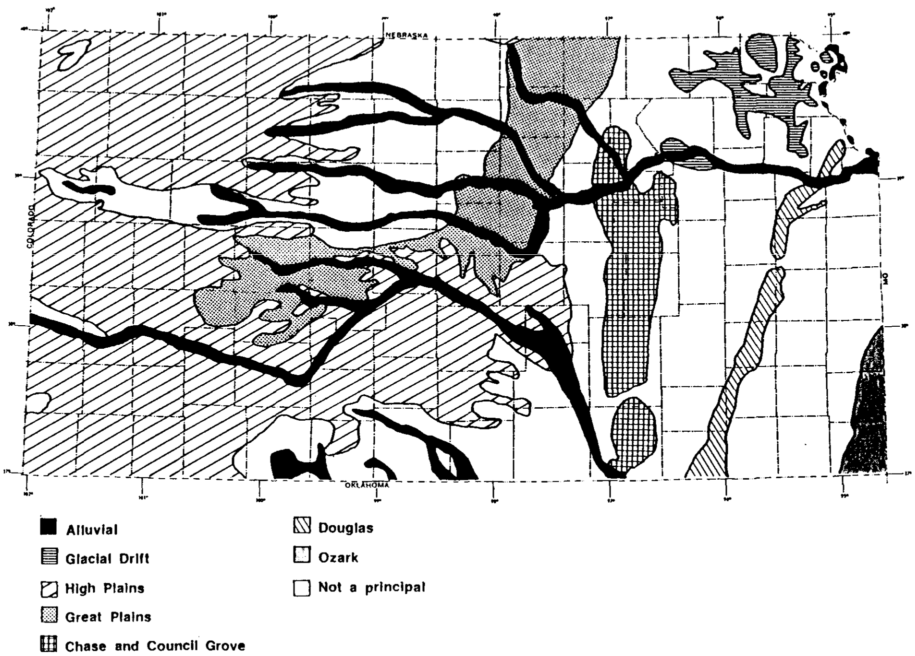
GROUNDWATER SUPPLIES

The storage system for groundwater are the voids, cracks, and spaces between particles of soil, sand, gravel, rock, and other sub-surface material. When saturated with water, these formations are called aquifers or groundwater reservoirs. Many people envision an underground river or lake when thinking about aquifers, but this is incorrect. In most areas of the world, and specifically in Kansas, water does not flow in and is not stored in large underground rivers or lakes.

AQUIFERS

Kansas has a number of principal aquifer systems (Figure 10). The largest of these is the High Plains or

Figure 10. *Principal aquifers of Kansas. (Source: Water Quality Assessment Report, KDHE, 1986)*



Ogallala aquifer. It is estimated this aquifer has about 245 million acre-feet of stored water. The amount of water in the Ogallala alone would cover the entire state with over 4.5 feet of water.

The materials that make up the aquifer determine how much water can be stored and whether the water can be easily extracted. The volume of pore space, or porosity, is a measure of the available storage area for water. For example, large uniformly sized sands would have high porosity compared to poorly sorted (different sized) sands which may have higher porosity than layers of shale.

An important measurement associated with groundwater is permeability. It is related to the porosity of a soil structure and is a measure of how well the pores are interconnected. A media which allows water to flow readily from pore to pore is said to be permeable. A media or structure that restricts the flow of water, or does not allow water to flow at all, is called impermeable. A soil can have a high porosity, but have pores that are not interconnected, and therefore be impermeable. Therefore, aquifers are layers of sufficiently porous materials that store water and are permeable enough to allow water to flow at useful rates. Layers of material that have low permeability and slow the movement of water are called aquicludes, and layers that have no permeability or stop the flow of water are called aquitards.

HOW GROUNDWATER MOVES

Some people attempt to associate the flow of water on the earth's surface with groundwater movement. However, one major difference between groundwater and surface water movement is the average water flow velocity.

Surface water flows in rivers or streams at velocities of 2 to 8 miles per hour. Kansas groundwater moves through the spaces between particles of a saturated material at rates between 0.1 foot per day to 3 feet per day. This translates into movement of 35 to 1,100 feet per year.

Groundwater moves principally in response to gravity. Rate of movement is determined by the hydraulic gradient, or slope (difference in elevation) of the water surface between two points in an aquifer, and the interconnection of pores. The hydraulic gradient and the aquifer material determines how rapidly water moves from one location to another.

Groundwater moves from high water surface elevations to low water surface elevations. Walter flows more rapidly where large differences exist in water surface elevations. Groundwater may move toward, or away from, streams or lakes, depending on the hydraulic gradient. As groundwater moves, it may be removed by a pumping well or it may be discharged to the earth's surface as a seep, spring, lake or stream.

DIFFERENT TYPES OF AQUIFERS

There are different types of structures in which groundwater can be found. A consolidated structure is one that is solid but still has pores or cracks which can contain water. An unconsolidated structure is one which is made up of loose, unattached particles such as sand and gravel, clay, or silt.

Another distinction between different types of aquifers is the location of a groundwater zone relative to impermeable layers. A zone of groundwater that lies below a layer of impermeable material (aquiclude or aquitard) is said to be confined. Confined aquifers can be under pressures greater than atmospheric pressure. Unconfined aquifers are not held below an impermeable layer and are free to seek out their own equilibrium level with respect to gravity and atmospheric pressure.

If a well penetrates the confining layer of a confined aquifer, the pressure of the confined aquifer will cause the water in the well to rise above the top of the confining layer. These wells are called artesian wells. If the pressure in the confined aquifer is great enough to cause the water in the well to rise above the surface level, they are called flowing artesian wells. Another type of aquifer is a "perched" aquifer. In this phenomenon, a localized area of aquitard is present, and as water percolates down to it, an underground equivalent of a pool or pond is formed. Figure 11 illustrates several of the terms and aquifers described above.

OBTAINING GROUNDWATER WITH A WELL

Wells are drilled into a variety of different aquifer formations to supply water for many different uses. Specialized equipment is required to meet the construction standards for drilling a well, installing the well casing and screen, back filling the well hole, and test pumping the well for its intended purpose. Without proper well drilling and construction techniques, the reliability of the well and the protection provided to the aquifer may not be adequate.

Water is removed from a well using pumps. Pumps use mechanical energy supplied by a drive motor or engine to force water toward the surface. Removing water lowers the water level in the well. The difference between the initial water level, or static water level, and the pumping water level causes water to move within the aquifer toward the well. Since the water level is always lowest in a well being pumped, a steeper gradient is caused and water from the surrounding aquifer flows toward the well to replace the water being removed.

When pumping starts in an unconfined aquifer, most of the water is removed from very near the well. With continued pumping, water is removed further from the well, lowering the water level at a greater distance from the well.

Drawdown decreases with the distance from the well until at some distance, the water level remains relatively unaffected by pumping. Drawdown in the well continues to increase slightly with pumping. After many hours of pumping, the water level nearly stabilizes. The resulting cone-like shape of the water surface is referred to as a cone of depression (Figure 12).

The size and shape of the cone of impression is determined by the aquifer materials and the amount of water being removed from the aquifer. For example, domestic wells generally pump for short periods of time at rates of 5 to 20 gallons per minute. This results in small, poorly defined cones of depression. Even low-yield aquifers often can be developed for domestic use.

Irrigation and municipal wells typically have pumping rates that range from 100 to more than 1,500 gallons per minute, and operate for long periods. Aquifers must yield large volumes of water, and much larger and deeper cones of depression result. In some cases, the cone of depression may extend several hundred feet from the well and be up to 100 feet deep. Where there are many wells in heavily developed irrigation areas, cones of depression for adjacent wells can overlap, increasing the depth and size of each well's cone of depression (Figure 12).

Figure 11. *Representation of aquifers and wells.*

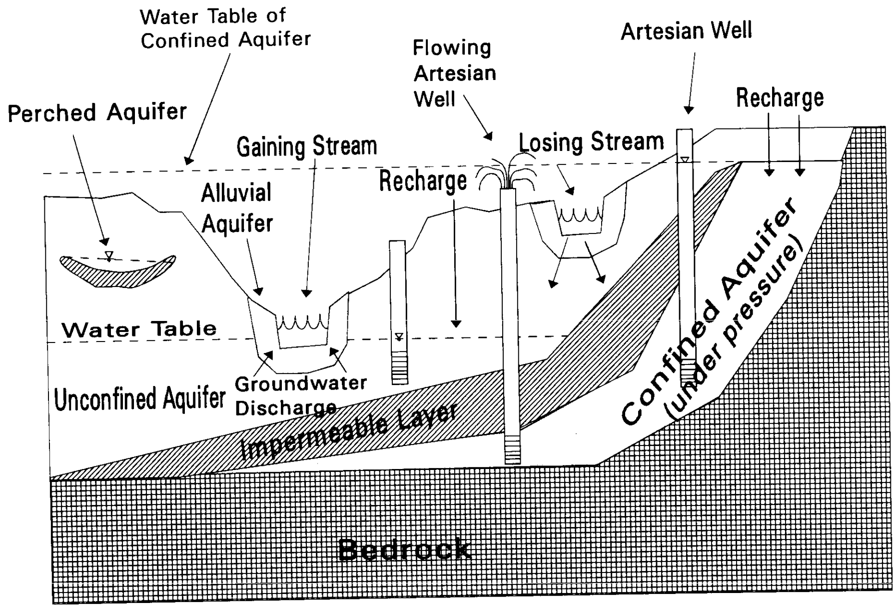
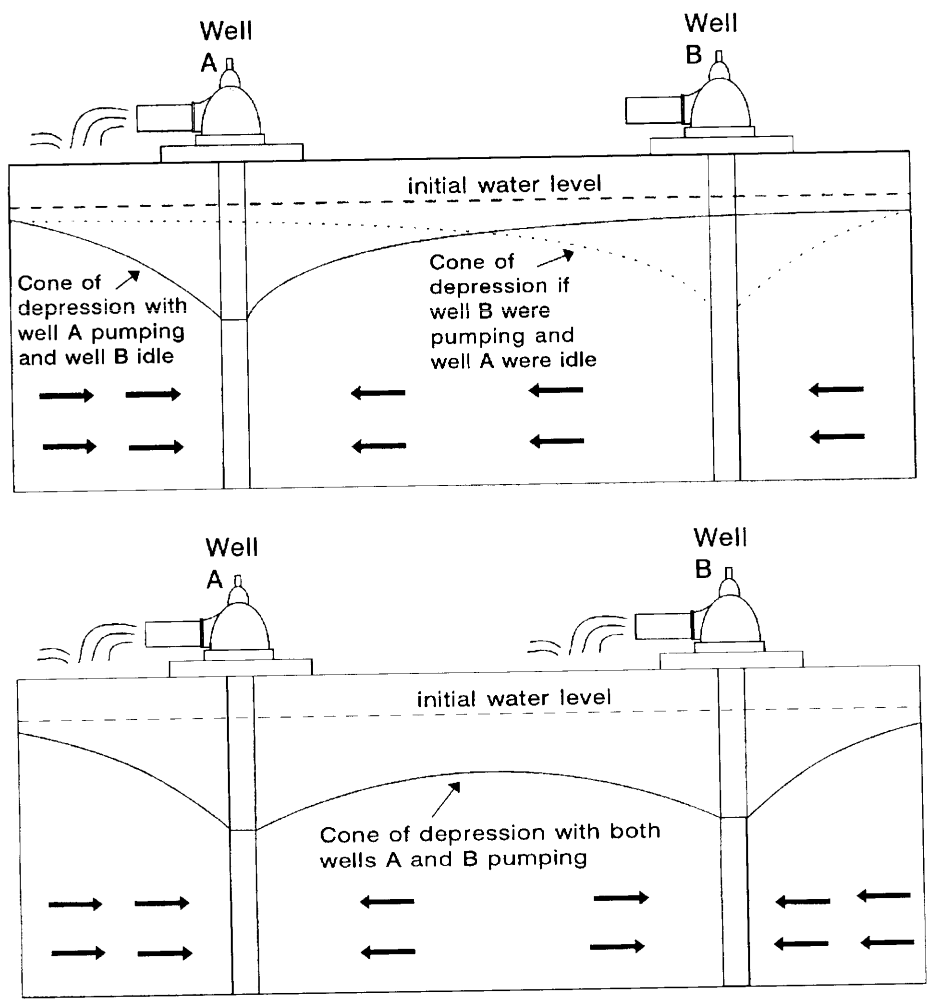


Figure 12. *Illustration of cones of depression. (Source: Kansas Gound Water, Kansas Geological Survey, 1993)*



FACTORS AFFECTING GROUNDWATER DECLINES

Under natural conditions, a balance exists between the volume of water entering an aquifer and the volume of water being discharged from an aquifer. With the development of wells, the natural balance between recharge rates and discharge rates is disrupted and the overall groundwater supply begins to become depleted due to the increased discharge from the system.

Groundwater supplies also can be altered due to natural causes. Years of below-normal precipitation can alter the amount of water entering the aquifer. Likewise, seasonal and year-to-year differences in regional stream flow can cause fluctuation in localized groundwater levels.

The major cause of Kansas groundwater level declines is intensive groundwater pumping. Since around 84 percent—and in some years more—of the groundwater pumped each year is used for irrigation purposes, most declines are attributed to irrigation pumping. In some areas, decades of irrigation pumping has lowered groundwater levels by over 200 feet, although most areas are considerably less.

The combination of intensive pumping and several years of below-normal precipitation can accelerate the downward trend in water levels. This is true because below-normal precipitation usually results in decreased groundwater recharge. More importantly, below-normal precipitation generally results in increased groundwater pumping.

THE SURFACE WATER AND GROUNDWATER CONNECTION

In recent years, there has been increased study of the connection between surface water and groundwater. It is commonly known that precipitation that infiltrates into the soil and percolates down below the root zone recharges the groundwater supplies. A surface water supply, such as the stream used for the following example, can either recharge or accept discharge from groundwater supplies depending on how the level of the stream compares to the water table. A stream that lies above the water table will recharge groundwater supplies, thus losing water. This type of stream is termed a losing stream.

A stream that lies at or below the water table will accept groundwater discharge, thus gaining water. This type of stream is known as a gaining stream. During a period of drought, a gaining stream's flow will be supported by groundwater inflow, whereas a losing stream will probably stop flowing. Figure 11 illustrates this connection as discussed above. This type of connection is common between surface water and groundwater supplies, and is a topic of concern when trying to administer surface and groundwater rights in localized areas.

WATER QUALITY ISSUES

Natural groundwater quality varies greatly from location to location. Water's natural quality is affected by the materials it must pass through on its way to, and within, the groundwater reservoir. In some areas, groundwater contains minerals in concentrations high enough to warrant treatment prior to domestic use. Generally, Kansas groundwater is fairly high in minerals with some localized areas of poor quality, but few widespread quality problems.

Some of the naturally occurring minerals found in groundwater are: calcium, magnesium, potassium, iron, sodium, chloride, sulfate and bicarbonate. The most common pollutant found in excess of U.S. Environmental Protection Agency public water standards is nitrate–nitrogen. Other chemicals occur naturally in localized areas of the state. While these chemicals reduce the quality of the water, health impacts generally are minor.

There are localized areas where human activities have caused water quality degradation. Some are serious enough to prevent the use of the water for human consumption. Industrial solvents, manufacturing chemicals, agricultural pesticides, fumigants used at large grain storage facilities and livestock wastes have been detected in groundwater at some locations. Detection of pollutants indicates practices may need to be modified to reduce or eliminate groundwater pollution potential.

For more information on the water quality and quantity in your area, contact one of the many local, state and federal water resources agencies. In particular, the Kansas Department of Health and Environment and the Kansas Geological Survey have both surface and groundwater quality information. Your County Extension Office also has many bulletins on protecting, testing, and treating drinking water supplies.

SUMMARY

Kansas has a wide range of precipitation, and is lucky to have vast underground aquifers in the western and south central areas of the state that can be used for agricultural and industrial pursuits. Kansas is losing approximately 820 billion gallons of water a year mostly in the form of groundwater reductions caused by irrigation practices. A better understanding of the hydrologic process and knowledge of Kansas resources will give incentive to develop more efficient irrigation practices as well as improve personal water usage. By trying to decrease the debt, water resources as well as other economic and health pursuits can be extended.

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KSU
KANSAS STATE UNIVERSITY

COOPERATIVE EXTENSION SERVICE, MANHATTAN, KANSAS

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