

Water Primer: Part 3

Groundwater

Introduction

There is a large need for water on Earth to sustain living systems and an increasing demand due to human activities. One supply of stored water being tapped by humans is groundwater. Groundwater is free or unbonded water located beneath the ground surface in an aquifer — a geologic formation containing a sufficient quantity of water that can be removed by pumping.

When a well is drilled into an aquifer, groundwater fills the well casing to the level of the water table. Groundwater is one of the natural ways water is stored and released to maintain and benefit the environment.

Water Movement in Soil and Geology

Gravity causes excess soil water to percolate (seep) through the soil and subsoils until an impervious layer is reached. Permeable soils, such as sand, hold only a small amount of water and allow quick percolation. Clay soils have extremely small openings between microscopic particles that significantly slow water movement. Many saturated clay soils are virtually impermeable. Depending on the geology of the soil or rock material, percolation rate may range from a fraction of an inch to a few feet per day.

Groundwater movement is also affected by the contour of the surface land (topography). Groundwater flows from a high-water surface elevation to a low-water surface elevation unless barriers are encountered. Since groundwater

moves toward lower elevations, a well driller often looks for water near the bottom of a hill. However, water quality should be protected by locating a well as far up the slope as possible to be away from sources of contamination such as a septic system or livestock area.

As water moves through the soil, it passes through an area above the water table known as the unsaturated, or vadose, zone. (See Figure 1.) This layer may be moist or wet, but the pores are only partially filled with water, leaving space for air. As water percolates through the soil it eventually reaches a zone where all the interconnected pore openings are filled with water. This is called the saturated zone. The top of the saturated zone is the water table. The layer directly above the water table is the capillary fringe. In this layer groundwater moves upward from the water table

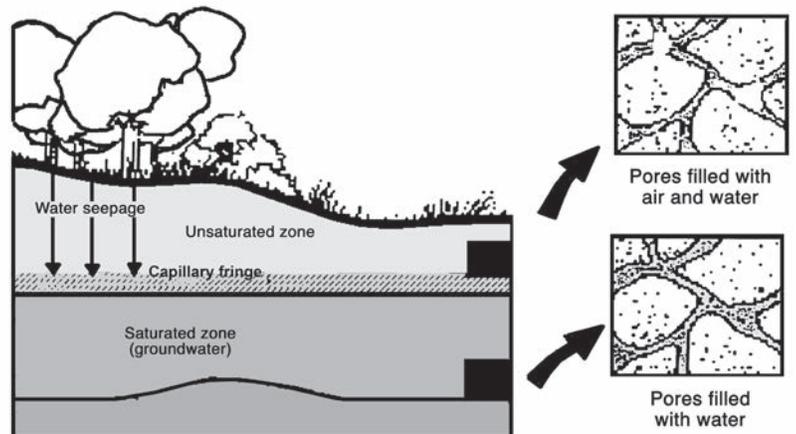


Figure 1. Water movement from the soil surface to groundwater.

by means of the capillary action of the pore spaces. Capillary action is caused by the surface tension of water. The water table rises and falls according to the season of the year, the amount of recharge, and the removal of groundwater. If groundwater is removed by pumping from wells, the water table lowers, which may change the direction of groundwater flow. As a result, sections of streams that once received groundwater decrease, and therefore, stream flow decreases. (Figure 2)

Aquifers and Recharge

The storage systems for groundwater are the spaces between particles of soil, sand, gravel, or rock, as shown in Figure 1. When saturated with water that can be removed by a pump, these formations are called aquifers or groundwater reservoirs. People often envision an underground river or lake when thinking about aquifers, but in most areas of the world, and specifically in Kansas, water is stored in the small openings between the soil and rock material and is more like a wet sponge. Aquifers may be as small as a few acres or larger than a state. The volume of contained water depends on the size, thickness, and porosity of the aquifer as well as the recharge. Storage volume is commonly known as the number of acre-feet per acre or feet of water. An acre-foot is the volume of water (325,851 gal.) it takes to cover an acre to a depth of 1 foot.

Aquifers are classified as either unconfined or confined. Unconfined aquifers lack a restrictive layer above the water table, as shown in Figure 3. Locations where water percolates down to the groundwater system are called

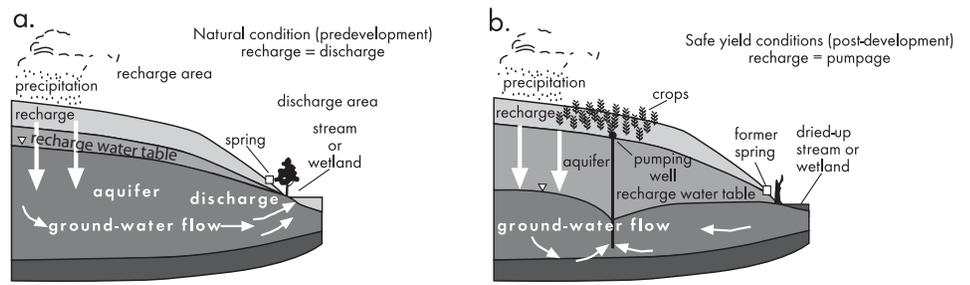


Figure 2. Stream-aquifer interaction. (Source: Sophocleus and Sarwin, 1997)

recharge areas. The recharge that supplies these aquifers infiltrates the soil directly above the aquifer. Unconfined aquifers, especially shallow ones that are covered by porous (sandy) soils, are the most susceptible to contamination. These unconfined aquifers are often close to the surface, with their only protection being overlying soil and geologic material. Figure 3 illustrates of both an unconfined and a confined aquifer.

A confined aquifer is a water-bearing layer between two impermeable, or confining, layers. The confining layers may be clay or rock, such as shale. The recharge area can be far away from the geologic formation penetrated by a well, but regardless

of distance the two are connected. The greatest recharge tends to occur in areas of coarse-textured or sandy soil with low water-holding capacity. Some recharge even occurs in clay soils because when heavy rains follow dry periods, cracks in the clay may allow water to enter deeply into the soil past the root zone. Recharge also occurs where seeps, springs, wetlands, streams, lakes, or other surface water percolate down to the aquifer. Areas of recharge can be small and localized or very extensive, covering hundreds of square miles.

Water in a confined aquifer is contained or restricted similar to water in a pipe. The water can become pressurized if the confined aquifer slopes away from the recharge area.

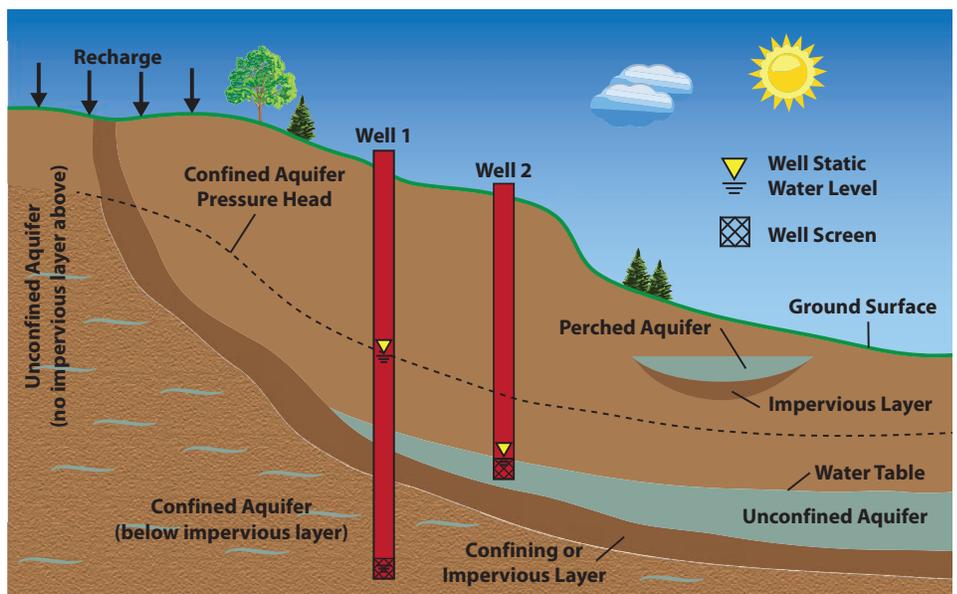


Figure 3. Wells, aquifers, and the water table.

Major Kansas Aquifers

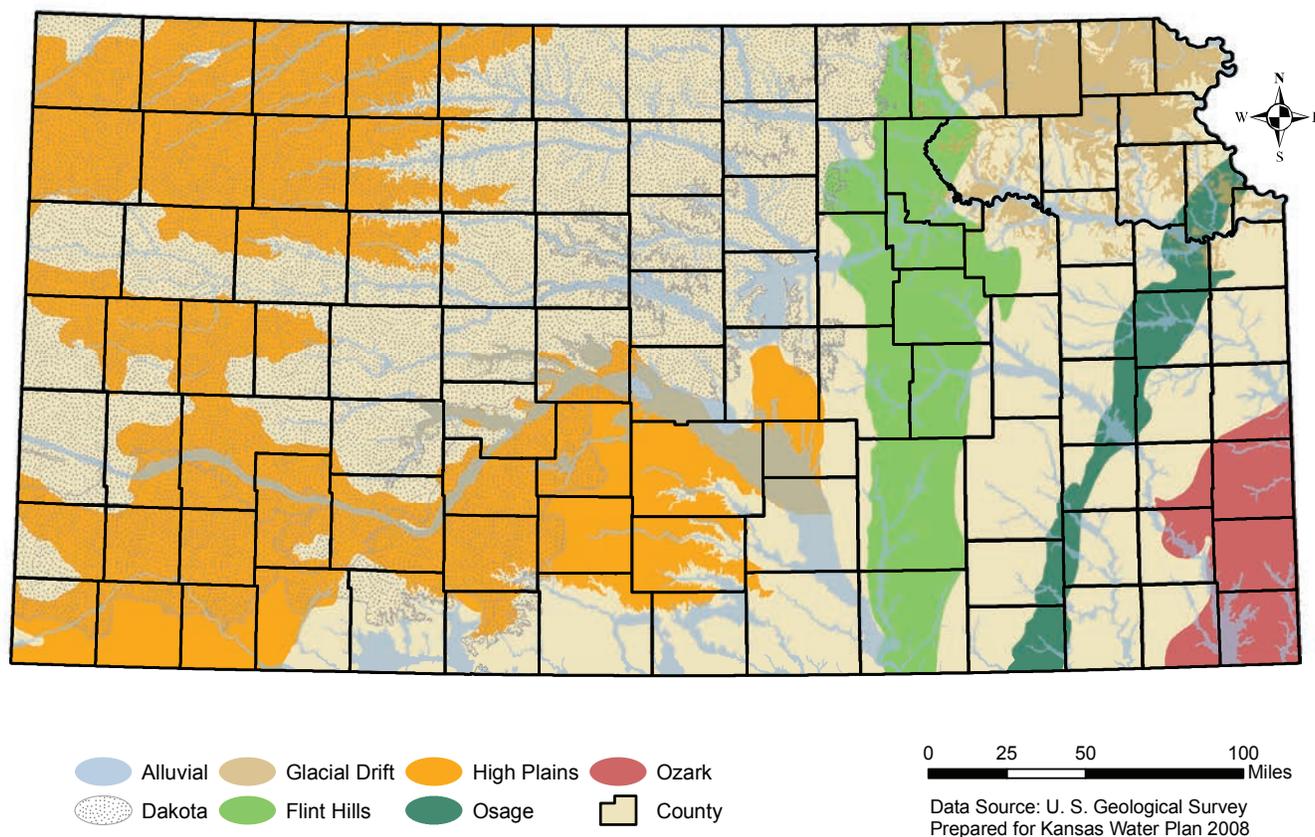


Figure 4. Principal groundwater aquifers in Kansas. (Source: Kansas Water Office)

When the pressurized water rises above the top of the confining layer, a condition called an artesian well is created — illustrated in Figure 3 by Well 1. A flowing artesian well occurs where the pressure is high enough to force water to the surface, causing water to flow freely from the well without using a pump. The water table rises and falls according to the season of the year, the amount of recharge, and the removal of groundwater. If groundwater is removed by pumping from wells, the water table lowers, which may change the direction of groundwater flow. As a result, sections of streams that once received groundwater decrease, and therefore, stream flow decreases.

Water Quality

The material overlying the aquifer protects the water quality of an aquifer by slowing the movement of water that may carry potential contaminants and allowing biological and chemical processes to remove some contaminants. These processes, however, can be overwhelmed by pollution or contamination that cannot be easily broken down or are applied in quantities in excess of the process capacity to break them down. Many older wells are either poorly constructed or poorly maintained and allow direct entry of surface water into the aquifer.

Because aquifers are not exposed to air or sunlight, they do not have the self-oxygenating, cleansing

properties of surface waters. Therefore, when groundwater becomes contaminated, the concentration (plume) of pollutants moves slowly with the aquifer water, allowing for minimal dilution or dispersion. By the time a plume reaches a well site, it may be difficult to determine where it originated, when it was released into the groundwater, and how long it will affect the well site.

Confined aquifers have greater protection from surface contamination, as long as the recharge area is protected from pollutants, because they are between layers of relatively impermeable materials. They are typically deeper underground than unconfined aquifers and have

an increased measure of protection from contamination from the ground surface. However, confined aquifers can be contaminated by pollutants in the recharge area or when confining layers are penetrated by test holes, poorly constructed wells, abandoned wells, or another breach of confinement that allows pollutant entrance.

Aquifers in Kansas

Kansas has seven principal groundwater aquifer systems (Figure 4).

Alluvial Aquifers

Alluvial aquifers are unconfined and associated with streams and rivers. The Kansas River Alluvial Aquifer is an important source of water for cities and irrigation along the border of the glaciated area and the Flint Hills. Other major unconfined alluvial aquifers include the Arkansas, Republican, and Pawnee rivers, on which high-yielding wells are possible (>500 gallons per minute, or gpm). Generally, the water quality of alluvial aquifers in Kansas is suitable for typical municipal, industrial, and agricultural uses, although many alluvial aquifers tend to have high enough iron and manganese

concentrations to cause staining. The water from some isolated areas of alluvial aquifers can be saline because of contact with underlying bedrock.

Water Table Aquifers

The Glacial-Drift Aquifer is a major source of water in northeast Kansas. The aquifer consists of unconfined, unconsolidated glacial deposits and produces wells that yield from 10 to 500 gpm with good quality water that is suitable for most uses.

The High Plains Aquifer is the largest, most important, and most extensively used aquifer in Kansas. This large regional aquifer extends from Texas and New Mexico, through Oklahoma, Kansas, eastern Colorado, and Nebraska, to extreme southern South Dakota. In Kansas, the aquifer is composed of three hydraulically connected but distinct formations: the Ogallala, Great Bend Prairie, and Equus Beds. The Ogallala formation is generally composed of unconsolidated sand, gravel, silt, and clay deposited by streams that historically flowed east from the Rocky Mountains. The Great Bend

Prairie and Equus Bed formations are also composed of silt, clay, sand, and gravel deposits left by streams flowing through central Kansas. In some areas, these formations are in contact with each other, creating one continuous aquifer. Wells in the High Plains Aquifer yield from 500 to 1,500 gpm. The water quality is suitable for most uses.

Great Plains Aquifer. This aquifer is a major source of water in central and north central Kansas. This aquifer consists of Dakota and Cheyenne sandstones. It is generally unconfined in the area shown in Figure 4; however, west and north of this area the aquifer is confined but typically contains poor quality water. Wells yield from 10 to 100 gpm in the northeast and more than 1,000 gpm in the south.

Chase and Council Grove Aquifer. The Chase and Council Grove Aquifer is an important water source in the Osage Plains, with well yields ranging from 10 to 200 gpm. The water quality generally is suitable for most uses; however, local sulfate concentrations can be high, especially in samples taken in the western part of the aquifer. (Figure 4)

Douglas Aquifer. The Douglas Aquifer is small but an important source where the sandstone formation is exposed. The aquifer generally is unconfined, and wells yield from 10 to 100 gpm. The water quality is suitable for most uses, although some wells produce water with high fluoride concentrations. As in the case of the Chase and Council Grove Aquifer, the water in western areas is not used because of high mineral content.

Ozark Aquifer. The Ozark Aquifer is the major source of groundwater

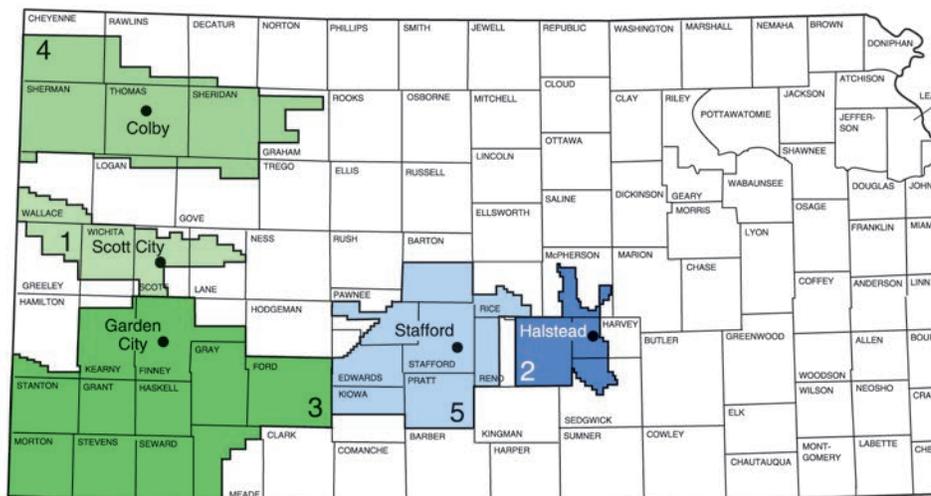


Figure 5. Groundwater management districts

Average Change in Water Table Elevations from 2000 to 2005 for the High Plains Aquifer in Kansas

B.B. Wilson, Kansas Geological Survey, University of Kansas, 1930 Constant Avenue, Lawrence, KS 66047

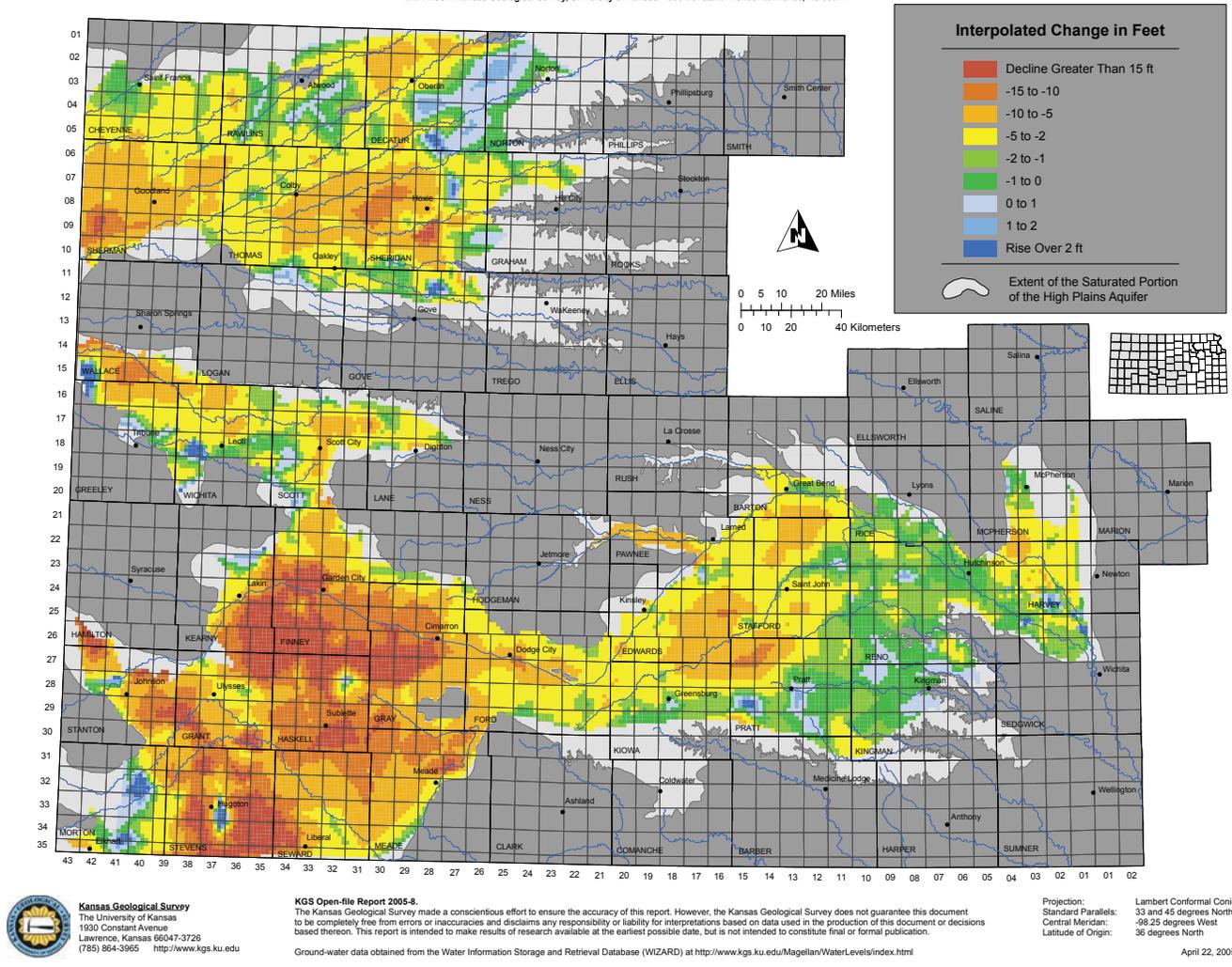


Figure 6. Average change in water table elevations in High Plains Aquifer.

in extreme southeast Kansas. This confined aquifer consists of weathered and sandy dolomites. Dolomite is a kind of sedimentary rock, much like limestone but rich in magnesium carbonate. At the shallowest point, the top of the formation in Kansas is 300 feet below land surface. Wells yield from 30 to 500 gpm, and the water is suitable for most uses. (Source: Adapted from Bevens, Spruill and Kenny, 1984.)

Groundwater Management in Kansas

Groundwater pumping since 1950 has severely depleted parts of the High Plains aquifer in western

Kansas. In southwest Kansas, groundwater levels have declined as much as 200 feet. These declines in groundwater, especially in west central Kansas, prompted the Legislature to pass the Kansas Groundwater Act in 1972. The act authorized the formation of local Groundwater Management Districts (GMDs) to help direct the development, use, and management of groundwater resources. Since passage of the act, five districts have been organized. (Figure 5.)

The three western districts — GMDs 1, 3, and 4 — overlay the High Plains Aquifer. These districts have the greatest number of

large-capacity wells and the greatest water level declines. This area of the state also has the least precipitation and groundwater recharge. Each of these districts has adopted a “planned depletion policy.” The policy allows groundwater withdrawals from an area in excess of the recharge rate for the aquifer but limits the withdrawals to a fixed depletion amount over a given time period. Other policies, such as well spacing, attempt to minimize direct interaction between pumping wells. At the current time, essentially all Kansas GMDs are closed to new appropriations. Groundwater declines still occurring in the Ogallala are shown in Figure 6.

Because GMDs 2 and 5 in south-central Kansas receive more precipitation and have greater recharge, they adopted the traditional safe-yield approach to groundwater management in the late 1970s and early 1980s. The amount of water appropriated for annual use was limited to the long-term annual recharge, implying a renewable groundwater resource. This was the first effort in Kansas to manage groundwater as a renewable resource.

Wells

Wells are used to access groundwater. The most common type of well pumps groundwater to the surface for use. Major uses for pumped water are irrigation, municipal, industrial, livestock, recreation, and domestic. Not all wells pump groundwater to the surface. Some wells, called monitoring wells, make observations on the water table level or allow for water quality measurements.

Another type of well is an injection well. Normally, these wells are used to dispose of wastewater, such as oil field brines and occasionally certain industrial wastes. Injection wells generally access geologic formations that are very deep and far below freshwater aquifers. These latter wells have specific construction criteria and allowable injection zones.

Today, however, all wells should be constructed and operated according to current standards. Modern standards allow access to groundwater while minimizing the potential pollution hazard since the well hole punctures the protective surface layers above the groundwater.

A basic well (Figure 7) is constructed by drilling a borehole through the soil and other

overburden material above the water bearing formation or aquifer. In the simplest well, the borehole penetrates into a single aquifer. In actuality, some wells may penetrate several aquifers that are separated by one or more geologic layers. Various well drilling methods are available. Once the borehole is complete, a well screen and casing are inserted into the borehole. The well screen is a slotted or screen type pipe that allows water to enter into the interior of the well but keeps the sands and gravels of the aquifer from entering the well interior. The well casing is usually PVC plastic or steel. The casing maintains an open hole for access to the groundwater.

The void area between the well casing or screen and the edge of the borehole is filled during the construction process. In an aquifer area, the fill material is called a gravel pack and consists of uniform-sized gravel or sand that is sized to prevent original aquifer material from migrating into the well as water is pumped. The upper portion of the void area around a well is filled with grout. Grout seals the well casing to the undisturbed aquifer material outside the borehole area. This is an extremely important part of the well construction process as this seal prevents surface water and surface contaminants from directly reaching the groundwater. In wells that penetrate the confining layer, a grout seal is required to be placed in confining layers between aquifer systems.

Other protective features of a well include a sanitary well cap, the use of a pitless adapter, and good site selection with no surfacing water ponding near the wellhead.

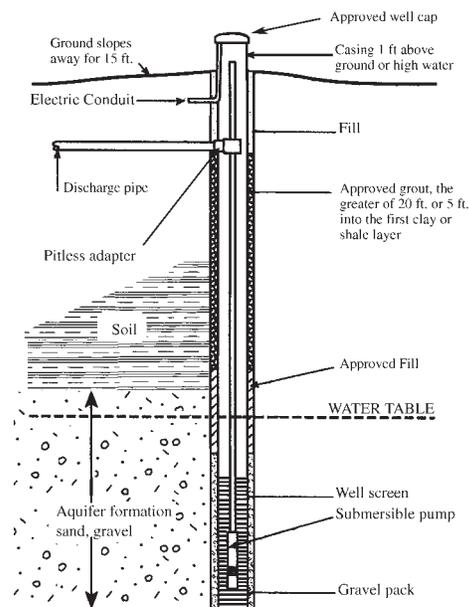


Figure 7. A basic well.

Historically, many farmsteads and rural homesteads have had either hand-dug or driven wells. Even with extensive efforts, these wells cannot be remade to meet modern safe well construction standards. To protect groundwater, these wells and any well that is abandoned (no longer used) should be properly plugged. Well plugging should be done using plugging procedures specified by regulation. Abandoned wells can be physical as well as pollution hazards.

Wells can be small diameter (4 inches or less) and shallow (less than 25 feet) or large diameter (24 inches or more) and deep (hundreds of feet) and yield little water (1 gpm) to thousands of gallons per minute. Regardless of their size or pumping rate, as water is pumped or removed from the well, the water level in the well drops. The initial or non-pumped water level is called the static water level. The difference between the non-pumped water level and pumped water level is called the drawdown. The area de-watered due to pumping is called

the cone of depression. The amount of drawdown or the size of the cone of depression rapidly increases when pumping is first started but gradually slows as pumping time increases until the increase is so slow that it may not be noticeable. How quickly this occurs depends on the pumping rate and the aquifer material. Some aquifers have large pores and allow water to move rapidly through the aquifer and into the well. Some are small pores with slow water movement. The thickness of the aquifer is also important to the well yield capability. In general, the thicker the water layer, the greater water yield potential.

The pump installed in a well needs to be sized appropriately for aquifer conditions. Installation of a pump that exceeds the water yield capability of the aquifer will result in a well that surges. This means the drawdown reaches the pump intake level, exposes the intake and allows air to enter the pump. These conditions cause pump and screen problems and should be avoided.

All nondomestic wells in Kansas are required to have a water permit before groundwater can be

diverted. All wells, regardless of use (domestic or nondomestic) must be constructed following well construction criteria. However, even properly constructed wells need to be properly operated and maintained, including using good well head protection management practices, to ensure longevity and groundwater protection.

Conclusion

Researchers, educators, and water regulators have come to realize that groundwater and surface water are often one closely inter-related system. Groundwater feeds springs and streams. Surface water recharges aquifers. The interaction of groundwater and surface water affects water quality and quantity. Groundwater can be contaminated by polluted surface water, and surface water can be degraded by discharge of saline or other low-quality groundwater. Streams and their alluvial aquifers are so closely linked in terms of water supply and water quality that neither can be properly understood nor managed by itself. The total combined stream-aquifer system must be considered.

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Authors:

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

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

Kerri Ebert, extension assistant, biological and agricultural engineering

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