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Water-Supply-Suitability Areas of the Dakota Aquifer in Kansas

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Introduction

In many areas of western and central Kansas, the water in shallow **aquifers** and at the surface will be inadequate to meet future demands. Because the only other available source of water for these areas is the Dakota aquifer, proactive management plans must be formulated to prevent overdevelopment.

The Dakota is a highly variable aquifer system in Kansas. Some parts of the aquifer contain abundant quantities of freshwater at shallow depths. Elsewhere, the aquifer is much deeper in the subsurface and may contain unusable groundwater with **salinities** (the sum of the dissolved constituents in the water) that exceed 10,000 mg/L. In some areas, well pumping in the Dakota may allow saltwater to move upward into shallower, fresher aquifers or induce freshwater recharge into the Dakota from other aquifers. In other areas, groundwater withdrawals may cause the eventual depletion of the aquifer. To insure the Dakota's continued use, management decisions must take into account this high degree of natural variability and the variable response of the aquifer system to pumping.

From our research, the Kansas Geological Survey (KGS) proposes the recognition of distinct water-supply-suitability areas in the Dakota aquifer based on local conditions in the aquifer or its response to pumping by wells. This circular provides information on these proposed suitability areas, information that groundwater management districts, basin advisory councils, state water agencies, and others may find useful in the development of water-management plans and policies for the Dakota aquifer in Kansas. The boldface terms are defined in the Glossary at the end of this publication.

Overview of the Dakota Aquifer

The Dakota aquifer system underlies much of the western two-thirds of Kansas (fig. 1) and consists of sandstone bodies interspersed in relatively impervious shales.

These sandstones and shales belong to the Cheyenne Sandstone, Kiowa Formation, and Dakota Formation (fig. 2). In western and parts of central Kansas, the Dakota aquifer system is separated into upper and lower aquifers by a relatively impervious shale unit within the Kiowa Formation, the Kiowa shale aquitard. The upper Dakota aquifer consists of sandstones in the Dakota Formation. The lower Dakota aquifer consists of the sandstones in the lower part of the Kiowa Formation and the Cheyenne Sandstone. In much of central Kansas, the Kiowa shale aquitard is not present and the upper and lower aquifer units in the Dakota are not recognized.

Over most of its extent in Kansas, the Dakota is overlain by a relatively impermeable sequence of younger

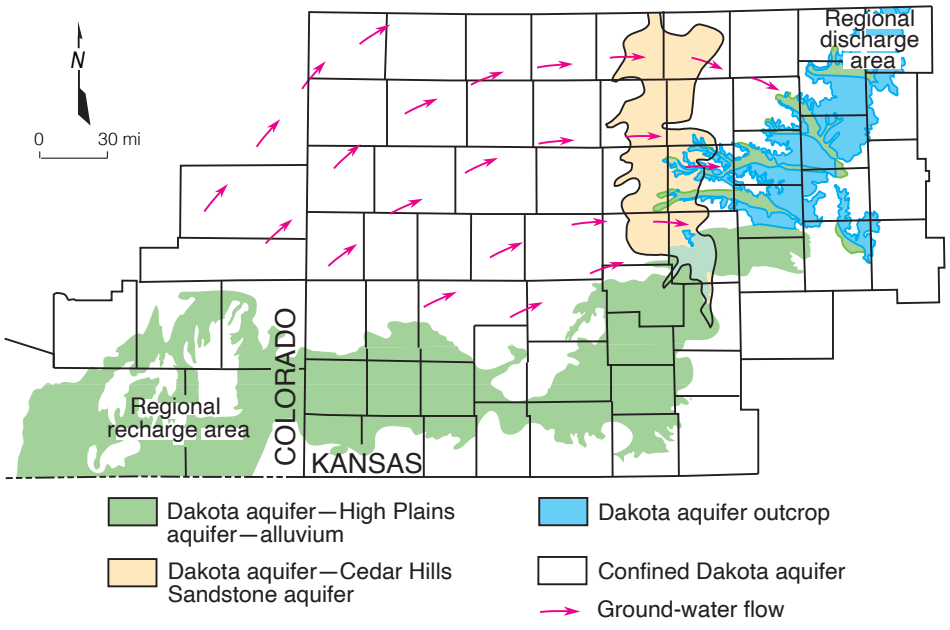

Figure 1. Map showing the confined and unconfined regions of the Dakota aquifer in Kansas and regions of hydraulic connection with other aquifer systems. Arrows indicate the directions of groundwater flow through the confined Dakota aquifer from the regional recharge to the discharge area.

shale and chalk units that form the Upper Cretaceous aquitard. Where this aquitard is present, the Dakota is a **confined aquifer**. In most of the confined Dakota aquifer in Kansas (fig. 1), groundwater moves very slowly from **recharge areas** in southeastern Colorado to **discharge areas** in central Kansas. Freshwater **recharge** from overlying sources is negligible in northwest Kansas where the Upper Cretaceous aquitard is more than 2,000 feet (610 m) thick. Consequently, groundwater salinity in the Dakota of northwest Kansas exceeds 10,000 mg/L (fig. 3).

In central Kansas, the Upper Cretaceous aquitard thins, and recharge to the Dakota from overlying sources is significant. However, in the confined part of the Dakota where it is **hydraulically connected** to the underlying Cedar Hills Sandstone in north-central Kansas (fig. 1), groundwater salinities in the upper Dakota generally exceed 10,000 mg/L (fig. 3).

Elsewhere, the Dakota is an **unconfined aquifer** (fig. 1). Recharge is locally derived from infiltrating precipitation and is estimated to be at most a few tenths of an inch per year. In most of the unconfined aquifer, groundwater in the upper part of the Dakota aquifer is fresh (fig. 3), but the salinity of groundwater may increase with depth locally in the lower part of the aquifer. Groundwater is discharged from the unconfined Dakota to nearby streams through fresh- and saltwater springs, seeps, and marshes. During periods of low streamflow, saltwater becomes a major component of the discharge to some of the streams in central Kansas, such as the Saline River. In southwestern and south-central Kansas, the Dakota is hydraulically connected to the High Plains aquifer (fig. 1). The High Plains aquifer consists of the Ogallala Formation and associated aquifers in **Pleistocene and Holocene deposits**. Groundwater moves easterly from the regional recharge area in southeastern Colorado into southwestern Kansas and discharges to the overlying High Plains aquifer near the Kansas-Colorado border. Further east, the High Plains aquifer recharges the Dakota in Gray and northern Meade counties.

Water-Supply-Suitability Areas

Because of the highly variable conditions in the Dakota aquifer system and the variable impacts of pumping, different management strategies are needed in different regions of the state. To assist local and state water agencies in managing this resource, the KGS has divided the Dakota aquifer into six water-supply-suitability areas. A **water-supply-suitability area** is defined by the KGS as a region of the Dakota aquifer in which the hydrologic and water-quality characteristics, as well as the impacts of pumping on the hydrologic system, are relatively uniform. The proposed boundaries between the suitability areas shown in fig. 4 mark significant changes in these characteristics or in the response of the hydrologic system to pumping.

In comparison to the High Plains and other shallow aquifers, the Dakota remains a relatively unknown aquifer system in Kansas. Therefore, the boundaries between suitability areas may change as new information becomes available. Also, the rate and intensity of development may necessitate the adjustment of these boundaries. Nonetheless, these water-supply-suitability areas are useful in the formulation of management strategies. The KGS is not suggesting the creation of regulatory bodies to manage each of these suitability areas. Rather, it is our intent that these suitability areas be incorporated into the formulation of policies and plans

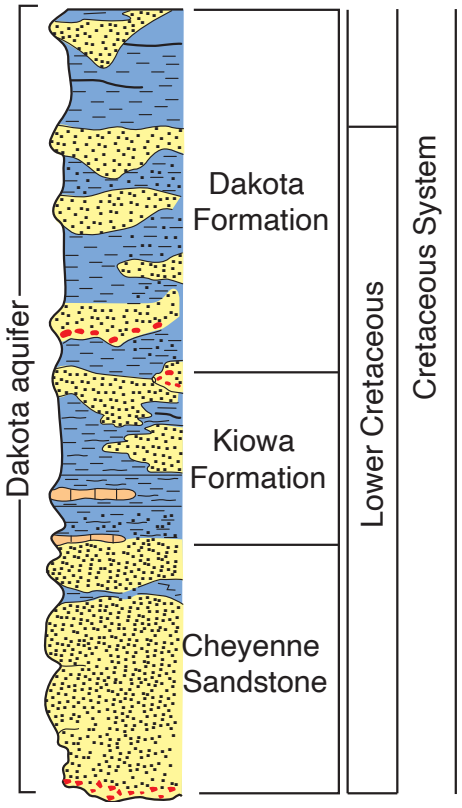

Figure 2. Geologic units and the major subdivisions of the Dakota aquifer in western and central Kansas.

by the existing local and state water agencies. With the recognition of these suitability areas, it may be possible for these agencies to more fully address the sustainability of the hydrologic system, which includes both surface and ground waters.

Suitability Area I

Suitability Area I encompasses the region where the Dakota and the High Plains aquifers are hydraulically connected in southwestern and south-central Kansas (figs. 1, 4). Where the High Plains is thickest, the depth below the surface to the top of the Dakota aquifer is more than 500 feet (152 m). In western Stanton, western Morton, and southern Hamilton counties, the High Plains aquifer is absent or is very thin and the Dakota aquifer is the primary shallow aquifer. Groundwater in the upper Dakota aquifer is fresh throughout this suitability area (fig.

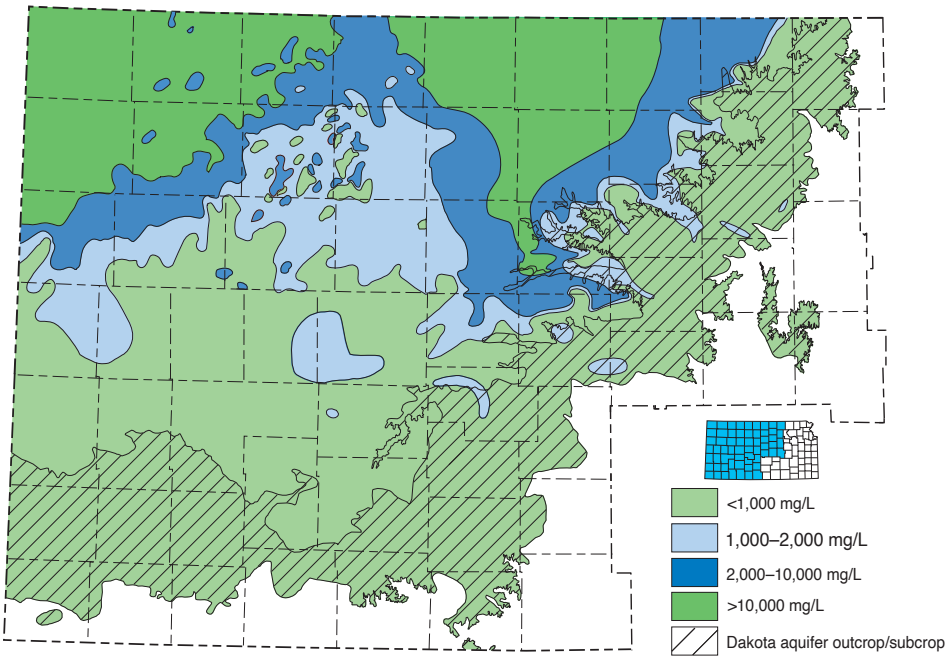

Figure 3. Map showing salinity, the sum of the dissolved constituents, of groundwater in the upper Dakota aquifer in western and central Kansas. Water containing less than 1,000 mg/L is defined as fresh. Water with 1,000–2,000 mg/L is usable for many purposes but is less desirable than freshwater. A concentration of 10,000 mg/L is defined in the state regulations of the Kansas Corporation Commission as the upper limit of usable water; above 10,000 mg/L a water is classified as unusable or mineralized..

3). However, groundwater chemical quality is variable in the lower Dakota aquifer because of the small amount of freshwater recharge that passes through the Kiowa shale aquitard. Groundwater salinities may exceed 2,000 mg/L (too high for human consumption but usable for livestock) in some parts of the lower Dakota. Nearer the Kansas-Colorado border and the Dakota's southern extent in southwestern Kansas, the lower Dakota contains freshwater because of its proximity to the regional recharge area in southeastern Colorado and local recharge from the High Plains aquifer. In this suitability area, the Dakota is used for drinking, industry, and agriculture, including irrigation. Water-level declines in the Dakota from previous development are generally less than 50 feet (15 m) in Suitability Area I.

Because the Dakota and the High Plains aquifers are hydraulically connected, they behave as a single system in this suitability area. The water-management policies developed for one of the aquifers will eventually have an impact on the other. Consequently, it is appropriate to consider both aquifer systems in policy development.

Suitability Area II

In Suitability Area II, the Dakota aquifer is confined by the Upper Cretaceous aquitard. This area is adjacent to Suitability Area I, where the Dakota is hydraulically connected to the High Plains aquifer (figs. 1, 4). The depth below the surface to the top of the Dakota aquifer is less than 400 feet (122 m) over most of this area. Because the aquitard is thin, recharge from overlying sources to the upper Dakota aquifer is significant, though less than the amount withdrawn by pumping. Groundwater in the upper Dakota is fresh (less than 1,000 mg/L) over most of the region (fig. 3). Groundwater salinity in the lower Dakota is believed to be less than 5,000 mg/L in the western half and more than 5,000 mg/L in the eastern half of the area. The upper Dakota is used for drinking water, industry, and agriculture, including irrigation. Use of the Dakota for irrigation is more common in Hodgeman and Ford counties. Water-level declines from previous development are generally less than 50 feet (15 m). Pumping wells in the Dakota aquifer in Suitability Area II may increase recharge from the High Plains aquifer into the Dakota aquifer in Suitability Area I.

Suitability Area III

In the eastern part of Suitability Area III, the Dakota is a shallow unconfined aquifer or is in contact with stream-aquifer systems (figs. 1, 4). In the western part of the suitability area, the Dakota is confined and the Upper Cretaceous aquitard is thin and relatively permeable. In the western (confined) part of this suitability area, the depth below the surface to the top of the Dakota aquifer is generally less than 150 feet (46 m). Where the Dakota is unconfined, recharge is estimated at a few tenths of an inch per year. Throughout this suitability area, groundwater quality in the upper part of the Dakota is locally variable, except where the salinity has been flushed from the aquifer by freshwater recharge. In the unconfined regions, groundwater near the top of the Dakota is mostly fresh (fig. 3). Salinity generally increases with depth near the bottom of the aquifer in the confined Dakota, and in the unconfined aquifer it increases near some of the major streams that cross central Kansas. In this suitability area, the Dakota is used for drinking water, industry, and agriculture, including irrigation. Irrigation use is concentrated primarily in southwestern Washington, southeastern Republic, and northern Cloud counties. Water-

level declines from development in Suitability Area III are believed to be less than 20 feet (6 m).

According to computer simulations, the primary impact of water-resources development in Suitability Area III is a reduction in discharge from the Dakota aquifer to streams, and the lateral movement of water from the confined to the unconfined Dakota aquifer from west to east. Further increases in development may only slightly increase water-level declines where the Dakota is a shallow aquifer.

Suitability Area IV

Suitability Area IV includes that part of the confined Dakota aquifer located west of its regional discharge areas in north-central Kansas (figs. 1, 4). Depth below the surface to the top of Dakota aquifer is generally less than 400 feet (122 m). Freshwater recharge from overlying sources varies locally and may have flushed some of the salinity from the upper part of the aquifer. However, natural saltwater in the lower part of the Dakota from the Cedar Hills Sandstone is widespread in this suitability area. Consequently, groundwater salinity generally increases with depth. Based on salinity, the suitability area is divided into two parts: in Suitability Area IVa, the salinity near the top of the Dakota is less than 1,500 mg/L, whereas in Suitability Area IVb, the salinity ranges from 1,500 mg/L to 10,000 mg/L (fig. 3). In Suitability Area IVa, water quality is acceptable for most uses, but in Suitability Area IVb, the aquifer is marginally usable. Groundwater salinities in the lower part of the Dakota aquifer probably exceed 10,000 mg/L over the entire suitability area. Water-level declines from development are believed to be less than 10 feet (3 m). In Suitability Area IVa, the upper part of the Dakota is used primarily for drinking water and stock water. In Suitability Area IVb, water from the aquifer may require advanced treatment technologies to reduce its salinity.

Wells in the upper part of the Dakota aquifer near the eastern edge of Suitability Area IV may reduce the eastward flow of fresher groundwaters into the regional discharge areas. This may allow deeper, more saline groundwater to move into the upper part of the Dakota and may increase the salinity of groundwater discharge to streams.

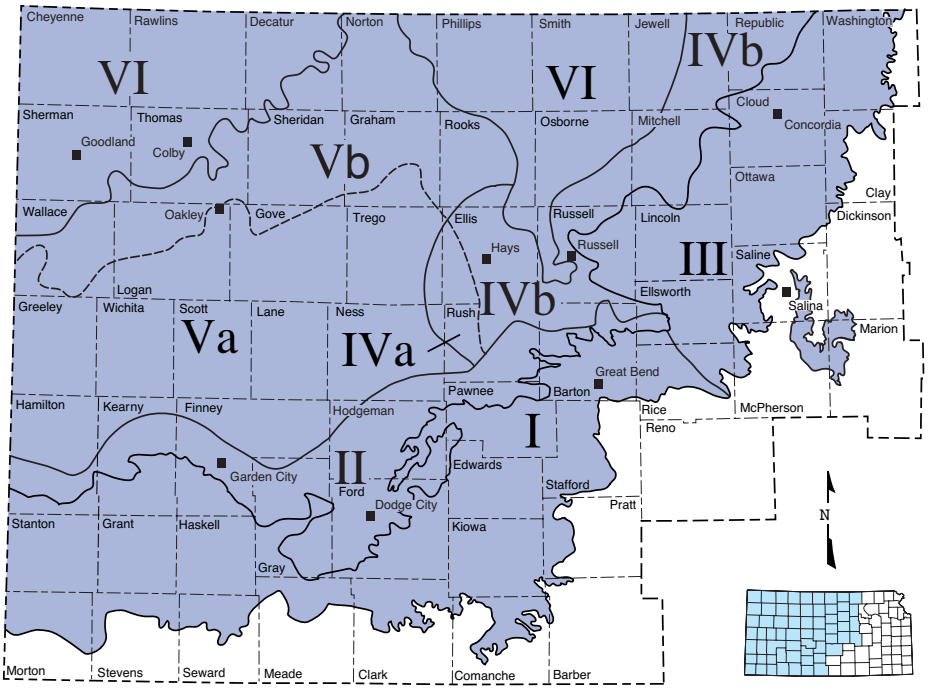

Figure 4. Map showing the six water-supply-suitability areas of the Dakota aquifer in western and central Kansas. In suitability areas IV and V, the dashed line separates fresher groundwaters to the south and west from more saline groundwaters (salinities greater than 1,500 mg/L) to the north and east.

Suitability Area V

In Suitability Area V, the confined Dakota aquifer receives negligible freshwater recharge from overlying sources (figs. 1, 4). Depth below the surface to the top of the aquifer ranges from 400 feet (122 m) to more than 1,500 feet (457 m) along the shared boundary with Suitability Area VI in northwest Kansas. The major source of freshwater is from the regional recharge area in southeastern Colorado. Groundwater salinities in the upper Dakota aquifer generally increase northeastward from less than 500 to 1,500 mg/L in Suitability Area Va and from 1,500 mg/L to 10,000 mg/L in Suitability Area Vb (fig. 3). Groundwater salinities in the lower Dakota aquifer are greater than 2,000 mg/L and may locally exceed 10,000 mg/L in the far northern and eastern parts of the Suitability Area V. In Suitability Area Va, water quality is acceptable for most uses and the Dakota is used primarily for drinking and livestock, but in Suitability Area Vb, the water quality is marginal. In general, the upper Dakota is more saline with depth to the north and east. Water-level declines from development are believed to be less than 50 feet (15 m) in this suitability area due to its limited use.

Water-resources development in this part of the aquifer is not likely to induce additional freshwater recharge from the High Plains aquifer into the unconfined Dakota aquifer in Suitability Area I. Pumping rates greatly exceed recharge from overlying sources. As a result,

pumping may locally deplete the aquifer if wells and wellfields are spaced too closely together.

Suitability Area VI

In Suitability Area VI, the Dakota is a confined aquifer and contains saline or "mineralized" groundwater, defined by state statute as water containing more than 5,000 mg/L chloride or more than 10,000 mg/L total dissolved solids. Mineralized groundwater is considered undesirable for most uses except oil and gas operations (such as secondary recovery) and is not protected by state and local regulations. In the northwest part of Suitability Area VI, the Dakota receives negligible freshwater recharge from overlying sources, flow rates are very low, and the depth to the top of the Dakota exceeds 1,500 feet (457 m). In the central part, vertical and lateral flow rates through the aquifer are higher and the top of the aquifer is less than 500 feet (152 m) below the surface. However, the flow of freshwater through the aquifer has been insufficient to flush the salinity from the aquifer where it is hydraulically connected to the Cedar Hills Sandstone.

Summary

The Dakota is a major aquifer system in Kansas and may become an important source of water in areas where shallower aquifers are inadequate. However, unlike other major shallow aquifer systems in Kansas, conditions in the Dakota are highly variable. Consequently, delineation of water-supply-suitability areas within the aquifer on the basis of hydrology, water quality, and the impact of pumping is an important first step in proactive policy development to prolong the use of this water resource.

Glossary

Aquifer: A part of a geologic formation, or one or more geologic formations, that is porous and permeable enough to transmit water at a rate sufficient to feed a spring or for economic extraction by a well. An aquifer transmits more water than an aquitard.

Aquitard: A part of a geologic formation (or one or more geologic formations) that is of much lower permeability than an aquifer and will not transmit water at a rate sufficient to feed a spring or for economic extraction by a well.

Confined aquifer: An aquifer that is bounded above and below by aquitard units; water levels in wells screened in the confined aquifer are higher than the top of the aquifer.

Discharge area: An area where groundwater is lost naturally from an aquifer through springs, seeps, or hydraulic connection to other aquifers. The water leaving the aquifer is referred to as discharge.

Hydraulically connected: A condition in which groundwater moves easily between aquifers that are in direct contact. An indication of this condition is that the water levels in both aquifers are approximately equal.

Pleistocene and Holocene deposits: Unconsolidated gravels, sands, silts, and clays in alluvial and wind-blown deposits that formed within the last 2 million years, mostly along the Arkansas River valley in southwestern and south-central Kansas.

Recharge area: A geographic area where water enters (**recharges**) an aquifer. Recharge areas usually coincide with topographically elevated regions where aquifer units crop out at the surface. In these areas infiltrated precipitation is the primary source of recharge. The recharge area may also coincide with the area of hydraulic connection where one aquifer receives flow from another adjacent aquifer.

Salinity: The sum of the dissolved materials in water expressed in milligrams/liter (mg/L). The upper limit for freshwater is 1,000 mg/L; natural seawater has a salinity of approximately 35,000 mg/L.

Unconfined aquifer: An aquifer that is not bounded above by an aquitard; water levels in wells screened in an unconfined aquifer coincide with the elevation of the water table.

Water-supply-suitability area: A region of the Dakota in which the hydrogeologic and water-quality characteristics of the aquifer and the impacts caused by pumping on the hydrologic system are relatively uniform.

Additional Information

Additional information on the Dakota aquifer can be obtained by contacting the Geohydrology Section at the Kansas Geological Survey (785-864-3965).

Further information on the topics covered in this pamphlet can be found in the following publications.

Buchanan, R. C., and Buddemeier, R. W., compilers, 1993, Kansas Ground Water: Kansas Geological Survey, Educational Series 10.

Macfarlane, P. A., and Sawin, R. S., 1996, A User's Guide to Well-spacing Requirements for the Dakota Aquifer in Kansas: Kansas Geological Survey, Public Information Circular 1.

Macfarlane, P. A., 1997, The Dakota Aquifer System in Kansas: Kansas Geological Survey, Public Information Circular 7.

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The Kansas Geological Survey (KGS) is a research and service division of the University of Kansas that investigates and provides information about the state's natural resources. KGS scientists pursue research related to surface and subsurface geology, energy resources, groundwater, and environmental hazards. They develop innovative tools and techniques, monitor earthquakes and groundwater levels, investigate water-quality concerns, and map the state's surface geology.

The KGS has no regulatory authority and does not take positions on natural resource issues. The main headquarters of the KGS is in Lawrence in the West District of the University of Kansas, and the Kansas Geologic Sample Repository of the KGS is in Wichita.

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