

**KANSAS GEOLOGICAL SURVEY  
OPEN-FILE REPORT 97-41**

INVASION OF SALINE WATER ALONG THE ARKANSAS RIVER

By

D.O. Whittemore  
J.J. Butler, Jr.

*Disclaimer*

The Kansas Geological Survey does not guarantee this document to be free from errors or inaccuracies and disclaims any responsibility or liability for interpretations based on data used in the production of this document or decisions based thereon. This report is intended to make results of research available at the earliest possible date, but is not intended to constitute final or formal publications.

Kansas Geological Survey  
1930 Constant Avenue  
University of Kansas  
Lawrence, KS 66047-3726

# INVASION OF SALINE WATER ALONG THE ARKANSAS RIVER

by

Donald O. Whittlemore and James J. Butler, Jr.  
Kansas Geological Survey

*Prepared for the  
30th Annual Conference and Exhibition for Public Water and Wastewater Systems  
sponsored by the  
Kansas Rural Water Association  
March, 1997*

Kansas Geological Survey Open-File Report 97-41

# INVASION OF SALINE WATER ALONG THE ARKANSAS RIVER

Donald O. Whittemore and James J. Butler, Jr., Kansas Geological Survey

## Abstract

The Arkansas River in southeastern Colorado and southwestern Kansas is one of the most saline rivers in the U.S. Consumptive loss of water by evaporation and transpiration in eastern Colorado has greatly concentrated dissolved solids over natural levels in the river. The dissolved constituents in highest concentrations are sulfate, sodium, calcium, and magnesium. As a result of ground-water table declines, the saline Arkansas River water usually seeps into the alluvium and thence into the underlying High Plains aquifer. Substantial amounts of river water have also been diverted for irrigation use in southwestern Kansas. Infiltration of this saline irrigation water also contributes to salinization of the ground water.

Zones containing clay layers underlie the alluvium and are present in parts of the upper High Plains aquifer (Pleistocene sediments and Ogallala Formation). These clays restrict the downward movement of the saline river water. As a result, perched saline water exists in some areas above the main body of the High Plains aquifer. Discontinuous clay layers also occur within the main aquifer and further retard the downward movement of saline water. When a water well is installed, a gravel pack is placed in the annular space between the well casing and the outer borehole wall. The gravel pack extends through the screened interval and often upwards across the clay layers. Except for newer public supply and domestic wells, grout seals in the well annulus generally do not extend through the entire perched aquifer. Thus, saline water can enter a gravel pack within the perched aquifer and flow down the gravel pack and into the deeper aquifer, thereby circumventing the intervening clays. Furthermore, the low-permeability skin of the borehole created during drilling causes most of the gravel-pack flow to enter the permeable developed interval opposite the well screen. The net effect is a low-flow injection well. Flow of perched saline water down gravel packs of unsealed wells, especially large diameter irrigation wells, could be responsible for a substantial portion of the contamination now seen in the deeper High Plains aquifer. Unsealed wells that are pumped probably capture much of the saline water that has flowed down the gravel pack. Abandoned or dormant wells could cause a much greater amount of contamination than pumping wells. However, long-term clogging of the screened interval of unused wells with sediment and bacterial and mineral matter could slow the contamination. Wells that have been plugged only inside the casing can still allow flow along the gravel pack. One of the goals of the Upper Arkansas River Corridor Study includes examination of the salinity distribution within the aquifer to assess the importance of these processes.

Sealing the annular space in newly constructed wells through the low permeability zone would be one of the most cost effective measures for locally protecting the High Plains aquifer not only in the Arkansas River corridor but across the entire aquifer. Plugging of abandoned wells to include grouting the annular zone, as well as the inside of the casing, would also slow the rate of contamination in the Arkansas River corridor. Such grouting would be substantially more expensive than just sealing the inside of the well casing. However, this action might be appropriate as a part of well-head protection for public supply wells, especially where the wells are located near substantial sources of water for infiltration such as the Arkansas River, irrigation canals, irrigated fields, and waste lagoons.

## INVASION OF SALINE WATER ALONG THE ARKANSAS RIVER

Donald O. Whittemore and James J. Butler, Jr.  
Kansas Geological Survey

The Arkansas River in southeastern Colorado and southwestern Kansas is one of the most saline rivers in the United States. Consumptive loss of water by evaporation and transpiration in eastern Colorado has greatly concentrated dissolved solids in the river. Flows entering Kansas are saline during both high and low discharge periods, although the salinity generally decreases with greater discharge. The water primarily contains high concentrations of sulfate, sodium, calcium, and magnesium, as well as elevated contents of many other inorganic constituents. The dissolved constituents are naturally derived from flow of rain and ground water through soils and bedrock in Colorado. These constituents are concentrated as a result of water being evaporated from reservoirs, irrigation ditches and laterals, and soils, and transpired by plants, especially in irrigated fields, while the dissolved salts remain behind in the residual water. Sulfate concentrations can reach 2,400 mg/L in water flowing across the state border. This compares with a maximum of 250 mg/L recommended for public drinking supplies and 400 mg/L proposed as a possible maximum contaminant limit by the U.S. EPA.

Other constituents that are high in the river water and which exceed surface water quality standards of the Kansas Department of Health and Environment for selected uses are selenium and boron. The river water entering Kansas from Colorado contains a selenium concentration that is nearly always greater than 5  $\mu\text{g/L}$ , the chronic criterion for aquatic life support, and that often exceeds 20  $\mu\text{g/L}$ , the acute criterion for aquatic life and the limit for irrigation water. The boron content in the saline water of low flows often exceeds the standard for irrigation water. Nitrate concentration is relatively low; ranges are generally  $<1$  mg/L nitrate-nitrogen for high flows, 1-2 mg/L for moderate flows, and 2-3 mg/L for low flows. Pesticide concentrations are nearly always below detection. Uranium concentration in the saline low flows generally exceeds the level of 20  $\mu\text{g/L}$  proposed by the U.S. EPA as a possible standard for drinking water.

In the past, most of the Arkansas River waters would interact with ground waters in the portion of the alluvial aquifer close to the river. Although river waters in southwestern Kansas could infiltrate into the alluvium during high flows, water from the shallow High Plains aquifer (comprised of Pleistocene sediments and the Ogallala Formation) could enter the alluvial aquifer and discharge to the river in some locations during low flows. The rate of ground-water withdrawals in southwestern Kansas during the last 50 years has been much greater than the rate of recharge into the alluvial and High Plains aquifers, causing large declines in ground-water levels. Saline Arkansas River water now seeps into the alluvium and thence into the underlying High Plains aquifer virtually all the time. Substantial amounts of river water have also been diverted for irrigation use in southwestern Kansas. Infiltration of this saline irrigation water also contributes to salinization of the ground water.

Natural levels of sulfate in water in the High Plains aquifer were probably less than 50 mg/L in much, and less than 100 mg/L in most, of the area underlying and adjacent to the river valley before contamination from infiltration of saline water. Water with a sulfate concentration

of over 1,000 mg/L is now produced by irrigation wells in the High Plains aquifer in the vicinity of the river and underlying areas irrigated by ditch diversions. The sulfate concentrations are usually smaller in water from domestic and public water supply wells than from irrigation wells.

A zone of low permeability clays and silty clays underlies most of the alluvium and is present in parts of the High Plains aquifer sediments. This low-permeability material restricts the downward movement of the saline river water to the deeper High Plains ground water. As a result, perched saline water exists in some areas above the main body of the High Plains aquifer. Discontinuous clay layers also occur within the main aquifer and further retard the downward movement of saline water.

Most of the wells in the region have been installed using reverse rotary drilling. Gravel packs are placed in the annular space between the well casing and the outer borehole wall. The gravel pack extends through the screened interval and often upwards across the clay and silty clay layers. Except for more recent public supply and domestic wells, grout seals in the well annulus are either not present or extend to only 10 or 20 feet below the land surface. However, the alluvium is usually 20-50 ft thick. Thus, saline water can enter a gravel pack within the perched aquifer and flow down the gravel pack and directly into the High Plains aquifer, thereby circumventing the underlying low-permeability zone.

Flow of perched saline water down gravel packs could be responsible for a substantial portion of the contamination now seen in the deeper parts of the High Plains aquifer. The hydraulic conductivity of a typical gravel pack is thousands of times greater than that of the clay layers. The limit on the flow through the gravel pack is probably not the permeability of the gravel, but the hydraulic conductivity of the skin of finer sediment around the borehole in the perched water zone. The lower permeability skin of the borehole results from invasion of fine drilling debris into the formation during drilling. Another factor affecting the flow through the gravel pack is the thickness of the perched water zone; the greater the thickness, the greater the head to drive downward flow. Thus, wells with unsealed gravel packs near the Arkansas River and close to leaky irrigation canals are expected to be greater point sources of contamination to the underlying High Plains aquifer than wells farther away.

Before development of a well for use as a water supply, the lower permeability skin extends along the entire open borehole. Development of a well removes most of this skin along the screened interval but does not appreciably affect it at shallower depths. As a result, most of the saline water slowly flowing down from the perched zone through the gravel pack does not enter the High Plains aquifer once it reaches the main water table, but continues downwards to the permeable interval opposite the well screen. The contaminated water can then flow directly into the aquifer near the top of the screened interval. The net effect is one of low-flow injection wells. With time, the flow of perched water through the borehole skin to the gravel pack could increase because some of the fine particles in the low-permeability skin could be entrained by the flow and moved into the coarse gravel. However, in abandoned wells, the flow into the screened zone could decrease as a result of fine sediment, bacterial growth, and chemical precipitates slowly clogging the pores of the aquifer material around the borehole. In active irrigation wells, however, pumping during the growing season would minimize this clogging effect.

Drillers' logs filed since 1975 indicate that the borehole and casing diameter of irrigation wells in southwest Kansas are generally 26 and 16 inches, respectively, and that the annular space is usually sealed to only 10 feet below land surface. The flow down the gravel pack of a typical irrigation well located near the river or a leaky canal could be a substantial fraction of the natural flow through the low-permeability layer underlying the alluvium in a quarter section. However, the natural flow will primarily contaminate the upper portion of the main aquifer, whereas the flow through gravel packs could affect the main part of the aquifer being pumped. Wells in the river valley and ditch irrigation area that are pumped probably capture much of the saline water that could flow down the gravel pack. Abandoned or dormant wells could therefore cause a much greater amount of contamination than pumping wells. The contamination pattern resulting from the combination of areal infiltration and point sources of salinity is expected to be a contaminated zone in the upper part of the saturated thickness of the High Plains aquifer punctuated by teardrop shaped plumes of higher salinity at greater depths around wells with unsealed gravel packs. One of the goals of current research in the Upper Arkansas River Corridor Study includes examination of this salinity distribution within the aquifer to confirm these mechanisms.

The gravel pack is not only an avenue for movement of saline water but also of other types of contaminants into the High Plains aquifer. High nitrate concentration and the presence of VOCs observed in High Plains waters probably are a result of movement down the gravel pack. The relatively low nitrate in Arkansas River water indicates that other sources such as infiltration of water below fertilized fields or animal waste sites must cause the contamination. Flow down the gravel packs of wells close to locations with perched water, such as possible below irrigated fields or waste lagoons, would be expected to be greater point sources than wells in dry land farming and pasture areas.

Sealing the annular space in newly constructed wells through the low permeability zone would be one of the most cost effective measures for locally protecting the High Plains aquifer in the Arkansas River corridor. Construction regulations under Kansas Article 30 (K.A.R. 28-30-6d) require that "waters from two or more separate aquifers shall be separated from each other in the bore hole by sealing the bore hole between the aquifers with grout." The alluvial aquifer of the Arkansas River valley and, where the alluvium is not present, the uppermost portion of the High Plains aquifer containing perched water should be considered as a separate aquifer from the main body of the High Plains. Another statute that applies to protecting the High Plains aquifer from contamination in the river and ditch irrigation corridor states that "all groundwater producing zones that are known or suspected to contain natural or man-made pollutants shall be adequately cased and grouted off during construction of the well to prevent the movement of polluted groundwater to either overlying or underlying fresh groundwater zones" (K.A.R. 28-30-6l).

Plugging of abandoned wells to include grouting the annular zone, as well as the inside of the casing, would also slow the rate of contamination in the Arkansas River corridor. Such grouting would be substantially more expensive than just sealing the inside of the well casing. However, this action could be appropriate as a part of well-head protection for public supply wells, especially where the wells are located near greater sources of water infiltration such as the

Arkansas River, irrigation canals, irrigated fields, and waste lagoons. Except for special cases that do not apply to the High Plains aquifer, K.A.R. 28-30-7 does not specifically require removal or perforation of casing and grouting of the annular zone at depths below several feet when plugging an abandoned well. Addition of such wording is worthy of consideration for areas such as the Arkansas River corridor where perched contaminated water has the potential to infiltrate down to fresher groundwater.

Mapping of the thickness of the alluvium, the permeable layer of the upper High Plains aquifer where the alluvium is not present, and the underlying low-permeability zone is in progress. These maps could be used as a general guide to assist in sealing the annular zone during construction and abandonment of water wells in the upper Arkansas River corridor. Work has also begun on the mathematical modeling of flow and transport in the gravel pack in an attempt to develop a more quantitative understanding of the impact of unsealed gravel packs on the contamination of the High Plains aquifer.

The Kansas Geological Survey wishes to acknowledge the assistance of local, federal, and other state agencies and institutions, and funding from the Kansas Water Plan in conducting the Upper Arkansas River Corridor Study.