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Effects of Artificial Recharge on Water Quality in the *Equus* Beds Aquifer, South-Central Kansas, 1995–2000

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This fact sheet describes the effects of artificial recharge on the Equus Beds aquifer for concentrations of four chemicals of concern—chloride, arsenic, total coliform bacteria, and atrazine. These four chemicals were determined to be of the greatest concern after determining the effects of recharge by comparing the median concentrations of more than 400 chemicals in more than 4,000 samples collected before and after artificial recharge activities began.

Introduction

The water supply for the city of Wichita, south-central Kansas, currently comes from the Wichita well field and Cheney Reservoir (fig. 1). Because these sources are not expected to meet projected city water needs into the 21st century (Warren and others, 1995), artificial recharge of the *Equus* Beds aquifer is being investigated as one alternative to meet future water-supply demands. An additional potential benefit of artificial recharge includes preventing degradation of the water quality of the aquifer by chloride plumes from the Arkansas River to the southwest and the Burrton oil field to the northwest (Ziegler and others, 1999).

In 1995, the *Equus* Beds Ground-Water Recharge Demonstration Project began evaluation of artificial recharge techniques and their effects on water quality in the aquifer. The demonstration project is a cooperative effort among the city of Wichita, Bureau of Reclamation (U.S. Department of the Interior), and the U.S. Geologicial Survey (USGS).

Water from the Little Arkansas River is diverted for artificial recharge when flow in the river exceeds base flow in accordance with the Kansas Department of Agriculture, Division of Water Resources, permit conditions (Burns and McDonnell, 1998). Water is artificially recharged to the *Equus* Beds aquifer, which is part of the High Plains aquifer and consists of alluvial (river-deposited) sediments of sand and gravel interbedded with clay and silt.

At the Halstead diversion well site (fig. 1), water is diverted from the Little Arkansas River by pumping a diversion well completed immediately adjacent to the river that induces the surface water into the well. This diverted source water then is pumped to the Halstead recharge site and recharged to the aquifer by basin, trench, or well. Recharge of the *Equus* Beds aquifer at the Halstead site began in May 1997.

Recharge water for the Sedgwick recharge site is diverted directly from the Little Arkansas River. It is treated to reduce turbidity (the cloudy appearance of water caused by suspended matter) and to remove organic compounds, including the herbicide atrazine, using powder activated carbon (PAC). The diverted water is recharged to the *Equus* Beds aquifer at the Sedgwick site through recharge basins (Ziegler and others, 1999). Recharge of the Equus Beds aquifer at the Sedgwick site began in April 1998.

From 1995–2000, the USGS monitored water-quality conditions during all aspects of the artificial

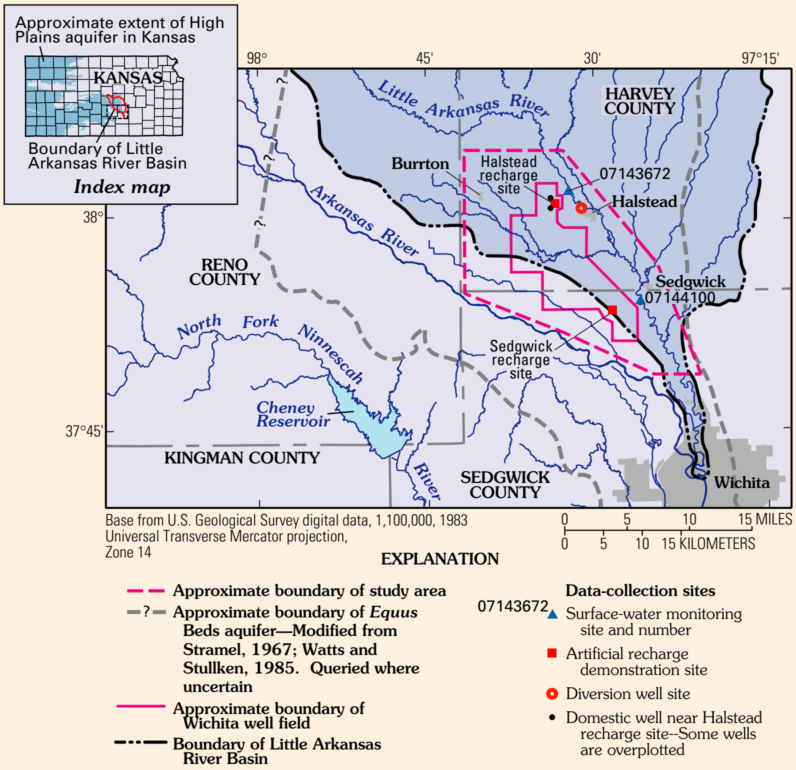

Figure 1. Location of study area near Wichita, south-central Kansas.

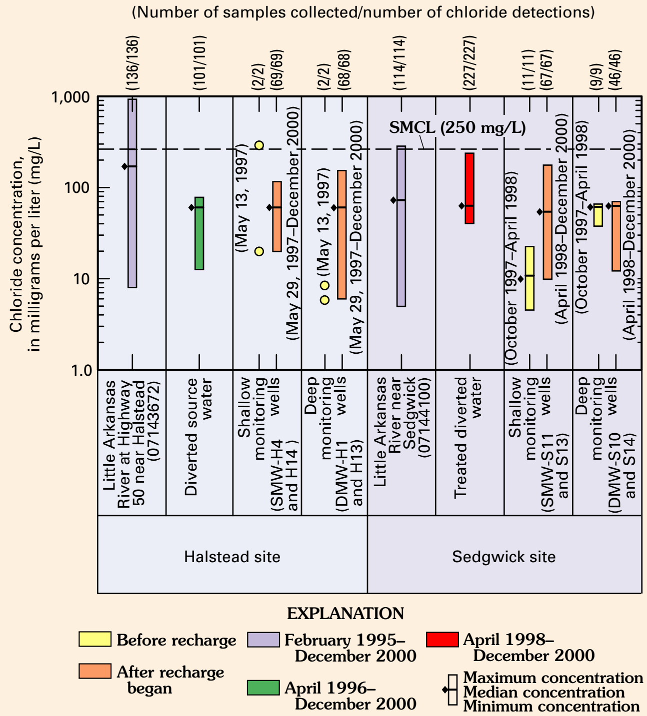

Figure 2. Chloride concentrations in ground water at both recharge sites generally were less than in surface water, were substantially less than the drinking-water standard, and approximated concentrations in diverted water. Secondary Maximum Contaminant Level (SMCL) from U.S. Environmental Protection Agency (2001).

recharge process. More than 4,000 water samples from the Little Arkansas River, diverted source water, and monitoring wells near the recharge areas were analyzed for more than 400 inorganic and organic chemicals including those with U.S. Environmental Protection Agency (USEPA) drinking-water standards. Water-quality monitoring prior to recharge indicated that sodium, chloride, nitrite plus nitrate, iron, manganese, total coliform bacteria, and atrazine were chemicals of concern relating to artificial recharge activities (Ziegler and others, 1999). Chemicals of concern were defined as those with concentrations in surface-water samples that exceeded 20 percent of the value of the drinking-water standard established for these chemicals. Recharging water with large concentrations potentially could degrade the water quality in the aquifer. Arsenic was added as a chemical of concern because of a proposed revision of the USEPA MCL (Maximum Contaminant Level) from 50 to 10 µg/L (micrograms per liter).

Since 1999, there has been little change in sodium, nitrite plus nitrate, iron, and manganese concentrations in water sampled for the *Equus* Beds Recharge Demonstration Project. These chemicals exceeded drinking-water standards in some before-recharge samples of surface water and ground water and are associated with saltwater (sodium), fertilizer application (nitrite plus nitrate), or the natural aquifer material (iron and manganese). Water-quality data presented in this report can be accessed on the Internet at **http://water.usgs.gov/ks/nwis/qwdata**

Through January 2001, 744 million gallons of water have been artificially recharged at the Halstead site, and 136 million gallons have been artificially recharged at the Sedgwick site. Current information about artificial recharge activities, including updated volumes of water recharged to the aquifer, are available on the Internet at **http://ks.water.usgs.gov/Kansas/equus**

Effects of Artificial Recharge on Water Quality

Chloride

Chloride is a chemical of concern because of its large and variable concentrations in the Little Arkansas River that can exceed drinking-water standards (Ziegler and others, 1999). Degradation of the ground water caused by mixing with surface water containing large chloride concentrations would be undesirable because one of the purposes of artificial recharge is to raise water levels in the aquifer to prevent contamination from chloride plumes already present in the ground water to the southwest and northwest of the Wichita well field (Ziegler and others, 1999).

Chloride concentrations varied in samples from both surface-water monitoring sites in the Little Arkansas River (fig. 2). Chloride concentrations (median concentration 60 mg/L, milligrams per liter) in diverted source water at the Halstead site were smaller and less variable than in samples of surface water because water from the Little Arkansas River was induced into the aquifer at higher streamflows when chloride concentrations were smaller. Dilution of the river water also occurs when it is mixed with ground water in the aquifer resulting in lower chloride concentrations in the diverted source water.

Since artificial recharge began at the Halstead site, median chloride concentrations in samples from the shallow and deep monitoring wells were similar to median concentrations in samples from diverted source water. Since recharge began, all chloride concentrations in samples from the diverted source water and from both shallow and deep monitoring wells were substantially less than the USEPA Secondary Maximum Contaminant Level (SMCL) for chloride of 250 mg/L in drinking water (U.S. Environmental Protection Agency, 2001). Concentrations exceeding the SMCL will impart objectionable taste or increased corrosiveness to the water.

The median chloride concentration in samples from the treated diverted source water at the Sedgwick site was 62 mg/L. Median chloride concentrations in water from the shallow monitoring wells increased from about 10 to about 50 mg/L after artificial recharge began. Median chloride concentrations in water from the deep monitoring wells at the Sedgwick recharge site have not changed substantially from before to after recharge began.

Arsenic

Arsenic is a trace metal that is toxic to humans and is considered highly undesirable in water supplies (Hem, 1992). The USEPA has recently (2001) proposed a revision to the arsenic MCL from 50 to 10 µg/L (U.S. Environmental Protection Agency, 2001). Arsenic concentrations in water from the Little Arkansas River ranged from about 2 to 13 µg/L, with a median concentration of about 5 μg/L (fig. 3).

Domestic wells near the Halstead recharge site also were sampled for arsenic in June 2000 to determine concentrations in ground water adjacent to the recharge site. Arsenic concentrations in water from five domestic wells (less than 100 feet deep) surrounding the Halstead recharge site ranged from 2.2 to 12.5 μg/L, and the median concentration was 10 μg/L. Arsenic concentrations in the diverted source water at Halstead ranged from about 16 to 24 μg/L.

Arsenic concentrations are naturally occurring at the Halstead site (Ziegler and others, 1999) and are derived from the aquifer material. Water from shallow monitoring wells at the Halstead recharge site had relatively small concentrations of arsenic that never exceeded 5 μg/L. After recharge began at Halstead, arsenic concentrations in water from the deep monitoring wells increased in one well to concentrations similar to the diverted source water and remained near 10 μg/L in water from the other deep monitoring well.

The median arsenic concentration determined in water samples from both deep monitoring wells at the Halstead site after artificial recharge began was 11 μg/L and exceeded the proposed MCL by 1.0 μg/L but was considerably less than the median concentration of 20 μg/L for samples from the diverted source water. These data suggest that geochemical reactions or dilution are occurring in the ground water at this site. At the Sedgwick site, arsenic concentrations in all ground-water samples before and after recharge were substantially less than the proposed MCL of 10 μg/L.

Total Coliform Bacteria

The presence of total coliform bacteria in water is not directly harmful to humans but, in large numbers, may indicate the presence of other microorganisms that may adversely affect health (Hem, 1992). Large bacterial densities have been detected in the Little Arkansas River. Median bacterial densities in samples from both the Halstead and Sedgwick surface-water monitoring sites were 800 and 1,200 col/100 mL (colonies per 100 milliliters of water), respectively. Large bacterial densities in the Little Arkansas River can be associated with large turbidity levels (large amounts of suspended materials) and streamflows (Christensen and others, 2000) and may result from runoff from livestock operations and wastewater discharge upstream. The MCL for total coliform bacteria is 0 col/100 mL in treated drinking water (U.S. Environmental Protection Agency, 2001).

Maximum total coliform bacteria densities were substantially smaller in samples of diverted source water at the Halstead site (less than 100 col/100 mL) and treated diverted water at the Sedgwick site (400 col/100 mL) than in samples from the Little Arkansas River. The median bacteria density in samples of diverted source water at the Halstead site was less than 1 col/100 mL, and for treated diverted water at the Sedgwick site, it was 80 col/100 mL. This difference in total coliform bacteria densities reflects the differing methods by which the water is diverted from the river. At the Sedgwick site where water to be recharged is diverted directly from the river and treated, the bacterial densities were larger. Densities in water from the shallow and deep monitoring wells at the Halstead site after artificial recharge began were generally less than 1 col/100 mL, with a few exceptions. At the Sedgwick site, maximum densities in water from the shallow and deep monitoring wells after artificial recharge began were 56 and 8 col/100 mL, respectively.

Effects of artificial recharge on total coliform bacteria densities at the Halstead site were minimal. At the Sedgwick site, treatment reduced the bacterial densities by a factor of about100, and the median concentration in ground water was less than 1 col/100 mL before and after recharge. Bacteria were detected infrequently in water from the shallow monitoring wells.

Atrazine

Atrazine, a herbicide used on corn and grain sorghum, has an MCL of 3.0 μg/L as an annual mean concentration (U.S. Environmental Protection Agency, 2001). It is a chemical of concern because it was detected in water from both surface-water monitoring sites and in water from nearly all monitoring wells at the recharge sites. Atrazine concentrations in ground water were much smaller than in surface water and were less than 3.0 μg/L (fig. 4). In water from the Little Arkansas River at Highway 50 near Halstead, the median atrazine concentration was 1.0 μg/L. Atrazine has been detected in the diverted source water and in before-recharge water samples from shallow and deep

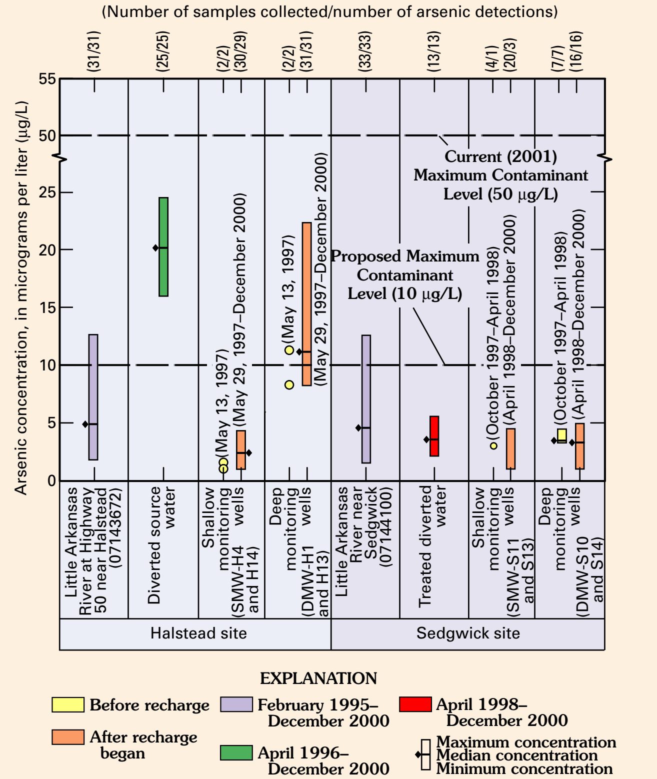

Figure 3. Arsenic concentrations were less than the current drinking-water standard in ground water at the Sedgwick recharge site. However, arsenic concentrations exceeded the proposed (2001) water-quality standard in diverted water and in most water from deep wells at the Halstead recharge site. Current and proposed Maximum Contaminant Levels from U.S. Environmental Protection Agency (2001).

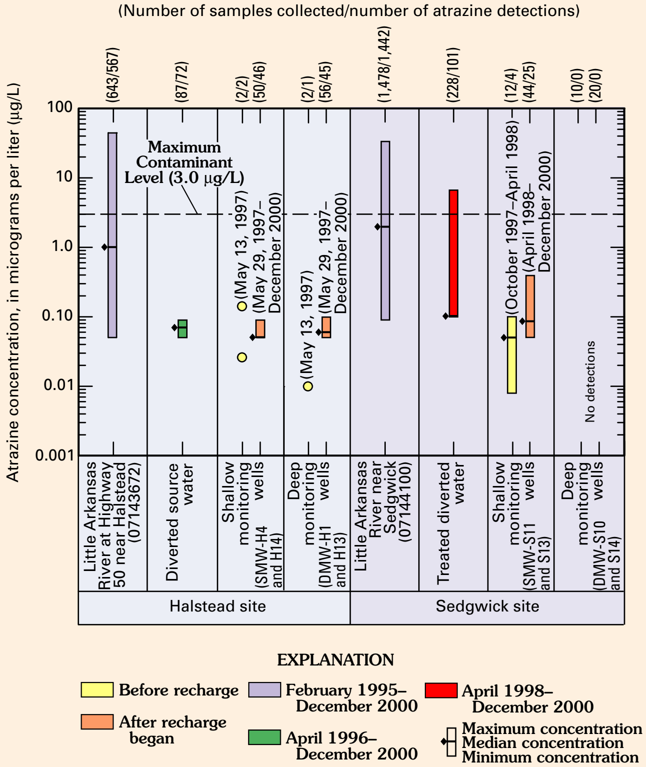

Figure 4. Atrazine was present in surface water at both the Halstead and Sedgwick sites at concentrations commonly exceeding 3.0 micrograms per liter. Median atrazine concentrations in ground water from both recharge sites were less than 0.10 microgram per liter. Maximum Contaminant Level (annual mean concentration for atrazine) from U.S. Environmental Protection Agency (2001).

monitoring wells at the Halstead recharge site, but all median concentrations determined for samples from these wells after recharge began were small and ranged from 0.04 to 0.06 µg/L.

The median atrazine concentration in water from the Sedgwick surface-water monitoring site was 2.0 µg/L. The maximum atrazine concentration in the treated recharge water at Sedgwick was 6.8 µg/L. This concentration occurred at the beginning of artificial recharge operations when the treatment process malfunctioned. Concentrations in water from the monitoring wells at the Sedgwick recharge site were smaller, but atrazine concentrations were as large as 0.39 µg/L in water from the shallow monitoring wells. Concentrations of atrazine in water from the shallow wells were substantially less than 3.0 µg/L. Concentrations in water from the deep monitoring wells were all less than 0.10 µg/L. Atrazine concentrations in samples from wells at both recharge sites were less than 0.10 µg/L, substantially less than 3.0 µg/L and generally were slightly larger than before-recharge concentrations.

Implications

The overall effects of artificial recharge on water quality in the *Equus* Beds aquifer are not substantial when comparing median concentrations before recharge to those after recharge began for chloride, arsenic, total coliform bacteria, and atrazine. There was a slight increase of atrazine in water from deep monitoring wells at the Halstead recharge site. There also was an increase in arsenic concentrations at the Halstead recharge site because of naturally occurring elevated concentrations in the diverted source water. Concentrations of the four chemicals of concern increased in water from some of the monitoring wells to about the same concentrations as those found in diverted or diverted treated source water, whereas concentrations in water from a few wells decreased. Median concentrations of chloride, arsenic, total coliform bacteria, and atrazine were all substantially less than their respective drinking-water standards. After recharge began, concentrations of these chemicals were similar to before-recharge concentrations. However, median arsenic concentrations in samples from the diverted source water and in water from deep wells at the Halstead site exceeded the proposed arsenic MCL of 10 µg/L. Continued monitoring of the chemicals of concern will help prevent artificial recharge from degrading water quality in the *Equus* Beds aquifer.

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For more information on recharge activities in the *Equus* Beds aquifer in Kansas, visit the USGS Web site at:
http://ks.water.usgs.gov/Kansas/equus
or contact:

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