

Prepared in cooperation with the City of Wichita, Kansas, as part of the *Equus Beds* Groundwater Recharge Project

Water Quality of the Little Arkansas River and *Equus Beds* Aquifer Before and Concurrent with Large-Scale Artificial Recharge, South-Central Kansas, 1995–2012

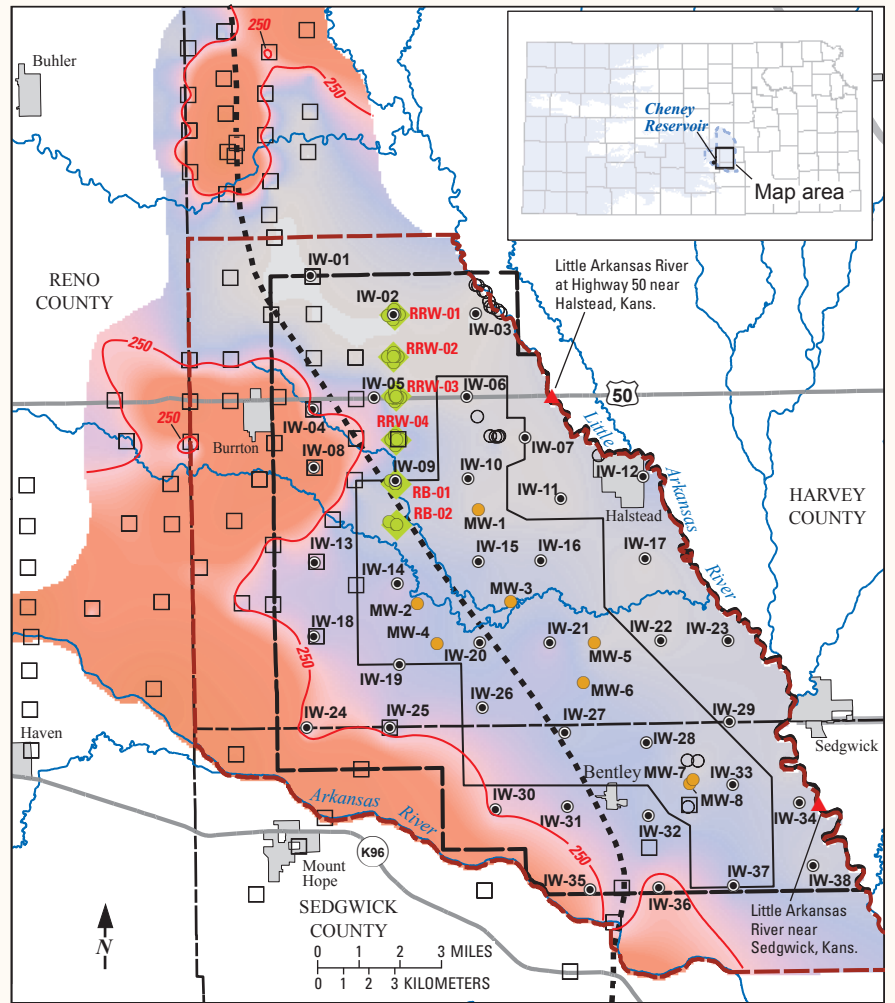
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Abstract

This fact sheet describes baseline water quality of the *Equus Beds* aquifer and Little Arkansas River and water-quality effects of artificial recharge by the city of Wichita associated with Phase I (2007–present) of the Aquifer Storage and Recovery project. During 1995 through 2012, more than 8,800 surface water and groundwater water-quality samples were collected and analyzed for more than 400 compounds, including most of the compounds on the U.S. Environmental Protection Agency’s primary drinking-water standards maximum contaminant level list and secondary drinking-water regulations secondary maximum contaminant level list. Water-quality constituents of concern discussed in detail in this fact sheet are chloride, arsenic, total coliform bacteria, and atrazine. Sulfate, nitrate, iron, manganese, oxidation-reduction potential, and specific conductance also are constituents of concern and are discussed to a lesser extent.

Introduction

The city of Wichita relies on groundwater from the *Equus Beds* aquifer and surface water from Cheney Reservoir for their municipal water supply (fig. 1). After several drought years in the late 1980s and early 1990s, 1993 aquifer water levels were as much as 50 feet lower than predevelopment (1940) levels. Exacerbating concerns regarding aquifer drawdown was the movement of a large chloride plume near Burrton, Kansas, from previous oil and gas exploration and naturally high chloride concentrations from the Arkansas River moving towards the city’s municipal well field (Ziegler and others, 1999; fig. 1). This prompted the city of Wichita to investigate and implement artificial recharge of the *Equus Beds* aquifer, beginning in 1997, by using water from the Little Arkansas River when streamflow exceeds base-flow requirements.



EXPLANATION

Average chloride concentrations in the deep layer of the *Equus Beds* aquifer, 2006–2012

Milligrams per liter

- 6,420
- 250
- 100
- 50
- Less than 5

- Boundary of study area
- Boundary of basin storage area
- Boundary of the central part of the study area
- 250— Average 2006–2012 chloride concentration in deep groundwater wells in this approximate location exceed the Environmental Protection Agency’s National secondary drinking water regulation of 250 milligrams per liter
- - - Approximate location of bedrock low (McPherson channel)
- RB-02 ◆ Phase I U.S. Geological Survey (USGS) monitoring well in the deep layer of the *Equus Beds* aquifer and identifier
- Phase I recharge location
- MW-7 ● Phase II USGS monitoring well in the deep layer of the *Equus Beds* aquifer—Number is site identifier
- IW-36 ● USGS index well in the deep layer of the *Equus Beds* aquifer—Number is site identifier
- USGS monitoring well in the deep layer of the *Equus Beds* aquifer
- Groundwater Management District No. 2 monitoring well in the deep layer of the *Equus Beds* aquifer
- ▲ Little Arkansas River near Sedgwick, Kans. USGS streamflow-gaging station and site name

Figure 1. Average chloride concentrations in and near the study area for deep wells, 2006–2012, south-central Kansas.

The purpose of this fact sheet is to describe *Equus* Beds aquifer and Little Arkansas River water quality during 1995 through 2012, including quantifying effects related to Phase I recharge activities of about 1 billion gallons during 2007 through 2012. This fact sheet is part of a long-term cooperative investigation (since 1940) between the city of Wichita and the United States Geological Survey to describe water quantity and quality conditions in the *Equus* Beds aquifer and the Little Arkansas River; and, more recently (since 1995), potential effects of artificial recharge on water resources in south-central Kansas. This description of water-quality conditions serves as a baseline to detect any subsequent water-quality changes of the *Equus* Beds aquifer and the Little Arkansas River during Phase II, which increased recharge design capacity by 30 million gallons per day in 2013. Refer to Tappa and others (2015) for more details about material presented in this fact sheet.

Artificial Recharge and Water Quality

Chloride

Chloride is a major constituent of concern because of its persistence in groundwater from a chloride plume near Burrton, Kans., and because of highly variable concentrations in the Little Arkansas River that can exceed drinking-water standards (Ziegler and others, 1999). The Federal secondary maximum contaminant level (SMCL) for chloride is 250 milligrams per liter (milligrams per liter [mg/L]; U.S. Environmental Protection Agency, 2009) for aesthetics, including taste and odor, and was exceeded in about 11 percent of samples from two surface-water monitoring sites on the Little Arkansas River during 1995 through 2012 (table 1). Chloride concentrations ranged from less than 5 to 932 mg/L.

During 2001 through 2012, chloride concentrations exceeded the SMCL in 5.6 percent of samples from shallow areal assessment index wells (IW) and 7.4 percent of samples from deep IWs. Concentrations exceeding 250 mg/L in deep

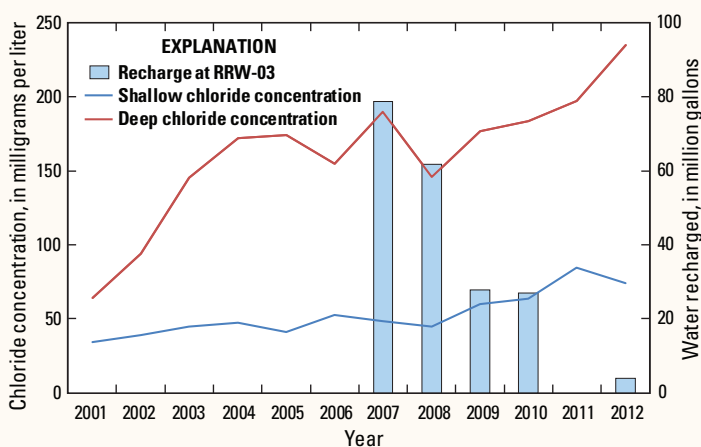


Figure 2. Chloride concentrations in IW-05 (shallow and deep) and Phase I recharge at RRW-03 in the *Equus* Beds aquifer near Burrton, Kansas, 2001–2012.

parts of the aquifer were detected in wells located near Burrton, Kans., and along the Arkansas River during 2006–2012 (fig. 1). Average chloride concentrations of all IWs (shallow and deep) decreased during 2007–2012 compared to 2001–2006 averages; however, median chloride concentrations increased from the first period to the second (table 2). The Burrton chloride plume was impeded or diluted at IW-05, which is about 0.5 miles west of a Phase I recharge well (RRW-03; fig. 1). Chloride concentrations stabilized with Phase I recharge at RRW-03 in 2007 through 2010, and concentrations began to increase after 2010 when Phase I recharge was minimal (fig. 2). Chloride movement through the *Equus* Beds aquifer is complex as a result of discontinuous clay and sand layers. The clay layers act as barriers, slowing the vertical movement of groundwater in certain areas, whereas sand layers allow groundwater to flow more easily.

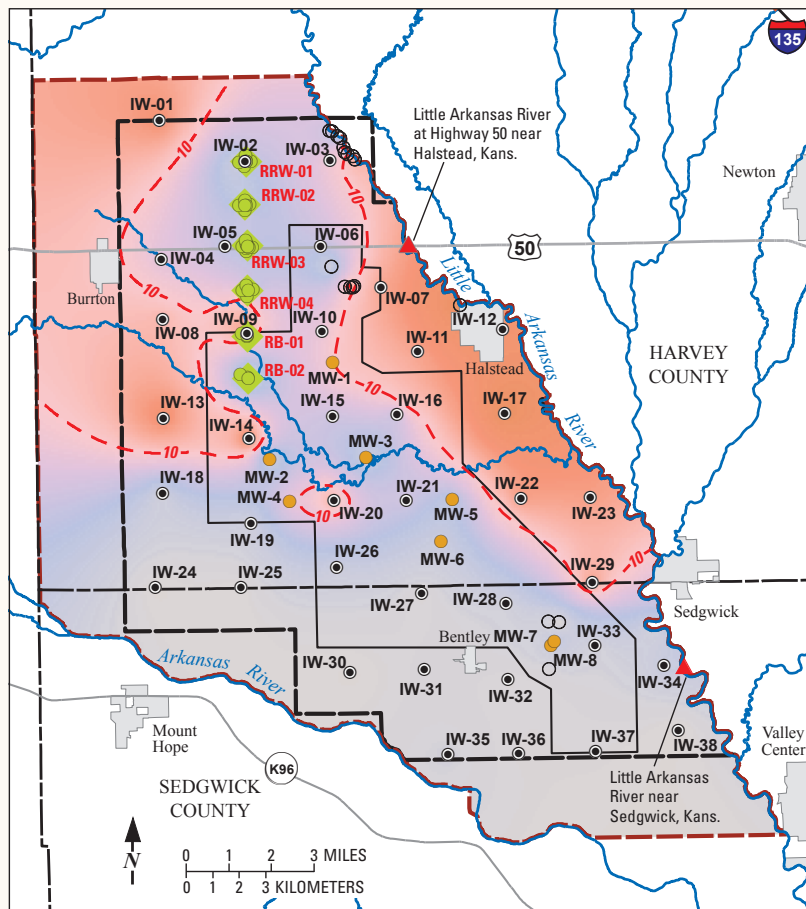
Arsenic

Arsenic occurs naturally in clay layers associated with iron sulfide minerals (Hem, 1992), and can be a health hazard to humans (U.S. Environmental Protection Agency, 2005). The Federal maximum contaminant level (MCL) for arsenic is 10 micrograms per liter ($\mu\text{g/L}$; U.S. Environmental Protection Agency, 2009). Water samples collected from the Little Arkansas River near Halstead, Kans., and near Sedgwick, Kans., from 1995 through 2012 had a median and average dissolved arsenic concentration of about 5 $\mu\text{g/L}$, which is one-half the MCL for arsenic. Dissolved arsenic concentrations ranged from less than 1 to 15.9 $\mu\text{g/L}$ and exceeded the MCL in about 11 percent of the samples from the Little Arkansas River (table 1). During 1995–2012, dissolved arsenic concentrations exceeded 10 $\mu\text{g/L}$ in water samples from 12 percent of shallow IWs and nearly 35 percent of samples from deep IWs. Larger concentrations of arsenic in the deep parts of the aquifer occurred on the west side of the study area and on the eastern side of the study area along the Little Arkansas River (fig. 3). Sources of arsenic in the *Equus* Beds aquifer are natural; however, changes in groundwater chemistry can result in changes in arsenic concentrations.

Total Coliform Bacteria

Coliform bacteria are a bacterial indicator that indicate presence of pathogenic organisms. The U.S. Environmental Protection Agency (EPA) Federal Maximum Contaminant Level Goal (MCLG) in drinking water for total coliform bacteria is that no more than 5 percent of samples test positive during 1 month for water systems that collect at least 40 routine samples per month (U.S. Environmental Protection Agency, 2009). In 2009, bacterial and viral indicators were detected at elevated levels in monitoring wells near RB-1 (fig. 1; Garinger and others, 2011).

Approximately 95 percent of the samples collected from the two sites on the Little Arkansas River had total coliform bacteria detections (table 1), which indicates that the MCLG for total coliforms was rarely met at these sites. Coliform bacteria



EXPLANATION

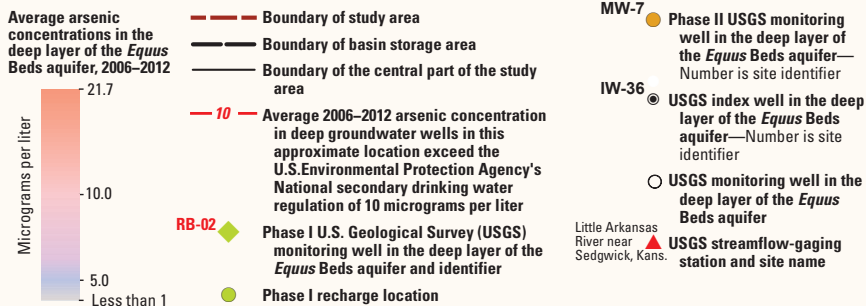


Figure 3. Average arsenic concentrations in the study area, 2006–2012, in deep wells.

detections in water samples collected from the Little Arkansas River during this period were as large as 2,000,000 colonies per 100 milliliters (col/100 mL) near Halstead, Kans., and as large as 9,000,000 col/100 mL near Sedgwick, Kans. Total coliform densities in groundwater were substantially lower than in samples from the Little Arkansas River. Total coliform detections exceeded the EPA Federal MCLG of 0 colonies in water samples from 25 percent of the shallow IWs and in 12 percent of the deep IWs in the aquifer. Many of these detections were in the first samples collected from wells after they were developed, indicating that at least some of these detections were likely related to the drilling process.

Atrazine

Atrazine is an herbicide used on corn and grain sorghum, crops commonly grown in and near the study area, and it does not occur naturally in the environment (Ziegler and others, 2010). The Federal MCL for atrazine in drinking water is 3.0 µg/L as an annual average (U.S. Environmental Protection Agency, 2009). During 1995–2012, the average atrazine concentration was 3.6 µg/L from all samples collected from the two Little Arkansas River surface water sites (table 1). Atrazine concentrations larger than the MCL of 3.0 µg/L generally occur in the Little Arkansas River from late spring to early fall. Average atrazine concentrations were less than 0.1 µg/L in both shallow and deep IWs during 1995–2012.

Equus Beds Water-Quality Changes

Constituents and physical properties of interest for shallow and deep IWs include arsenic, chloride, iron, manganese, nitrite plus nitrate, oxidation-reduction potential (ORP), specific conductance, and sulfate. As a group, all constituents of interest except chloride, arsenic, and ORP had the average value increase from the 2001 to 2006 period to the 2007 to 2012 period in the IW network (table 2). Average concentration increases for constituents of interest and the ORP decrease from 2006 to 2012 is likely linked to drought conditions during 2011–2012 (Hansen and others, 2014). Lower precipitation amounts limit the diluting effect of new-water recharge.

Artificial recharge activities associated with Phase I have not resulted in substantial effects on groundwater quality in the area. The amount of water recharged associated with Phase I is relatively small (1 billion gallons) compared to the aquifer storage in the winter of 2012 of approximately 990 billion gallons (Hansen and others, 2014). An exception is the temporary stabilization of chloride concentrations in the north-central part of the study area near the Burrton chloride plume. Water-quality constituents of concern outlined here have not increased substantially and are likely more affected by climatological (natural recharge by precipitation) and natural (geochemical oxidation/reduction, metabolic and decay rates) processes than artificial recharge. Arsenic remains a water-quality constituent of concern because of natural and continued persistence of concentrations exceeding the Federal MCL, especially in the deeper parts of the *Equus* Beds aquifer.

Table 1. Little Arkansas River and *Equus* Beds Aquifer water quality summary.

[*n*, number of samples; mg/L, milligrams per liter; µg/L, micrograms per liter; col/100 mL, colonies per 100 milliliters; <, less than; EPA, U.S. Environmental Protection Agency]

Constituent	Water-quality criteria	<i>n</i>	Average	Median	Percent exceeding
Little Arkansas River (1995–2012)					
Chloride	250 mg/L ^a	501	110	97	11
Arsenic	10 µg/L ^b	314	5.6	4.8	11
Total coliform bacteria	0 col/100 mL ^c	380	39,000	1,500	95
Atrazine	3 µg/L as annual average ^b	4,888	3.6	1.7	33
Shallow index wells (2001–2012)					
Chloride	250 mg/L ^a	568	70	36	5.6
Arsenic	10 µg/L ^b	563	3.9	1.6	12
Total coliform bacteria	0 col/100 mL ^c	441	6.4	0.1	25
Atrazine	3 µg/L as annual average ^b	761	<0.1	<0.1	0
Deep index wells (2001–2012)					
Chloride	250 mg/L ^a	568	116	65	7.4
Arsenic	10 µg/L ^b	563	7.4	5.9	35
Total coliform bacteria	0 col/100 mL ^c	443	1.2	<0.1	12
Atrazine	3 µg/L as annual average ^b	686	<0.1	<0.1	0

^aEPA Secondary Drinking Water Regulation.

^bEPA Maximum Contaminant Level.

^cEPA Maximum Contaminant Level Goal.

Table 2. Average and median concentration changes at all areal assessment index wells (IW) between time periods 2001–2006 and 2007–2012.

[mg/L, milligrams per liter; µg/L, micrograms per liter; mV, millivolts; µS/cm at 25 °C, microsiemens per centimeter at 25 degrees Celsius; IW, areal assessment index well; orange box indicates median or mean concentration increase from 2001–2006 to 2007–2012; green box indicates median or mean concentration decrease from 2001–2006 to 2007–2012]

Constituent, units	Time	Median	Average
Sulfate, mg/L	2001–2006	76.3	129
	2007–2012	76.5	141
Chloride, mg/L	2001–2006	54.8	90.5
	2007–2012	56.1	87.5
Nitrite plus nitrate, mg/L as nitrogen	2001–2006	0.12	2.08
	2007–2012	0.11	2.22
Arsenic, µg/L	2001–2006	3.4	5.6
	2007–2012	2.8	5.6
Iron, µg/L	2001–2006	95	1,913
	2007–2012	105	2,059
Manganese, µg/L	2001–2006	244	346
	2007–2012	257	357
Oxidation reduction potential, mV	2001–2006	256	294
	2007–2012	217	242
Specific conductance, µS/cm at 25 °C	2001–2006	853	926
	2007–2012	862	953

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