Guide for Field Trip, March 27, 2019
Geological Society of America
2019 Joint Section Meeting, Manhattan, Kansas

Kansas River Alluvial Aquifer: Water Use and Real-Time Monitoring

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Google Earth view of Kansas River valley looking toward Belvue, Pottawatomie County.

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GEOHYDROLOGY

KU KANSAS GEOLOGICAL SURVEY The University of Kansas

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ACKNOWLEDGMENTS

The U.S. Geological Survey provided partial funding for the installation of the index wells in the Kansas River alluvial aquifer through the National Groundwater Monitoring Network program. The Kansas Water Office (Kansas Water Plan funding) also provided partial funding for the installation of the index wells and fully supported the purchase and maintenance of the index well monitoring equipment.

Randy Dewitt, Assistant Director of Public Works, City of Manhattan, Kansas, led the trip during Stop 1 at the Manhattan well field. Jared Morrison, Senior Manager, Water and Waste Programs, KCP&L and Westar, Evergy Companies, led the trip during Stops 4 and 5 associated with the Jeffrey Energy Center.

Field Trip Schedule

1:10–1:20 p.m. Overview of field trip at Hilton Garden Inn, Manhattan

1:20 p.m. Leave from Hilton Garden Inn

1:30–2:00 p.m. Stop 1. Municipal water supply well field of the City of Manhattan in the Kansas River alluvial aquifer. Description of the old and new well field, the impact of pumping on flow of the Big Blue and Kansas rivers, and spatial and temporal variations in the quality of pumped water related to distance from the river.

2:00–2:25 p.m. Travel to stop 2

2:25–2:50 p.m. Stop 2. KGS real-time groundwater-level monitoring well in the alluvial aquifer southeast of Wamego and the new water-level monitoring network for the Kansas River alluvial aquifer. Description of existing water-level record and river-aquifer interactions.

2:50–2:58 p.m. Travel to stop 3

2:58–3:10 p.m. Stop 3. Wamego Riverfront Park (with restrooms); next to U.S. Geological Survey gaging and water-quality monitoring station for the Kansas River at Wamego.

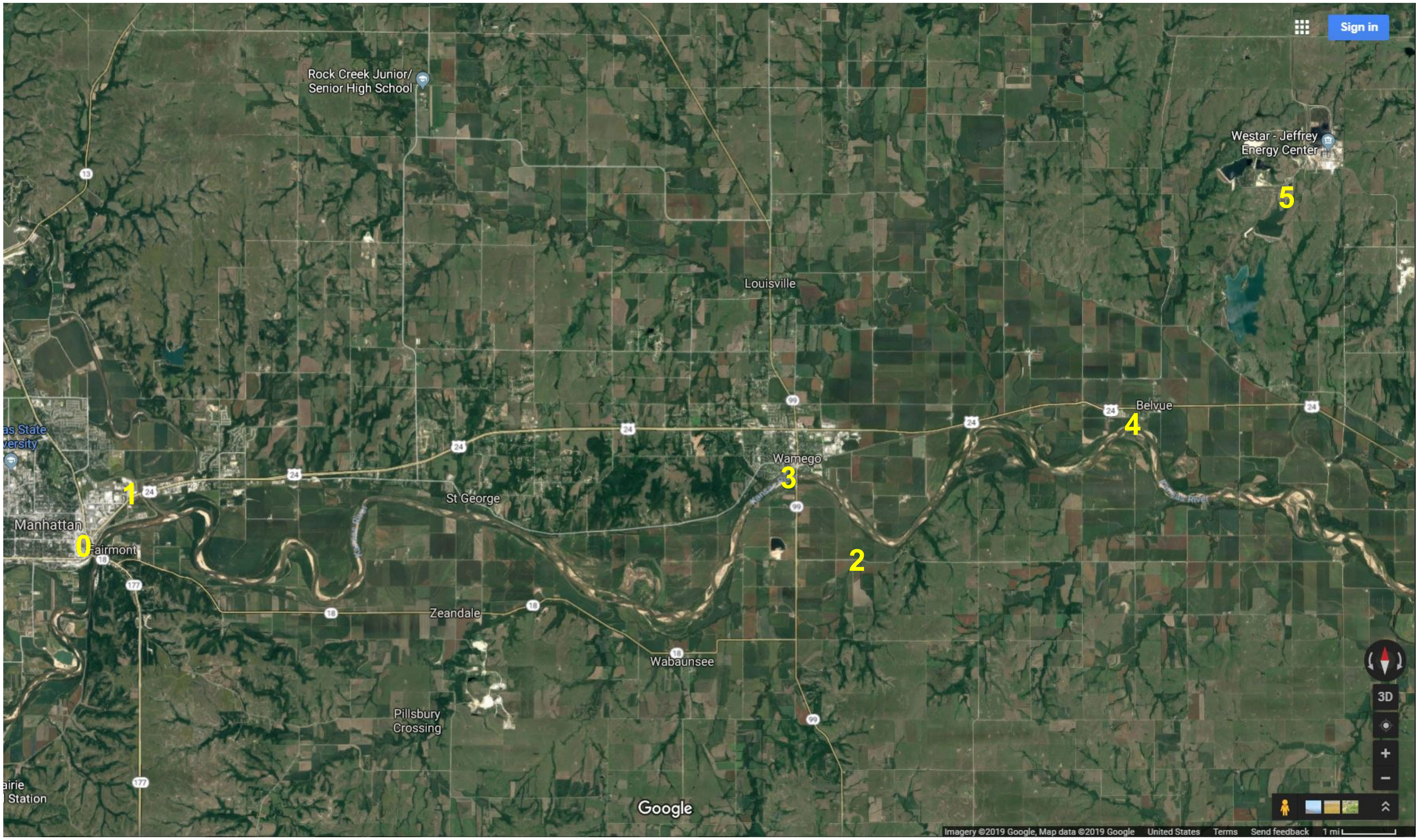
3:10–3:25 p.m. Travel to stop 4

3:25–3:45 p.m. Stop 4. Jeffrey Energy Center well and river water supply station southwest of Belvue on north side of Kansas River. Overview of water supply to Energy Center: groundwater and surface water supply and surface water reservoir.

3:45–4:10 p.m. Travel to stop 5

4:10–5:10 p.m. Stop 5. Jeffrey Energy Center wetland in upland north of Kansas River floodplain, southwest of Energy Center. Overview of wetland system treatment of flue gas desulfurization wastewater.

5:10–6:00 p.m. travel back to Hilton Garden Inn



Overview of field trip route along the Kansas River corridor. The trip starts in Manhattan. Stop 1 is in the City of Manhattan well field next to the Big Blue River east of Manhattan. Stop 2 is a KGS real-time water-level monitoring well southeast of Wamego. Stop 3 is a rest stop at a Wamego park next to the Kansas River. Stop 4 is the Jeffrey Energy Center water intake facility next to the Kansas River southwest of Belvue. Stop 5 is the constructed wetlands southwest of the Energy Center.

Kansas River Alluvial Aquifer: Water Use and Real-Time Monitoring

Overview

General Characteristics of the Alluvial Aquifer

The main part of the Kansas River extends through northeast Kansas from Manhattan to Kansas City, where it joins the Missouri River (figure 1). Surface water from the Kansas River and groundwater from the alluvial aquifer system in the river valley provide most of the water supply for all uses within and adjacent to the river corridor. The Quaternary alluvial deposits that fill the bedrock valley range to more than 80 ft in the deepest buried channels under terrace deposits occurring along parts of the sides of the river valley. The bedrock is from Pennsylvanian to Permian age and consists primarily of limestone and shale, although some short sections of the valley are underlain by sandstone. The sediment in the lower part of the main alluvial aquifer is generally coarse (arkosic sand and gravel) and is overlain by finer-grained deposits (sand, silt, and silty clay). The sediment in the lower deposits below some terrace deposits is sand to fine gravel (Davis and Carlson, 1952; Dufford, 1958; O'Connor, 1960, 1971). Depths to the water table in the river valley range from near surface to 50 ft below land surface. Where the alluvial deposits are of substantial thickness, the aquifer has a high transmissivity and can commonly yield more than 1,000 gpm to large-capacity vertical wells (Fader, 1974). The quality of the water is fresh, although it is hard due to groundwater flow passing through the calcareous bedrock underlying the aquifer and in the valley walls. High iron and manganese occur in some portions of the alluvium as a result of chemically reducing conditions probably generated by organic matter in sediment in buried meander cutoffs and overbank deposits (Whittemore et al., 2014).

Future Management of the Aquifer

Groundwater from the alluvial aquifer of the Kansas River valley supplies a substantial portion of the total water supply for municipal, irrigation, industrial, and other uses in the counties along its extent. Additional development might be considered along edges of the aquifer system away from the river but only in locations where the saturated thickness and permeable sediment are great enough to sustain high-yield wells. A substantial distance between new well locations and the river should minimize the effect of groundwater-level declines on lowering river-water levels during periods of severe droughts. Development in an area where major tributaries enter the river valley would take advantage of tributary recharge. During wet periods, recharge of the alluvial aquifer along the edge of the valley wall and geomorphic terraces, over the terrace and floodplain expanse, and by bank storage from the Kansas River and tributaries would all work to restore water levels (Whittemore et al., 2014).

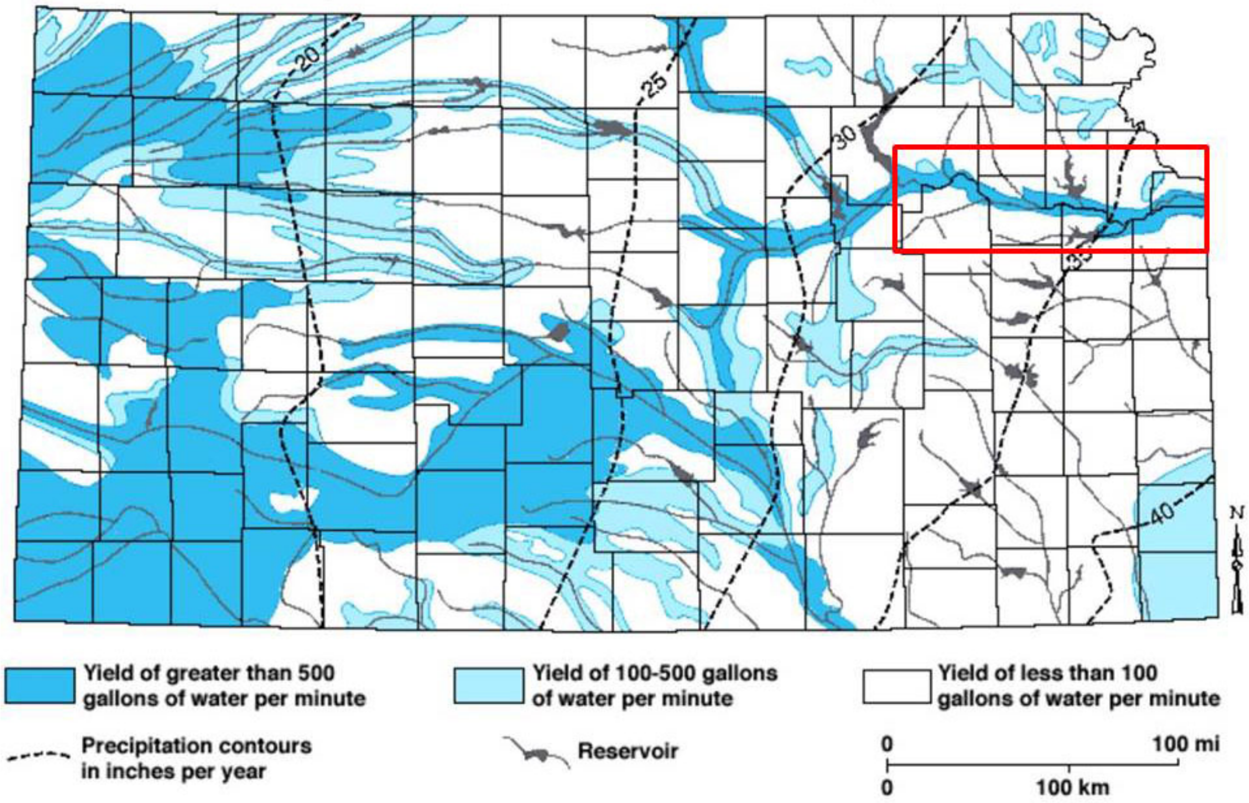


Figure 1. General availability of groundwater and annual precipitation in Kansas (Kansas Geological Survey Special Map 9, generalized from Map M-4A, Kansas Geological Survey, 1975).

Decreasing reservoir storage caused by sedimentation could result in lower river water levels during drought because less water would be available for release, which, in turn, could affect the river water intakes of the large capacity users of river water. The location of possible future wells that induce river water infiltration and could potentially decrease water levels in the river will need to be considered relative to the location of river water intakes. The loss of storage capacity within the reservoirs could possibly be offset by managing groundwater storage in the alluvial aquifer. Overall, it would be appropriate to examine storage losses in reservoirs and storage management in the alluvial aquifer system in concert. This would be part of managing the surface water and groundwater as a single resource.

The Kansas Geological Survey (KGS) has proposed construction of a stream-aquifer model of the Kansas River alluvial aquifer from Manhattan to its junction with the Missouri River to determine whether the alluvial aquifer can sustain substantial additional development without significantly affecting water levels both in the river and in the connected alluvial aquifer. The model could be used to assess in which part of the alluvial aquifer future development would have the least influences on river flow. It also could be used to determine the effect of different management plans and how they relate to future decreases in reservoir storage as sedimentation continues as well as to determine the influence of climate change.

As a first step toward the development of a stream-aquifer model of the aquifer system, additional water-level data are needed, both in terms of locations and finer temporal resolution. During 2018, the KGS established a network of 10 observation wells in the Kansas River alluvial aquifer (although one well near Lawrence [KAW-DG01] was installed in 2017 as a replacement for a former USGS monitoring well). The wells operate under the Kansas Index Well Program to provide continuously recorded water levels of the aquifer throughout the year (figure 2). Funding for the project was made possible by the Kansas Water Plan and the USGS National Groundwater Monitoring Network. The wells include pressure transducers to measure water levels and telemetry equipment to transmit the data to a computer database at the KGS in Lawrence. At the time this field guide was prepared, the telemetry installations were operational at nine of the wells; installation of telemetry equipment at the other well was scheduled to be completed in the spring of 2019. An interactive map of the observation well locations (figure 2), with links to the continuous data, is available at the Kansas River Index Well Network web page (http://www.kgs.ku.edu/Hydro/KansasRiver/index.html). Water levels are recorded every hour and can be displayed or downloaded for the period desired by the viewer.

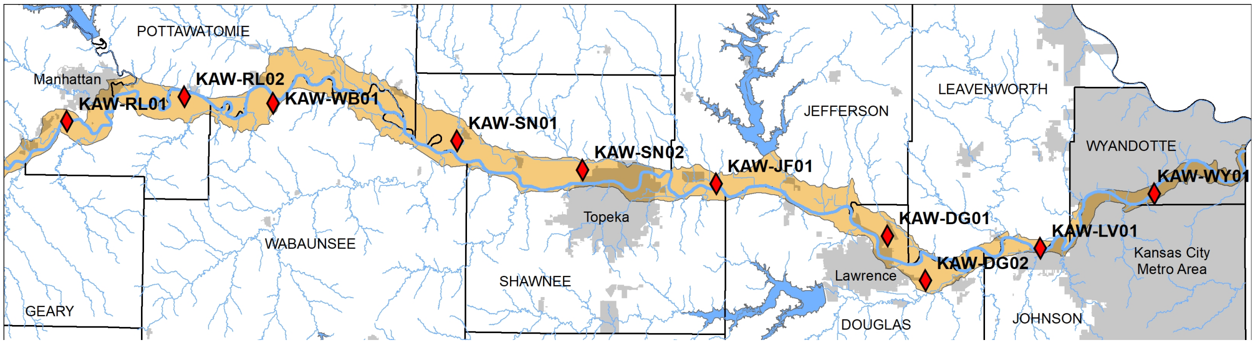


Figure 2. Location of the 10 observation wells with pressure transducers and telemetry systems that measure and transmit water levels in the Kansas River alluvial aquifer to the Kansas Geological Survey.

Water Rights and Water Use in the Kansas River Valley

Figures 3 and 4 display hydrologic features and the location of water rights for the upper and lower stretches, respectively, of the Kansas River valley from Manhattan to Kansas City. The map for the upper river valley extends from just west of Manhattan to the eastern side of Topeka. The valley in this stretch passes through southern Riley, southern Pottawatomie, northern Wabaunsee, and west-central Shawnee counties. Parts or all of the incorporated cities of Manhattan, St. George, Wamego, Belvue, St. Marys, Rossville, Willard, Silver Lake, and Topeka are located in this area. The lower river valley extends from the eastern side of Topeka to Kansas City and passes through east-central Shawnee, southern Jefferson, northern Douglas, southern Leavenworth, northern Johnson, and southern Wyandotte counties. Parts or all of the incorporated cities of Topeka, Lecompton, Perry, Lawrence, Eudora, Linwood, De Soto, Bonner Springs, Edwardsville, Shawnee, and Kansas City are located in this stretch.

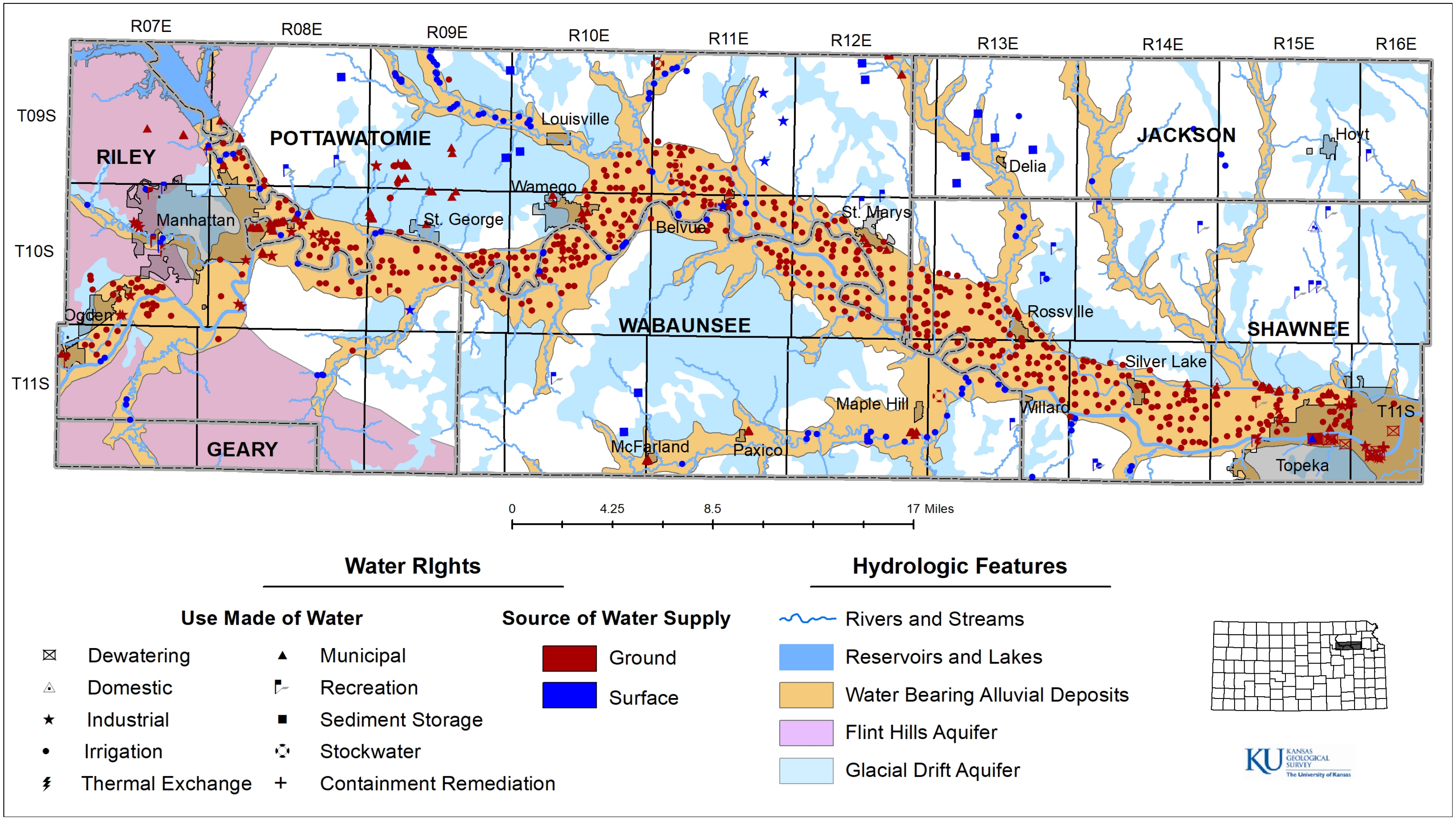


Figure 3. Map of the location of water rights and hydrologic features for the upper stretch of the Kansas River corridor from Manhattan to Topeka in northeast Kansas. Shaded brown areas indicate urban areas. Note the substantial number of points for groundwater rights in the extent of the alluvial deposits in the Kansas River valley (the main alluvial feature crossing the entire map) compared to the scarcity of points for groundwater rights in the tributary streams.

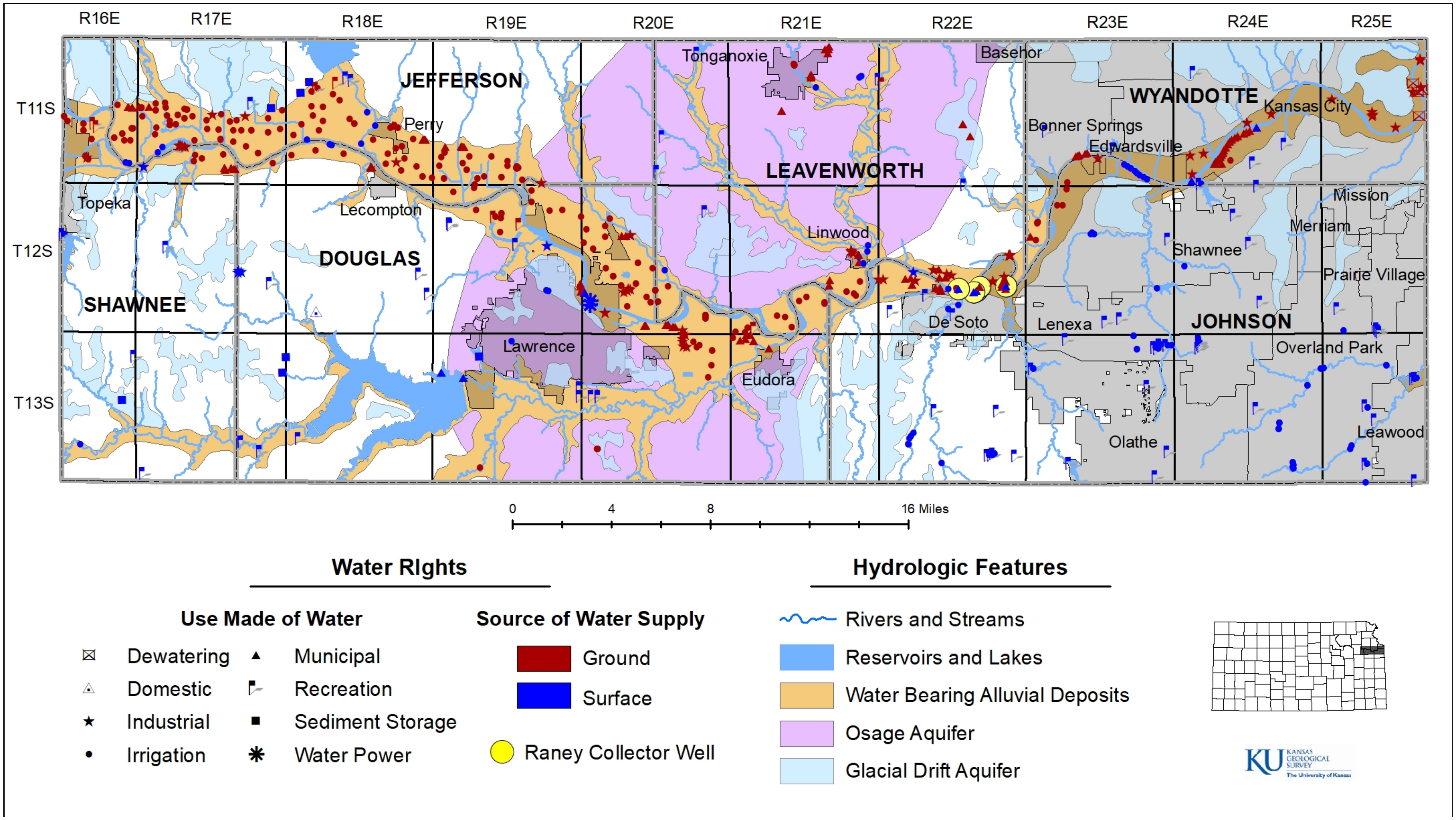


Figure 4. Map of water rights and hydrologic features for the lower stretch of the Kansas River valley from Topeka to Kansas City in northeast Kansas. Note the substantial number of points for groundwater rights in the extent of the alluvial deposits in the Kansas River valley (the main alluvial feature crossing the entire map) compared to the lack of points for groundwater rights in the tributary streams, especially the Wakarusa River valley (the alluvial feature that extends from the southwest corner of the map to Clinton Reservoir just southwest of Lawrence and downstream south of Lawrence).

Table 1 summarizes the reported surface water and groundwater used during 2017 for the three major purposes (industrial, irrigation, and municipal) for water rights whose source of supply is from the section of the river and the alluvial aquifer of the Kansas River in the area of figures 3 and 4 (which includes the Big Blue River valley below Tuttle Creek Reservoir down to its junction with the Kansas River). Each one of these use values includes some consumptive loss. The largest use of surface water in the valley, the hydroelectric power plant (Bowersock) on the Kansas River in Lawrence, was excluded from the industrial use because it is a non-consumptive, pass-through use. Bowersock has the largest water right in Kansas, and its rate is so large (1,962,661 acre-feet in 2017) that it distorts the comparisons to other uses.

The total reported surface-water and groundwater use for industrial, irrigation, and municipal purposes within the map area of the alluvial aquifer of the Kansas River in figure 2 was 4.2% of the total water use in all of Kansas during 2017. However, although the irrigation water use was only 0.67% of the total irrigation use in the state, the industrial and municipal uses accounted for 34.2% and 22.7%, respectively, of the total use for these purposes. The reported groundwater use within the alluvial aquifer of the Kansas River in figures 3 and 4 represented 14.6%, 0.69%, and 18.2% of the total industrial, irrigation, and municipal groundwater use, respectively, in Kansas in 2017. The reported water use in table 1 represents a total of 1,036 unique water rights and 1,029 unique points of diversion that reported water use in 2017.

Figure 5 illustrates the distribution of industrial, irrigation, and municipal water used within the area of the alluvial aquifer of the Kansas River shown in figures 3 and 4. The largest surface-water user for municipal purposes in Wyandotte County is Johnson County Water District No. 1. The large groundwater use in Johnson County is mainly attributable to the City of Olathe.

The character of the alluvial aquifer of the Kansas River contrasts with the alluvium in tributaries to the river, such as the Wakarusa River valley to the south of Lawrence (figure 4). The lower part of the alluvial aquifer of the Kansas River contains a substantial thickness of sand and gravel, whereas the alluvial deposits of the tributary valleys are mainly fine-grained sediment with only a very small amount of sand or gravel at the bottom of the alluvium in some locations. This explains the disparity in the distribution of points for groundwater rights within the alluvial aquifer of the Kansas River valley compared to that for tributary valleys in figures 3 and 4. However, parts of Mill Creek valley in Wabaunsee County to the south of the Kansas River have up to a dozen feet of gravel at the base of the alluvial valley; a few municipal supply wells tap this alluvial aquifer.

Table 1. Surface water and groundwater use by county for active water rights within the map extent of the alluvial deposits of the Kansas River valley in figures 3 and 4 during 2017. The water use is in acre-ft for only the three major use types. Water use is not included for alluvial deposits in tributary valleys. Douglas County surface water use does not include the 1,962,661acre-ft from the Bowersock hydroelectric power plant, which is a pass-through flow of the Kansas River. The table does not include 10 acre-ft of surface water used for stockwater and 59 acre-ft of groundwater used for recreation, which together account for 0.25% of the total water use in the area. No water use was recorded in 2017 for domestic water rights.

	Industrial Use	% of Grand Total	Irrigation Use	% of Grand Total	Municipal Use	% of Grand Total	Total Use	% of Grand Total
Riley County								
Surface water	0	0.00	113	11.75	0	0.00	113	0.13
Groundwater	139	1.83	1,919	10.26	5,489	18.75	7,546	13.59
Total	139	0.35	2,032	10.33	5,489	6.31	7,660	5.24
Pottawatomie County								
Surface water	25,954	81.36	315	32.70	0	0.00	26,270	29.01
Groundwater	2,133	28.20	6,188	33.10	4,262	14.56	12,583	22.66
Total	28,087	71.17	6,504	33.08	4,262	4.90	38,853	26.60
Wabaunsee County								
Surface water	0	0.00	280	29.07	0	0.00	280	0.31
Groundwater	38	0.50	3,287	17.58	192	0.65	3,517	6.33
Total	38	0.10	3,568	18.15	192	0.22	3,797	2.60
Shawnee County								
Surface water	50	0.16	0	0.00	21,355	37.03	21,405	23.64
Groundwater	4,268	56.44	4,436	23.72	2,109	7.20	10,813	19.47
Total	4,319	10.94	4,436	22.56	23,463	26.99	32,218	22.06
Jefferson County								
Surface water	0	0.00	108	11.19	0	0.00	108	0.12
Groundwater	13	0.17	1,649	8.82	802	2.74	2,463	4.43
Total	13	0.03	1,757	8.93	802	0.92	2,571	1.76
Douglas County								
Surface water	5,294	16.59	43	4.46	3,850	6.68	9,187	10.15
Groundwater	465	6.16	1,092	5.84	899	3.07	2,456	4.42
Total	5,760	14.59	1,135	5.77	4,749	5.46	11,643	7.97
Leavenworth County								
Surface water	0	0.00	33	3.45	0	0.00	33	0.04
Groundwater	17	0.22	90	0.48	492	1.68	599	1.08
Total	17	0.04	124	0.63	492	0.57	633	0.43
Johnson County								
Surface water	286	0.90	71	7.38	2,956	5.12	3,313	3.66
Groundwater	431	5.70	32	0.17	10,524	35.95	10,988	19.79
Total	717	1.82	103	0.53	13,480	15.50	14,300	9.79
Wyandotte County								
Surface water	318	1.00	0	0.00	29,515	51.17	29,832	20.42
Groundwater	58	0.77	5	0.02	4,505	15.39	4,568	3.13
Total	376	0.95	5	0.02	34,020	39.13	34,400	23.55
Grand Totals for Total Area								
Surface water	31,902	80.84	964	4.90	57,675	66.33	90,541	61.98
Groundwater	7,562	19.16	18,698	95.10	29,274	33.67	55,534	38.02
Grand Total	39,464	100.00	19,662	100.00	86,949	100.00	146,075	100.00

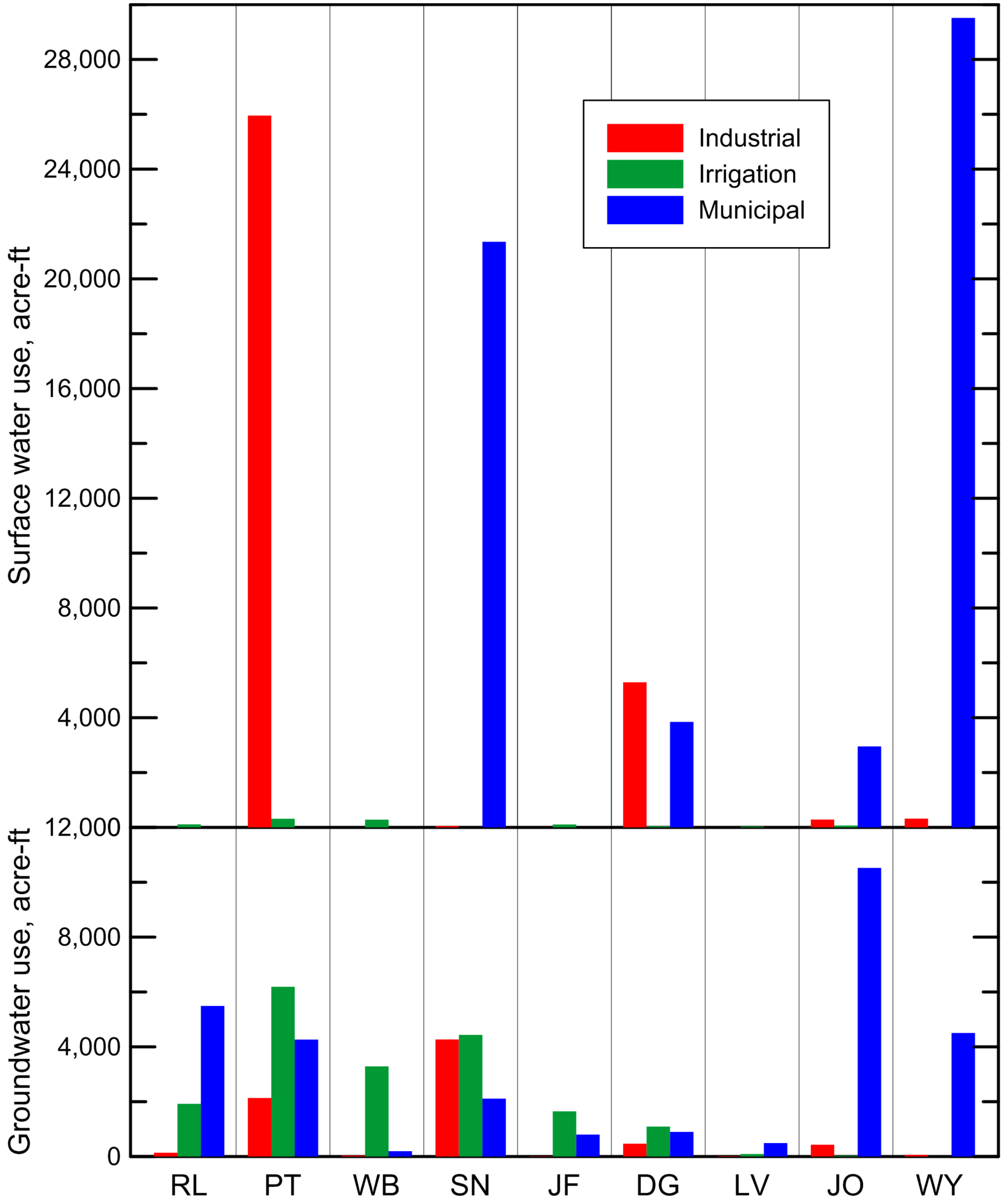


Figure 5. Graphical representation of the distribution of industrial, irrigation, and municipal water used within the extent of the alluvial deposits of the lower Kansas River valley shown in figures 3 and 4. The county codes represent Riley (RL), Pottawatomie (PT), Wabaunsee (WB), Shawnee (SN), Jefferson (JF), Douglas (DG), Leavenworth, (LV), Johnson (JO), and Wyandotte (WY) counties.

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DESCRIPTIONS FOR FIELD TRIP STOPS

Stop 1. City of Manhattan Public Water Supply Well Field

Location: Area on the floodplain east of Manhattan near the junction of the Big Blue River with the Kansas River

Lead presenter: Randy Dewitt, P.E., Assistant Director of Public Works, City of Manhattan

The City of Manhattan has 20 wells completed in the alluvial aquifer of the Big Blue and Kansas rivers east of the city. Figure 6 shows the well field area in 1994 as diagrammed by Jian et al. (1997). The older part of the well field is in the western half of the well-field boundary; newer wells are located in the eastern half of the well field. The four newest wells are located near the Big Blue River just east of the easternmost boundary of the well field shown in figure 6.

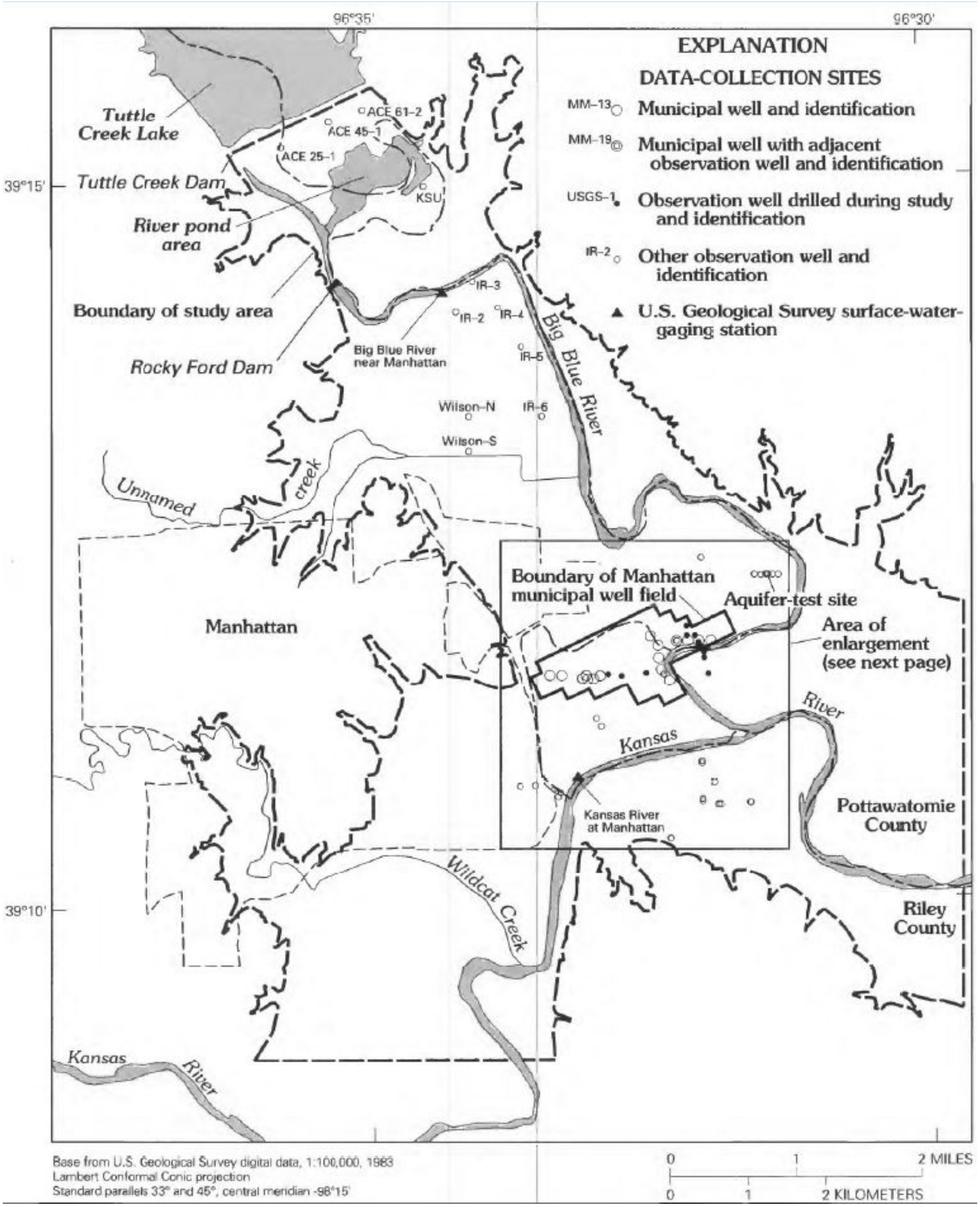
The total water rights of Manhattan's well field are approximately 5 billion gal (15,000 acre ft). The city reported that it used just over half (51.3%) of its water rights and treated 2.56 billion gal (7,860 acre ft) of water in 2017. Most of that water (2.23 billion gal, 6,840 acre ft) was distributed to residents and businesses in Manhattan. The city sold 180 million gal (550 acre ft) to customers outside of Manhattan. The total population served by the water is about 55,000 (City of Manhattan, n.d., 2017a).

The groundwater pumped from the alluvial aquifer is hard; an example analysis of groundwater from the area includes Ca and Mg concentrations of 110 mg/L and 25 mg/L, respectively, a HCO_3 concentration of 420 mg/L, and a Na content of 15 mg/L. The concentrations of Cl and SO_4 generally range from a few to several tens of mg/L depending on the location. The nitrate (as NO_3-N) and F concentrations are typically low (<1 mg/L). Atrazine concentrations, which can exceed the maximum contaminant limit (MCL) of 3 µg/L for public supplies of drinking water in Kansas rivers, are below the MCL in the groundwater tapped by the wells. The raw groundwater is piped to a nearby water treatment plant, where the treatment includes lime softening to reduce the calcium and magnesium concentrations (hardness), secondary disinfection by chloramines to reduce levels of undesirable disinfection byproducts, and introduction of carbon dioxide to stabilize pH. In addition to monitoring the quality of the water served to its distribution system, the city has also voluntarily monitored the quality of the water directly pumped from the wells since 1999. The city's utility report indicates that it manually collects nearly 12,000 samples from the distribution system and the wells, and it automatically samples water at every step of the water treatment process (City of Manhattan, n.d., 2017a, 2017b).

The oldest of the city's current wells was installed in the early 1940s. Other of the older current wells were installed in the 1950s and 1960s. Several wells were constructed in 1987. The most recent four wells were installed in 2010. The depths of the wells extend from 64 ft to more than 70 ft below land surface. The depth to the Permian shale bedrock is usually 64–70 ft. The main portion of the aquifer generally consists of several feet of fine to coarse sand starting at a depth of about 10–17 ft below the surface underlain by medium to coarse sand and gravel to the bedrock. The average saturated thickness of the aquifer in the city well field varies from about 36 ft to 44 ft depending on the river level (Jian et al., 1997). The city wells are typically screened in the lowermost 27–30 ft of the aquifer. The estimated yields of the wells when drilled generally ranged from about 800 gpm to 1,200 gpm for the earlier wells to 1,000 gpm to 1,500 gpm for the later wells. The water rights for the wells authorize maximum pumping rates in the range of 750 gpm for the oldest well in use to 1,000–1,500 for most of the wells to 2,200 gpm for the most recent four wells. The maximum of the total annual diversions (single or multiple water rights for a well) range from a few hundred to between 1,100 and 1,200 acre ft.

Groundwater flows down the Big Blue and Kansas River valleys, and either toward or away from the rivers depending on the relative water levels in the aquifer and the river. Jian et al. (1997) found that pumping in the city well field created a depression in the water table. The authors modeled the alluvial aquifer in the general area of the Manhattan wellfield using a hydraulic conductivity of 650 ft/day (determined from aquifer tests) and a specific yield of 0.20. The simulations of Jian et al. (1997) for May 1993 found that municipal well pumping decreased simulated flow in the Big Blue and Kansas rivers: “Of the total 414 acre-feet pumped…, about 48 percent was from induced infiltration, and about 31 percent was from intercepted base flow.” Their simulations for October 16 through November 14, 1995, determined that “Of the total 506 acre-feet pumped…, about 76 percent was induced from infiltration, and about 2 percent was from intercepted base flow.”

During Stop 1, City of Manhattan staff described quantity aspects of the groundwater supply, including well construction, capacity, variations in pumping that typically occur during the year, the effect of river water levels on pumping, and maintenance of the wells to remove iron and manganese biofouling. They also discussed water-quality considerations, including variations in quality (such as total dissolved solids, hardness, and atrazine concentrations) related to pumping and river levels as well as differences in water quality observed for wells at different distances from the river. In general, the closer the wells are to the river, the lower the total dissolved solids, hardness, and iron and manganese concentrations. This reflects the greater amount of river water that infiltrates into the subsurface and flows to a well near the river than farther from the river during pumping of a well. The quality of water in the Big Blue River is typically better than that in the Kansas River, which has a higher salinity and hardness due to the intrusion of saline water derived from Permian formations underlying selected portions of the Saline, Solomon, and Smoky Hill rivers that are tributaries to the Kansas River. If future expansion of the Manhattan well field is needed, city staff indicated that wells probably would be installed within the bend of the Big Blue River to the north of the current well field to take advantage of the good quality groundwater influenced by the Big Blue River upstream of the well field and the Kansas River.



Base from U.S. Geological Survey digital data, 1:100,000, 1983
Lambert Conformal Conic projection
Standard parallels 33° and 45°, central meridian -98°15'

Figure 6. Location of the Manhattan municipal well field in the Big Blue and Kansas River valleys. The image is from figure 2 in the U.S. Geological Survey report of Jian et al. (1997) and shows the boundary of the Manhattan municipal well field, the Big Blue and Kansas rivers, and the boundary and data-collection sites of the Jian et a. (1997) study.

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Stop 2. Kansas Geological Survey Real-Time Water-Level Monitoring Well

Location: Southwest of Wamego; Well KAW-WB01 in figure 2, T10S-R10E-15DDC

Presenter: Jim Butler

As described on page 5 of this field guide, the KGS has installed a network of 10 observation wells in the Kansas River alluvial aquifer that either have been or will soon be fitted with telemetry to transmit continuous (hourly) water-level measurements from downhole pressure transducers to the KGS. Water-level data for the sites can be obtained online from the Kansas River Index Well Network web page (http://www.kgs.ku.edu/Hydro/KansasRiver/index.html). Table 2 lists the 10 well sites, the well depth, and the current status of the telemetry installation for continuous measurements.

Table 2. Well sites, well depth, and current status of telemetry systems for continuous measurements.

Well	Location	Well Depth, ft	Status of Telemetry Installation as of March 2019
RL01	Riley County southwest of Manhattan	50	will be installed soon
RL02	Riley County near St. George	37	available
WB01	Wabaunsee County southeast of Wamego	37	available
SN01	Shawnee County near Rossville	46.5	available
SN02	Shawnee County north of Topeka	65	available
JF01	Jefferson County southeast of Grantville	43	available
DG01	Douglas County near Lawrence Municipal Airport	66.5	available
DG02	Douglas County between Lawrence and Eudora	70	available
LV01	Leavenworth County north of De Soto	65	available
WY01	Wyandotte County north of Lake Quivira	65	available

The wells were installed using Geoprobe direct push equipment to create a 3.25-in hole and extend into the permeable portion of the alluvial aquifer but not to the bedrock. They have 2-in PVC casing with a 5- to 20-ft screen at the bottom and are bentonite grouted to 16.5–41 ft below land surface, depending on the location and aquifer characteristics. An In-Situ pressure transducer is hung in the well to about 10 ft above the bottom of the well. The telemetry system transmits data via cell modem.

The WB01 well southeast of Wamego (T10S-R10E-15DDC), the location on Stop 2, extends to 37 ft below land surface. The upper 7 ft below land surface is composed of soil and fine-grained sediment and is underlain by sands of the permeable zone. When the well was installed on May 10, 2018, the static water level was 23 ft below land surface.

The presenter described the construction and operation of the real-time monitoring well, the system of real-time water-level wells in other areas of Kansas (the index well program http://www.kgs.ku.edu/HighPlains/OHP/index_program/index.shtml), and the serving of real-time groundwater-level data on the internet and how to access these data.

Figures 7–12 display hydrographs of six of the wells along the Kansas River valley compared to the gage height of the nearest river gaging station of the USGS. These are preliminary results that the KGS will examine to improve the understanding of river and groundwater interactions and other effects on the groundwater levels of the alluvial aquifer.

The USGS operated a water-level monitoring well from February 1952 to May 2015 at the same location as KGS network well DG01, which is near the Lawrence municipal airport. The KGS installed well DG01 in 2017; continuous (every 15 minutes) water-level measurements began on August 15, 2017. Annual water-level change at the monitoring well location based on USGS data is well correlated with annual climatic index values (figure 13), indicating the importance of the long-term response of groundwater recharge to climate (primarily precipitation) in controlling water levels in the Kansas River alluvial aquifer. The climate datum used in figure 13 is the December value for the 12-month Standardized Precipitation Index for the northeast climatic division of Kansas. Correlations between groundwater-level change and climatic indices, as well as between water-level change and water use, are being studied for the KGS index wells in the High Plains aquifer (HPA) and for the groundwater management district regions of the HPA in Kansas (Whittemore et al., 2016; Butler et al., 2016, 2018). These methods will be further applied to water-level data in the Kansas River alluvial aquifer as additional measurements are obtained.

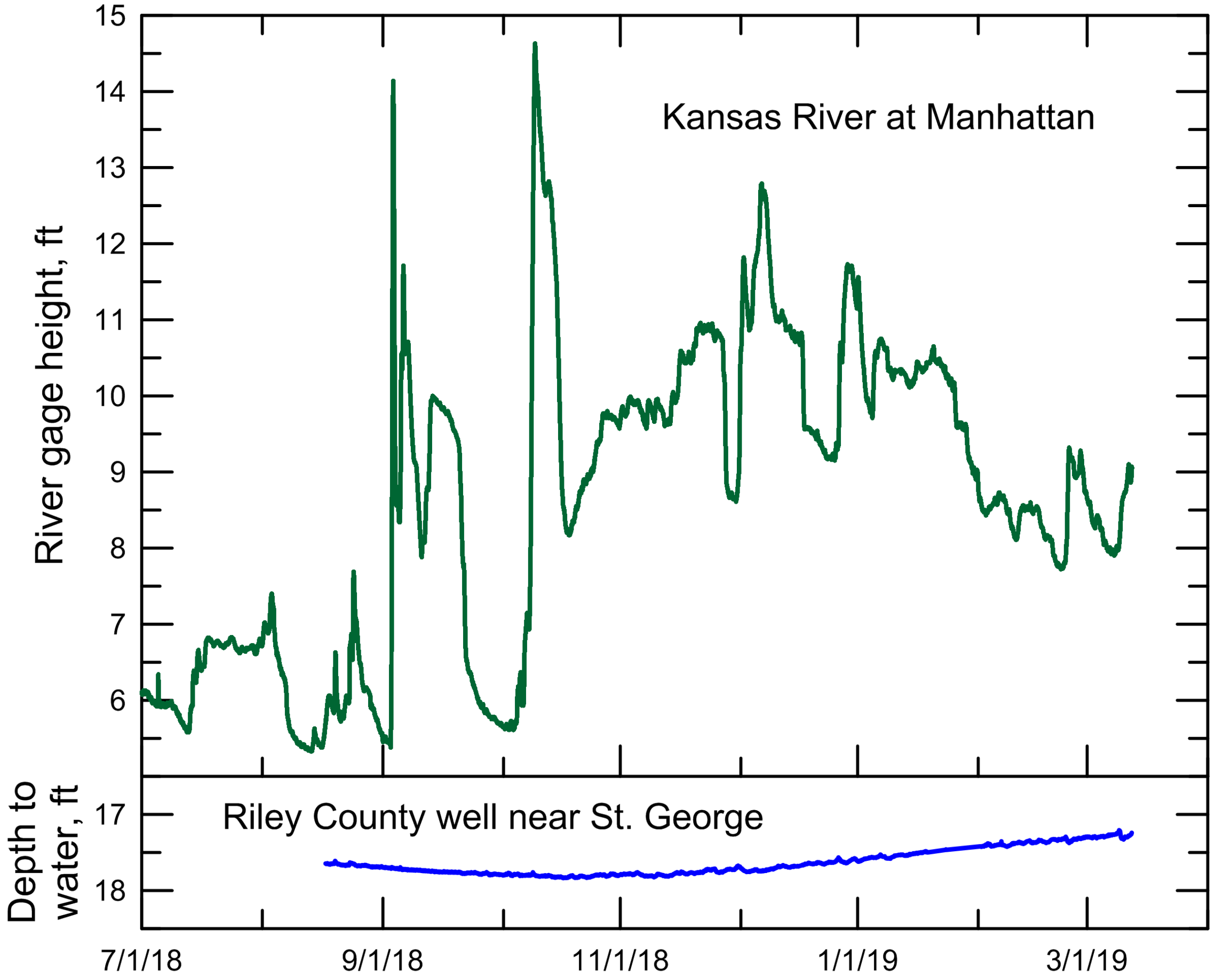

Figure 7. Comparison of hydrographs of Kansas River gage height at Manhattan and depth to water at the KGS network well in Riley County near St. George (KAW-RL02). The tick spacing per foot of change is the same for both portions of the graph.

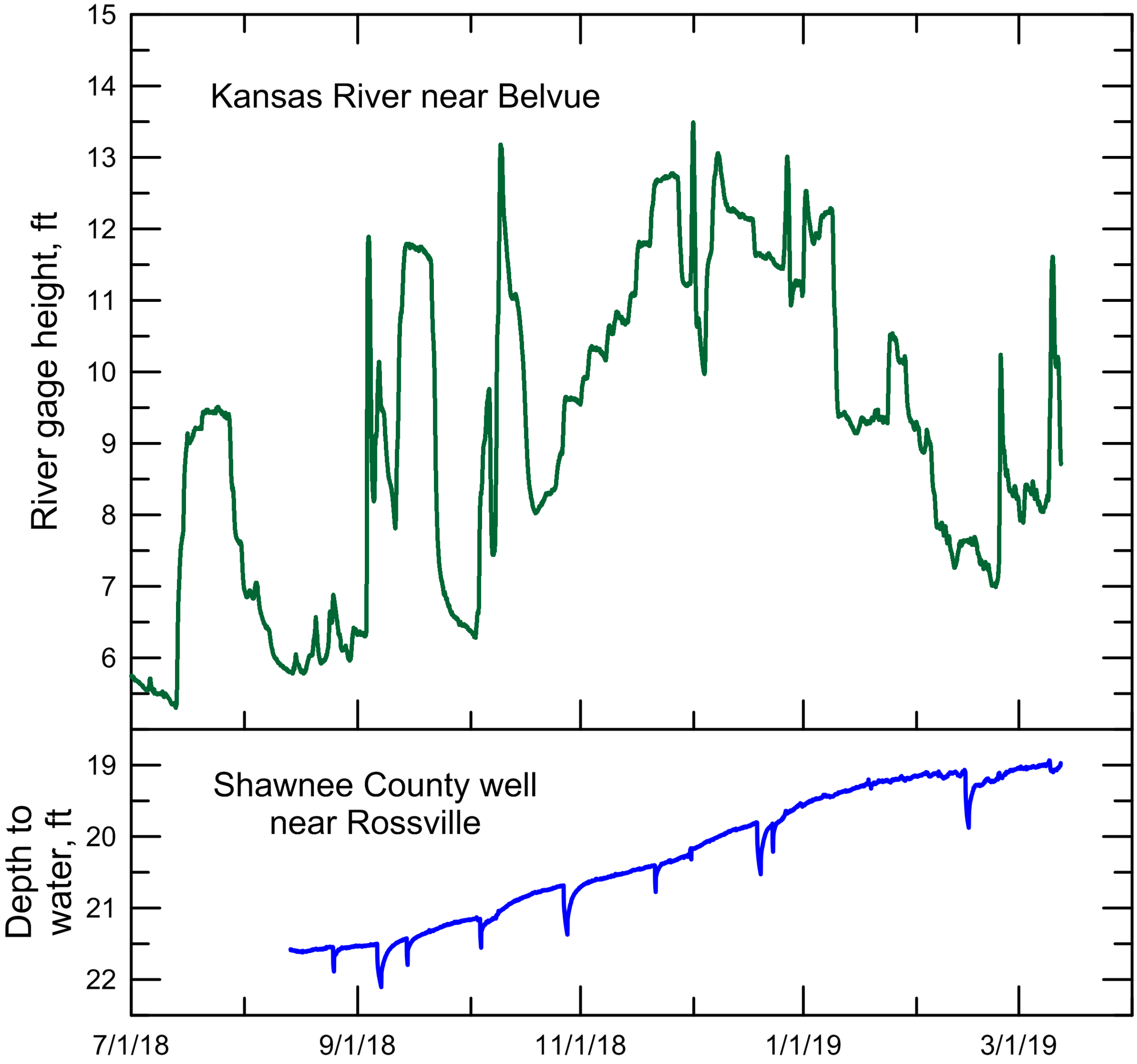

Figure 8. Comparison of hydrographs of Kansas River gage height near Belvue and depth to water at the KGS network well in Shawnee County near Rossville (KAW-SN01). The tick spacing per foot of change is the same for both portions of the graph. The well hydrograph appears to be affected by the occasional pumping of a well in the vicinity of the monitoring well.

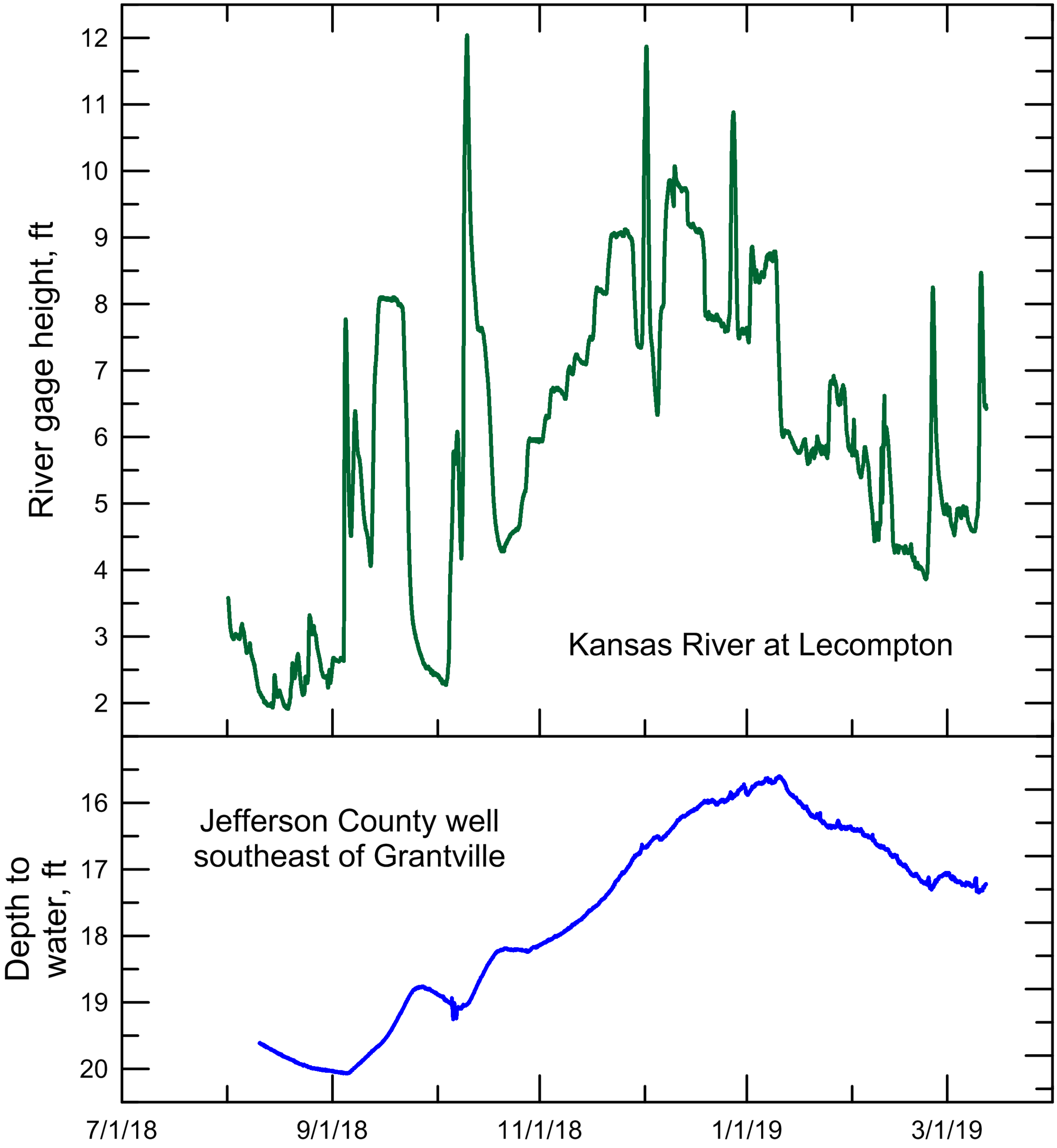

Figure 9. Comparison of hydrographs of Kansas River gage height at Lecompton and depth to water at the KGS network well in Jefferson County southeast of Grantville (KAW-JF01). The tick spacing per foot of change is the same for both portions of the graph.

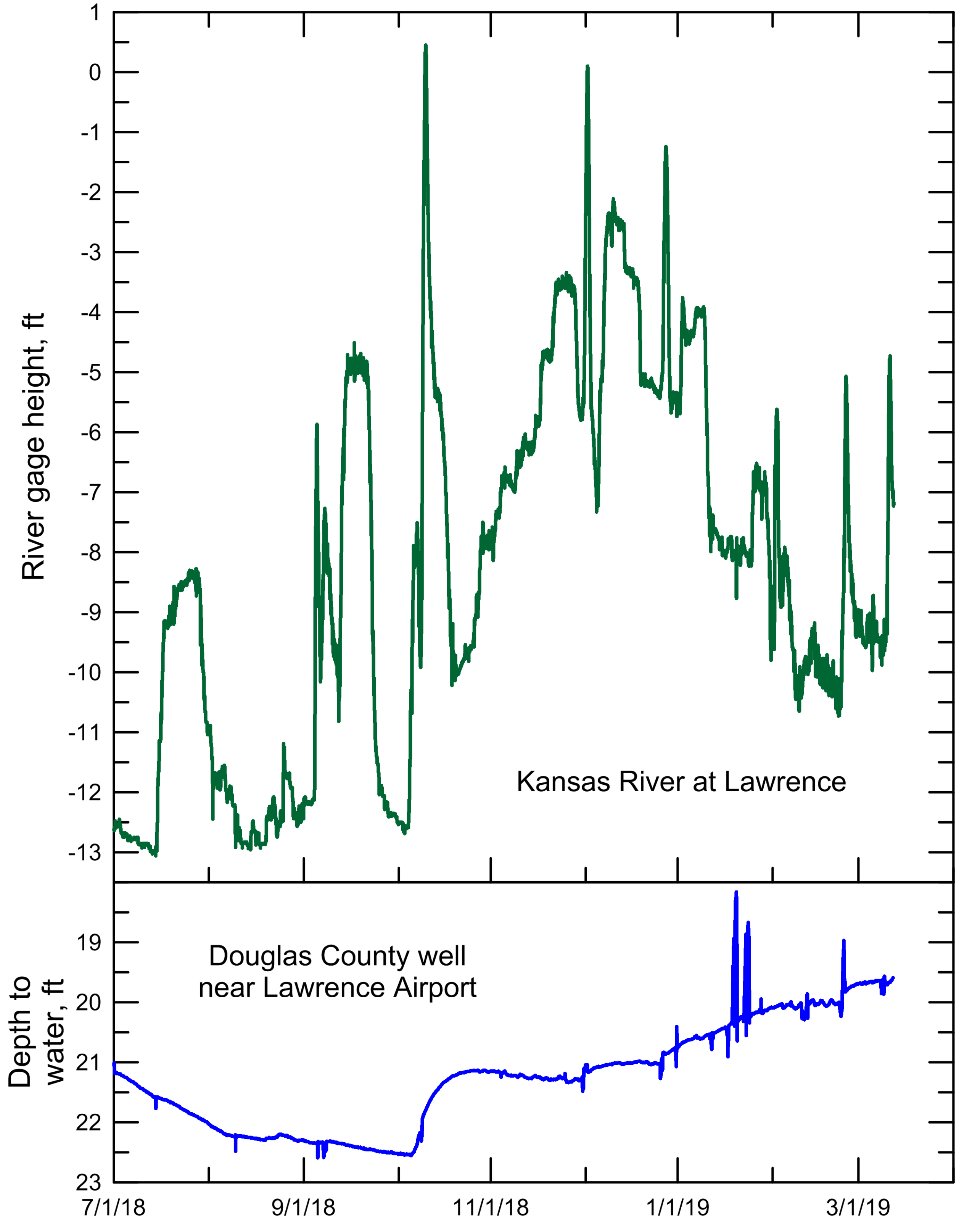

Figure 10. Comparison of hydrographs of Kansas River gage height at Lawrence and depth to water at the KGS network well in Douglas County near the Lawrence airport (KAW-DG01). The tick spacing per foot of change is the same for both portions of the graph.

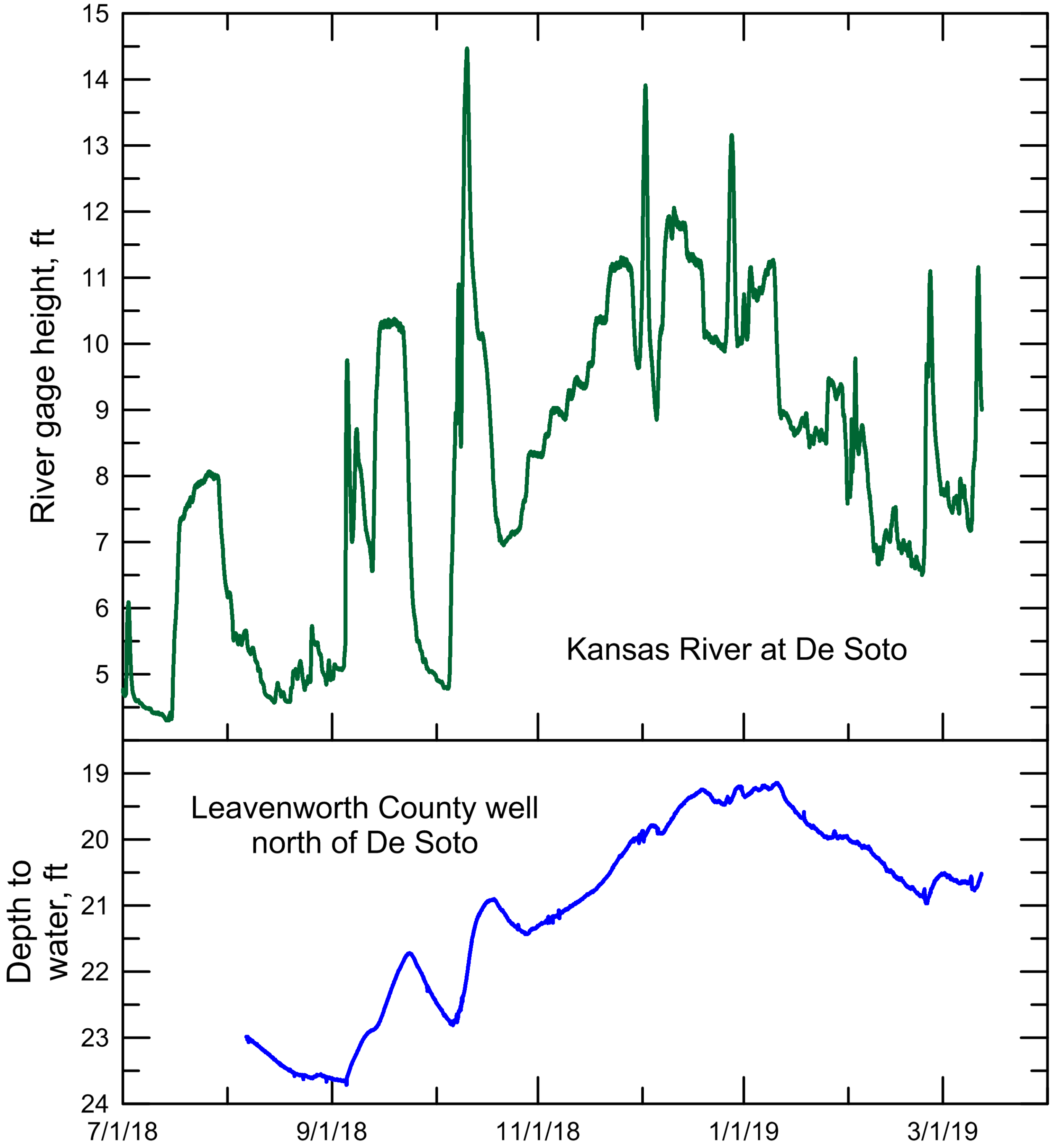

Figure 11. Comparison of hydrographs of Kansas River gage height at De Soto and depth to water at the KGS network well in Leavenworth County north of De Soto (KAW-LV01). The tick spacing per foot of change is the same for both portions of the graph.

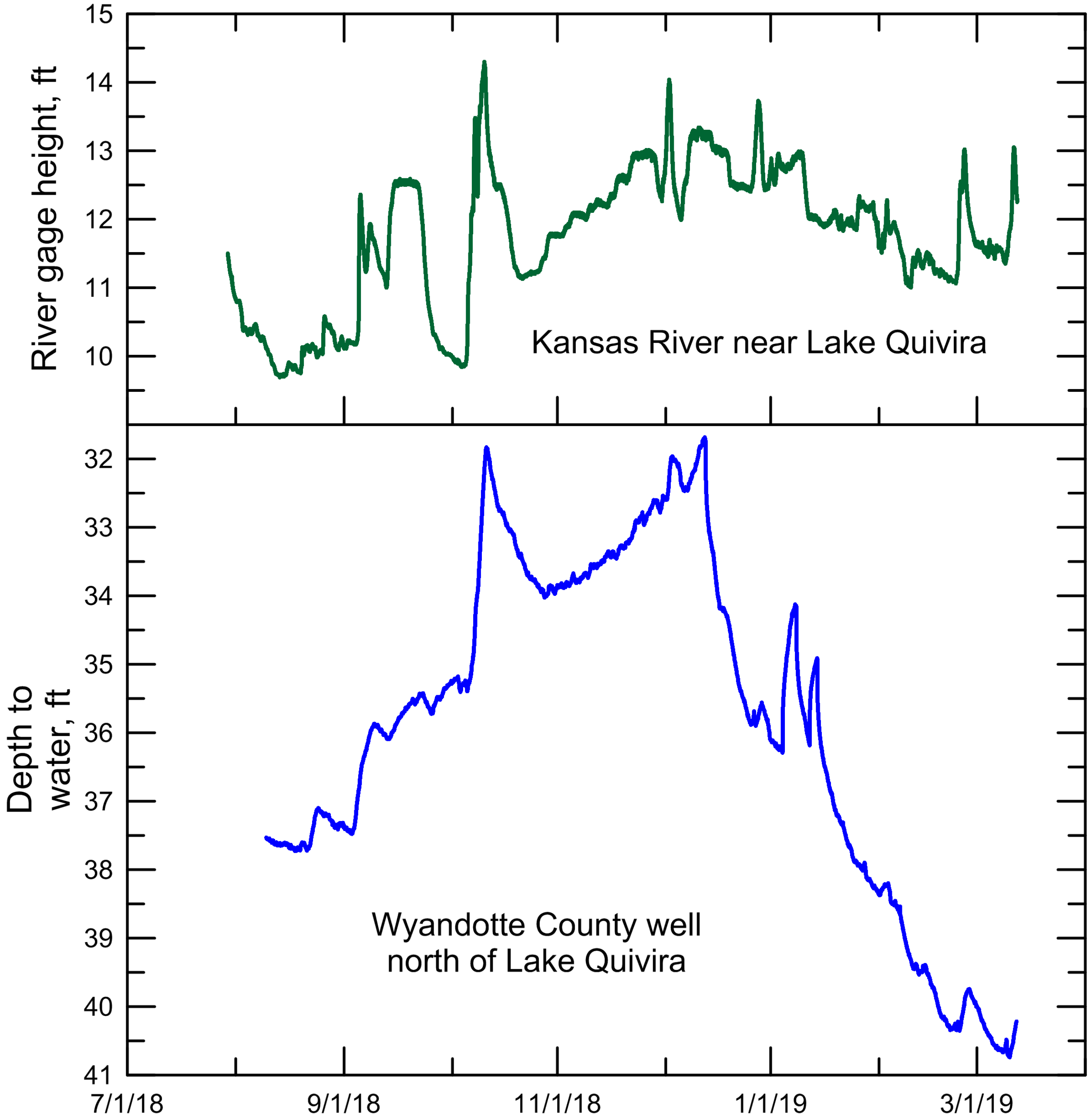

Figure 12. Comparison of hydrographs of Kansas River gage height near Lake Quivira and depth to water at the KGS network well in Wyandotte County north of Lake Quivira (KAW-WY01). The tick spacing per foot of change is the same for both portions of the graph. The well hydrograph appears to be affected by the occasional pumping of wells in the vicinity of the monitoring well.

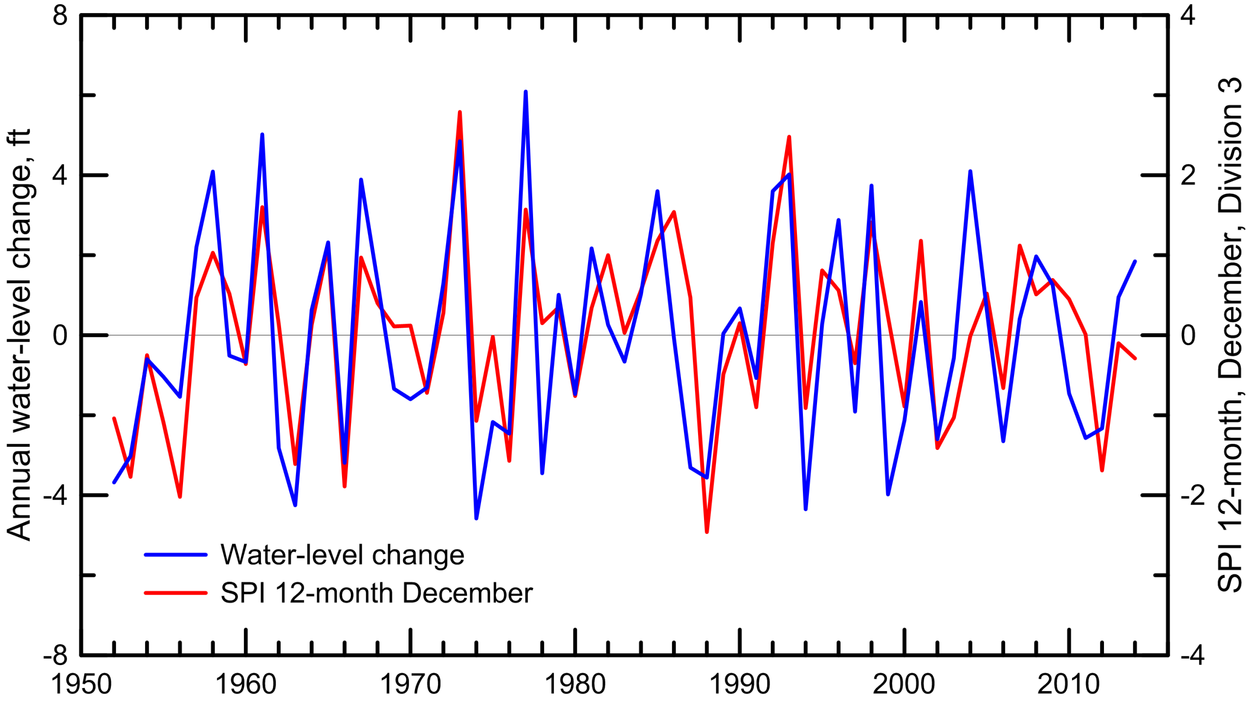

Figure 13. End-of-year groundwater-level change at the USGS monitoring well near the Lawrence airport and the December value for the 12-month standardized precipitation index (SPI) for the northeast climatic division of Kansas. The last full year of record for the well was 2014. The coefficient of determination (R^2) for the linear correlation between the groundwater-level change and SPI is 0.58, which is significant at a P value of <0.001.

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Stop 4. Jeffrey Energy Center Well and River Water Supply Station

Location: Southwest of Belvue on the north side of the Kansas River

Lead presenter: Jared Morrison, Senior Manager, Water and Waste Programs
KCP&L and Westar, Evergy Companies

The Jeffrey Energy Center (JEC) is located in the uplands north of the Kansas River valley and north-northeast of Belvue in Pottawatomie County (figure 14). Jeffrey Energy Center, which began operation in 1978, generates electricity through its coal-fired power plant. It uses water for cooling, desulfurization of flue gas, and other purposes associated with the center. JEC draws water from a surface water reservoir on its property in the uplands north of the Kansas River; in addition to direct precipitation on and runoff into the reservoir, JEC pumps surface water from the Kansas River and groundwater from the alluvial aquifer of the river south of the center into the reservoir.

The energy center used to have more than a dozen wells in the general area of Belvue that withdrew groundwater from the alluvial aquifer of the Kansas River. Many of these wells were located along Highway 24, and most were drilled in 1978 (one in 1975 and another in 1982). These wells have now been plugged (from 2007 to 2016). JEC installed two high capacity wells next to its surface water withdrawal facility next to the Kansas River (figure 15), and it now uses those wells to withdraw groundwater. The depth to bedrock at that location is about 77 ft. The lithologic log for one of two wells (drilled in July 2006) indicates 3 ft of soil underlain by 9 ft of clay. The aquifer material starts at a depth of 12 ft and consists of 26 ft of fine to medium sand that is underlain by 39 ft of medium sand and gravel, with cobbles in the deepest sediment. The casing diameter of the well is 36 inches and the screen extends from 38 to 78 ft below land surface. The estimated yield of the well is 2,100 gpm. The annular space of the borehole is grouted to 20 ft below land surface. The static water level when the well was drilled was 24 ft below land surface.

The water rights for the two wells next to the Kansas River now in use indicate that the authorized quantities are 3,646 acre ft and 3,723 acre ft; the authorized maximum pumping rates are 2,400 gpm and 2,600 gpm. The average annual amounts of water use reported for the two wells during the last 10 years of record available (2008–2017) are 1,429 acre ft for one well and 501 acre ft for the other well, giving a total annual average of 1,930 acre ft. In 2017, one well was not pumped and the other withdrew 2,119 acre ft. The amount of surface water withdrawn from the Kansas River is substantially greater than that pumped from the alluvial aquifer. The average annual total of river water extracted for the 10-year period of 2008–2017 was 24,136 acre ft.

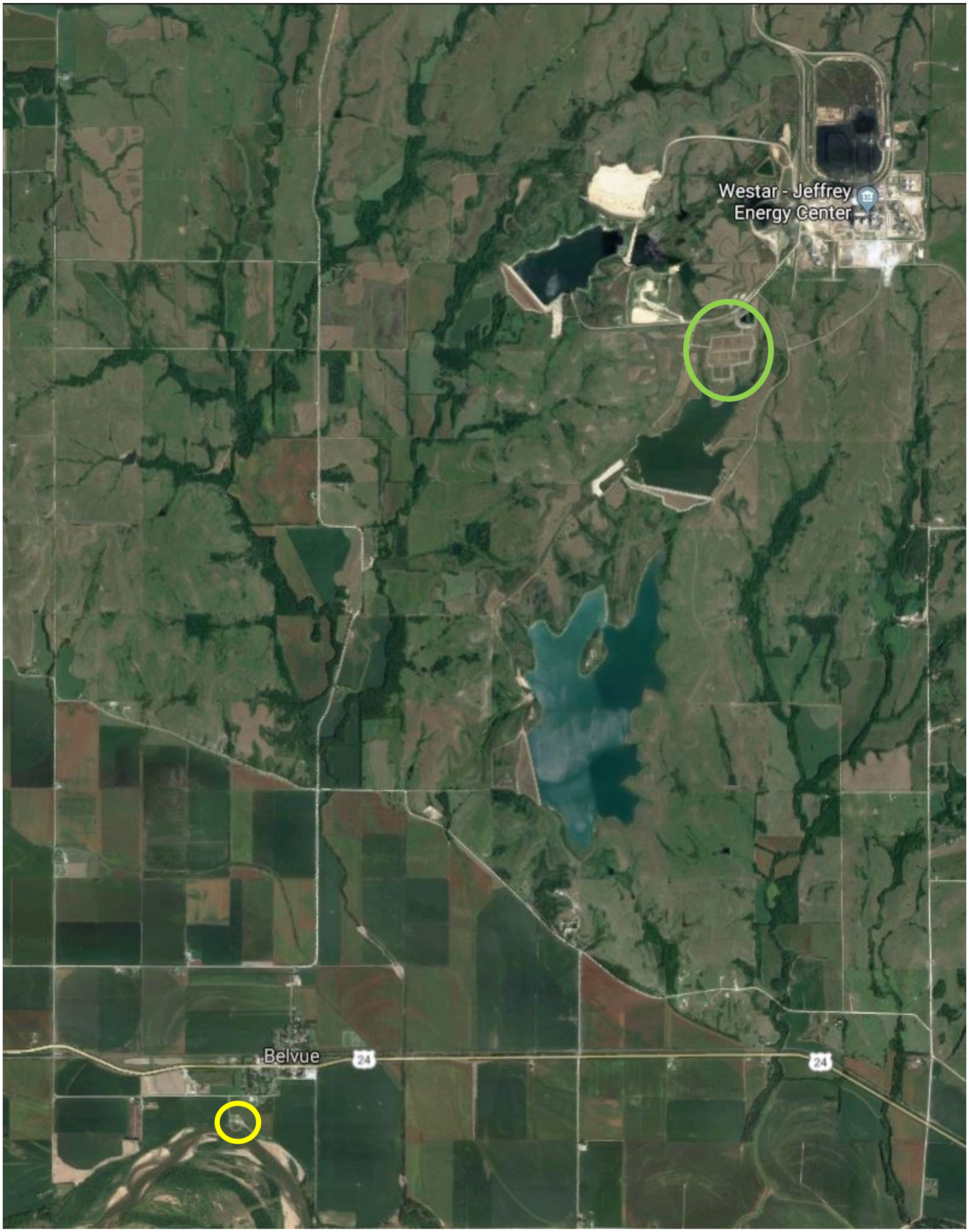


Figure 14. Satellite view of Jeffrey Energy Center north of the Kansas River valley, including a water supply reservoir, ash ponds, and wetland (green circle) and the center's surface and groundwater extraction facility (yellow circle) next to the Kansas River (from Google Maps).

Figure 15. Satellite view of the Jeffrey Energy Center station for withdrawal of surface water from the Kansas River and groundwater from the alluvial aquifer southwest of the City of Belvue (from Google Maps).

Stop 5. Jeffrey Energy Center Constructed Wetland

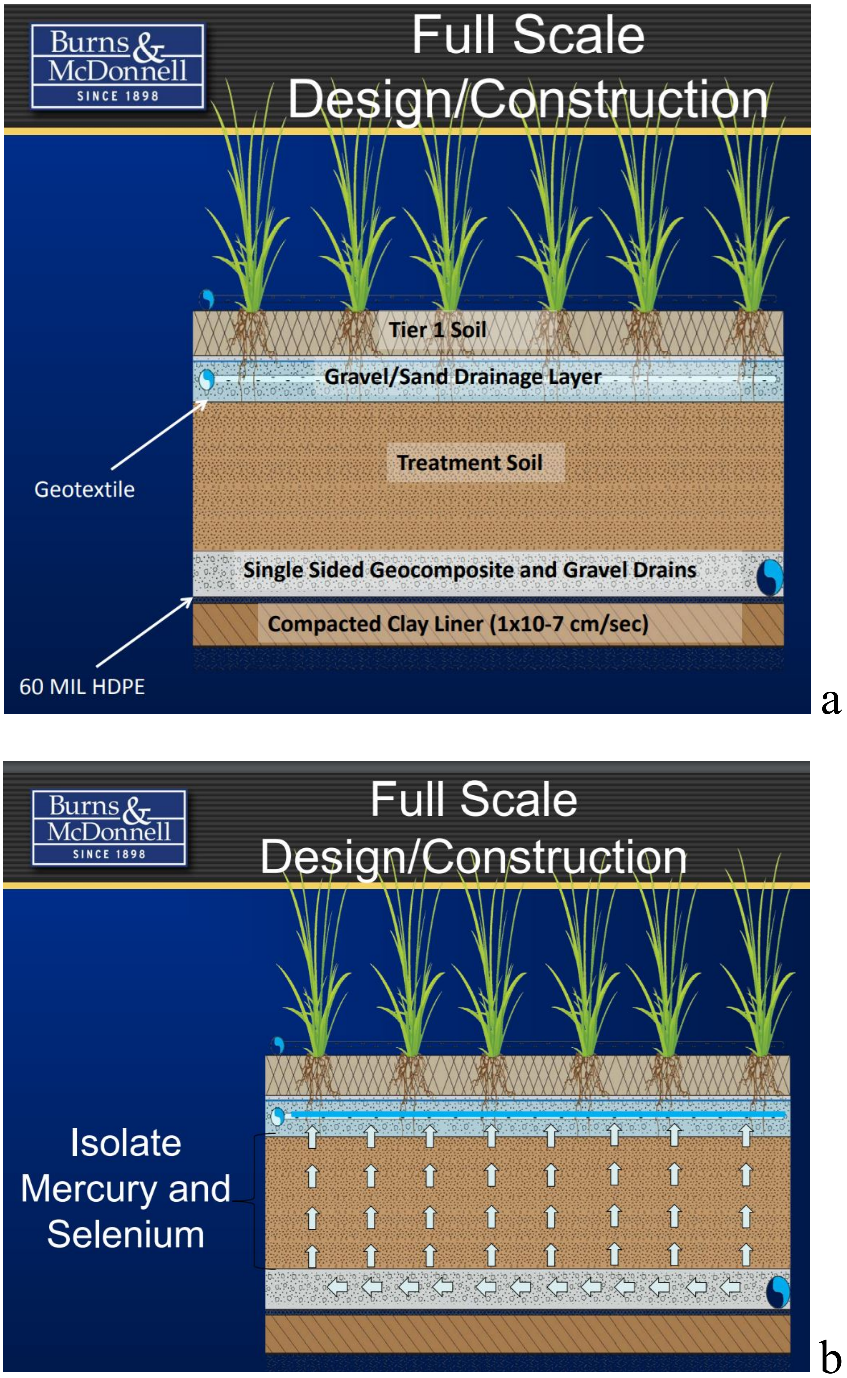
Location: Southwest of Jeffrey Energy Center in uplands north of the Kansas River valley

Presenter: Jared Morrison, Senior Manager, Water and Waste Programs
KCP&L and Westar, Evergy Companies

Residual materials associated with coal combustion at the Jeffrey Energy Center include bottom ash, fly ash, and flue gas desulfurization wastewater. Although the plant burns low-sulfur coal from the Powder River Basin, the sulfur dioxide in the combustion gas is still high enough that it requires scrubbing. In 2009, a better flue gas desulfurization system was completed and improved the removal of sulfur dioxide from 60% to 97%. The desulfurization process uses water and pulverized limestone and also reduces the emissions of particulate matter and trace metals such as mercury, selenium, and arsenic. Gypsum is produced during the reaction between the pulverized limestone and sulfur dioxide (Morrison, 2014). The gypsum-water slurry is dewatered and the gypsum is placed in an on-site landfill. Before 2013, the wastewater was clarified, treated for mercury, and discharged to a creek based on an agreement with the Kansas Department of Health and Environment (Reitenbach, 2014).

After completion of the new desulfurization system, Westar investigated different methods for the most cost-effective way to treat the wastewater to remove trace metals. The system selected was a constructed wetland. Because sulfate in the wastewater is high and would not be removed by the wetland, sulfate is first removed in a traditional wastewater treatment plant by sulfate precipitation. A two-acre pilot wetland was installed in 2010 to treat about 10% of the desulfurization wastewater. Researchers at Kansas State University helped in the examination of the wetland treatment process (Galkaduwa et al., 2017). After successful results were obtained from the pilot wetland, a full-scale wetland that covers 28 acres was constructed; it was completed in 2014 and now treats 100% of the desulfurization wastewater (Reitenbach, 2014). The wetland daily treats up to 230,000 gal of wastewater. The project "received both state and national Engineering Excellence Awards in 2015 from the American Council of Engineering Companies, as well as the first-ever Water Award from Power magazine. The project also received the 2014 Edison Award from the Edison Electric Institute" (Burns & McDonnell, n.d.). Water released from the wetland is pumped back to the energy center for reuse (Westar Energy, n.d.).

The wetland, which was designed by Burns & McDonnell and constructed by UCI (Utility Contractors, Inc., n.d.), includes both soils and wetland plants in a tiered filtering system. The constructed wetland includes "two parallel vertical flow cells (19.2 acres combined) followed in series by two parallel vegetative submerged cells (4.5 acres combined)" (Reitenbach, 2014). Figure 16a shows a schematic of the wetland design. "In the vertical-flow beds, water moves upward through a lower tier of saturated soil before reaching the same root-and-soil system in the upper-tier wetland" (McFarland, 2016); see figure 16b for representation of the flow. The vertical water flow through the soils filters the water and removes metals and other constituents; the removal process includes precipitation and adsorption of metals in a chemically reducing environment mediated by microorganisms. The process is especially effective for removing selenium (Galkaduwa et al., 2017) but also decreases the concentrations of other constituents such as mercury, fluoride, nitrate, and nitrite (Reitenbach, 2014). The upward vertical flow design means that the water appearing at the surface of the wetland has already had treatment to decrease the concentrations of trace metals and other constituents such that wildlife in the wetlands would not be affected by contaminants in the water.


Burns & McDonnell SINCE 1898

Full Scale Design/Construction

Burns & McDonnell SINCE 1898

Full Scale Design/Construction

Figure 16. Construction design (a) and representation of vertical flow (b) in the Jeffrey Energy Center constructed wetland. From Bland et al. (2014).

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