Ozark Plateau

2010-2019 Field Analysis Summary

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Parsons Field Office

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I. Introduction

The Ozark Plateau is a four-state region located primarily in southern Missouri and northern Arkansas and includes smaller areas in northwest Oklahoma and southeast Kansas (Figure 1). The Ozark Plateau consists of four physiographic regions: the Springfield Plateau, Salem Plateau, Saint Francois Mountains and Boston Mountains. Of these four regions only a small portion of the Springfield Plateau extends into the far southeastern corner of Kansas. Under this corner of Kansas lies the Ozark Plateau aquifer.

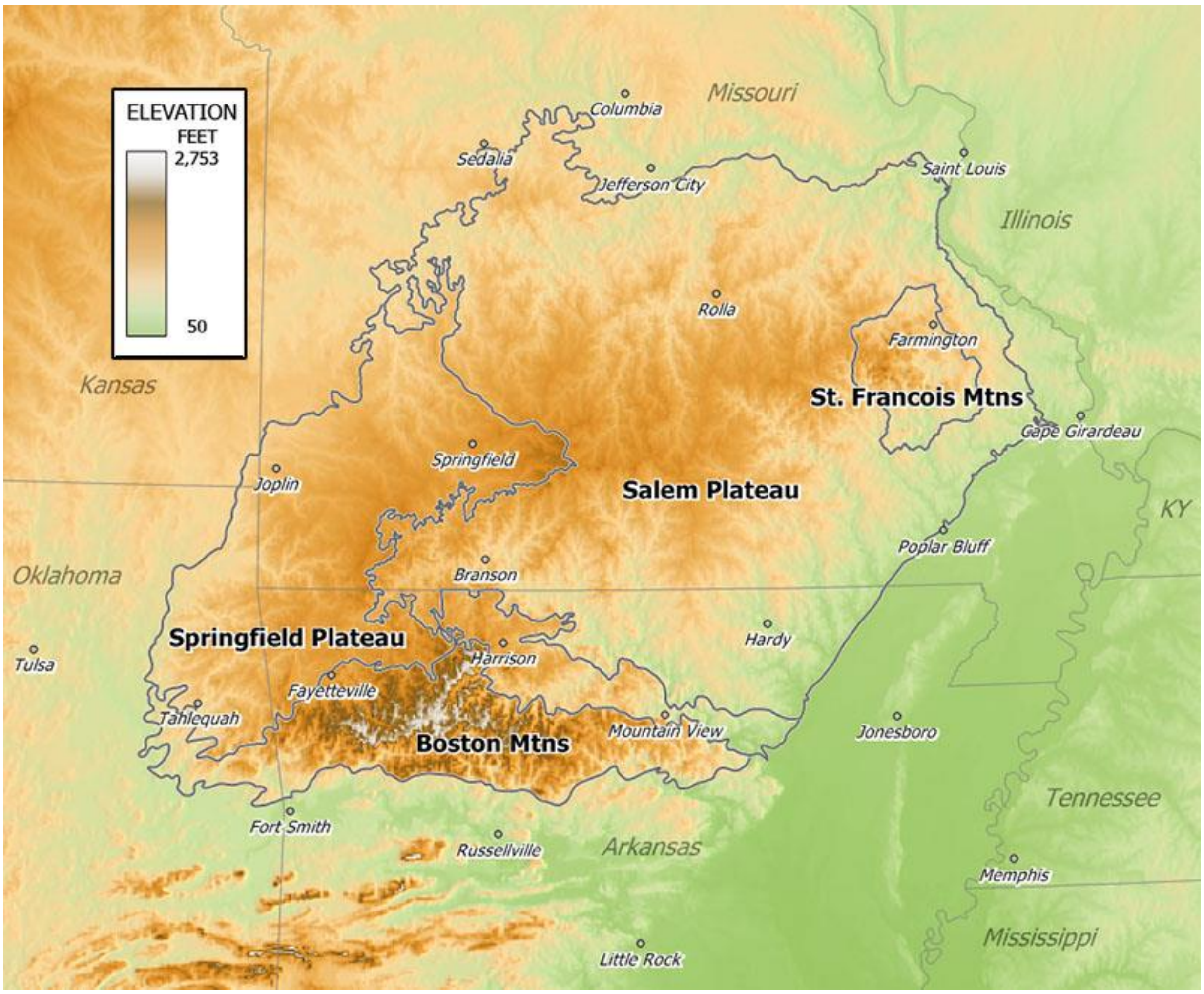

Figure 1: Ozark Plateau
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The Ozark Plateau aquifer is an important source of water for the quad-state region of southeast Kansas, southwest Missouri, northeastern Oklahoma and a small portion of northwest Arkansas.

The Ozark Plateau aquifer consists of two aquifers separated by a discontinuous confining unit. The upper, shallower aquifer is the Springfield Plateau aquifer; the lower, deeper aquifer is the Ozark aquifer (Figure 2).

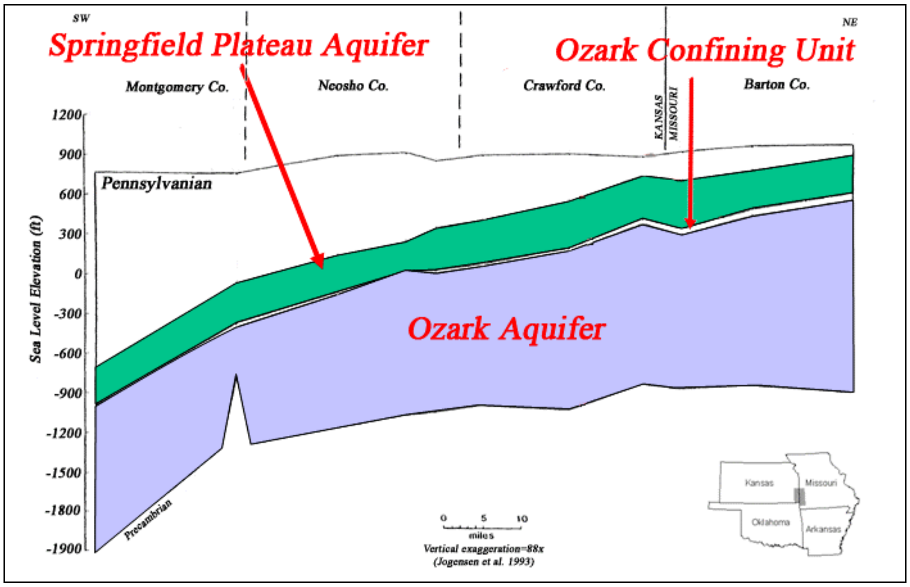

Figure 2: Ozark and Springfield Plateau Aquifers

Figure taken from Kansas Geological Survey Open File Report 2007-20 *The Southeast Kansas Ozark Aquifer Water Supply Program*.

The Springfield Plateau aquifer contains fresh water in southwest Missouri and northeast Oklahoma, where it is shallow and can produce water sufficient for domestic purposes. However, water quality of the Springfield Plateau aquifer in Kansas is poor and may be unfit for domestic use due to the prior extensive lead and ore mining in the area. Mining shafts have allowed contaminated water to move from the surface into the aquifer.

The Ozark aquifer contains usable water in southeast Kansas and is the source for most of the groundwater supplied to area municipalities and rural water districts. At the bottom of the Ozark aquifer is a brine layer (saltwater) that is moving west to east across Kansas. There has been some concern that significant groundwater pumping in areas could potentially cause upwelling of brines within the aquifer and adversely impact water quality.

In 2004, the Kansas Department of Agriculture's Division of Water Resources (KDA-DWR) established a moratorium on new appropriations from the aquifer in Kansas, except for some specified exceptions, due to uncertainty at that time about the available water supply in the Ozark aquifer, and potential water quality concerns. The moratorium referenced a study of the Springfield Plateau aquifer and Ozark aquifer that was to be completed by December 31, 2010 (K.A.R. 5-3-29). (http://ks.water.usgs.gov/Kansas/studies/OzarkAquifer/index.html).

The study by the U.S. Geological Survey (USGS), with state and local involvement, was actually completed in August 2009. A decision was made by Chief Engineer David Barfield in December 2010 to lift the moratorium and reopen the area to new appropriations. The development of regulation to address safe yield for these aquifers is under consideration.

A groundwater well monitoring network was re-established in 2004 for the former Ozark aquifer moratorium area. The network originally consisted of 26 existing wells and 3 DWR-owned dedicated monitoring wells that were drilled in 2006. Two of these dedicated observation wells monitor the Ozark aquifer, one at McCune and one at Pittsburg, while the last well, also located at Pittsburg, monitors the Springfield aquifer. The dedicated monitoring wells were initially equipped with transducers for continuous data collection. However, in the timeframe of 2011-2017, the data logging equipment on the DWR wells underwent ongoing failures. Equipment issues, coupled with turnover in Parsons Office staff, resulted in little to no usable data for the DWR well levels. Between 2017 and 2018, transducers were removed, and the wells were manually measured as part of the regular monitoring network. There are now 24 wells on the Ozark monitoring network (including the 3 DWR wells). The Crawford RWD 4 wells (CR01 & CR03) were removed from the network in 2007. Pittsburg Well 11 (CR08) was replaced by Pittsburg Well 10 (CR17) around 2009. Reconfigured well heads, resulting in restricted tape-down access, led to the removal from the network of Girard well 3 (CR05) in 2013, Consolidated Crawford RWD 1 (CR10) in 2014, and Galena tower well (CK08) in 2018. In 2015, the frequency of measurements was reduced from quarterly (Mar, Jun, Sep, Dec) to tri-annually (Oct, Jan, May).

In order to detect the potential eastward movement or upwelling of saltwater, a network consisting of 12 wells was established within the existing network from which water quality samples are taken. Two sites have since been removed for sampling, and there are now ten wells from which quality samples are taken tri-annually.

II. Precipitation

Precipitation in the Ozark Plateau area in Kansas averages 42 inches per year since 1900 based on 6 precipitation stations. Figure 3 shows the annual variation in precipitation; the red line represents the average rainfall. This chart was derived from National Centers for Environmental Information (NCEI) stations located in Columbus (Cherokee County), Erie (Neosho County), Fort Scott (Bourbon County), Moran (Allen County), Parsons (Labette County) and Pittsburg (Crawford County). The data is downloaded then averaged to create the following chart.

In 2019, the highest precipitation total occurred with 68 inches. In contrast, the lowest precipitation occurred in 1963 with 22 inches. Annual rainfall in the 5-year period of 2015-2019 averaged 52 inches, which is well above average. Annual precipitation data for these NCDC stations is currently available through 2019.

Precipitation does have a direct effect on streamflow and recharge to the Springfield aquifer, as these areas are open to receive precipitation in southeast Kansas. However, the Ozark aquifer is largely recharged near Springfield, Missouri where the rocks crop out at the surface. Therefore, precipitation falling in southeast Kansas provides minimal recharge to the Ozark aquifer, as it is largely separated from the Springfield aquifer by the confining layer.

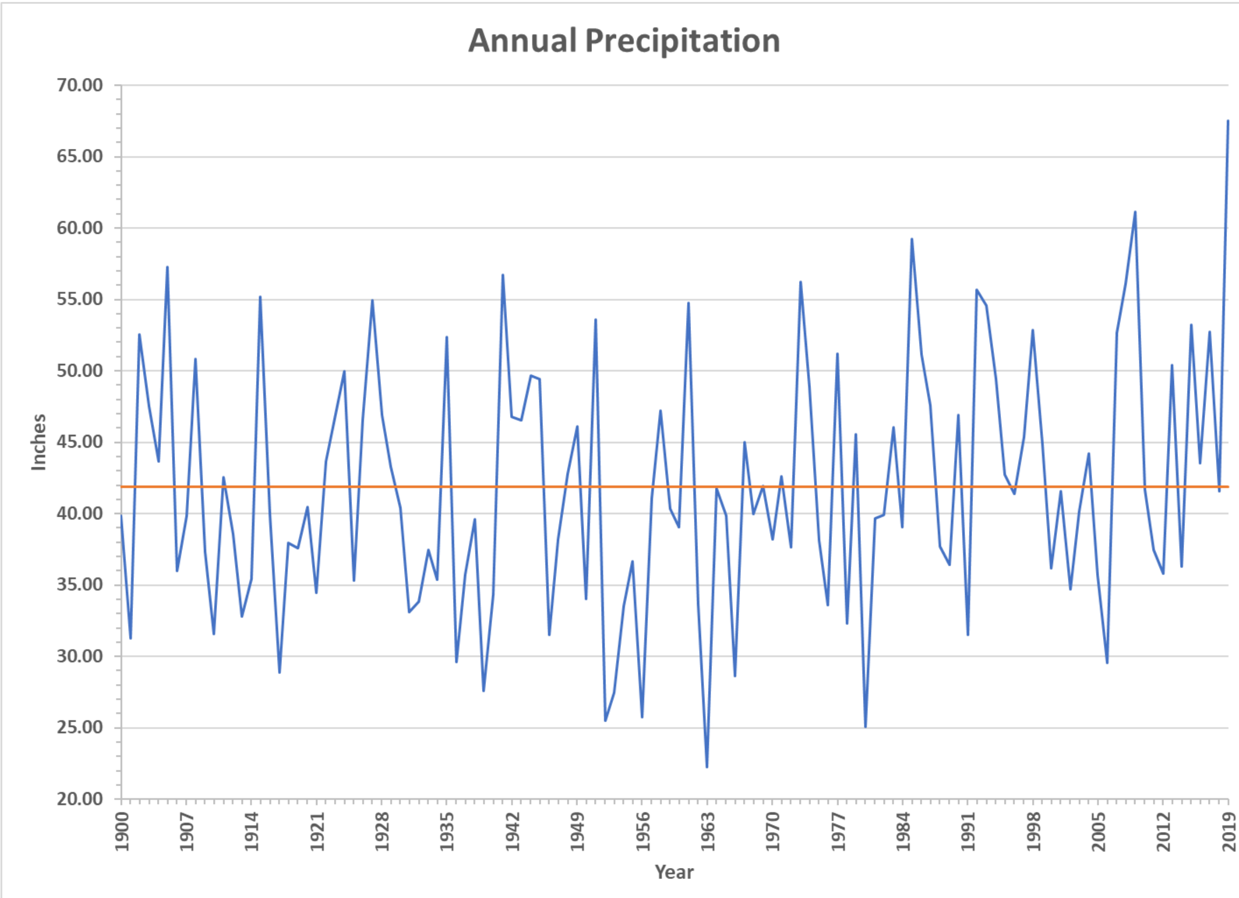

Figure 3: Average Ozark Precipitation 1900-2019

III. Surface Water

As seen in Figure 4, the Neosho River and the Spring River are the two major river systems that cut through the former moratorium area boundary of the Ozark Plateau aquifer, though a portion of the Marmaton River Basin is also encompassed in the northeastern area of the boundary. The lower Neosho River flows through Neosho and Labette counties, and briefly flows through the southwest corner of Cherokee County before flowing out of Kansas into Oklahoma. The Spring River enters Kansas from Missouri on the eastern side of Cherokee County, flows through Cherokee County, and exits the state at the southern part of the county into Oklahoma.

Both river systems are monitored by the USGS and have streamflow gages positioned near Parsons, Kansas on the lower Neosho River and near Baxter Springs, Kansas and Quapaw, Oklahoma on the Spring River (Figure 5). In addition, the USGS Spring River gage near Waco, Missouri is shown, as well as the USGS Shoal Creek gage near Joplin, MO (Figure 5). These gages measure flow entering Kansas since the water systems flow west over the state line from Missouri. Shoal Creek is the tributary to the Spring River, meeting it at the Empire District Lake.

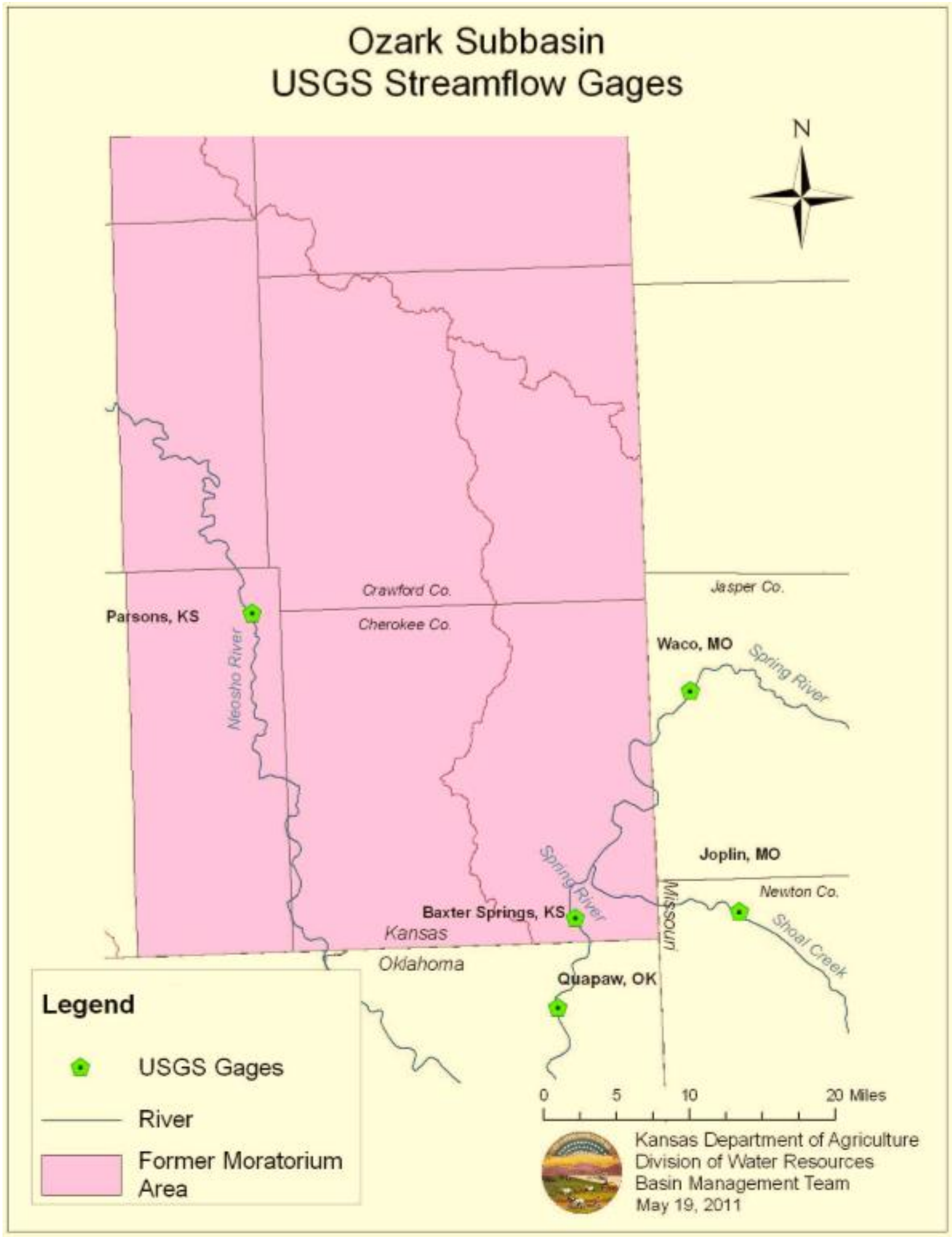

Figure 4: Neosho River and Spring River USGS streamflow gages

Figure 5 was derived from the Parsons, KS, Baxter Springs, KS, Quapaw, OK, Joplin, MO, and Waco, MO USGS gages and demonstrates how flow can vary each year. The Baxter Springs gage was installed in 2009. Following the 1951 flood the Neosho River reached periods of little to no flow during the subsequent drought. Flows in 2019 were high across the board, with a record average flow of 8,963 cfs at the Parsons Gage. Table 1 shows average annual streamflows for specific timeframes.

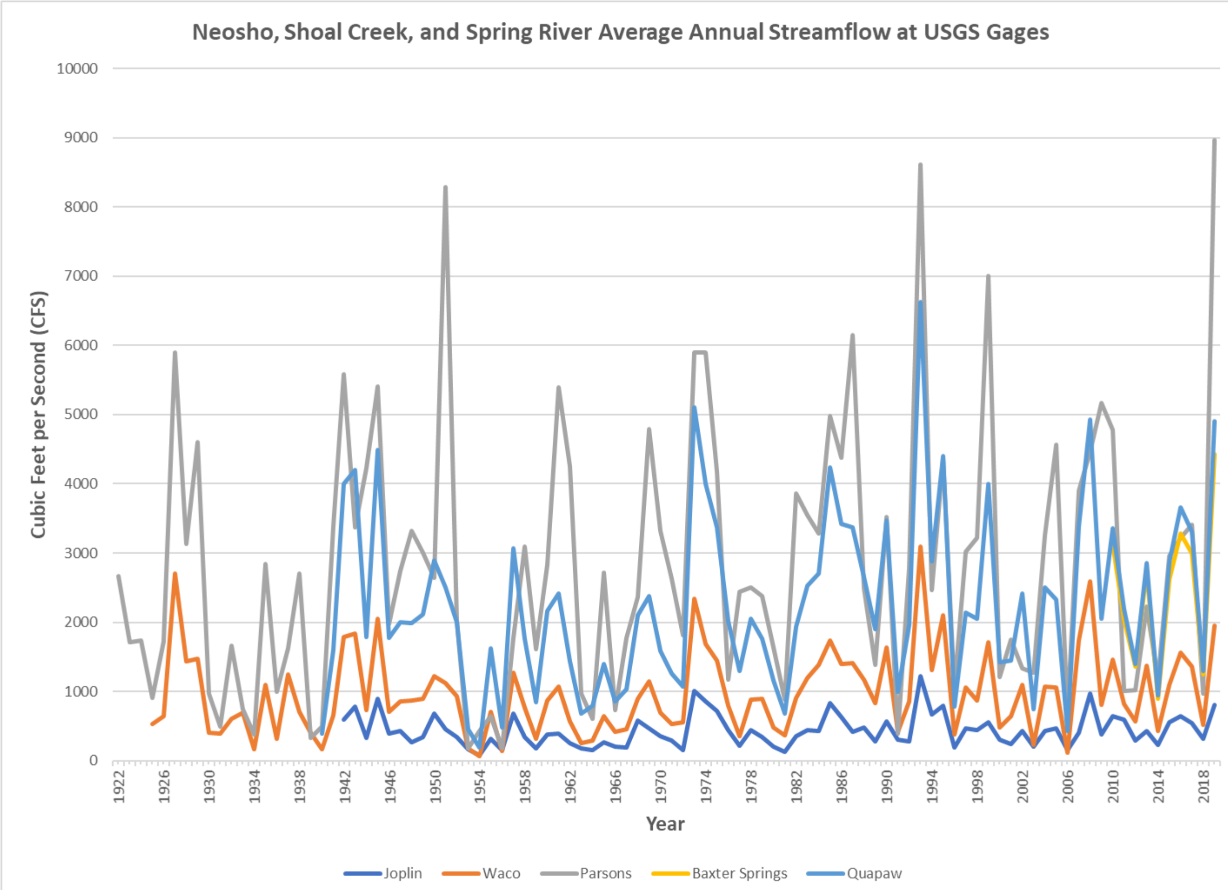

Figure 5: Streamflow at USGS Gages 1922-2019

Table 1: Average Annual Streamflow

	Average Annual Streamflow			
Gage (Period of Record)	**Period of Record**	**1990-1999**	**2000-2009**	**2010-2019**
Parsons (1922-2019)	2801	3643	2758	2973
Quapaw (1940-2019)	2266	2932	2168	2678
Baxter Springs (2010-2019)	2470	N/A	N/A	2470
Waco (1925-2019)	969	1342	984	1114
Joplin (1942-2019)	435	547	395	504

In 1984, the Kansas legislature amended the Kansas Water Appropriation Act to establish Minimum Desirable Streamflows (MDS) on certain watercourses in Kansas. The statutory provision provided for the establishment of MDS flow criteria to be designated on a number of Kansas streams prior to a 1990 deadline. MDS flow criteria was established on the Neosho and Spring Rivers at specific USGS streamflow gages. Table 2 represents the MDS values for the lower Neosho River and the Spring River USGS streamflow gages.

The lower Neosho River gage is located near Parsons, Kansas and is used in administering MDS between the Iola, Kansas USGS gage and the Parsons, Kansas USGS gage. The Spring River gage near Quapaw, Oklahoma is used in administration of MDS at Baxter Springs, Kansas. The

MDS values for the Neosho River near Parsons in parenthesis in Table 2 represent the spawning flows that are managed if the reservoir is in flood pool.

Table 2: Minimal Desirable Streamflow (MDS)

River	Gage	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Neosho	**Parsons**	50	50	50	50 (100)	50 (300)	50 (300)	50	50	50	50	50	50
Spring	**Quapaw**	175	200	250	300	450	350	200	160	120	120	150	175

Figure 6 charts the number of days in each year that the mean daily flow at each gage was below the MDS target flow. Please note, this does not represent actual days that MDS administration occurred for each system. Administration is triggered when the actual daily average streamflow at the gage has been less than the streamflow trigger value for seven consecutive days. Cessation of MDS administration occurs when the streamflows at the gage have exceeded the target flows for 14 consecutive days. Since MDS was established in 1984, the frequency of streamflow below the MDS criteria has been less at the Quapaw gage than at the Parsons gage. This is partly due to the fact that streamflows on the lower Neosho River are affected by operations of three federal reservoirs located within the basin (Marion, Council Grove, and John Redmond Reservoirs). The lower Neosho has a greater potential for flows below MDS criteria for consecutive years, resulting in the administration of MDS on the Neosho River in 2002, 2003, 2006, 2007, 2011, 2012, and 2013. MDS administration occurred for the first time on the Spring River in 2006 and then again in 2012.

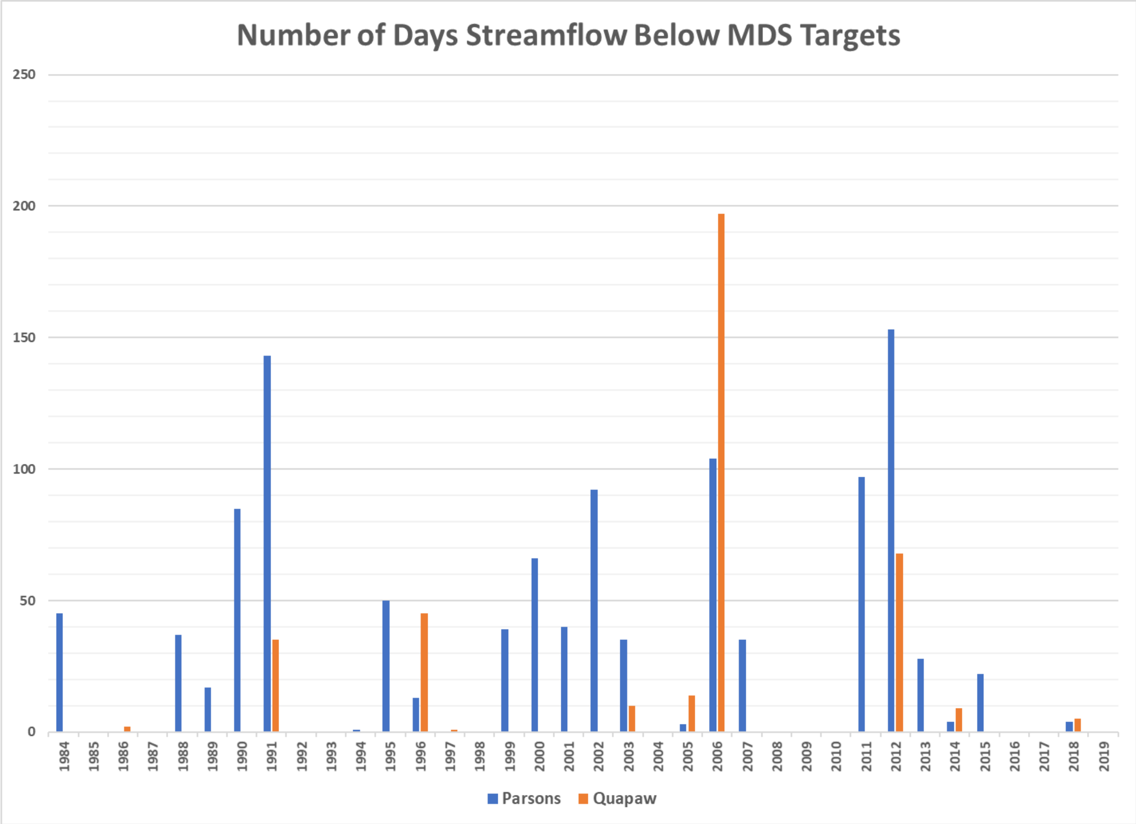

Figure 6: Number of days mean streamflow below MDS targets.

IV. Groundwater

Monitoring wells used in this report are located in the Ozark aquifer and what we refer to as the Ozark Plateau aquifer (wells believed to be screened in both the Ozark and the Springfield Plateau aquifers). There are no known monitoring wells solely screened in the Springfield Plateau aquifer besides the dedicated observation well at Pittsburg, Kansas (CR15), which is charted in Figure 8. For this fieldwork summary, groundwater data was grouped by geographic proximity, not by aquifer. The monitoring well network is shown in Figure 7. Figure 8 through Figure 10 chart the groundwater levels in the Ozark Plateau aquifers.

The KDA-DWR currently measures a total of 24 wells in the Ozark Plateau region. In the past, up to 30 different wells have been measured as part of the monitoring network. Legal descriptions and names for monitoring wells are available in Appendix A. Since the wells monitored in these sub-basins are mostly municipal wells that pump year-round, capturing a consistent period of recovery would be difficult. This lends to often extreme variability in well level measurements. Therefore, annual average well levels were compiled for each location from the individual measurements taken each year. These annual average well levels are available in Appendix B. The well levels were further charted into five-year rolling averages to discern long-term trends and smooth the variability inherent in the datasets. The five-year averages at 2010 (the first year for which a full five-year average exists) and 2020 were then compared.

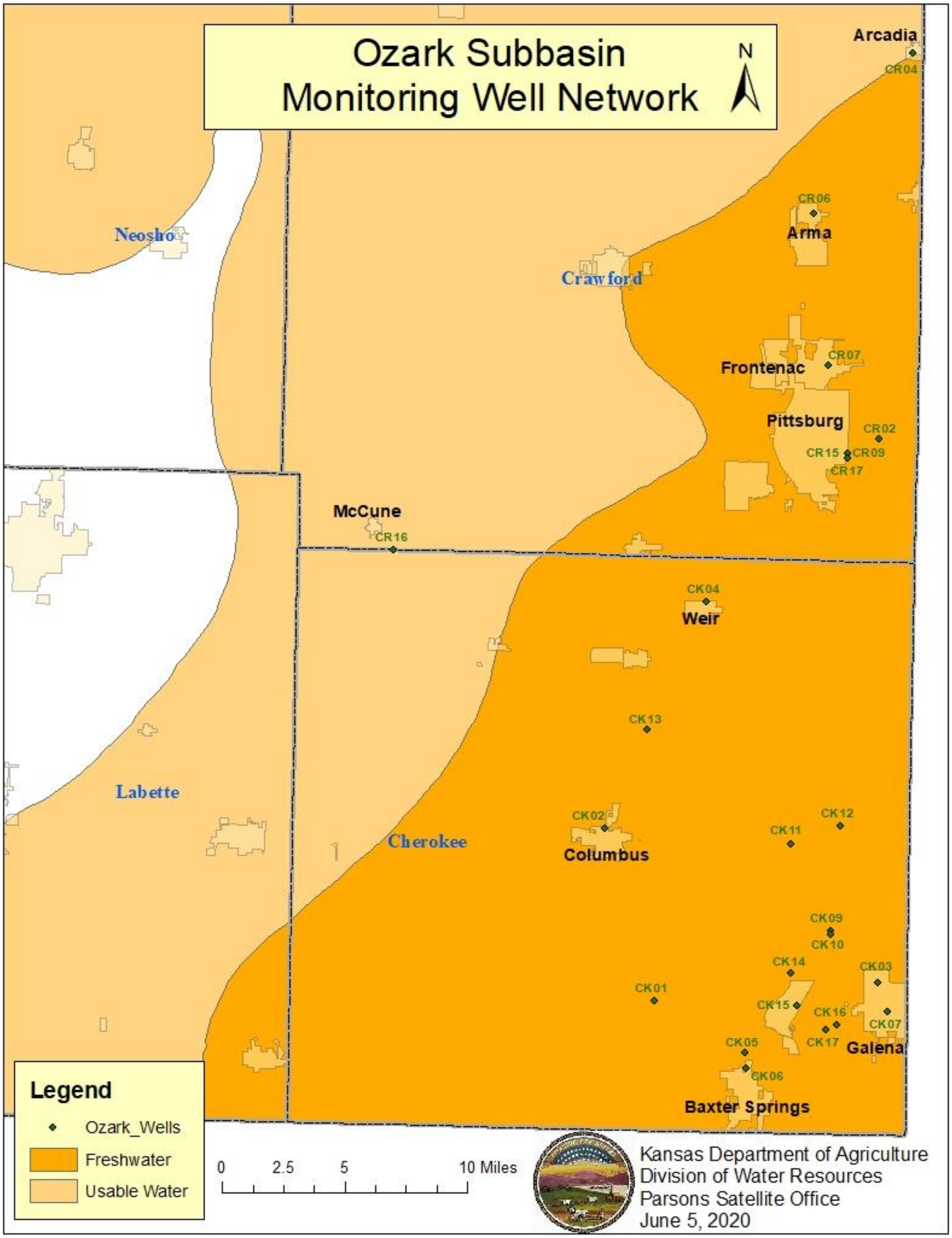

Figure 7: Ozark Monitoring Wells

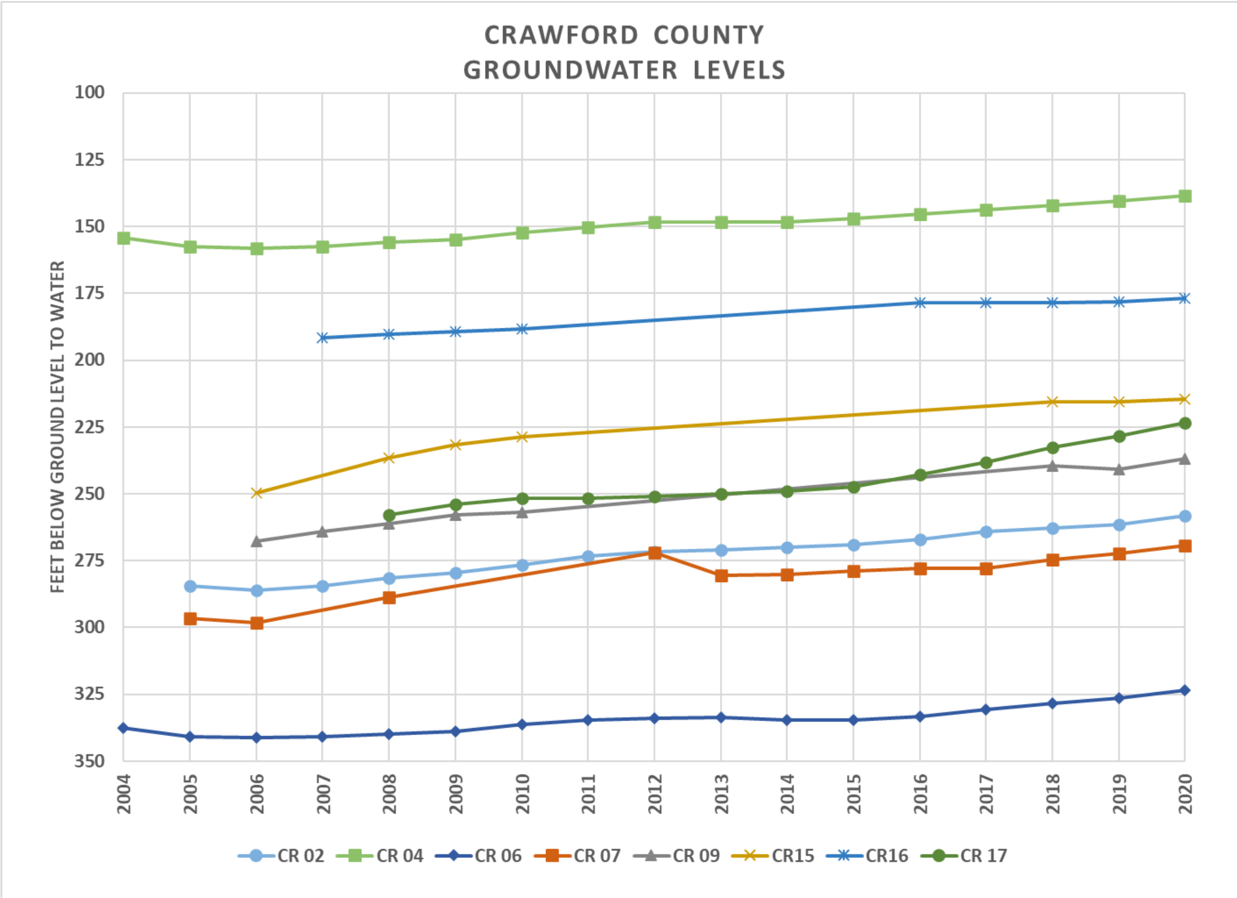

Figure 8: Five-year rolling average of groundwater levels in Crawford County wells

In Crawford County, there are currently eight monitoring wells. Figure 8 shows the groundwater levels on a five-year rolling average. Between 2010 and 2020, the five-year average levels recovered by a mean 17.27 feet. These recoveries varied from a minimum of 11.48 ft at the DWR McCune well (CR16) to a maximum of 28.32 feet at the Pittsburg Water Plant well 10 (CR17). The standard deviation in the recoveries of the eight wells was 5.48 feet. In this analysis, the Frontenac (CR07) 2008 value was substituted for 2010 due to a lack of measurement data from 2009-2011.

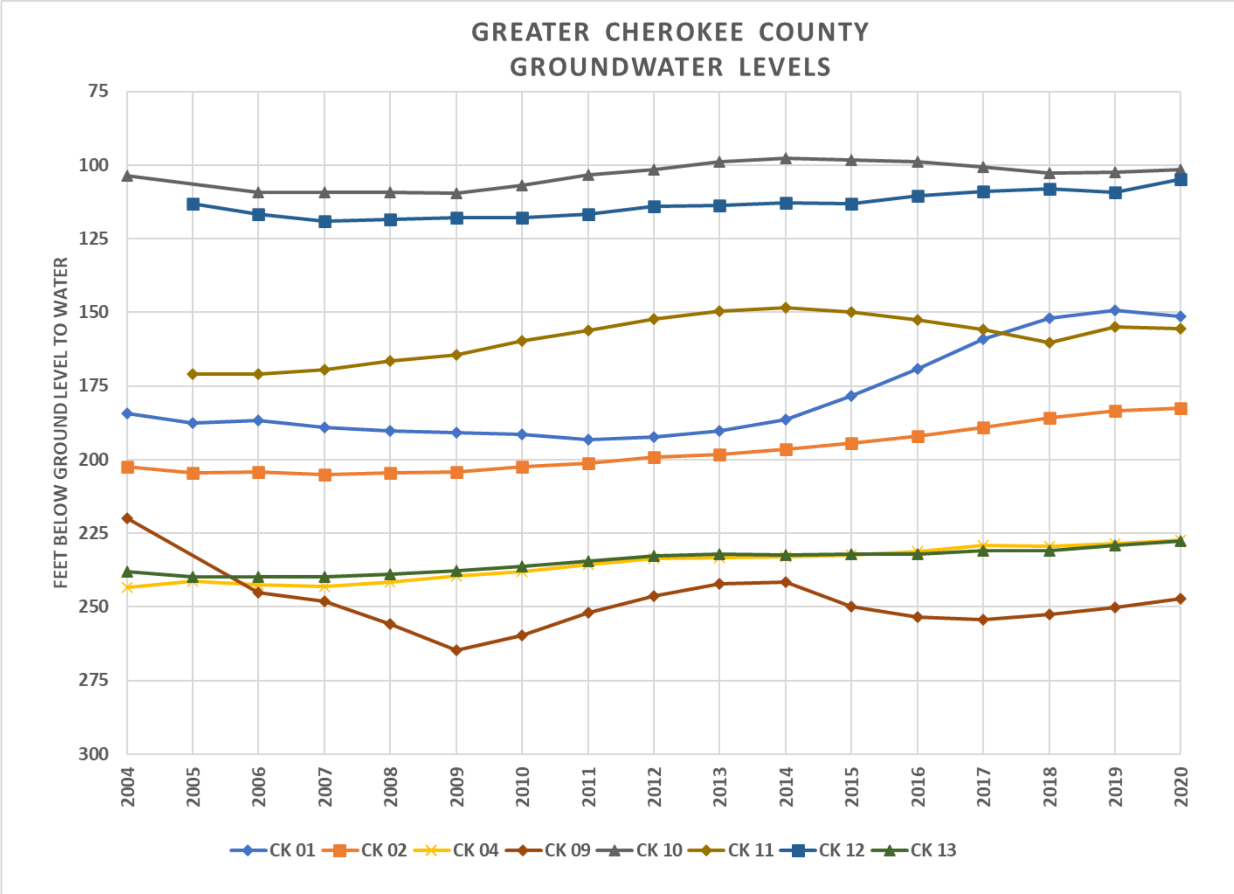

Figure 9: Five-year rolling average of groundwater levels in Cherokee County wells north of 37.10⁰ latitude and west of -94.75⁰ longitude (NAD 83)

There are another eight wells in the spatial majority of Cherokee County excluding the far southeast corner. Figure 9 shows the groundwater levels on a five-year rolling average. Between 2010 and 2020, the five-year average levels recovered by a mean 14.37 feet. These recoveries varied from a minimum of 4.34 feet at the CK RWD 1 Crestline well (CK11) to a maximum of 40.14 feet at the CK RWD 3 well 1 (CK01). The standard deviation in the recoveries of the eight wells was 11.52 feet.

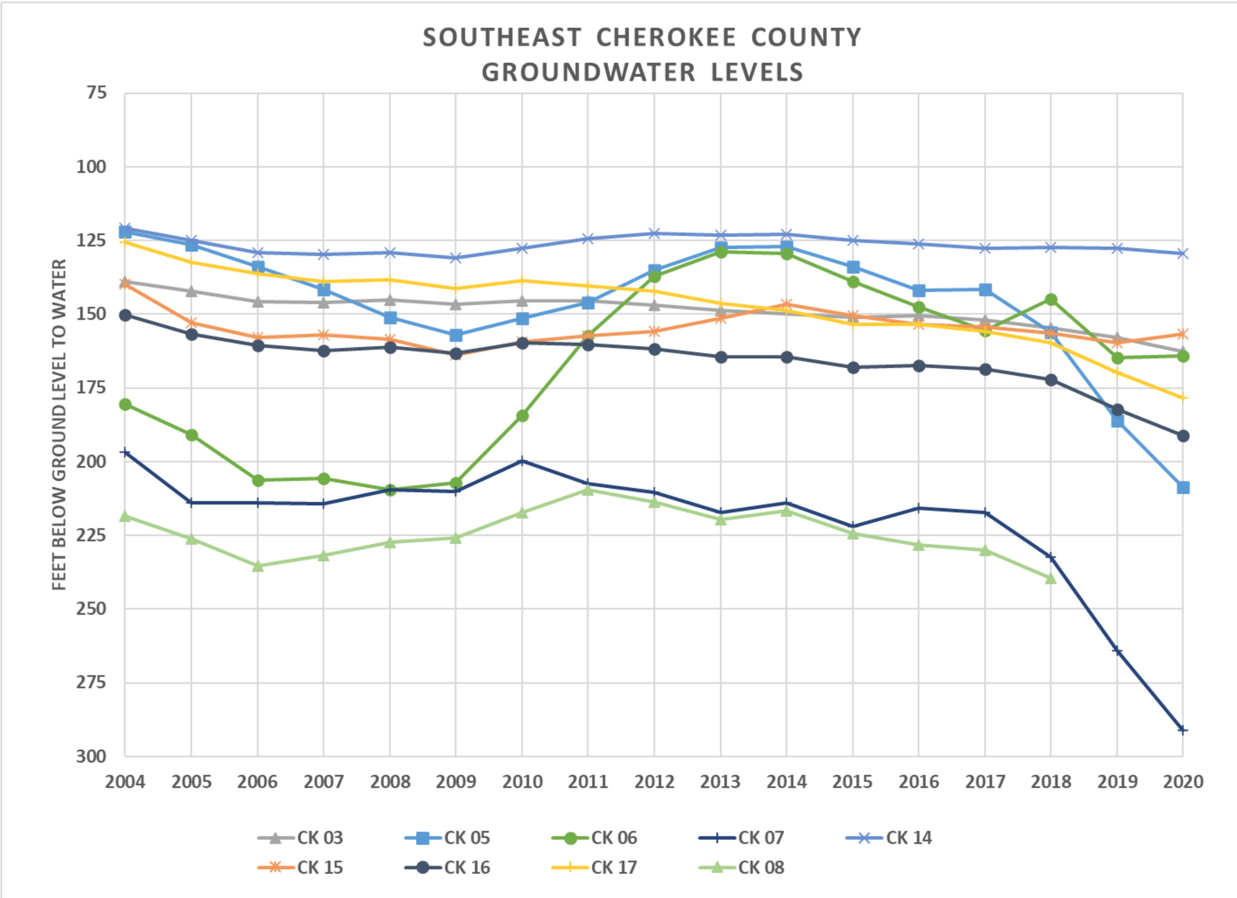

Figure 10: Five-year rolling average of groundwater levels in Cherokee County wells south of 37.10⁰ latitude and east of -94.75⁰ longitude (NAD 83)

There are currently another eight monitoring wells in the far southeastern corner of Cherokee County. A ninth, Galena Tower (CK08), was also included in this dataset, because it does contain complete and useful data up to 2018. Figure 10 shows the groundwater levels on a five-year rolling average. Between 2010 and 2020, the five-year average levels declined by a mean 26.46 feet. These changes in the rolling average well levels varied from a decline of 91.44 feet at the Galena Vested well (CK07) to a recovery of 20.27 feet at the Baxter Springs well 5 (CK06). The standard deviation in the changes in the levels of the eight wells was 33.77 feet.

V. Water Quality

Figure 11 to Figure 14 chart salinity and conductivity values in the Ozark aquifer and Ozark Plateau aquifer. Annual average values were compiled for each location from the individual salinity and conductivity readings taken each year. These annual average water quality metrics are available in Appendix C. The annual average values were further charted into five-year rolling averages to discern any long-term trends. The five-year averages at 2012 (the first year for which a full five-year average exists) and 2020 were then compared.

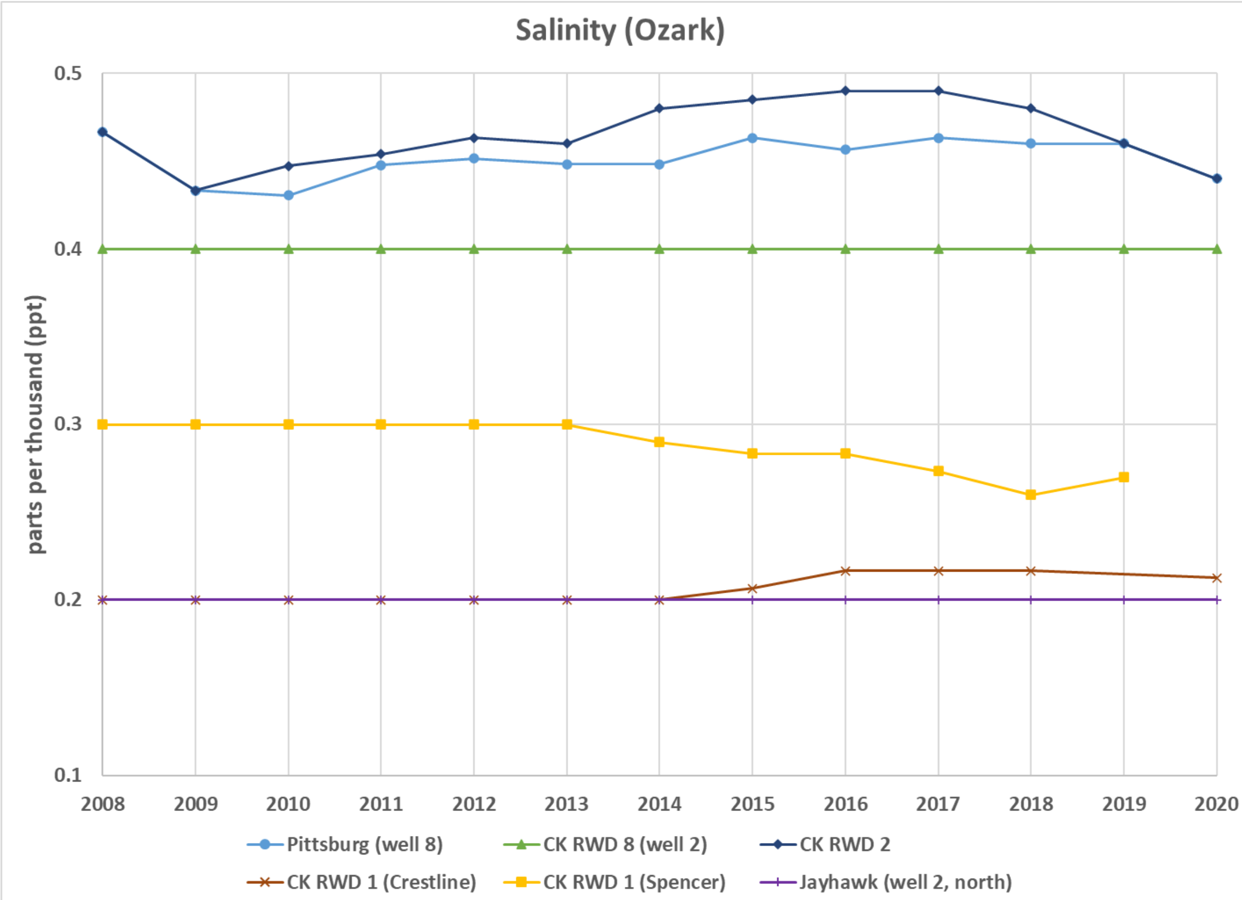

Figure 11: Five-year rolling average of salinity in the Ozark Aquifer

Figure 11 shows the salinity levels for six wells in the Ozark Aquifer on a five-year rolling average. Between 2012 and 2020, the five-year average salinities differed by a mean -0.01 ppt. The differences in salinity averages varied from a minimum of -0.03 ppt at the CK RWD 01 Spencer well to a maximum of +0.01 ppt at the CK RWD 01 Crestline well. The standard deviation in the salinity differences for the 6 wells was 0.02 ppt. In this analysis, 2019 data for the CK RWD 01 Spencer well was substituted for 2020 because data had not been collected for that site in 2020.

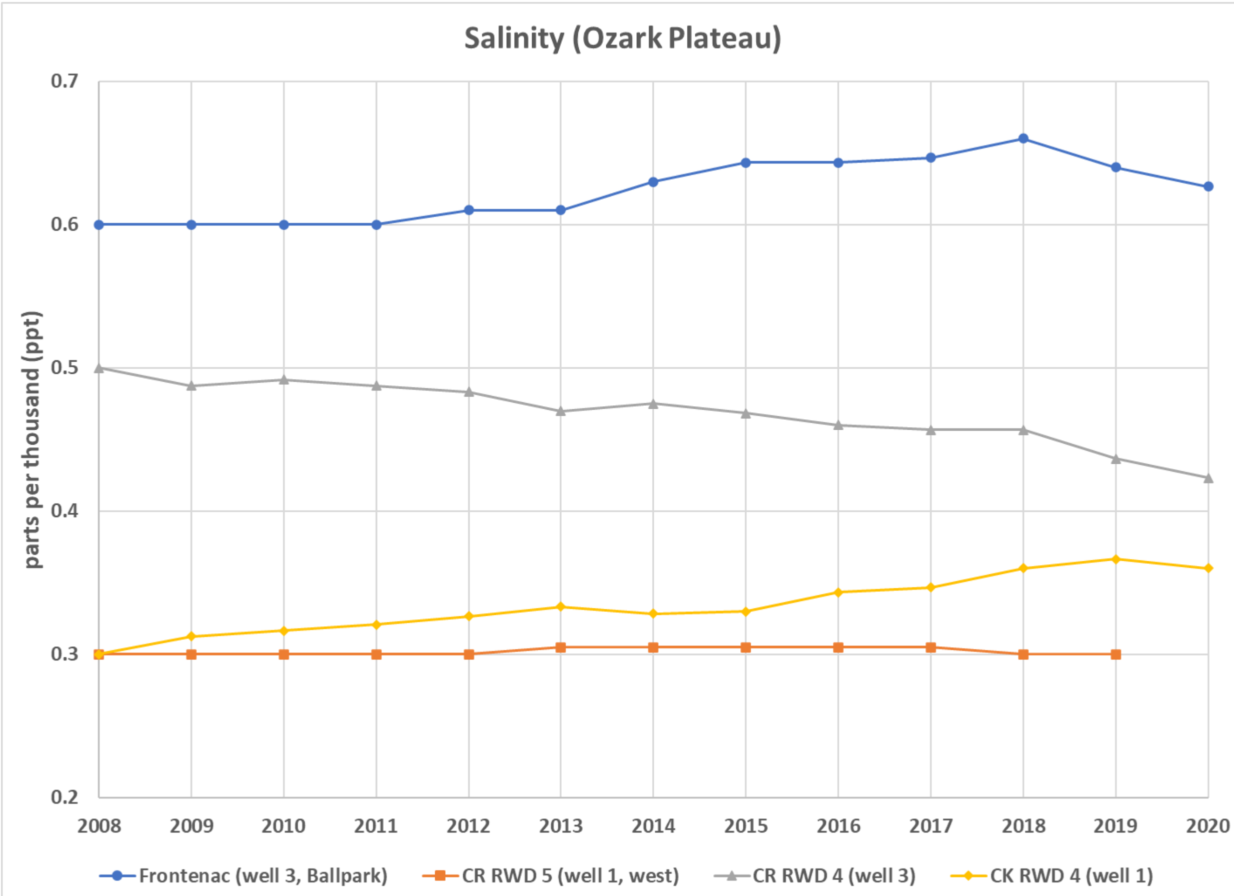

Figure 12: Five-year rolling average of salinity in the Ozark Plateau Aquifer

Figure 12 shows the salinity levels for four wells in the Ozark Plateau Aquifer on a five-year rolling average. Between 2012 and 2020, the five-year average salinity differences of the four wells showed almost no mean change. The differences in salinity averages varied from a minimum of -0.06 ppt at the CR RWD 04 well 3 to a maximum of +0.03 ppt at the CK RWD 04 well 1. The standard deviation in the salinity differences for the 4 wells was 0.04 ppt. In this analysis, 2019 data for the CR RWD 05 well was substituted for 2020 because data had not been collected for that site in 2020.

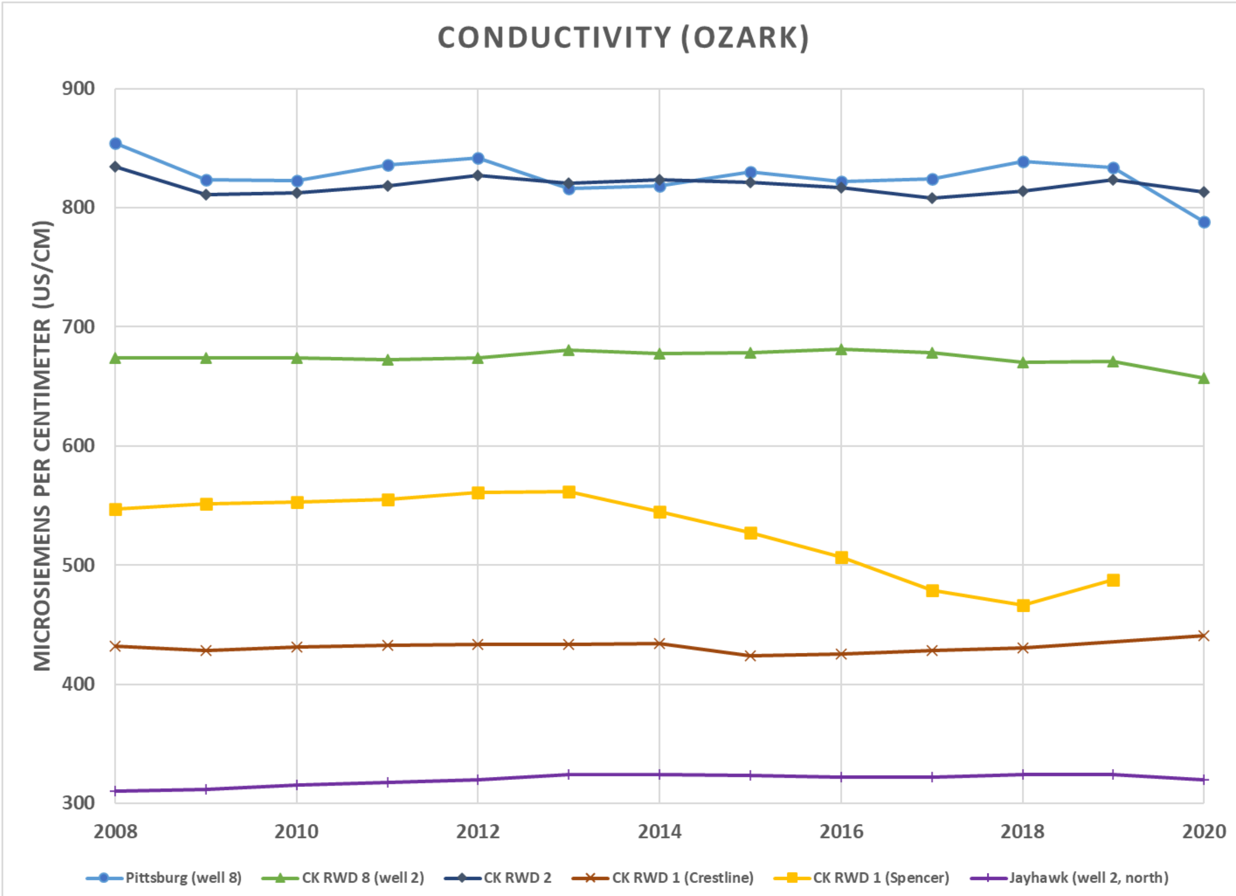

Figure 13: Five-year rolling average of conductivity in the Ozark Aquifer

Figure 13 shows the conductivity for six wells in the Ozark Aquifer on a five-year rolling average. Between 2012 and 2020, the five-year average conductivity differed by a mean -24 uS/cm. The differences in conductivity averages varied from a minimum of -0.68 uS/cm at the CK RWD 01 Spencer well to a maximum of +8 uS/cm at the CK RWD 01 Crestline well. The standard deviation in the conductivity differences for the 6 wells was 30 uS/cm. In this analysis, 2019 data for the CK RWD 01 Spencer well was substituted for 2020 because data had not been collected for that site in 2020.

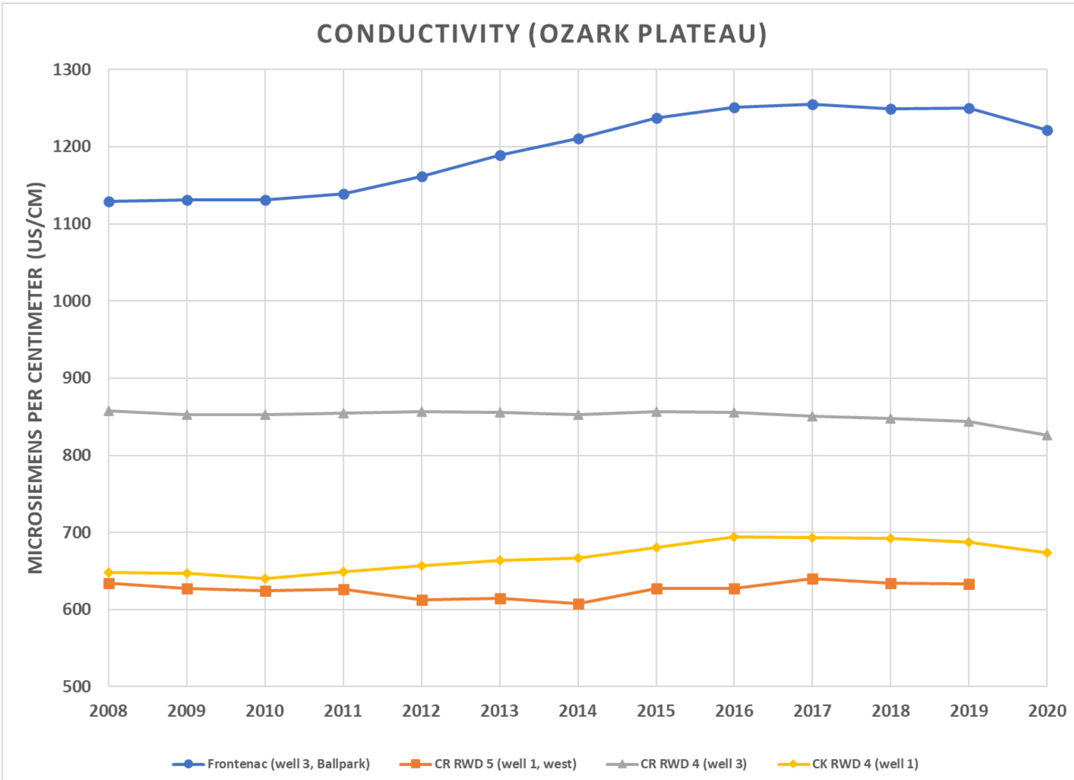

Figure 14: Five-year rolling average of conductivity in the Ozark Plateau Aquifer

Figure 14 shows the conductivity for four wells in the Ozark Plateau Aquifer on a five-year rolling average. Between 2012 and 2020, the five-year average conductivity differed by a mean +12 uS/cm. The differences in conductivity averages varied from a minimum of -0.31 uS/cm at the CR RWD 04 well 3 to a maximum of +61 uS/cm at the City of Frontenac well 3. The standard deviation in the conductivity differences for the 4 wells was 38 uS/cm. In this analysis, 2019 data for the CR RWD 05 well was substituted for 2020 because data had not been collected for that site in 2020.

VI. Water Use

The portions of the Neosho River basin, Spring River basin, and Marmaton River basin within the Ozark Plateau moratorium region has a total of 314 water rights with an authorized quantity of 103,403 acre-feet[1]. The source of supply is groundwater for 117 water rights, or 37% of the total rights (Table 3).

Table 3: Water Rights in the Former Ozark Moratorium Area[1]

Type	**Source**	**Number of Rights**	**Authorized Quantity** (to nearest acre-foot)
Vested	Surface Water	17	55,264
Appropriated	Surface Water	180	33,093
Vested	Groundwater	14	2,111
Appropriated	Groundwater	103	12,934
Total		**314**	**103,403**

The points of diversion associated with these water rights are shown in Figure 18. One water right may have multiple points of diversion. In the Neosho River basin, some municipal and industrial users obtain some of their water supply from federal reservoirs through Water Marketing contracts. Since Marketing Program contracts do not require water appropriation permits, diversions under contract are not reflected in Table 3. Additionally, all municipal and industrial users who divert surface water in the Neosho River basin are required to be members of the Cottonwood and Neosho River Basins Water Assurance District No. 3, which supports diversions of its members from a dedicated pool in Assurance reservoirs.

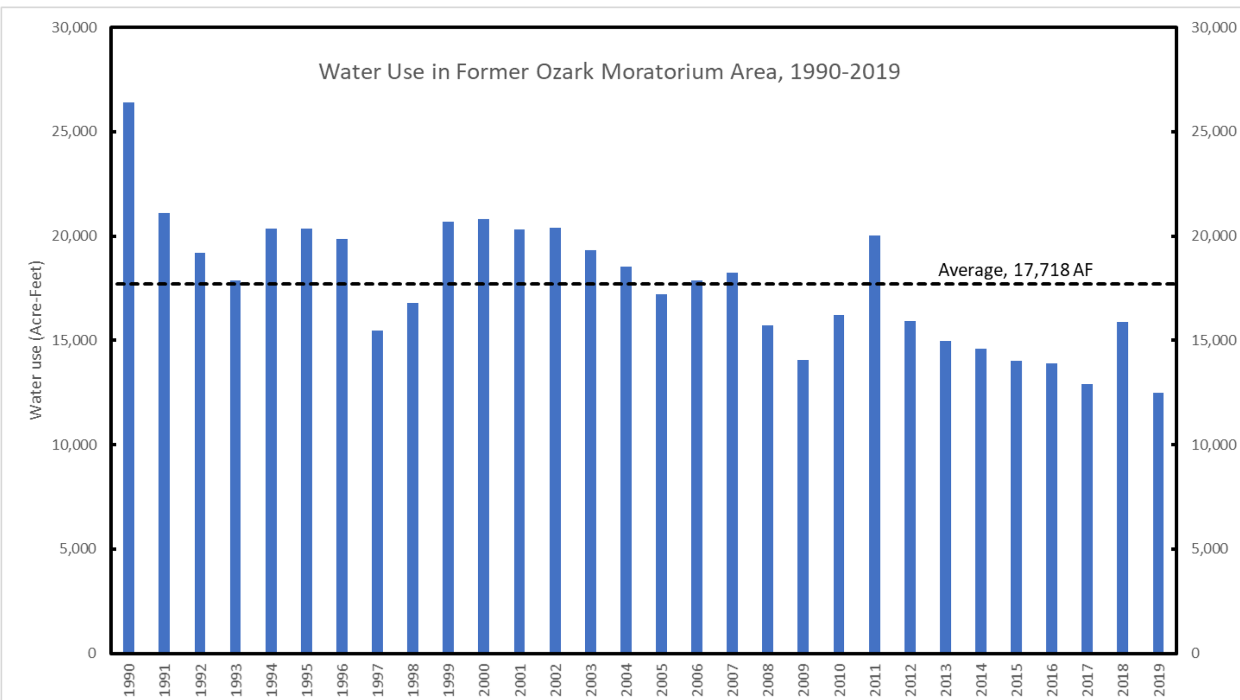

Figure 15: Ground and Surface Water Use 1990-2019[1]

[1] The authorized acre-feet and annual water use for surface water include the vested and appropriated water rights of the Empire District Electric Company. Previous Ozark Plateau subbasin reports included total authorized quantities and total diversions for operations at the plant, which are largely flow-through cooling and a large portion of that water is discharged back into the Spring River. This report reflects the total authorized and reported consumptive use of water only for the Empire District water rights to better reflect actual use of water in the subbasin.

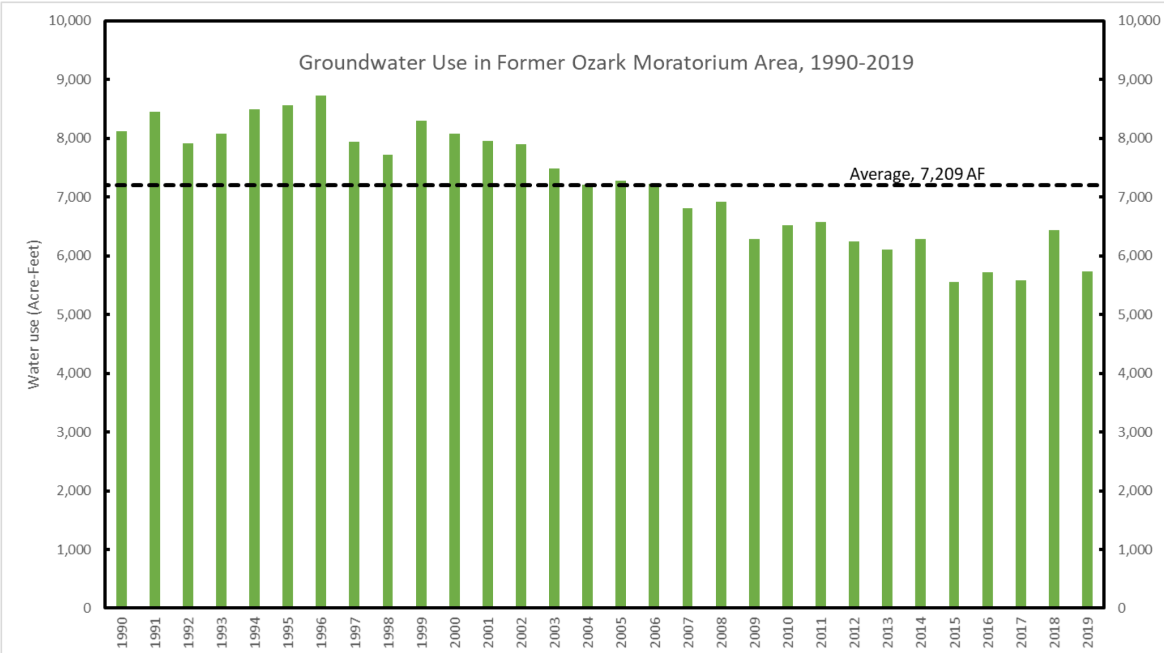

Figure 16: Groundwater Use 1990-2019

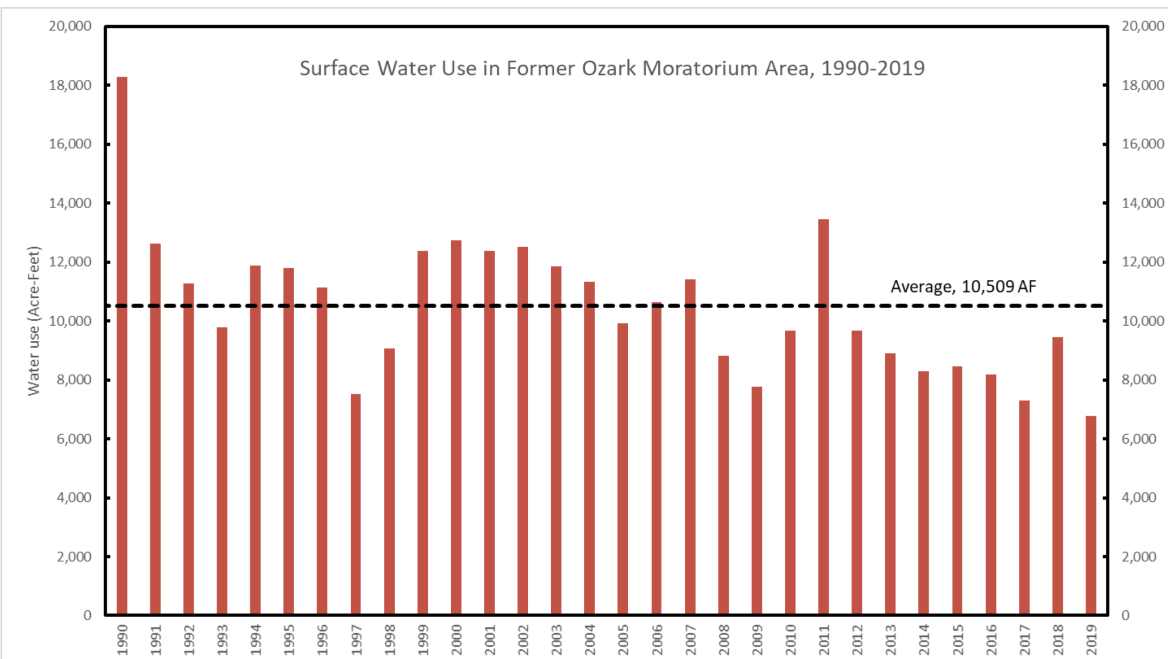

Figure 17: Surface Water Use 1990-2019

Overall area water use in the former Ozark Moratorium Area has shown a somewhat downward trend in the past 30 years. From 1990-2019, water use ranges from 26,414 acre-feet in 1990 to 12,504 acre-feet in 2019. The total average water use over the thirty-year span was 17,718 acre-feet. Groundwater use averages 7,209 acre-feet per year from 1990-2019, which is 48% of authorized quantities. Average surface water use is 10,509 acre-feet, which is 12% of authorized quantities. The thirty-year downward trend in water use is reflected in both surface and groundwater use individually.

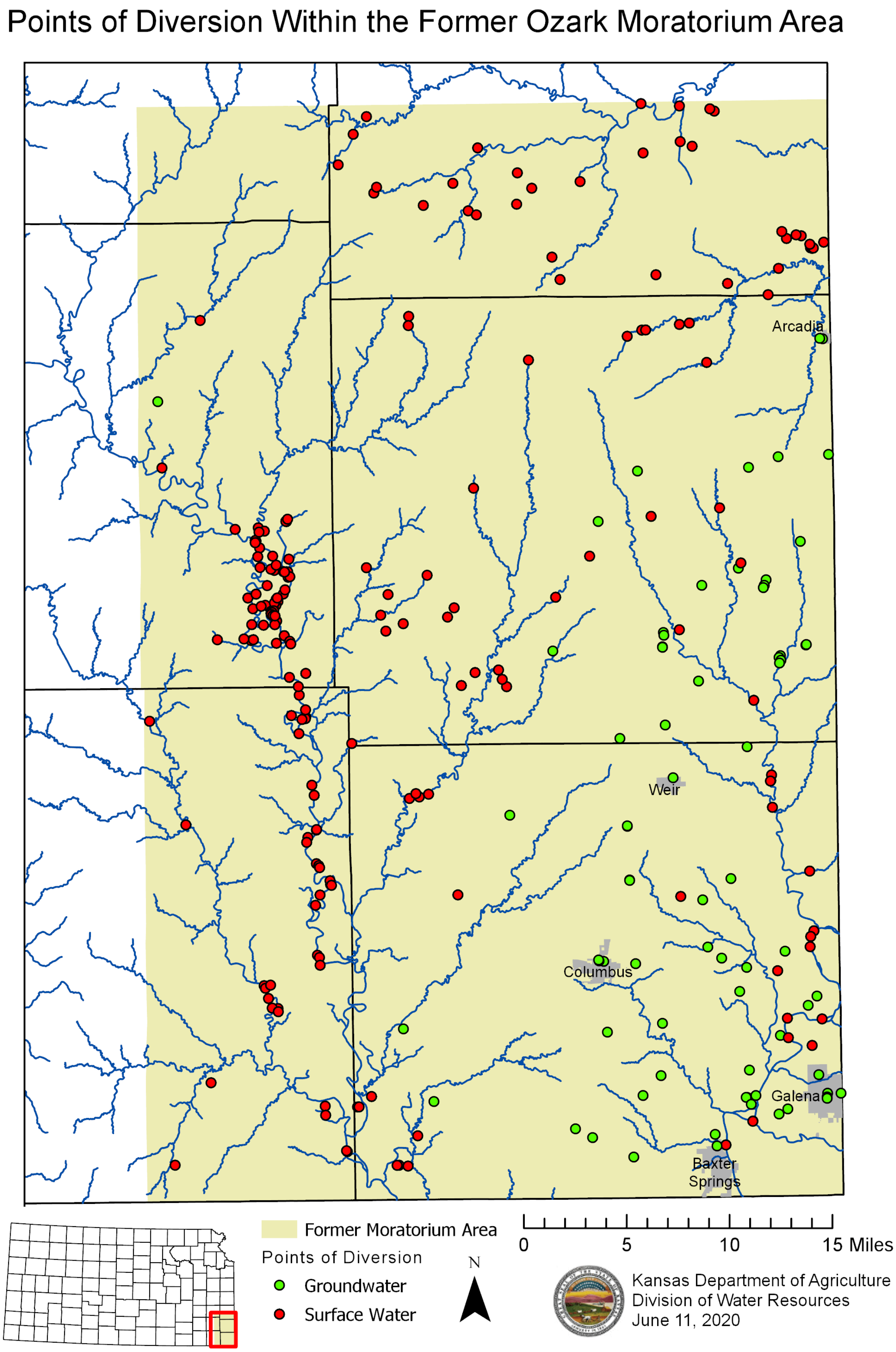

Figure 18: Points of Diversion within the Former Ozark Moratorium Area

VII. Conclusions

In conclusion, precipitation in the formerly regulated boundary area has been mostly above average in the past ten years, despite drought conditions in the early part of the decade. Both groundwater and surface water use in the 2010-2019 period has been, for the most part, well below the thirty-year average usage. Water usage has declined despite new appropriations and greater authorized quantities in the area as compared to ten years ago. Decreased usage can likely be explained, at least in part, by above average rainfall, most notably in the latter half of the decade. Increased precipitation results in an overall lower demand for both municipal and irrigation use of water. In general, the Ozark aquifer and the Ozark Plateau aquifer water levels have increased over the past decade. The increasing trend in water level is most pronounced in wells located in Crawford county. Most of the wells located in Cherokee county have also shown some increases in water level as well. However, when looking at wells in far southeastern Cherokee county, some have remained static, some have shown slight declines, and some (notably Galena and Baxter Springs) appear to show somewhat drastic declines. It is difficult to pinpoint causes for decreased well levels, especially because these wells have historically shown large drawdown effects from local municipal pumping; so, there is a relatively large degree of variability in measurement data. Proximity to the state line and out of state demand on the aquifer for industrial and municipal use is a likely contributing factor to the decreasing trend. Water quality data appears to remain largely consistent over time for both salinity and conductivity metrics. There does not seem to be any long-term trends, either increasing or decreasing, in the five-year average water quality measurements.

Due to the overall increasing water levels in most of the monitoring wells, a reduction in time and resources spent collecting data seems warranted. However, the water levels in southeastern Cherokee remain a possible concern. It is suggested that water level measurements continue for the monitoring network semiannually (down from the current tri-annually) in the early winter and early summer periods, six months apart (December and June). Given the consistency of water quality data, and no obvious correlations with water levels, it is suggested that water quality measurements be discontinued. Going forward, these actions will balance the time resources of DWR personnel with ensuring a continued presence and information source on the health of the Ozark Plateaus aquifer system.

VIII. Appendix A

KGS No.	Description	Aquifer	Legal	Lat (NAD 83)	Long (NAD 83)
CK 01	CK RWD 3 (well 1)	Ozark	34S24E17SWSWSE	37.075 N	94.804 W
CK 02	Columbus (well 4)	Ozark	32S23E13NENENW	37.177 N	94.843 W
CK 03	Galena (empire)	Ozark	34S25E14NWNWNE	37.089 N	94.639 W
CK 04	Weir (well 1)	Ozark Plateaus	31S24E27NWSESW	37.313 N	94.771 W
CK 05	Baxter Springs (well 6)	Ozark	34S24E36NENWNW	37.046 N	94.737 W
CK 06	Baxter Springs (well 5)	Ozark	34S24E36NWNWSW	37.037 N	94.735 W
CK 07	Galena (vested)	Ozark	34S25E23SENENE	37.072 N	94.632 W
CK 09	Jayhawk (well 2, north)	Ozark	34S25E4NENWNE	37.119 N	94.674 W
CK 10	Jayhawk (well 1, south)	Ozark	34S25E4NENWNE	37.117 N	94.675 W
CK 11	CK RWD 1 (Crestline)	Ozark	33S25E18NENESE	37.170 N	94.705 W
CK 12	CK RWD 1 (Spencer)	Ozark	33S25E9SENESE	37.180 N	94.669 W
CK 13	CK RWD 4 (well 1)	Ozark Plateaus	32S24E29NWNWNW	37.237 N	94.813 W
CK 14	CK RWD 2 (well 1)	Ozark	34S25E8SWNWSW	37.093 N	94.704 W
CK 15	CK RWD 9 (well 1)	Ozark	34S25E20NWNENW	37.074 N	94.693 W
CK 16	CK RWD 8 (well 1)	Ozark	34S25E21NWNESE	37.064 N	94.669 W
CK 17	CK RWD 8 (well 2)	Ozark	34S25E28NWNWNW	37.060 N	94.677 W
CR 02	CR RWD 5 (well 2)	Ozark Plateaus	30S25E23SESWSW	37.411 N	94.645 W
CR 04	Arcadia (well 2)	Ozark	28S25E1NESWNE	37.398 N	94.670 W
CR 06	Arma (well 2)	Ozark Plateaus	29S25E5SESESW	37.464 N	94.779 W
CR 07	Frontenac (well 1)	Ozark Plateaus	30S25E4NESWSW	37.455 N	94.684 W
CR 09	DWR Pittsburg Deep	Ozark	30S25E28NENESE	37.398 N	94.670 W
CR15	DWR Pittsburg Shallow	Springfield	30S25E28SENESE	37.402 N	94.669 W
CR16	DWR McCune	Ozark	31S22E16SESESW	37.340 N	95.000 W
CR 17	Pittsburg (well 10)	Ozark	30S25E28NESESE	37.398 N	94.670 W
CR01	*CR RWD 4 (Well 1)**	*Ozark Plateaus*	30S24E28NENENE	*37.411 N*	*94.780 W*
CR03	*CR RWD 4 (Well 3)**	*Ozark Plateaus*	31S24E16NENENE	*37.353 N*	*94.778 W*
CR05	*Girard (well 3)**	*Ozark*	30S24E21NESENE	*37.536 N*	*94.742 W*
CR08	*Pittsburg (Well 11)**	*Ozark*	30S25E28SESESE	*37.398 N*	*94.670 W*
CR10	*CR RWD 1C (NW well)**	*Ozark*	30S24E2SESESE	*37.460 N*	*94.734 W*
CK 08	*Galena (tower)**	*Ozark*	34S25E13SWSWSW	*37.075 N*	*94.631 W*

**Denotes well no longer actively measured on the monitoring network*

XI. Appendix B

Average Annual Well Levels - Ozark Well Monitoring Network

Description	KGS No.	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CK RWD 3 (well 1)	**CK 01**	184.21	191.16	184.76	196.65	195.11	186.72	194.17	192.74	192.33	184.93	167.22	155.42	146.13	142.17	148.43	154.70	165.29
Columbus (well 4)	**CK 02**	202.54	206.46	203.25	208.13	202.24	201.09	198.12	196.82	197.71	197.59	191.80	188.36	184.57	183.27	181.23	180.30	183.03
Galena (empire)	**CK 03**	138.91	145.36	152.95	146.35	141.65	146.58	140.03	152.93	152.97	151.13		147.35	150.57	158.23	162.13	170.60	171.405
Weir (well 1)	**CK 04**	243.51	239.16	245.15	245.02	234.50	233.34	232.12	232.78	235.46	232.28	232.21	229.32	227.35	224.70	234.20	227.50	222.975
Baxter Springs (well 6)	**CK 05**	121.84	131.21	148.74	164.81	188.40	151.25	103.86	121.52	110.27	150.25	149.60	137.51	161.55	109.50	221.92	300.15	249.65
Baxter Springs (well 5)	**CK 06**	180.58	200.90	237.76	203.70	225.11	167.98	86.89	102.53	103.19	183.60	170.60	133.92	146.60	142.47	131.14	269.14	130.75
Galena (vested)	**CK 07**	196.64	231.45	214.20	214.84	190.61	199.03	179.95	252.99	229.76	224.45	183.10	220.33	220.53	237.43	300.27	341.52	356.06
Jayhawk (well 2, north)	**CK 09**	219.87		270.56	253.58	278.90	255.78	240.15	231.51	225.57	257.65	252.79	282.32	248.95	230.40	247.95	241.80	266.94
Jayhawk (well 1, south)	**CK 10**	103.57		114.92	109.40	109.01	104.92	96.38	97.37	99.93	95.60	98.66	99.55	100.87	107.80	106.50	97.13	94.71
CK RWD 1 (Crestline)	**CK 11**		170.88	171.03	166.29	157.48	155.90	147.98	152.38	148.11	143.26	150.84	154.42	166.20	164.17	166.43	123.10	157.07
CK RWD 1 (Spencer)	**CK 12**		113.02	120.19	123.84	117.04	115.52	113.08	113.26	111.61	114.55	112.08	114.26	99.87	103.27	110.07	118.75	91.7
CK RWD 4 (well 1)	**CK 13**	237.92	241.73	239.41	240.14	234.75	233.23	233.22	231.61	230.99	231.35	234.47	232.20	230.80	226.07	230.40	226.10	225.275
CK RWD 2 (well 1)	**CK 14**	120.84	128.94	137.31	131.80	127.38	129.17	112.67	121.37	122.13	130.10	128.13	123.40	126.23	130.20	128.90	129.63	131.99
CK RWD 9 (well 1)	**CK 15**	139.66	165.78	168.19	154.51	164.73	165.55	144.13	158.30	146.76	141.42	142.60	162.77	174.33	150.87	151.10	160.04	146.945
CK RWD 8 (well 1)	**CK 16**	150.09	163.10	168.84	167.42	156.35	160.89	145.33	172.07	173.87	170.54	159.89	163.99	168.27	180.27	187.70	211.07	208.525
CK RWD 8 (well 2)	**CK 17**	125.57	138.90	144.43	146.63	135.70	140.62	125.01	153.25	155.59	156.78	153.08	148.49	153.00	168.25	176.05	202.75	192.34
CR RWD 5 (well 2)	**CR 02**		284.40	287.96	280.51	273.10	271.64	269.68	272.00	272.28	269.58	265.89	265.58	261.57	258.67	262.22	258.75	249.27
Arcadia (well 2)	**CR 04**	154.20	160.50	159.61	155.73	149.79	148.33	147.85	149.73	145.42	150.14	148.08	141.91	140.90	137.90	141.47	139.75	133.005
Arma (well 2)	**CR 06**	337.57	344.11	342.15	339.44	336.86	332.06	331.42	333.01	336.27	336.08	335.70	331.63	326.07	323.97	325.17	325.47	316.78
Frontenac (well 1)	**CR 07**		296.62	299.73		270.00				274.03	286.90	279.31	275.10	274.13	274.27	270.00	267.80	260.84
DWR Pittsburg Deep	**CR 09**			267.66	260.41	255.00	249.00	252.00								239.62	242.00	229.37
DWR Pittsburg Shallow	**CR15**			249.76		223.00	222.00	220.00								215.61	215.28	212.86
DWR McCune	**CR16**				191.56	189.00	187.00	186.00						178.48	178.40	178.37	176.83	172.495
Pittsburg (well 10)	**CR 17**					257.77	249.94	247.61	250.64	248.49	253.78	244.85	238.40	228.43	224.97	226.73	223.60	213.55
CR RWD 1C (NW well)*	***CR10***	288.31	287.26	281.20	278.95	268.94	266.09	266.16	268.48	270.75	262.38	248.33						
Pittsburg (Well 11)*	***CR08***	256.51	263.33	265.40	254.21	248.92	250.19											
Girard (well 3)*	***CR05***	247.00	255.57	255.53	253.90	247.08	244.56	244.74	245.60	247.74	245.37							
CR RWD 4 (Well 1)*	***CR01***	255.01	255.18	253.93														
CR RWD 4 (Well 3)*	***CR03***		242.99	241.58														
Galena (tower)*	**CK 08**	218.37	233.74	253.75	221.15	210.13	210.45	190.69	215.42	242.34	239.00	195.60	229.08	234.53	252.40	286.50		

*Denotes wells no longer actively measured on montoring network

**DWR wells (CR09, CR15, & CR16) annual mean levels for years 2008 - 2010 were approximated from Figure 12 of the 2010 Ozark Hydrological Report produced by the DWR Basin Management Team

XI. Appendix C

Avg Annual Salinity (ppt)													
Description	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Frontenac (well 3, Ballpark)	0.60	0.60	0.60	0.60	0.65	0.60	0.70	0.67	0.60	0.67	0.67	0.60	0.60
CR RWD 5 (well 1, west)	0.30	0.30	0.30	0.30	0.30	0.33	0.30	0.30	0.30	0.30	0.30	0.30	
Pittsburg (well 8)	0.47	0.40	0.43	0.50	0.47	0.45	0.40	0.50	0.47	0.50	0.43	0.40	0.40
CR RWD 4 (well 3)	0.50	0.48	0.50	0.48	0.47	0.43	0.50	0.47	0.43	0.45	0.43	0.40	0.40
CK RWD 4 (well 1)	0.30	0.33	0.33	0.33	0.35	0.33	0.30	0.33	0.40	0.37	0.40	0.33	0.30
CK RWD 8 (well 2)	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
CK RWD 2	0.47	0.40	0.48	0.48	0.50	0.45	0.50	0.50	0.50	0.50	0.40	0.40	0.40
CK RWD 1 (Crestline)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.23	0.25	0.20	0.20		0.20
CK RWD 1 (Spencer)	0.30	0.30	0.30	0.30	0.30	0.30	0.25	0.27	0.30	0.25	0.23	0.30	
Jayhawk (well 2, north)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Avg Annual Conductivity													
Description	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Frontenac (well 3, Ballpark)	1130	1134	1130	1161	1253	1270	1239	1265	1231	1269	1243	1241	1127
CR RWD 5 (well 1, west)	634	620	619	630	557	645	589	714	630	622	617	584	
Pittsburg (well 8)	854	792	821	877	864	727	803	879	836	876	798	781	649
CR RWD 4 (well 3)	857	849	853	858	866	855	832	871	853	845	837	815	781
CK RWD 4 (well 1)	648	646	626	676	691	682	660	695	746	685	675	637	627
CK RWD 8 (well 2)	674	674	675	668	681	704	660	681	679	667	666	661	613
CK RWD 2	835	787	817	836	861	804	800	807	814	816	833	847	758
CK RWD 1 (Crestline)	432	425	436	438	435	434	429	385	445	450	443		427
CK RWD 1 (Spencer)	547	556	556	562	585	549	472	468	461	446	484	581	
Jayhawk (well 2, north)	310	313	322	326	327	332	313	319	319	328	343	312	299