ASSESSMENT OF WATER LEVEL DECLINE RATES
WITHIN THE OGALLALA AQUIFER
KANSAS

By 2010, reduce water level decline rates within the Ogallala Aquifer and implement enhanced water management in targeted areas.

INTRODUCTION

In October 1998, the Kansas Water Authority approved objectives for the year 2010 as part of the Kansas Water Plan. The objectives were developed to define targets to quantify achievements of the Kansas Water Plan. The above objective is included in the Water Right Management Policy Section of the FY 2003 Kansas Water Plan.

Assessment of this objective is two fold: 1) Identify the annual rate of change in the Ogallala Aquifer based on ground water monitoring wells with at least thirty years of recorded measurements and 2) Estimate the average depth to water in the year 2010 based on regression equations from monitoring wells that that have been measured at least six times in the last eleven years.

The Kansas Water Office (KWO) used KWP funds to contract with the Geohydrology Section of the Kansas Geological Survey (KGS) to establish historical trends in the water table and make projections to the year 2010 that are shown in this assessment.

ASSESSMENT DATA SETS

In order to determine the water level rates of change within the Ogallala, data from the KGS WIZARD database was used. The WIZARD database is the repository for the State of Kansas cooperative monitoring well program operated by the KGS and the Kansas Department of Agriculture, Division of Water Resources. Previously, this dataset was maintained by the United States Geological Survey as part of the Ground Water Site Inventory (GWSI).

ASSESSMENT DATA PARAMETERS

To establish the historic rate of water level change in the Ogallala Aquifer, monitoring wells that had at least one measurement during the winter months (Dec, Jan, or Feb) in a three-year period centered around 1969, 1979, 1989, and 1999 were selected. Each well had to have at least one measurement within each of the three year, decadal time periods. Winter measurements are selected under the assumption that demands to the aquifer are lessened since most irrigation pumping, the Ogallala's primary use of water, is idle. Where multiple measurements existed for a single well in a three-year time frame, the most recovered value (the highest elevation observed) was chosen to represent the water table for that well.

The selected monitoring wells were further identified based on the spatial distribution to the appropriate western Groundwater Management Districts (Western Kansas GMD #1, Southwest Kansas GMD #3, and Northwest GMD #4) and the overlying western KWO planning basins (Cimarron, Smoky Hill-Saline, Solomon, Upper Arkansas, and Upper Republican). The arithmetic average, first standard deviation, and a 95 percent confidence interval for the true average water level were then calculated. Calculating the difference in measurements for each monitoring well between the ten-year time periods of 1969 to 1979, 1979 to 1989, and 1989 to 1999 and dividing it by 10 provided the estimated annual rate of change for each decadal period.

To project the average depth to ground water in the Ogallala Aquifer region of the state in the year 2010, all monitoring wells from the WIZARD database that had at least six years of measurements from 1989 to 1999 were selected. Based on the spatial distribution of the monitoring wells in relation to the extent of the three western Groundwater Management Districts and the western KWO planning basins, the average depth to water was determined. These values provided the source data for the regression equations and resulting 2010 depth to water projections.

ASSESSMENT RESULTS

Annual Rate of Change Based on Thirty Years of Measurements

As can be seen in Figure 1, the rate of decline across the Ogallala Aquifer region of the state has slowed substantially between the 1969-1979 and 1989-1999 time periods. The vertical lines on the graph represent an uncertainty of one standard deviation. This is the range that can be expected to include roughly 66 percent of all the measurements for that period and region of the state.

As a whole, the rate of ground water decline in the Ogallala has decreased from an annual rate of approximately 1.4 feet per year from 1969 to 1979 to just over 0.5 feet per year from 1989 to 1999 (Table 1). Relatively, the annual rate of decline for both the Groundwater Management Districts and KWO planning basins is higher in the southern extent of the Ogallala in the state and shows progressively lower declines towards the northern extent of the Ogallala in Kansas.

Figure 1
Annual Rate of Decline, by Decade, for the Ogallala Aquifer, 1969 - 1999

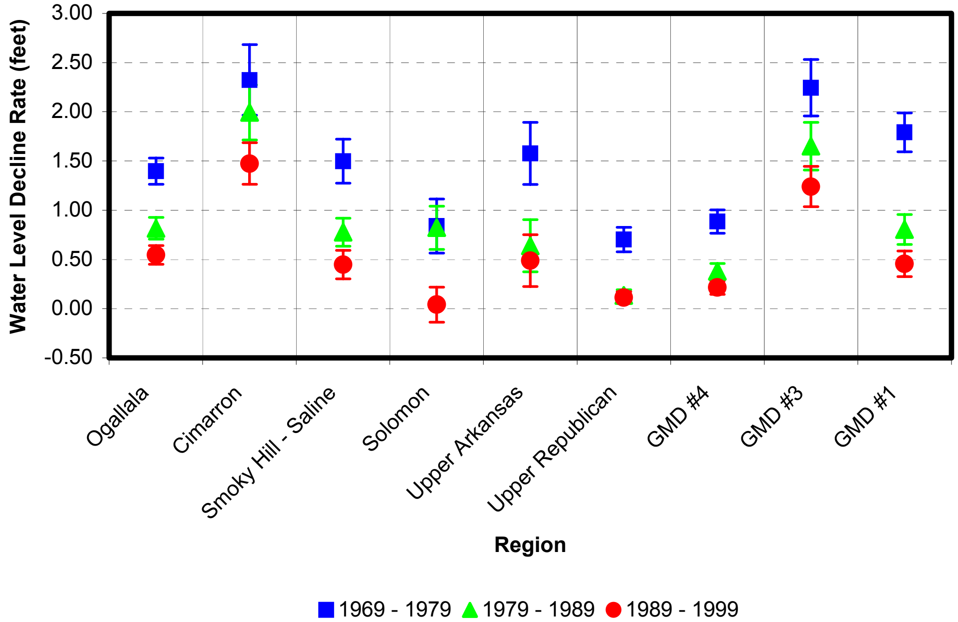


Table 1 **Average Annual Rate of Decline, in Feet per Year, by Decade and Region, Ogallala Aquifer, 1969 – 1999**			
Region	**1969-1979**	**1979-1989**	**1989-1999**
Cimarron	2.32	1.99	1.47
Smoky Hill- Saline	1.50	0.78	0.45
Solomon	0.84	0.82	0.04
Upper Arkansas	1.58	0.64	0.49
Upper Republican	0.70	0.13	0.11
Northwest Kansas GMD #4	0.88	0.38	0.21
Southwest Kansas GMD #3	2.24	1.65	1.24
Western Kansas GMD #1	1.79	0.80	0.46
Entire Ogallala Aquifer	**1.40**	**0.82**	**0.55**

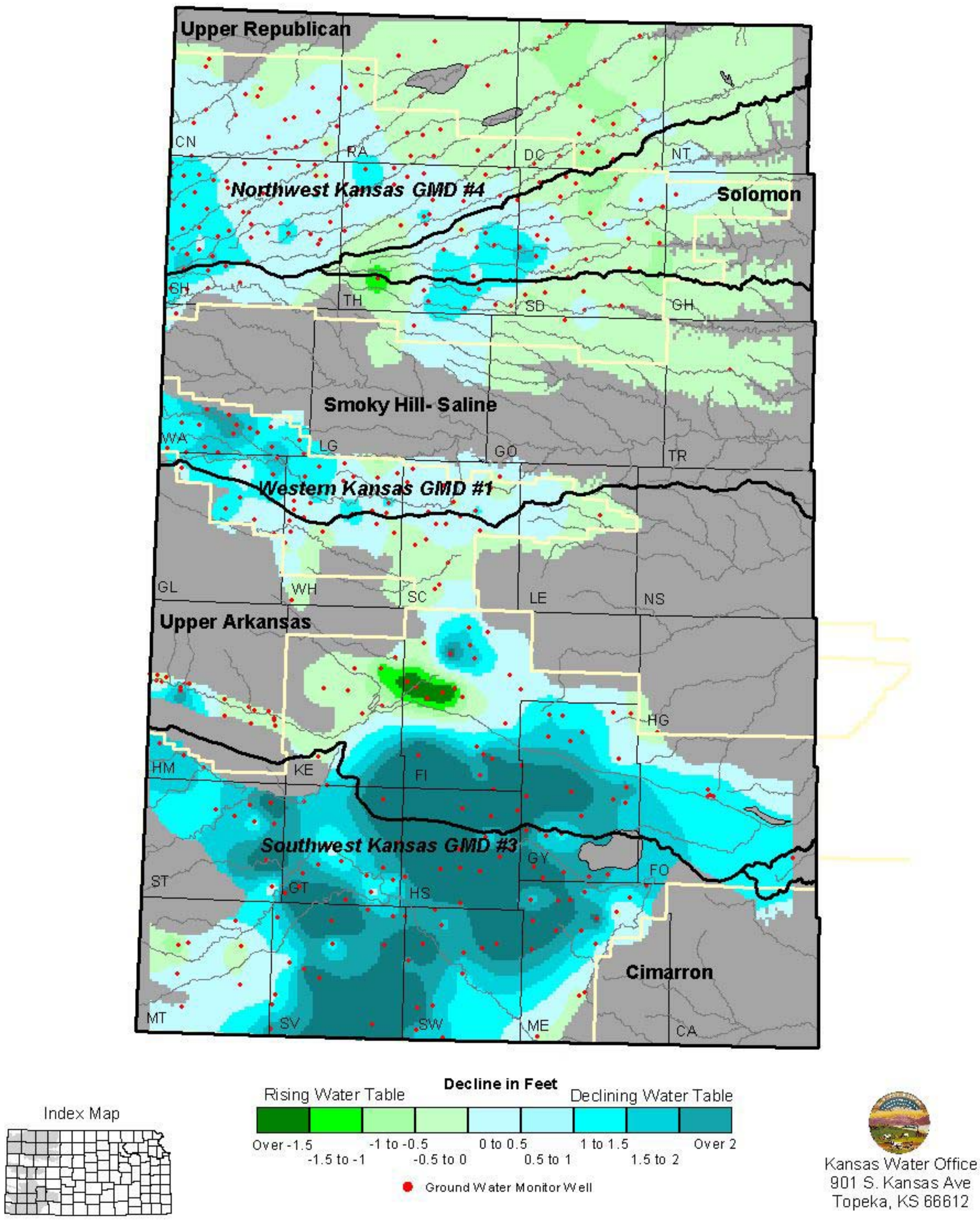
For each of the decadal time periods, the rate of ground water decline shows the most reduction from the 1969-1979 to 1979-1989. Likely factors for this reduction include the introduction of State law in 1978 that a water right permit had to be obtained before a well could be drilled and the combination of advancements in crop yield response to water applications and the further adoption of improved irrigation sprinkler systems across the state.

For all the identified regions of the Ogallala, the most recent time period of 1989-1999 shows the lowest rates of decline. The decade of the 1990s was significantly wetter resulting in lower water use and higher rates of ground water recharge. Other factors that may have contributed to the overall reduction include untimely climatic events, more efficient use of water, and an increasing awareness by the general public towards water conservation.

In terms of KWO planning basins, the Solomon and Upper Republican Basins have historically and more recently had a lower rate of ground water decline than the other western, Ogallala basins. The Cimarron Basin has the highest rate of ground water decline overall. This likely attributed to more ground water right development, relative to other areas in the region. The Upper Arkansas and Smoky Hill- Saline Basins have shown the greatest overall reduction in the rate of decline from 1.58 and 1.50 feet/year, respectively, between 1969 and 1979 to 0.49 and 0.45 feet/year, respectively, from 1989 to 1999.

The annual rates of decline listed in Table 1 represent regional averages of the overall trends in the change of the water table. These averages can mask-out very real differences occurring within the regions themselves as can be seen in Figure 2. The map in Figure 2 is an interpolated change in the water table from 1989 to 1999 based on the same data points used in Table 1. Areas of green indicate a rising water table, while areas in blue represent a declining water table. In every KWO planning basin, there are areas where the water table is estimated to be either declining or rising almost one foot a year during the 1989-1999 time period. The notable areas of rising water levels in northern Kearny and Finney counties are likely caused by water seepage from the surface water irrigation ditches operating in the region. Figure 2 illustrates that even within basins or GMD boundaries, differences in the rate of ground water decline do occur which supports the focus of this 2010 objective for implementing enhanced management strategies in targeted areas.

Figure 2
Interpolated Annual Rate of Decline- Ogallala Aquifer, 1989-1999



Projected Depth to Water Based on Recent Ground Water Elevation Trends

As was noted in the Assessment Data Parameters section of this report, to estimate the average depth to water in the year 2010, regression equations were generated for monitoring wells that have been measured at least six times in the last eleven years. It would be expected that these values should be similar to those obtained in Table 1 for the 1989-1999 time-period, which were based on wells measured in a three year time-period around the years 1969, 1979, 1989, and 1999.

Where the rate of water level decline was statistically significant, a linear trend line was found to have the best fit with the data points compared to other non-linear methods. The trend lines were extrapolated to the year 2010 and a projected value determined for that year. In cases where the change was not statistically significant, a constant term function was used. Table 2 shows the average depth to water for 1999, the average rate of decline from 1989 to 1999, the projected depth to water in the year 2010, and if the change is statistically significant.

Table 2
Average Water Levels and Trends, in Feet, Projected to the Year 2010
Ogallala Aquifer, 1989 to 1999

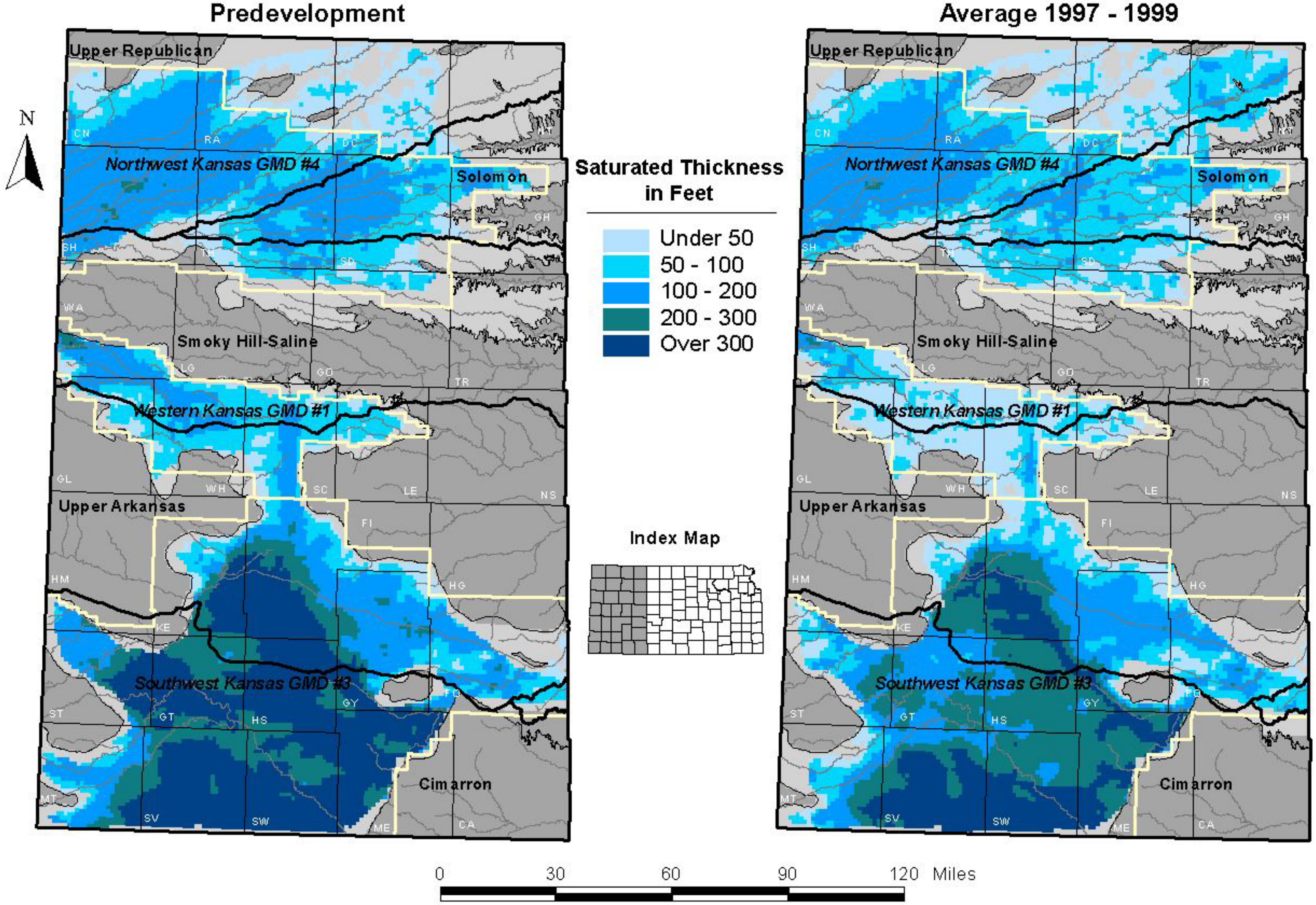
Region	Average Depth to Water 1999	Average Rate of Decline	Projected Depth to Water, 2010	Signif-icance
Cimarron	182.77	1.340	197.50	Yes
Smoky Hill- Saline	126.43	0.142	128.00	No
Solomon	111.12	0.003	111.15	No
Upper Arkansas	112.09	1.181	125.08	Yes
Upper Republican	132.81	0.326	136.40	Yes
Northwest Kansas GMD #4	131.37	-0.171	129.49	No
Southwest Kansas GMD #3	155.59	1.594	173.12	Yes
Western Kansas GMD #1	133.09	0.836	142.29	Yes
Entire Ogallala Aquifer	**135.29**	**0.900**	**145.19**	**Yes**

The regression equations, for all regions of the Ogallala Aquifer, project varying levels of decline in the water table in the year 2010, with the exception of the Northwest GMD #4 (Table 2). As a whole, if the average annual decline rates in the Ogallala Aquifer continue at a rate of 0.9 feet per year, the average depth to water for the entire aquifer is projected to increase from 135.29 feet to 145.19 feet in the year 2010. Both Table 2 and Table 1 find an average rate of decline of over a foot per year for the GMDs and KWO planning basins in the southern extent of the Ogallala within the state and progressively smaller declines towards the northern extent of the Ogallala in Kansas. However, Table 1 estimates higher declines in the Smoky Hill- Saline Basin and Northwest GMD #4 during the 1989-1999 time-period while Table 2 estimates greater decline rates in the Upper Arkansas Basin. The differences in averages between the two tables are the result of specific data selection criteria. Table 1 required that only wells selected in each three-year period around 1969, 1979, 1989, and 1999 where Table 2 selected all wells measured at least six times over the last eleven years.

It should be noted that Table 1 and Table 2 simply quantify the rate of change in the water table. It is rational to consider the rate of change in relation to amount and spatial distribution of ground water availability. Lower rates of decline in areas of the Ogallala where the saturated thickness is thinner may be more significant than other areas of the aquifer where the declines are higher but there is a greater amount of water in storage. In terms of resource availability, the saturated thickness of an aquifer is often used as an indicator of how much water is available for use. Figure 3 shows the estimated saturated thickness for the saturated portion of the Ogallala Aquifer during predevelopment periods, generally the late 1940s and early 1950s, and the average from 1997-1999.

For the deeper portions of the Ogallala, a saturated thickness of 30 feet has often been used as an approximate value for the minimum thickness needed to support large volume water pumping. In areas of the northern and in particular, central extents of the Ogallala, ground water declines are smaller relative to other areas, however, as can be seen from Figure 3, there are areas within these regions where the saturated thickness is estimated to be under 50 feet. Conversely, the southern areas of the Ogallala in Kansas, where the declines have been greater, generally have larger amounts of water in storage, both historically and in present day.

Figure 3
Estimated Predevelopment and Average 1997-1999 Saturated Thickness for the Ogallala Extent of the High Plains Aquifer



CONCLUSION

Overall, results of this assessment indicate the goal of reducing decline rates in the Ogallala Aquifer are being achieved. The regionalized average rate of decline is variable across the Ogallala. When looking at long-term historical wells measured since 1969, the rates of ground water decline have slowed substantially over the last three decades. However, the calculated rate of change varies when compared to monitoring wells measured at least six times in the last eleven years. Relatively, ground water declines in the southern part of the Ogallala have been and are projected to be greater than those in the central and northern portions of the Ogallala in Kansas.

The rate of ground water decline in relation to the existing saturated thickness of the aquifer is also highly variable. In terms of resource availability, areas where the saturated thickness of aquifer has been reduced to a point where large volume pumping is close to becoming impractical, any further reduction in the water table, regardless of the actual rate, may have a greater impact in reducing the amount of usable water than areas where the rate of decline is greater but more water is in storage.

The Ogallala Aquifer in Kansas has been intensely managed for several years with the passage of several key acts, namely, the Water Appropriation Act, the Groundwater Management District Act, and the Kansas Water Planning Act. These efforts in combination of other management activities have all work towards slowing the rate of ground water decline and have served to conserve and extend the usable life of the Ogallala. However, as a whole, the amount of water that has been legally appropriated in the Ogallala is well above the amount of water that is recharged to the aquifer system each year. As such, it can only be expected that the Ogallala Aquifer will continue to be stressed and will continue to decline at varying, albeit, improved levels. With continued declines in the amount of water in storage, it can be only assumed there will be some point in time when the aquifer will not be able to support all water demands placed upon it.

Given the heterogeneity of the Ogallala Aquifer in terms of the wide variances in the rate of change of the water table and the estimated saturated thickness, this assessment lends to support of targeted enhanced management plans to targeted areas. This focus of targeting management programs to specific areas in turn supports the report of the Kansas Water Authority's Ogallala Management Advisory Committee where it is recommended that the Ogallala Aquifer be managed by setting water use goals for aquifer subunits (areas of the aquifer that have common characteristics). Under this strategy, enhanced management plans can be tailored to specific issues for specific areas.