CRP Effects on the Ogallala Aquifer

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Introduction

The regional assessments undertaken as part of the Conservation Effects Assessment Program-Wetland Components (CEAP-Wetlands) are designed to produce regional estimates of wetland ecosystem services. More specifically, these regional assessments are designed to quantify the effects with and without implementation of USDA conservation practices and programs; develop predictive wetland functional condition indicator models; quantify and compare effects of alternative environmental or program scenarios on regional wetland services; and, where applicable, develop scientific and technological tools that improve the conservation and sustainability of wetlands in agricultural landscapes.

To support the CEAP-Wetlands regional assessment for The High Plains (THP), the purpose of this study is to examine the influence of Conservation Reserve Program (CRP) on local and regional groundwater-levels. This effort specifically aims to investigate and quantify consequences of targeting reenrollment in the FSA Commodity Credit Corporation (CCC's) Conservation Reserve Program (CRP) to conserve groundwater.

In particular, this research aims to identify the consequences of enrolling lands into the CRP based on groundwater-levels. By better identifying land for water savings and groundwater recharge, the Department of Agriculture will be better able to target financial assistance (FA) and technical assistance (TA) enrollment to landowners participating in the CRP, thereby furthering the water conservation goals of the CRP.

Within this broader context, results of the research will benefit wetland science, enhance conservation of natural resources, and ultimately benefit society at large.

Background

As part of the USDA-ARS, Ogallala Aquifer Program, the Texas Tech University Center for Geospatial Technology (CGST) developed a geodatabase containing data from thousands of wells in west Texas covering a period from 1990 to 2004. The raw well-data were obtained from the Texas Water Development Board well-monitoring network as reported from local groundwater conservation districts. Well data were then processed using a geographic information system (GIS) to develop regional map layers depicting the depth to water, saturated thickness, and change in saturated thickness and water in storage for the southern High Plains Aquifer in Texas.

The map layers developed during this study of the Ogallala (High Plains) Aquifer then served as the basis for a subsequent study concerned with the effects of CRP on water-levels and water storage on the Texas High Plains. For the Texas CRP study, areas underlying CRP and areas not underlying CRP were extracted from the regional dataset. This permitted calculating changes in the elevation of the water table surface and available water in storage beneath CRP and non-CRP areas for the period from 1990 to 2004.

Results from the original Texas CRP study suggest CRP benefitted groundwater levels, especially in those counties with the most intensive irrigation and highest water use. For example, Table 1 compares the decline in the water table elevation beneath CRP and non-CRP land in Castro, Parmer, Swisher, Lamb and Hale counties. In areas where CRP land overlaid the aquifer, rates of aquifer depletion were generally less – compared to those areas without CRP. Areas without land enrolled in the CRP showed much higher rates of water-level decline.

County	Change in Saturated Thickness 1990-2004 (feet)	
	CRP land	Non-CRP land
Castro	-8.8	-34.3
Parmer	-11.3	-36.9
Swisher	-8.1	-15.1
Lamb	-10.4	-25.1
Hale	-17.0	-27.7

Table 1. Change in saturated thickness for selected Texas counties, 1990-2004.

From a groundwater management perspective, these results from the original Texas study are promising insofar as they suggest that land enrolled in the CRP provides a significant ecosystem service beyond soil conservation and preserving wetland habitat. These results suggest that land enrolled in the CRP also has the added benefit of reducing the rate of groundwater depletion.

While these results suggest that the CRP might reduce rates of aquifer depletion, it is important to recognize that much of the land enrolled in the CRP in Texas is located in areas where the saturated thickness of the aquifer is already less than 30 feet. In those places where the saturated thickness of the aquifer is relatively thin (less than 30 feet), there is generally insufficient water available to support large-volume irrigation (e.g. quarter section or full section center pivots). Thus, it is difficult to conclude that the CRP was directly responsible for the observed difference in rates of aquifer depletion. In fact, if the CRP did not exist, it might be that CRP land areas would be shallow groundwater areas dedicated to range or dryland farming (e.g. it would not be suitable for large-volume irrigation) – resulting in similar differences in the observed rates of water-level decline. Consequently, it is unclear whether or not the results from the original Texas study are unique – and whether or not these results will hold true if they are extrapolated to the other states that overlie the aquifer.

This is an important research question that needs to be addressed because it has important policy implications for agriculture on the Great Plains. If it can be demonstrated that land enrolled in the CRP has a significant benefit in terms of groundwater conservation, then there is a scientific basis and quantitative rationale to justify targeting reenrollment in the CRP as an ecosystem service designed to conserve groundwater.

To help determine relevance of results from the original Texas study, the comparison of groundwater-level changes beneath CRP and non-CRP land was expanded to cover the High Plains Aquifer in neighboring states. Furthermore, this study examined the effects of CRP over multiple time periods of groundwater-level change on a regional and county level for the entire High Plains Aquifer. This report describes the results of the research conducted as part of the first phase of the study covering Oklahoma, Kansas and Colorado.

Study Area

The spatial extent of the study area overlying the Ogallala (High Plains) Aquifer on the Great Plains is shown in Figure 1. In this study, the analysis focused on the areas overlying the aquifer in Oklahoma, Kansas and Colorado.

Figure 1. States overlying the High Plains Aquifer. Aquifer boundary created from data developed by the USGS (McGuire, et al., 2012).

Methodology

To assess the effects of the Conservation Reserve Program on the Ogallala (High Plains) Aquifer, the USGS provided aquifer data in the form of five raster datasets (McGuire et al., 2012). These data included a saturated thickness layer for 2009 and water-level-change (WLC) rasters for four periods; 1980-1995, 1995-2000, 2000-2005, and 2005-2009. Given that water level measurements are typically made at the beginning of a calendar year, it is customary to name water-level change data using the year in which the wells were measured. In this report the naming convention was changed to reflect the actual number of years in each water-level time interval. Thus, the time interval 1980-1994 refers to the 15 year period from 1980 through 1994. In a similar manner, the two five-year time intervals are referred to as 1995-1999 and 2000-2004 and the last four-year time interval is 2005-2008 in this report.

In addition to these raster data layers, the Farm Service Agency provided a CRP polygon layer for 2011. The polygon attributes in this layer include the Conservation Practice Code for the contract and the expiration date of the CRP contract that was in effect in early 2011.

To quantify the effects of CRP on aquifer levels, the water-level change beneath CRP land was compared to the water-level change beneath non-CRP land. The analysis was predicated on the idea that the aggregate mean water-level decline beneath CRP land should be less than the aggregate mean water-level decline beneath non-CRP land – assuming that some significant percent of the non-CRP land is used for irrigated agriculture. If it can be shown that the water-level decline beneath CRP land is less than the water-level decline beneath non-CRP land, then this result would suggest that the Conservation Reserve Program is having a positive effect on the aquifer by reducing the rate of aquifer decline. This conclusion, however, is predicated on the assumption that the CRP has taken at least some irrigated land out of production – or has precluded land from going into irrigated production, which might allow for more water available for recharge.

To perform the analysis, it was first necessary to identify which CRP polygons were present during each of the four WLC time intervals and extract these polygons from the FSA CRP database. The end product of this processing step were four CRP polygons layers and four non-CRP polygons layers for each county – with the counties clipped to include only those areas that overlie the aquifer. Once this task was complete, the CRP and non-CRP polygon layers were overlaid on the corresponding WLC raster. Zonal statistics (Esri, 2012) were then run to calculate the aggregate mean water-level change beneath the CRP and non-CRP land for each county, or portion of a county that overlies the aquifer. The zonal statistics process calculated statistics on values of the cells of the WLC rasters within the zones of the CRP polygons.

Estimating the Presence of CRP Land

It is important to recognize that the FSA CRP database is not structured in such a way that it can provide a separate CRP layer to coincide with each time interval of the study. For each of the four water-level-change time intervals, it was necessary to estimate the presence of CRP polygons based on an assumed contract length. While the CRP database was current for 2011, the database contains only a few thousand records with contract dates that expired prior to 2011, mostly in

2007, 2008, 2008 and 2010. In fact, there are only 21 records that predate 2007 and none of the records predate 2000. Obviously, there have been many more CRP contracts that expired prior to 2011, but it is not possible to include these missing contracts in the analysis.

To map the acreage in CRP present during a WLC time interval, it was necessary to assume a contract length and work backward from the contract expiration date. For each record in the FSA CRP database, the presence of CRP land was estimated assuming: 1) the contract length was 10-years for all CRP features and 2) each 10-year contract had one 10-year renewal (total of 20-years). Furthermore if a CRP contract was present for at least one year in any WLC time interval, then the CRP land was included in that interval because it had the potential to affect water-levels.

Tables 2a and 2b shows the relationship between the CRP contract expiration-year, assumed contract length, the presence of CRP land in each water-level-change (WLC) time interval, the total number of CRP polygons over the aquifer, and calculated CRP acreage over the aquifer.

CRP Contract Expiration-Year	Assumed Contract (yrs)	WLC Time Interval with CRP Land	CRP Polygons (database records)	GIS Calculated CRP Acres
2005 – 2019	10	2005-2008	113,760	6,730,970
2000 – 2015	10	2000-2004	40,696	2,869,897
2000 – 2010	10	1995-1999	2042	211,840
2000 – 2005	10	1980-1994	6	71

Table 2a. Estimated presence of CRP land in each WLC time interval assuming 10-year contract length.

CRP contract expiration-year	Assumed Contract (yrs)	WLC Time Interval with CRP Land	CRP Polygons (database records)	GIS Calculated CRP Acres
2005 – 2029	20	2005-2008	113,759	6,730,963
2000 – 2025	20	2000-2004	109,153	6,522,345
2000 – 2020	20	1995-1999	72,599	4,020,954
2000 – 2015	20	1980-1994	40,683	2,869,863

Table 2b. Estimated presence of CRP land in each WLC time interval assuming 10-year contract length with one 10-year renewal for a total of 20 years in CRP.

For the most recent 2005-2008 WLC time interval the number of polygons and calculated acreage is virtually the same assuming either a 10-year or 20-year contract length. For the 2000-2004 WLC time interval, the number of polygons and calculated acreage assuming a 10-year contract are only about 40 percent of the values assuming a 20-year contract. Lastly, there are only a few thousand records in the CRP database which predate 2011. As a result, the number of polygons and calculated acreage for the 1995-1999 and 1980-1994 WLC time intervals are far lower. Assuming a contract length of 10-years, the 1980-2004 WLC time interval has only 6 records.

Given that there are only a few thousand contracts in the FSA CRP database that expired and were not renewed prior to 2011, it is likely that the methodology for estimating the presence of CRP land in any of the WLC time intervals will underestimate the number of CRP polygons and

CRP acreage regardless of whether the assumed contract length is 10-years or 10-years with one renewal for a total of 20 years. Assuming either a 10-year or 20-year period should provide a reasonable estimate of CRP acreage for the most recent time interval (2005-2008) but it seems that the assumption of a 10-year contract with at least one 10-year renewal provides a much better estimate for the second time interval (2000-2004).

For the 1995-1999 and 1980-1994 WLC time intervals, it becomes obvious that the assumed 10-year contract length is unrealistic. Assuming a 20-year total contract length likely provides a better estimate of CRP acreage during these two time intervals, but the calculated acreage likely underestimates the actual acreage going progressively further back in time.

To assess the effect of expired contracts not being present in the FSA CRP database, the calculated CRP acres derived from the database were compared to the CRP acres published in the FSA CRP Annual Summary reports for each WLC end-year. Table 3 compares the data summed for 28 counties that are completely within the Ogallala (High Plains) Aquifer boundary of Oklahoma, Kansas and Colorado. For these 28 counties, the GIS calculated CRP acres underestimate the reported FSA CRP acres by 17 percent in 2008, 14 percent in 2004, 48 percent in 1999 and 65 percent in 1994.

WLC Period End Year	GIS Calculated CRP Acres	FSA Reported CRP Acres	GIS Acres / FSA Acres (Percent)	GIS Calculated Acres Underestimate (Percent)
2008	1,629,012	1,967,619	82.8	17.2
2004	1,571,479	1,834,943	85.6	14.4
1999	878,882	1,695,987	51.8	48.2
1994	586,024	1,665,605	35.2	64.8

Table 3. Comparison of GIS calculated CRP acres and FSA reported CRP acres for 28 counties that lie completely within the boundary of the aquifer in Oklahoma, Kansas and Colorado.

Based on the results in Table 3, it is obvious that the GIS calculated CRP acreage (derived assuming a 20-year total contract length) provides a reasonable estimate of the reported CRP acreage for the two most recent WLC time intervals (2005-2008 and 2000-2004), but strongly underestimates actual CRP acreage for the 1995-1999 and 1980-1994 WLC time intervals. To better understand this relationship between calculated and published CRP acres, Figures 2 to 5 compare calculated and reported acres in the form of scatter plots. For each plot a best-fit line has been placed through the data to illustrate how the underestimate deviates from an ideal 1:1 relationship.

For the 2008 and 2004 WLC end-years the R^2 value is quite high (Figures 2 and 3). While these R^2 values are not meaningful in this context because no causal relationship is implied, they are reported here to illustrate the strength of the relationship. More importantly, the slope of the best-fit line illustrates how the calculated CRP acres compare to the published acres. Based on these scatter plots, the data once again suggest that the calculated CRP acres (derived assuming a 20-year total contract length) provides a fairly reasonable estimate of the actual acreage in the two more recent WLC time intervals, but progressively underestimates the actual CRP acreage for the two earlier WLC time intervals.

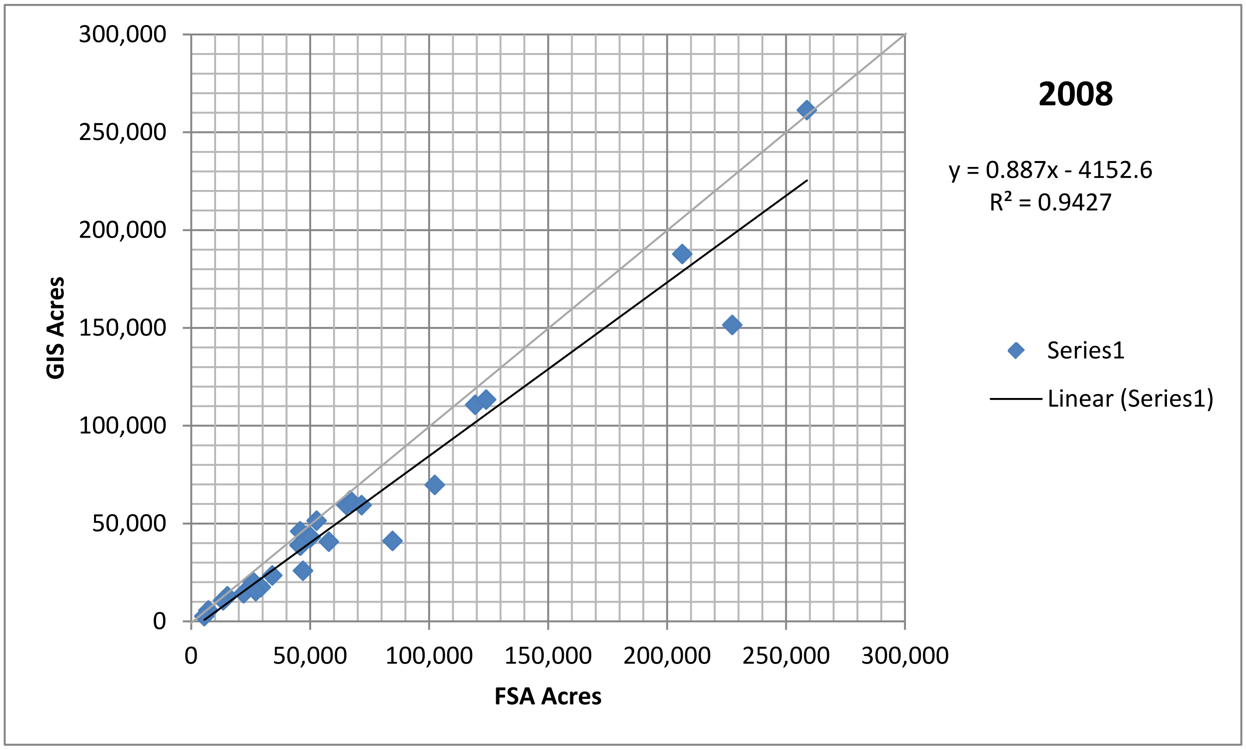

Figure 2. Comparison of total GIS and total FSA reported CRP acres for counties completely contained within the boundary of the High Plains Aquifer, 2008.

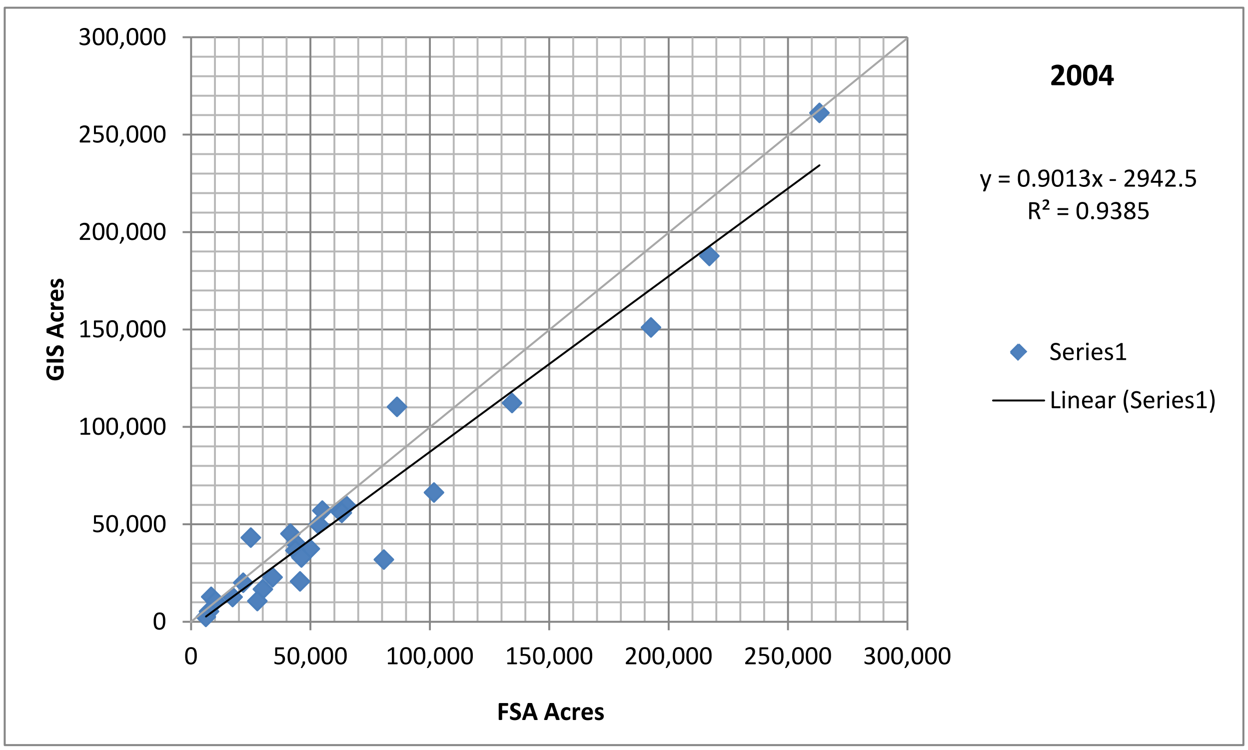

Figure 3. Comparison of total GIS and total FSA reported CRP acres for counties completely contained within the boundary of the High Plains Aquifer, 2004.

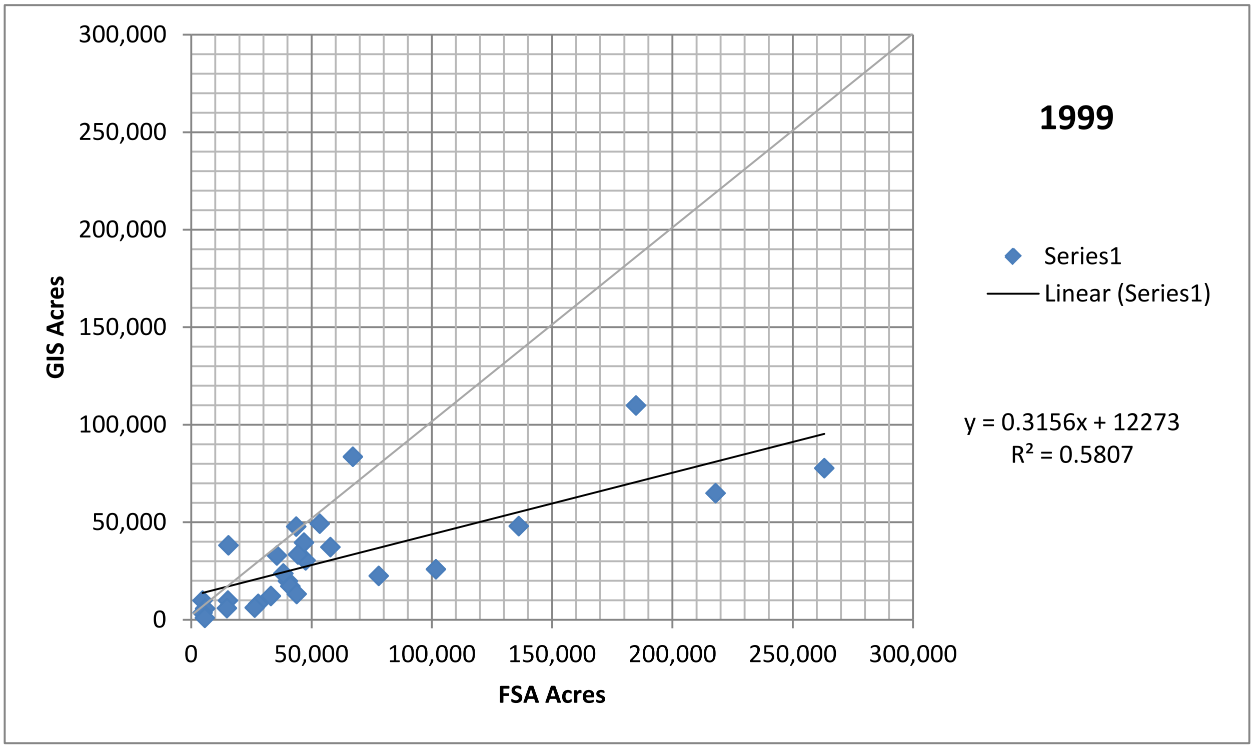

Figure 4. Comparison of total GIS and total FSA reported CRP acres for counties completely contained within the boundary of the High Plains Aquifer, 1999.

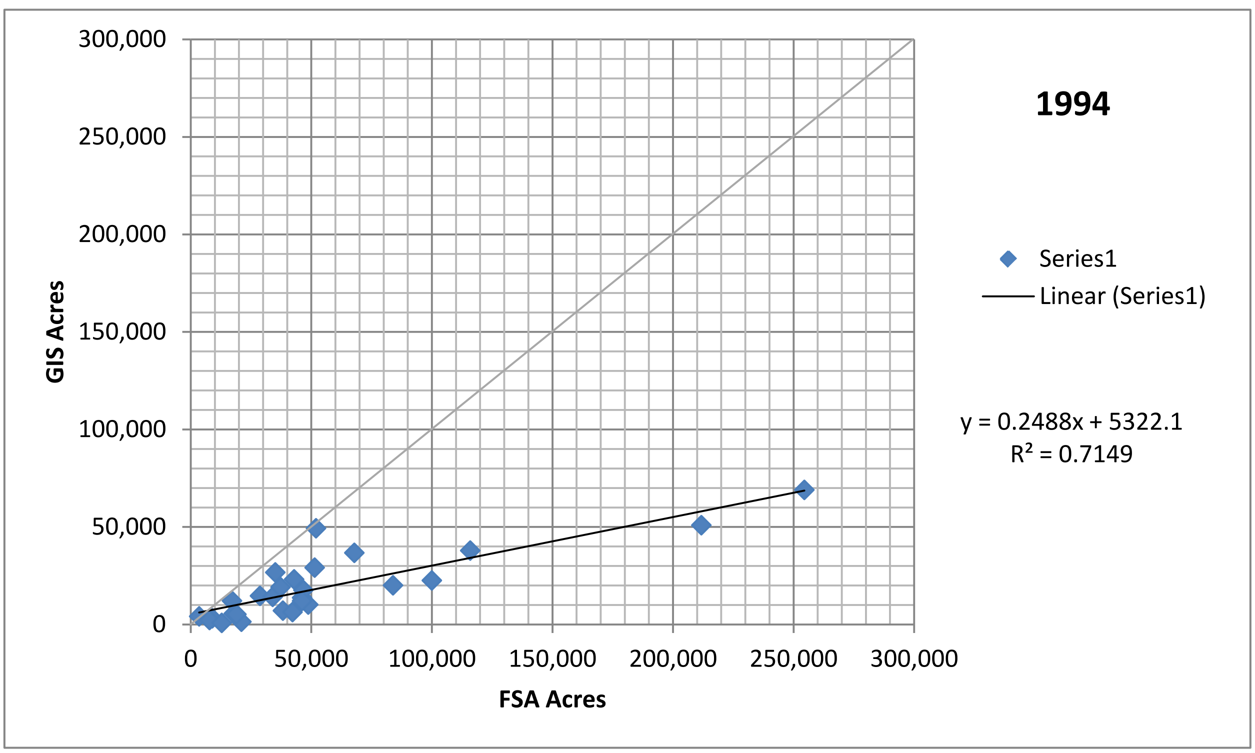

Figure 5. Comparison of total GIS and total FSA reported CRP acres for counties completely contained within the boundary of the High Plains Aquifer, 1994.

The Conservative Nature of Analytical Results

From Figures 2 through 5, it becomes apparent that any maps of CRP land created from the FSA CRP database (assuming a 20-year total contract length) will under-report the actual CRP area present during any of the WLC time intervals. While there is potential for some non-CRP polygons to be mapped as CRP (because the contract length for a parcel was in fact less than 20 years), it is much more likely that a significant amount of CRP land is being mapped as non-CRP. In this case, CRP polygons are being mapped as non-CRP because the CRP contract expired before 2011 and the record was not present in the CRP database. While this condition is not ideal, it does not rule out an analysis of the effects of CRP land on water-level change. If the calculated CRP acreage is an underestimate of the actual CRP acreage (Table 3), this approach implies that some CRP polygons are mapped as non-CRP. In this situation the results of any analysis will simply provide a conservative estimate of the effects of CRP land on water-level change – and the conservative nature of this estimate will increase for the earlier WLC time intervals.

To illustrate this point, consider the hypothetical results of an analysis. First, logic dictates that the aggregate mean water-level decline beneath CRP land should be less than the water-level decline beneath non-CRP land – assuming some portion of the non-CRP land is being used for irrigated agriculture. Now consider that the results of an analysis show that the aggregate mean water-level decline beneath CRP land is less than the aggregate mean water-level decline beneath non-CRP land – as might be expected. In this case findings would suggest that the presence of the CRP land is reducing the rate at which the aquifer is being drawn down and the difference between the two measures of water-level decline might be attributed to the CRP.

Now consider that the calculation method to assign contracts to a time interval has the consequence of assigning CRP to locations where they might not have been present. This would result in some non-CRP land assigned as CRP. In this case if this result is obtained with some CRP land mapped as non-CRP, then the lower rate of water-level decline beneath the CRP land is being attributed to non-CRP land. Presumably, if the non-CRP land was mapped correctly as CRP land, the aggregate mean water-level decline beneath non-CRP land would be greater – thus producing a difference in water-level decline that would be larger.

Conversely, in the case of a water-level rise, logic dictates that the aggregate mean water-level rise beneath CRP land should be greater than the rise beneath non-CRP land – again assuming that some portion of the non-CRP land is being used for irrigated agriculture. If the results of an analysis show that the rise beneath CRP land is greater than the rise beneath non-CRP land, this difference might then be attributed to the presence of the CRP. In this case, if the results are obtained with CRP land mapped as non-CRP, then the greater rise in the water table beneath CRP land is being attributed to non-CRP land. Presumably, if the non-CRP land was mapped correctly as CRP land, the rise beneath the non-CRP rise would decrease – producing a difference in water-level rise that would be larger.

It is also important to recognize that the analysis undertaken here assumes that land enrolled in CRP for at least one year during a water-level-change time interval has the potential to affect the water-level change during that interval. If the groundwater beneath the land was pumped for, say, four years before the land went into a CRP contract, then the water-level change beneath that land is still attributed to land in CRP. Once again, this assumption produces a conservative estimate of the effects of CRP. In the final results of this analysis, the calculated effect of CRP on mean aggregate water-level change will tend to be a conservative estimate – and, again, the conservative nature of this estimate will increase for the earlier time periods.

Water-level Change

To evaluate effects of the CRP on groundwater-levels in the aquifer, the water-level change beneath CRP land was compared to the water-level change beneath non-CRP land. To perform this analysis, the CRP and non-CRP polygons derived from the FSA database were overlaid on the four water-level-change raster datasets provided by the USGS. Once again, these raster datasets covered the water-level change for four time intervals: 2005-2008, 2000-2004, 1995-1999, and 1980-1994.

The four WLC raster datasets provided by the USGS were projected using an Albers Equal Area projection – which was necessary to generate area calculations. The spatial resolution (grid cell size) of the rasters, however, was 500 m. For the zonal statistics process to output a result, at least one grid cell must be completely contained within a CRP polygon (Esri, 2012). With the USGS WLC rasters developed using a 500 m grid cell size, many of the CRP polygons were too small to generate a water-level change calculation.

To capture water-level change beneath these smaller CRP polygons, it was necessary to resample the USGS WLC rasters to create new datasets at a higher spatial resolution (smaller grid cell size). To resample the USGS rasters, the nearest neighbor sampling technique was used (Esri, 2012). This process assigned the water-level change value of the original grid cell to all of the new smaller grid cells. Using this approach, the new higher-resolution WLC rasters were created without changing the underlying data.

To find the appropriate grid cell size, the 2005-2008 raster was re-sampled using progressively smaller cell sizes. At each stage of the process, the input CRP polygon layer was overlaid on the raster and zonal statistics were re-run to determine how many records were captured by the process. In the end, the resolution of rasters was resampled down to 25 m. At this spatial resolution the input CRP for one time interval contained 79,615 records, and output zonal statistics contained 79,126 records. In this test case, 489 polygons were too small to generate a result. This number represented less than 1 percent of the polygons in the input CRP layer – which was deemed adequate and should only have a minor effect on the final results. To resample at a grid cell size smaller than 25 m would cause particularly long processing times.

To evaluate groundwater-level change beneath non-CRP lands, the same zonal statistics process was run on the non-CRP datasets for each time interval.

Mapping Saturated Thickness and Water-level Change

Figure 6 shows the spatial variability in the saturated thickness of the High Plains Aquifer in 2009. Clearly, the aquifer is thickest in the area underlying the Sand Hills in Nebraska. In other parts of the Great Plains, the thickness of the aquifer varies – with significant groundwater in northern Texas, the Oklahoma panhandle, southwestern Kansas and northeastern Colorado.

Of particular concern in this study are those areas of the aquifer with significant drawdown. Figure 7 shows the cumulative water-level change measured between 2000 and 2008. This map was created by summing the USGS water-level change rasters for 2000-2004 and 2005-2008. Over the nine year period, the greatest decline in the aquifer has occurred in parts of northern Texas, western Kansas and eastern Colorado.

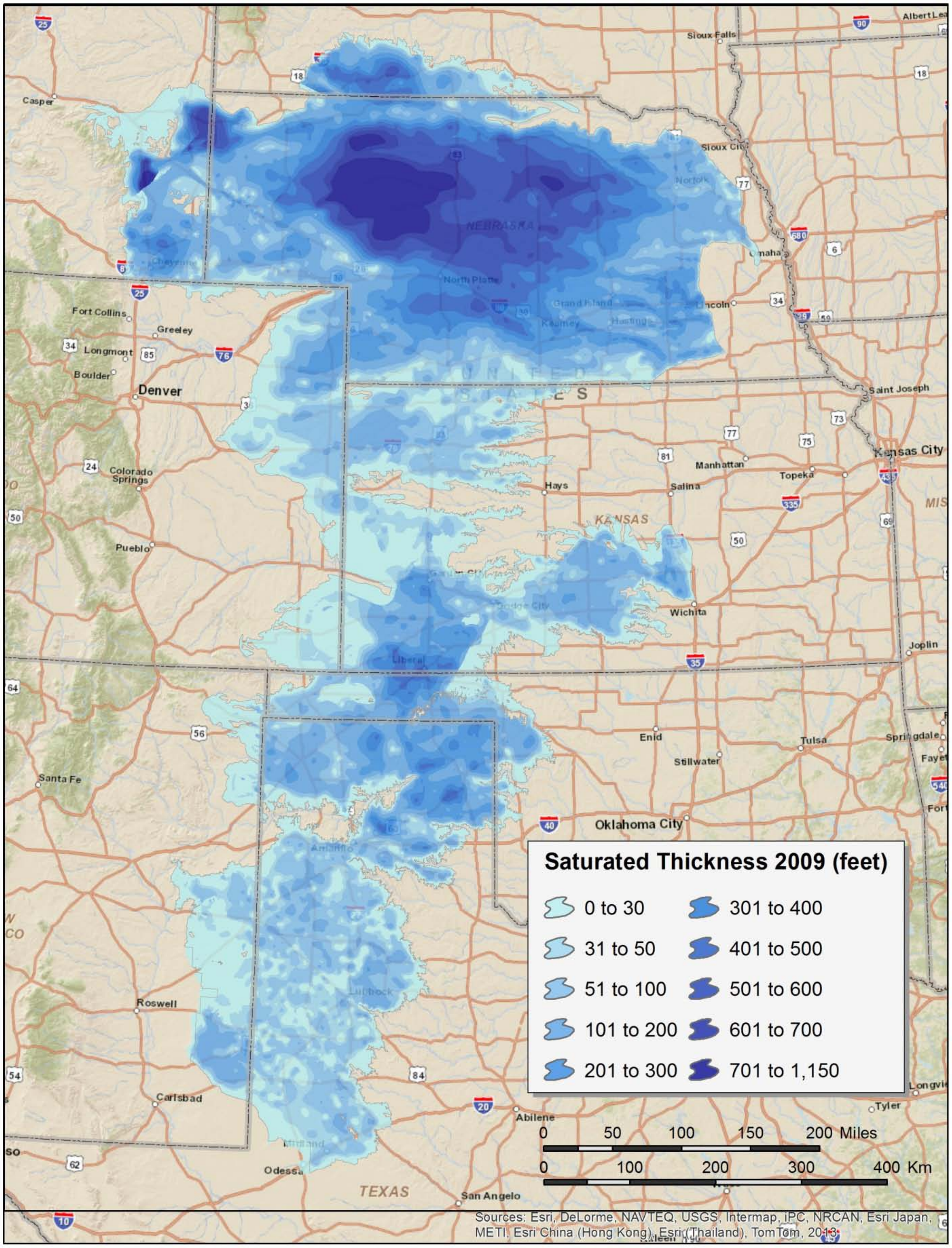

Figure 6. Saturated thickness of the High Plains Aquifer, 2009. Map created from saturated thickness data developed by the USGS (McGuire et al., 2012).

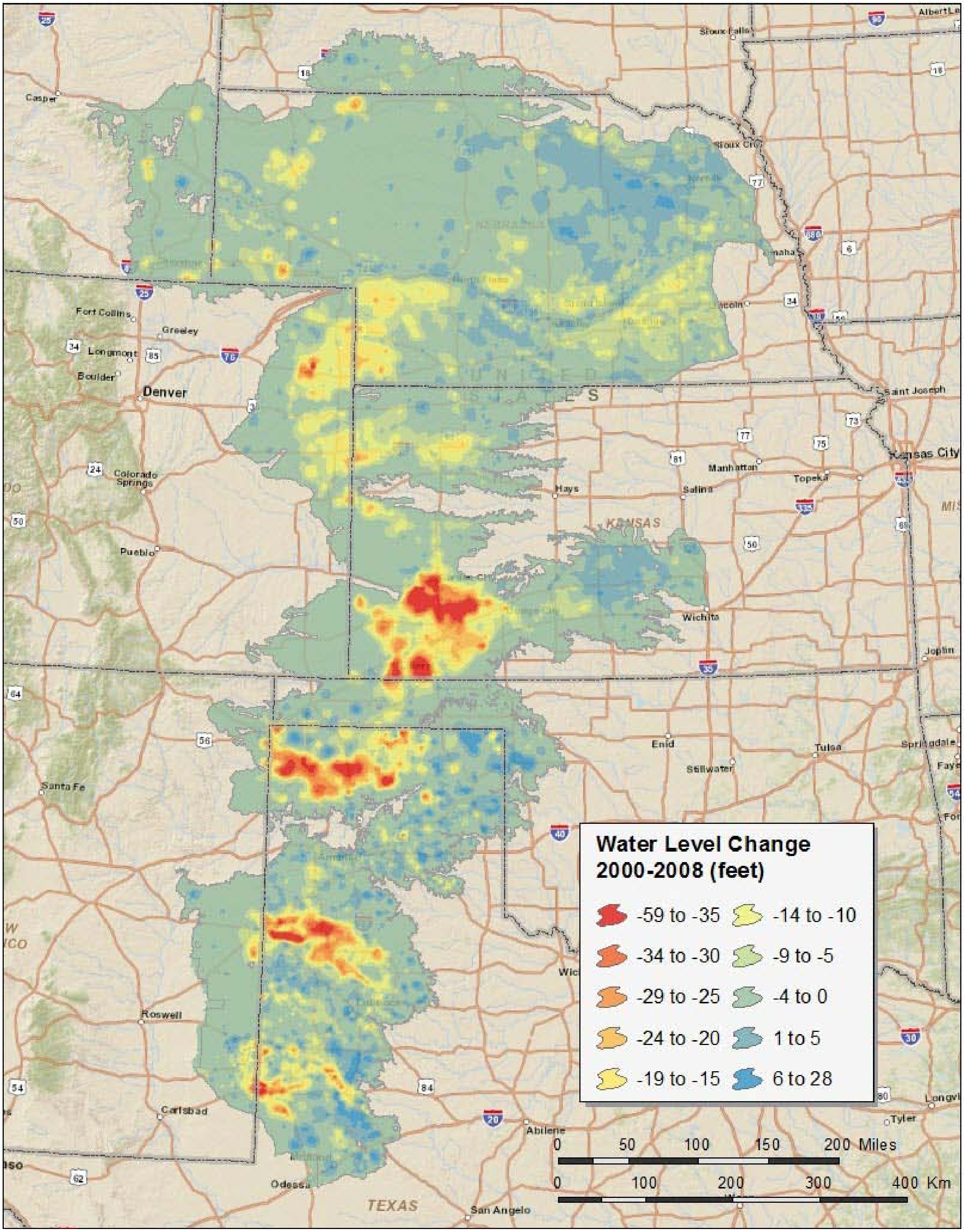

Figure 7. Cumulative water-level change measured between 2000 and 2008. Map created from water-level data developed by the USGS (McGuire et al., 2012).

Oklahoma

CRP Effects on Water-level Change by County

Summary Results: Oklahoma

In Oklahoma, the Ogallala (High Plains) Aquifer underlies all of part of nine counties – covering an area of approximately 7,407 square miles. To analyze the effects of the CRP on water-level change, the CRP and non-CRP polygons present during each time interval (assuming a 20-year contract length) were overlaid on each of the four water-level-change rasters.

Figures 8, 10, 12 and 14 show the rate of water-level change during each of the four time intervals for Oklahoma. To create these maps, the original water-level change data in each USGS raster was divided by the length of the respective time interval. In this way the water-level change data are normalized in the maps to facilitate a direct comparison between the different time periods.

For each of the time intervals, the largest drawdown of the aquifer was measured in Texas County where the decline beneath CRP was consistently less than the county average. Comparing the decline in the water-level beneath CRP land and non-CRP land for the four time intervals, the drawdown beneath CRP was 25 percent less in 2005-2008, 34 percent less in 2000-2004, 25 percent less in 1995-1999 and 6 percent less in 1980-1994. It is also of special interest to note that the maps for 2005-2008 (Figure 8) and 2000-2004 (Figure 10) show a rather large concentration of CRP land in the western part of Texas County. Compared to the map for 1995-1999 (Figure 12) this concentration of CRP land appears to be related to a significant decrease in the rate of water-level decline. At the same time, it is important to recognize that the 2009 saturated thickness of the aquifer is rather thin in this part of the county (Figure 6).

In contrast to these results for Texas County, the results for Cimarron County were mixed. Comparing the decline in water-level between CRP and non-CRP land there was almost no difference in 2005-2008 and the decline was 35 percent less in 2000-2004 – although the total drawdown was less than 1 foot during both intervals. In the two earlier periods, the decline beneath CRP land was greater than non-CRP, 18 percent greater in 1995-1999 and 8 percent greater in 1980-1994. Moreover, the decline beneath CRP land was greater than the county average in both of these earlier periods.

Most of the other counties in Oklahoma show very little water-level decline in 2005-2008 (less than about 0.5 ft), so it is difficult to make any generalizations. In the 2000-2004 time interval, however, Ellis County shows a significant increase in water-level. Beneath CRP land, the water-level rose 2.1 feet, compared to 1.4 feet beneath non-CRP land. While this rise is a small over five years, it does represent a 50 percent greater rise beneath CRP land. More importantly, this is evident in the two earlier time periods as well. In Ellis County the rise in water-level beneath CRP land is 33 percent greater in 1995-1999 and 31 percent greater in 1980-1994.

Harper, Woodward, Dewey, Roger Mills and Beckham counties all lay on the eastern fringe of the aquifer. In a manner similar to Ellis County, Roger Mills and Woodward show a greater rise in the water-level beneath CRP land in 1995-1999 and 1980-1994 – although the rise beneath both CRP and non-CRP land is relatively small (less than about 1 foot). In contrast, data for Harper County show that the rise in water-level is greater beneath non-CRP land in 1995-1999 and 1980-1995, but again the rise in water-level is small (less than about 1.5 feet).

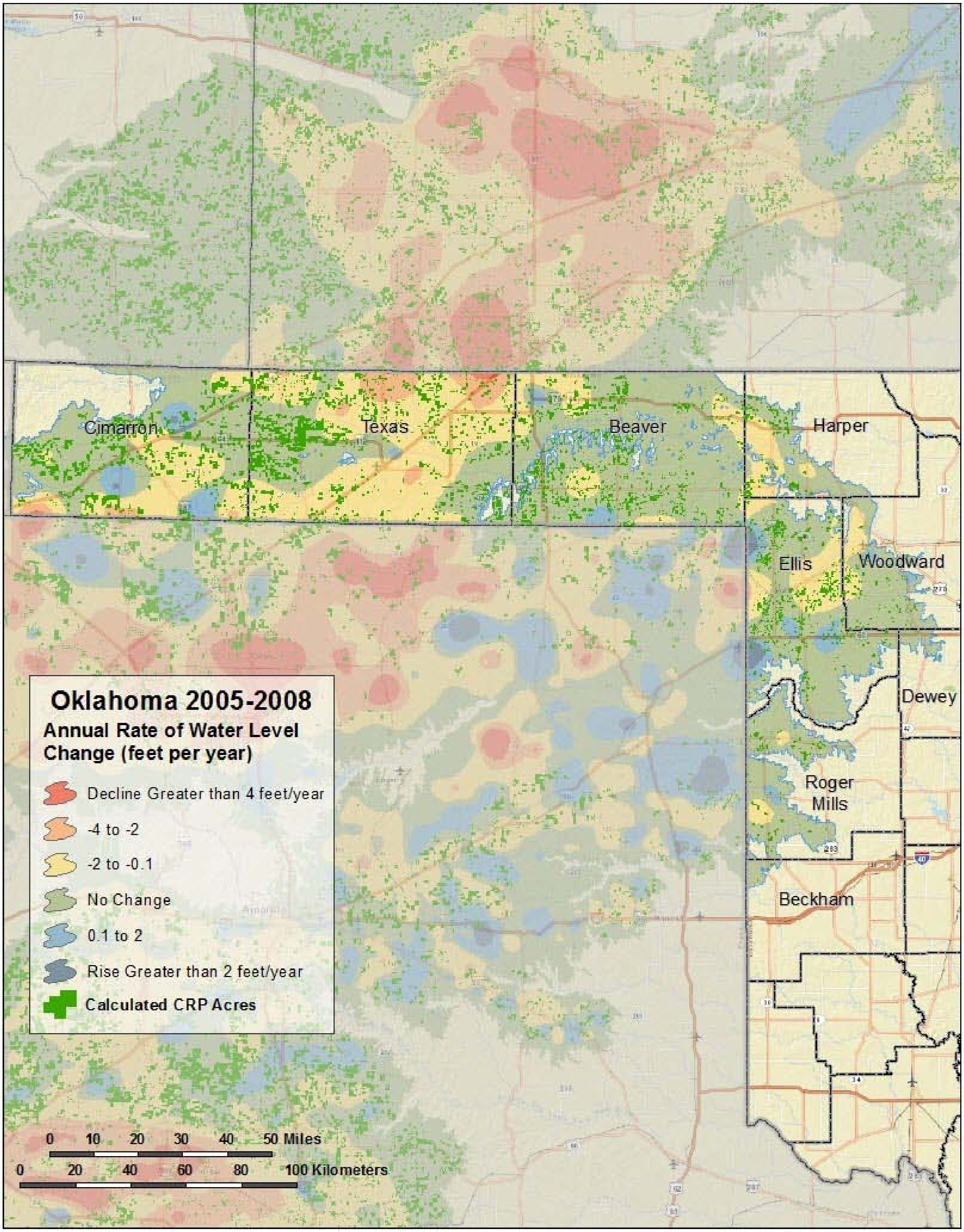

Figure 8. Oklahoma CRP polygons for 2008 over water-level change, 2005-2008.

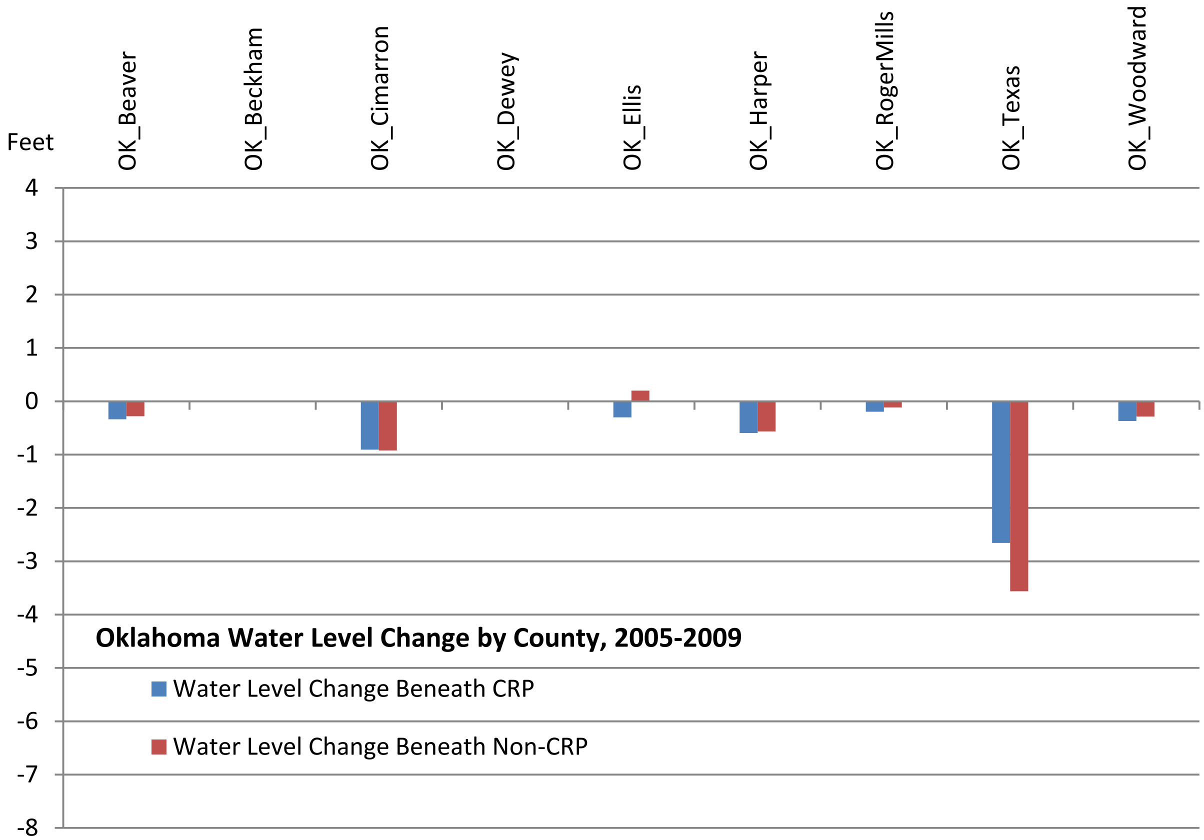

Figure 9. Comparison of water-level changes beneath CRP and non-CRP land, 2005-2008.

2005-2008 Mean Water-level Change						
State_County	**County WLC (ft)**	**CRP WLC (ft)**	**Non-CRP WLC (ft)**	**Total County CRP Acres Over the Ogallala Aquifer**	**Total County Acres Over the Ogallala Aquifer**	**Percent of County Over the Ogallala Aquifer in CRP**
OK_Beaver	-0.29	-0.34	-0.28	113,398	1,102,525	10.29
OK_Beckham	0.00	0.00	0.00	313	19,314	1.62
OK_Cimarron	-0.92	-0.91	-0.92	128,616	934,790	13.76
OK_Dewey	0.00	0.00	0.00	266	23,906	1.11
OK_Ellis	0.16	-0.30	0.20	59,583	660,393	9.02
OK_Harper	-0.57	-0.60	-0.56	17,534	205,118	8.55
OK_RogerMills	-0.12	-0.19	-0.11	12,329	270,544	4.56
OK_Texas	-3.43	-2.66	-3.56	187,787	1,289,426	14.56
OK_Woodward	-0.29	-0.37	-0.28	10,014	232,829	4.30

Table 4. Oklahoma water-level change beneath CRP and non-CRP land by county, 2005-2008.

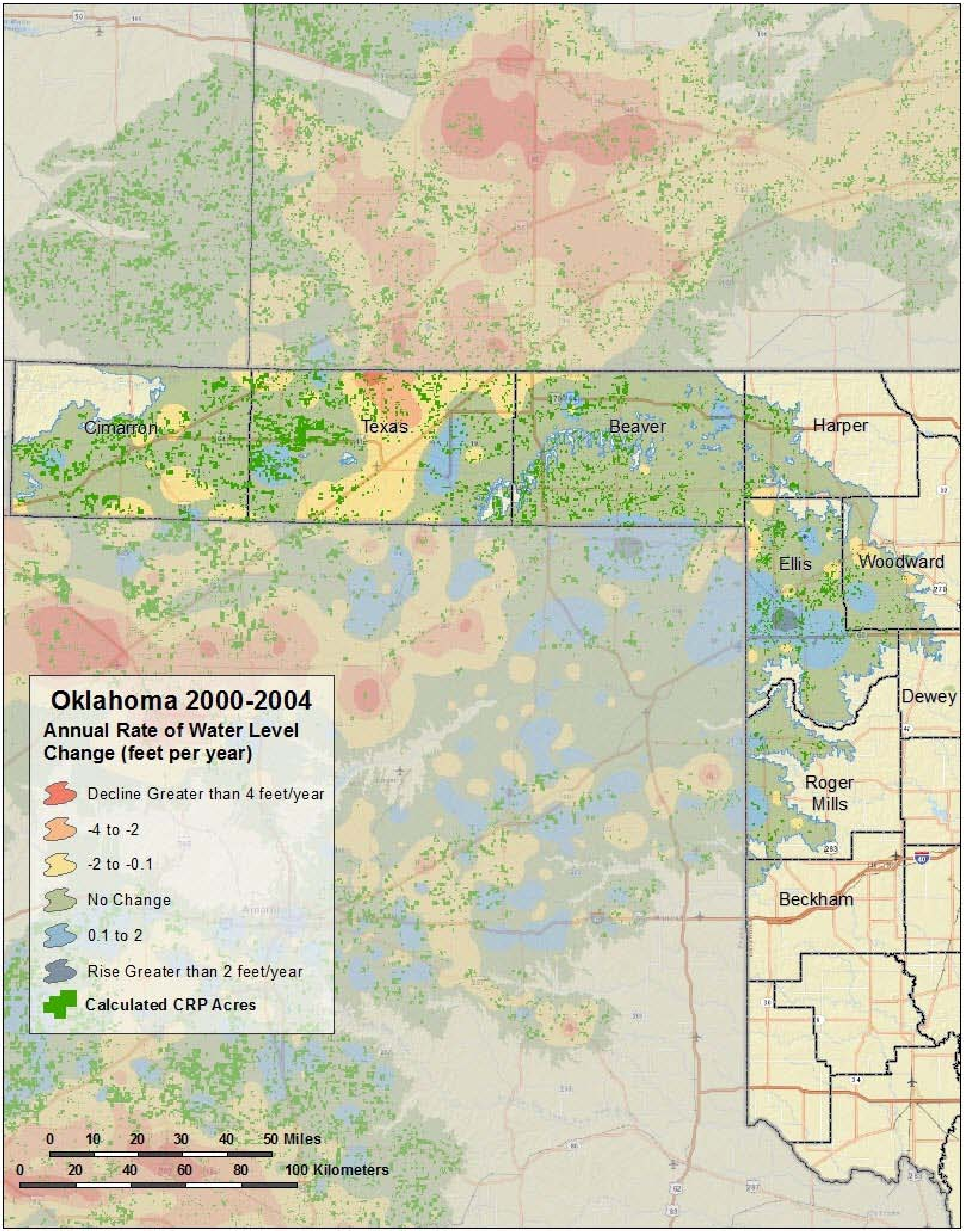

Figure 10. Oklahoma CRP polygons for 2004 over water-level change, 2000-2004.

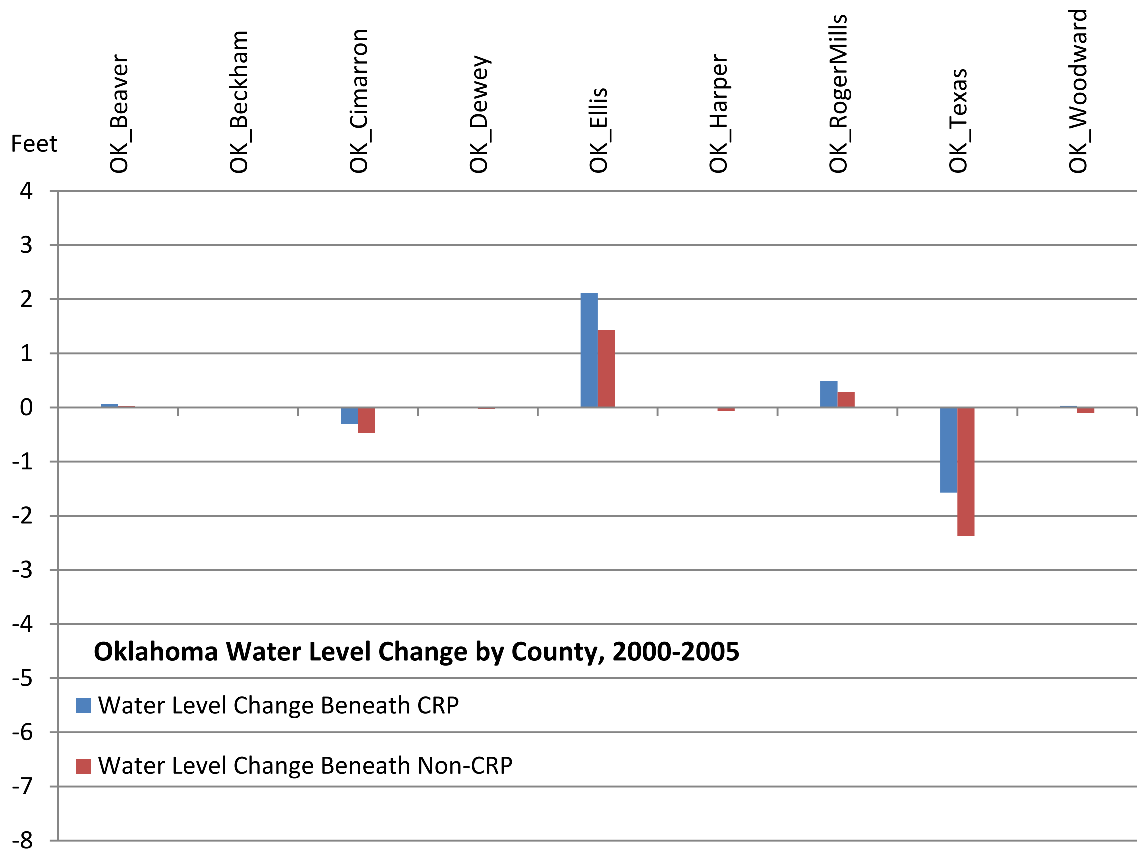

Figure 11. Comparison of water-level changes beneath CRP and non-CRP land, 2000-2004.

2000-2004 Mean Water-level Change						
State_County	**County WLC (ft)**	**CRP WLC (ft)**	**Non-CRP WLC (ft)**	**Total County CRP Acres Over the Ogallala Aquifer**	**Total County Acres Over the Ogallala Aquifer**	**Percent of County Over the Ogallala Aquifer in CRP**
OK_Beaver	0.03	0.07	0.02	112,308	1,102,525	10.19
OK_Beckham	0.00	0.00	0.00	313	19,314	1.62
OK_Cimarron	-0.45	-0.31	-0.47	128,616	934,790	13.76
OK_Dewey	-0.03	0.00	-0.03	266	23,906	1.11
OK_Ellis	1.49	2.12	1.43	59,571	660,393	9.02
OK_Harper	-0.06	-0.01	-0.07	16,831	205,118	8.21
OK_RogerMills	0.29	0.49	0.29	12,329	270,544	4.56
OK_Texas	-2.26	-1.57	-2.37	187,787	1,289,426	14.56
OK_Woodward	-0.09	0.03	-0.10	10,014	232,829	4.30

Table 5. Oklahoma water-level change beneath CRP and non-CRP land by county, 2000-2004.

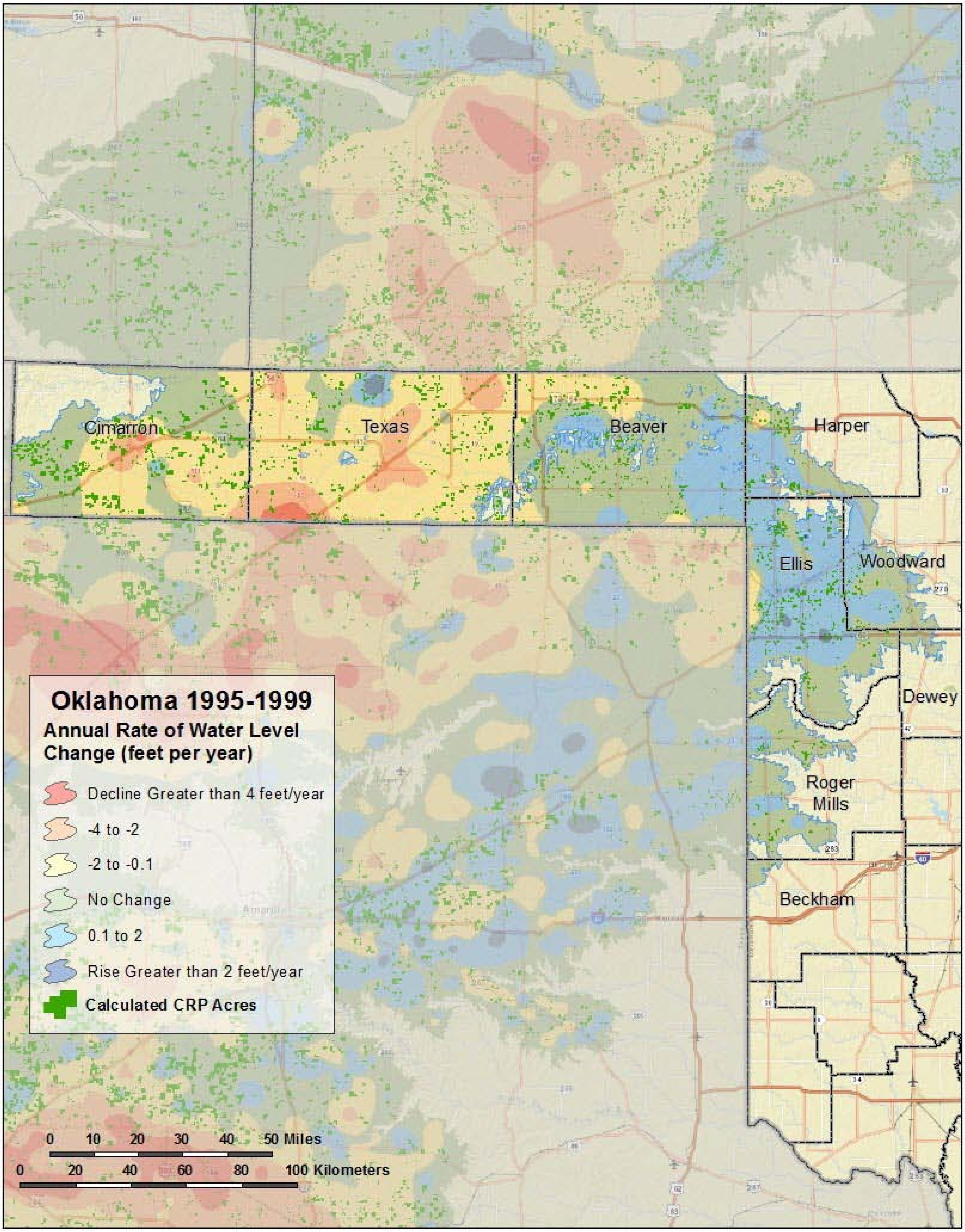

Figure 12. Oklahoma CRP polygons for 1999 over water-level change, 1995-1999.

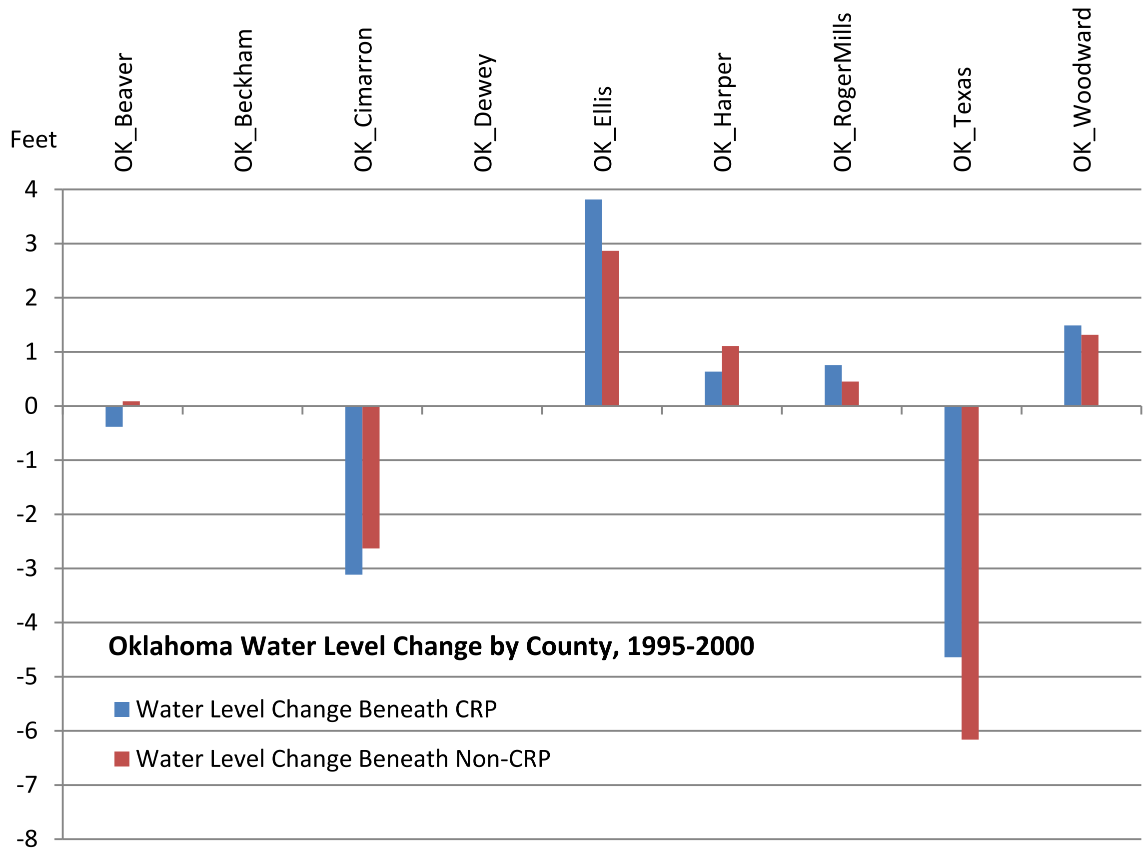

Figure 13. Comparison of water-level changes beneath CRP and non-CRP land, 1995-1999.

1995-1999 Mean Water-level Change						
State_County	**County WLC (ft)**	**CRP WLC (ft)**	**Non-CRP WLC (ft)**	**Total County CRP Acres Over the Ogallala Aquifer**	**Total County Acres Over the Ogallala Aquifer**	**Percent of County Over the Ogallala Aquifer in CRP**
OK_Beaver	0.07	-0.38	0.09	48,056	1,102,525	4.36
OK_Beckham	0.00	0.00	0.00	198	19,314	1.02
OK_Cimarron	-2.67	-3.11	-2.63	82,582	934,790	8.83
OK_Dewey	0.00	0.00	0.00	183	23,906	0.76
OK_Ellis	2.92	3.81	2.87	37,296	660,393	5.65
OK_Harper	1.08	0.64	1.11	11,590	205,118	5.65
OK_RogerMills	0.46	0.75	0.45	8,905	270,544	3.29
OK_Texas	-6.09	-4.64	-6.16	64,940	1,289,426	5.04
OK_Woodward	1.32	1.49	1.32	6,270	232,829	2.69

Table 6. Oklahoma water-level change beneath CRP and non-CRP land by county, 1995-1999.

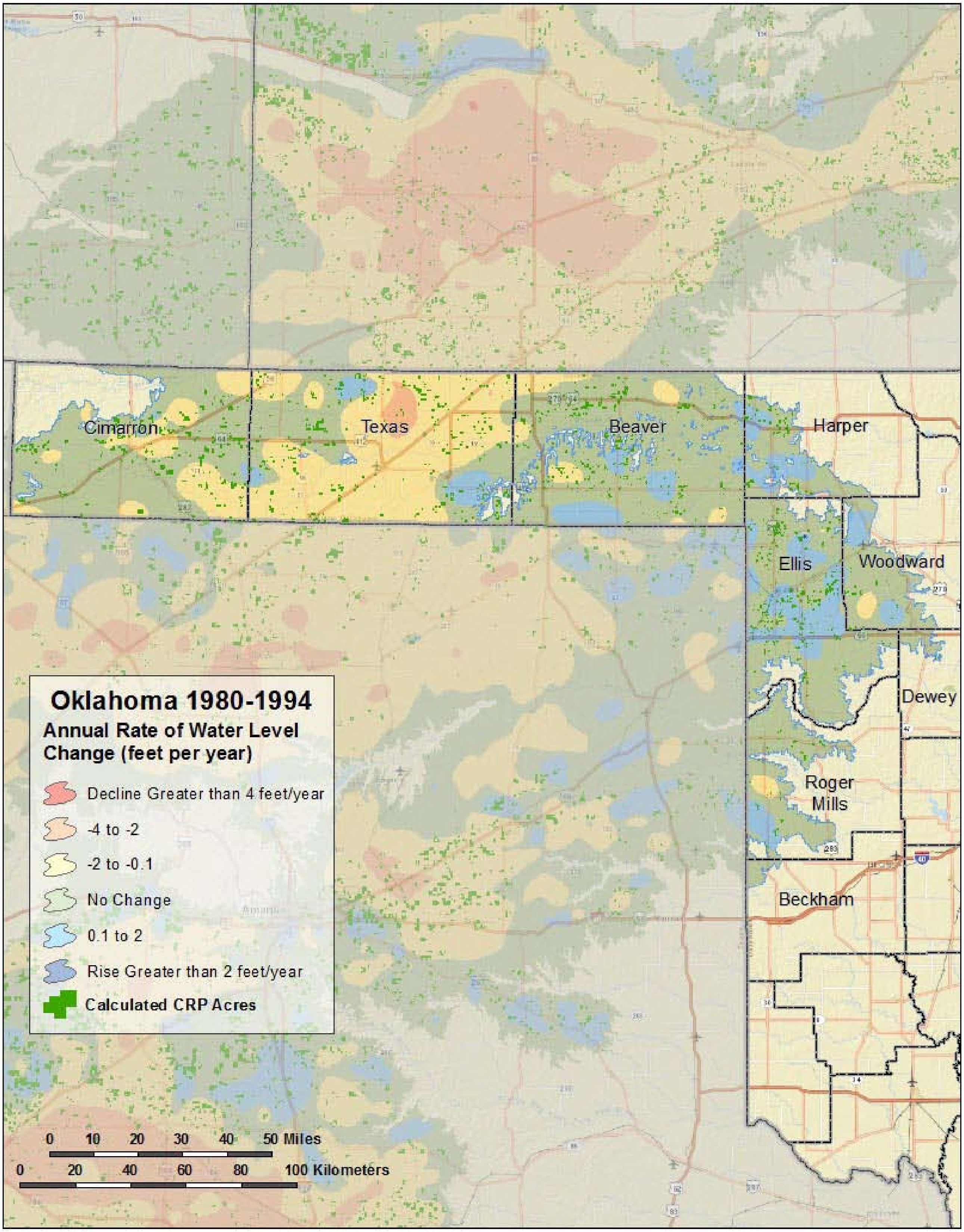

Figure 14. Oklahoma CRP polygons for 1994 over water-level change, 1980-1994

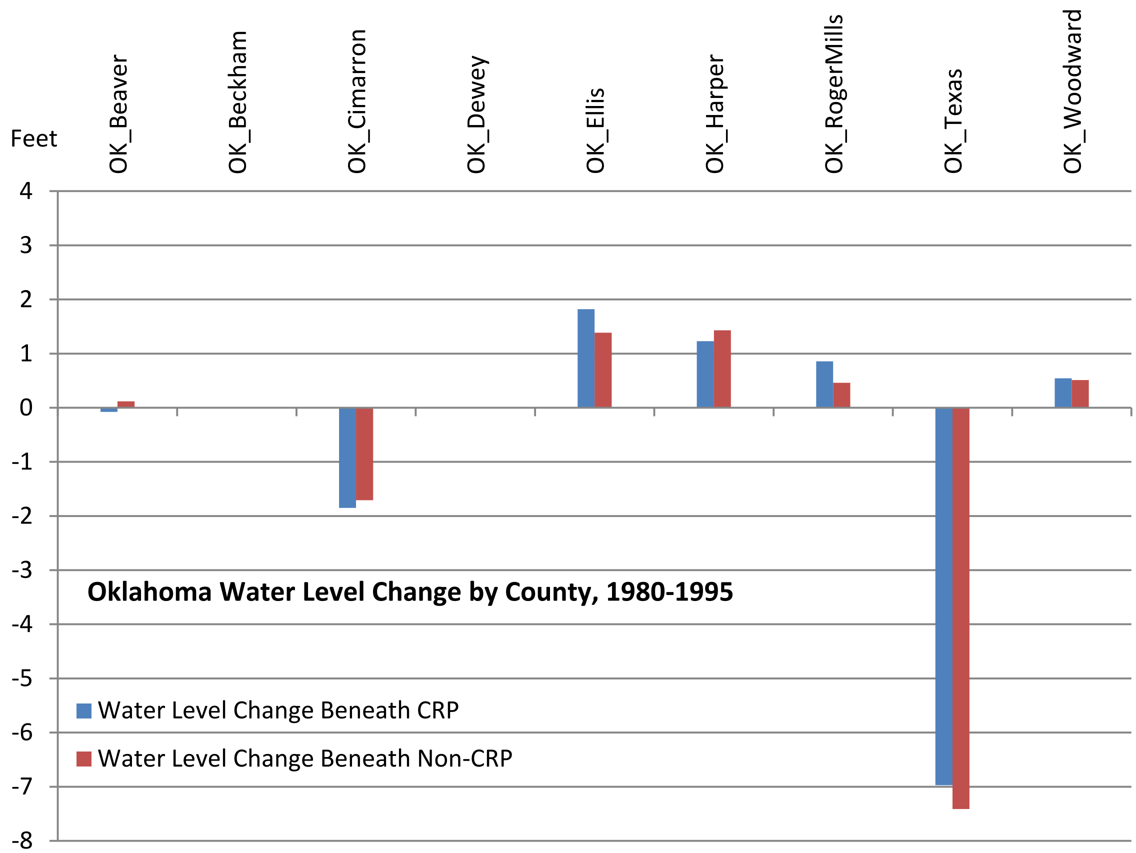

Figure 15. Comparison of water-level changes beneath CRP and non-CRP land, 1980-1994

1980-1994 Mean Water-level Change						
State_County	**County WLC (ft)**	**CRP WLC (ft)**	**Non-CRP WLC (ft)**	**Total County CRP Acres Over the Ogallala Aquifer**	**Total County Acres Over the Ogallala Aquifer**	**Percent of County Over the Ogallala Aquifer in CRP**
OK_Beaver	0.11	-0.08	0.12	37,869	1,102,525	3.43
OK_Beckham	0.00	0.00	0.00	101	19,314	0.52
OK_Cimarron	-1.72	-1.85	-1.71	42,520	934,790	4.55
OK_Dewey	0.00	0.00	0.00	52	23,906	0.22
OK_Ellis	1.40	1.82	1.39	29,129	660,393	4.41
OK_Harper	1.42	1.23	1.43	8,439	205,118	4.11
OK_RogerMills	0.47	0.86	0.46	4,397	270,544	1.63
OK_Texas	-7.40	-6.97	-7.41	50,871	1,289,426	3.95
OK_Woodward	0.51	0.54	0.51	2,555	232,829	1.10

Table 7. Oklahoma water-level change beneath CRP and non-CRP land by county, 1980-1994.

Kansas

CRP Effects on Water-level Change by County

Summary Results: Kansas

In Kansas, the High Plains Aquifer underlies all or of part of 56 counties – with an area covering approximately 30,844 square miles. As before, the maps of water-level change are expressed as the average rate over each time interval.

Comparing the Kansas maps of water-level change for each of the four time intervals, it becomes obvious that the most significant water-level decline has occurred in the southwestern part of the state. In contrast, the counties in the central and northwestern part of the state tend to show far less drawdown and, in many cases, a significant rise.

For each time interval, the largest drawdown of the aquifer was consistently measured in a core area defined by nine contiguous counties in the southwest part of the state. This core area includes Grant, Gray, Finney, Haskell, Seward and Stevens –and to a lesser extent Kearny, Meade and Stanton counties. During each time interval drawdown of the aquifer exceeded 2 feet per year in at least part of each of these counties.

In the 2005-2008 time interval seven of these nine counties showed less decline beneath CRP land, the exceptions being Gray and Stevens counties. In the other three earlier WLC time intervals, eight of nine counties showed less decline beneath CRP compared to non-CRP land.

It is also important to recognize that these data represent county-wide averages. Within a county there can be a considerable difference in the water-level changes – and these differences are masked in the county wide average. For example, in Finney County the rate of water-level decline in the southern part of the county far exceeds the rate of water-level decline in the central and northern part of the county. In fact, in the two earliest time intervals, 1980-1994 and 1995-1999, there was a significant rise in the water-level in the central part of the county. Thus, the large decline in the water-level in the southern part of the county was partially offset in the county average by the apparent rise in the water-level in the central part of the county. Despite these marked differences in water-level change, Finney County had consistently less water-level decline beneath CRP than non-CRP for all four periods. The drawdown beneath CRP in Finney County was 44 percent less in 2005-2008, 45 percent less in 2000-2004, 17 percent less in 1995-1999, and 38 percent less in 1980-1994.

Changes in central and northwestern parts of Kansas were relatively modest compared to changes in the southwestern part of the state. In the central part of Kansas none of the counties experienced a change in water-level exceeding 1 foot per year. In a similar manner, water-level changes in the northwestern counties were also relatively modest, with the largest decline measured in Sherman, Thomas and Sheridan counties. The other counties show either a small overall decline or a small overall rise. With these small changes in water-level it is difficult to assess the effects of the CRP land and the results are mixed. In some cases the water-level decline beneath CRP was less than non-CRP land, in other cases it was more.

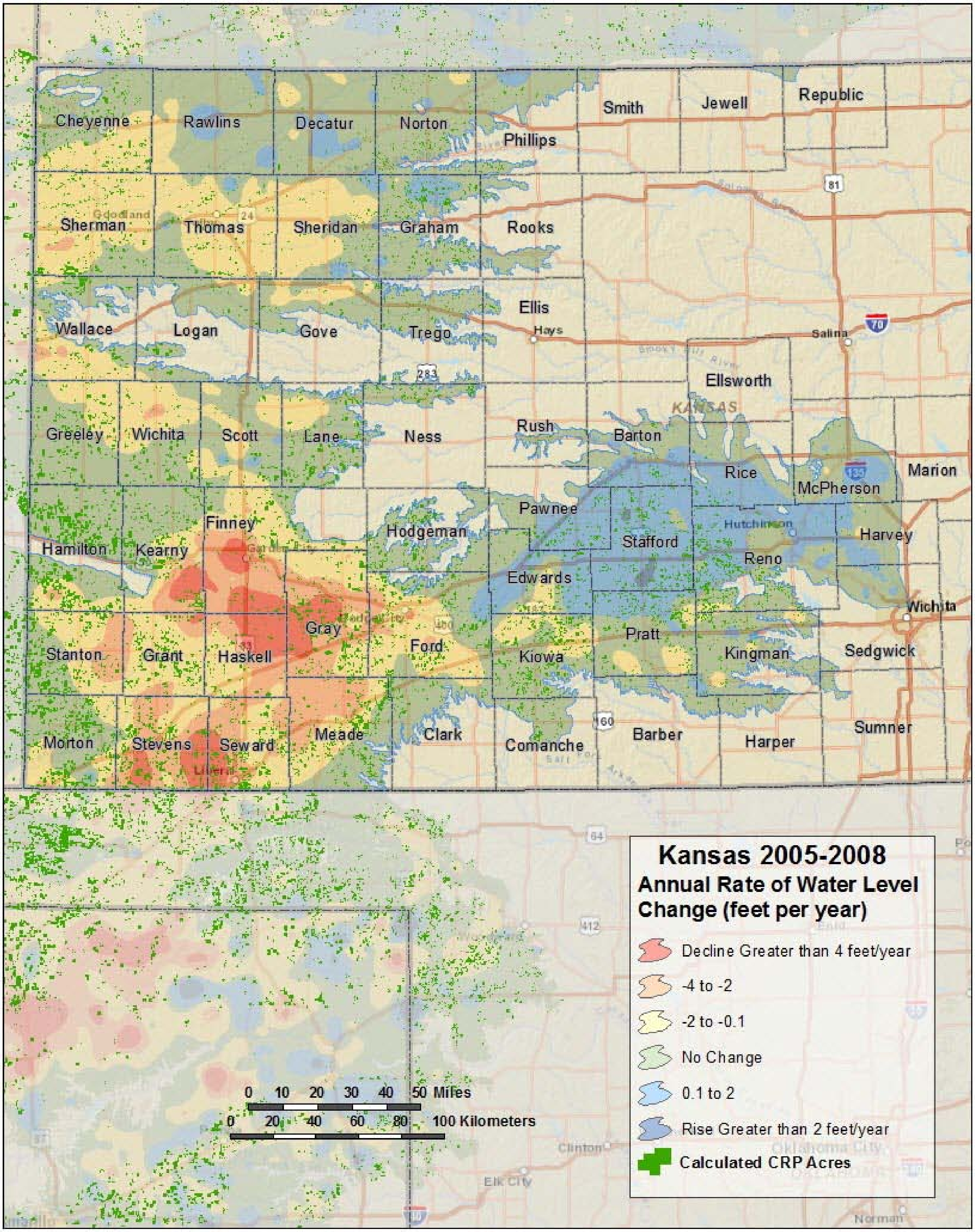

Figure 16. Kansas CRP polygons for 2008 over water-level change, 2005-2008.

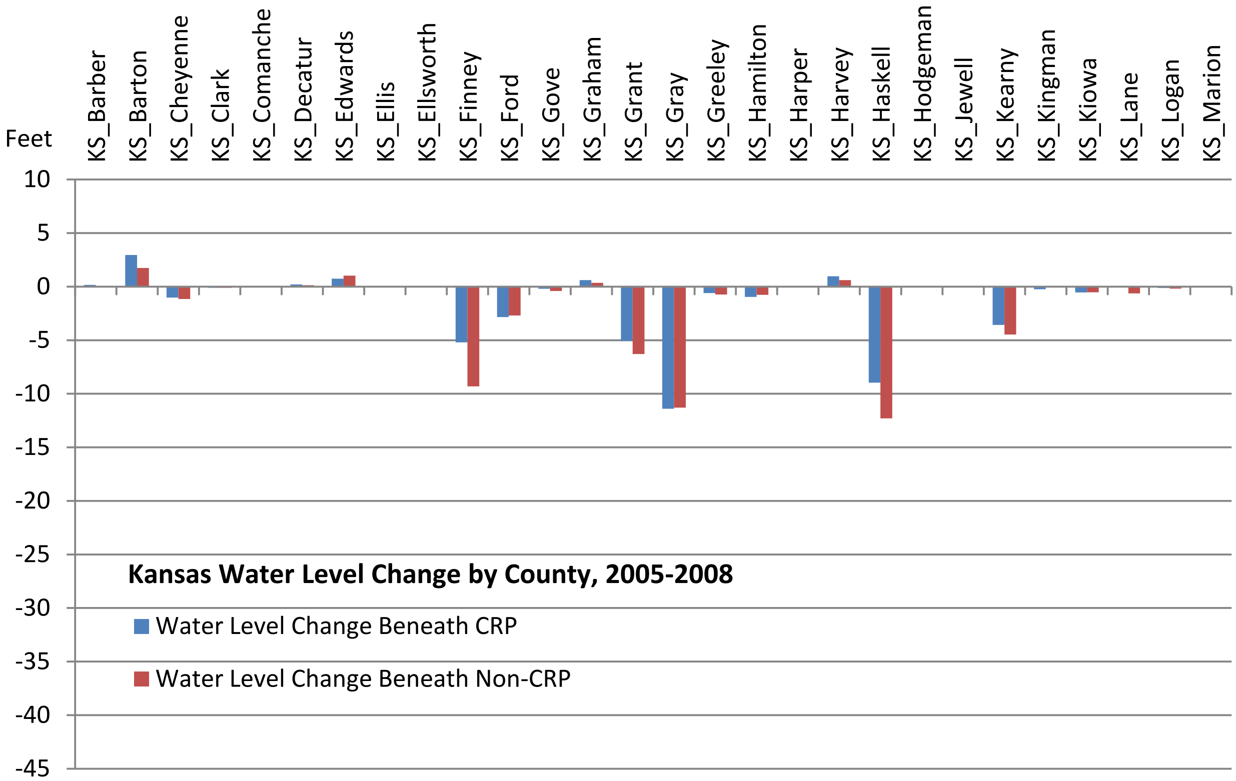

Figure 17. Comparison of water-level changes beneath CRP and non-CRP land, 2005-2008.

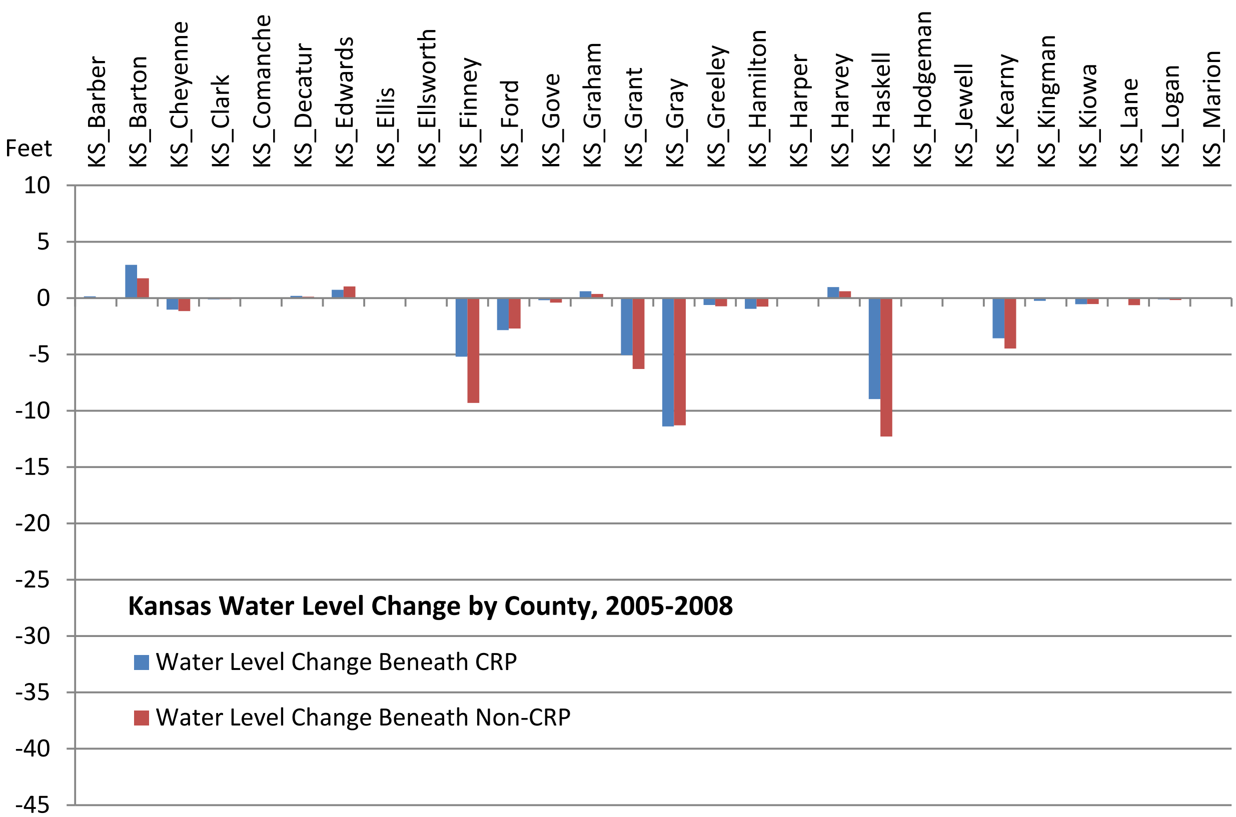

Figure 17 Continued. Comparison of water-level changes beneath CRP and non-CRP land, 2005-2008.

2005-2008 Mean Water-level Change						
State_County	**County WLC (ft)**	**CRP WLC (ft)**	**Non-CRP WLC (ft)**	**Total County CRP Acres Over the Ogallala Aquifer**	**Total County Acres Over the Ogallala Aquifer**	**Percent of County Over the Ogallala Aquifer in CRP**
KS_Barber	0.05	0.16	0.05	2,992	113,402	2.64
KS_Barton	1.78	2.95	1.75	8,233	302,242	2.72
KS_Cheyenne	-1.14	-1.02	-1.15	42,983	592,596	7.25
KS_Clark	-0.11	-0.11	-0.11	10,883	210,858	5.16
KS_Comanche	0.00	0.00	0.00	11,418	123,516	9.24
KS_Decatur	0.12	0.20	0.12	5,596	572,254	0.98
KS_Edwards	1.02	0.74	1.03	23,500	396,116	5.93
KS_Ellis	0.00	0.00	0.00	1,470	19,042	7.72
KS_Ellsworth	0.00	0.00	0.00	379	31,112	1.22
KS_Finney	-9.07	-5.21	-9.30	37,327	643,130	5.80
KS_Ford	-2.71	-2.84	-2.70	58,925	677,287	8.70
KS_Gove	-0.40	-0.19	-0.41	8,643	287,900	3.00
KS_Graham	0.38	0.61	0.36	33,886	407,892	8.31
KS_Grant	-6.14	-5.06	-6.29	46,079	368,092	12.52
KS_Gray	-11.31	-11.40	-11.30	59,417	556,350	10.68
KS_Greeley	-0.72	-0.61	-0.73	41,140	498,208	8.26
KS_Hamilton	-0.80	-0.96	-0.76	118,617	558,226	21.25
KS_Harper	0.00	0.00	0.00	1,905	59,249	3.22
KS_Harvey	0.61	0.97	0.60	1,601	214,546	0.75
KS_Haskell	-12.16	-8.97	-12.29	15,461	369,839	4.18
KS_Hodgeman	-0.01	-0.01	-0.01	33,322	273,007	12.21
KS_Jewell	-0.01	0.00	-0.01	5	11,100	0.04
KS_Kearny	-4.38	-3.58	-4.47	52,830	527,869	10.01
KS_Kingman	-0.09	-0.24	-0.08	19,410	409,907	4.74
KS_Kiowa	-0.53	-0.54	-0.53	54,768	420,432	13.03
KS_Lane	-0.58	-0.08	-0.63	36,209	372,852	9.71
KS_Logan	-0.18	-0.12	-0.18	11,540	301,442	3.83
KS_Marion	0.00	0.00	0.00	4	7,676	0.05

Table 8. Kansas water-level change beneath CRP and non-CRP land by county, 2005-2008.

2005-2008 Mean Water-level Change						
State_County	**County WLC (ft)**	**CRP WLC (ft)**	**Non-CRP WLC (ft)**	**Total County CRP Acres Over the Ogallala Aquifer**	**Total County Acres Over the Ogallala Aquifer**	**Percent of County Over the Ogallala Aquifer in CRP**
KS_McPherson	0.38	0.38	0.38	3,083	339,724	0.91
KS_Meade	-4.92	-3.96	-5.02	60,627	599,515	10.11
KS_Morton	-1.21	-0.93	-1.27	76,213	467,153	16.31
KS_Ness	0.01	0.01	0.01	14,185	118,891	11.93
KS_Norton	-0.04	0.00	-0.04	17,514	501,102	3.49
KS_Pawnee	2.35	2.98	2.31	14,753	303,100	4.87
KS_Phillips	0.31	0.04	0.31	4,492	244,095	1.84
KS_Pratt	0.58	1.30	0.51	38,940	470,862	8.27
KS_Rawlins	0.07	0.18	0.06	2,669	684,529	0.39
KS_Reno	1.54	1.23	1.56	57,045	691,499	8.25
KS_Republic	0.00	0.00	0.00	25	11,663	0.22
KS_Rice	1.44	2.54	1.41	6,389	334,974	1.91
KS_Rooks	0.00	0.00	0.00	2,736	100,026	2.73
KS_Rush	0.00	0.00	0.00	3,988	50,122	7.96
KS_Scott	-0.75	-0.58	-0.76	14,382	456,686	3.15
KS_Sedgwick	0.21	1.51	0.21	532	143,014	0.37
KS_Seward	-10.03	-10.81	-9.91	51,510	409,912	12.57
KS_Sheridan	-1.86	-1.00	-1.87	10,759	567,053	1.90
KS_Sherman	-3.26	-2.80	-3.29	40,752	676,018	6.03
KS_Smith	0.00	0.00	0.00	168	19,035	0.88
KS_Stafford	4.83	4.98	4.82	38,729	508,747	7.61
KS_Stanton	-4.11	-2.07	-4.50	69,774	435,466	16.02
KS_Stevens	-12.49	-12.58	-12.48	61,864	465,582	13.29
KS_Sumner	0.12	0.50	0.11	197	20,742	0.95
KS_Thomas	-2.17	-2.12	-2.18	20,390	687,871	2.96
KS_Trego	0.00	0.00	0.00	11,841	248,663	4.76
KS_Wallace	-2.68	-1.77	-2.76	30,578	398,282	7.68
KS_Wichita	-1.83	-0.97	-1.88	25,899	459,899	5.63

Table 8. Continued Kansas water-level change beneath CRP and non-CRP land by county, 2005-2008.

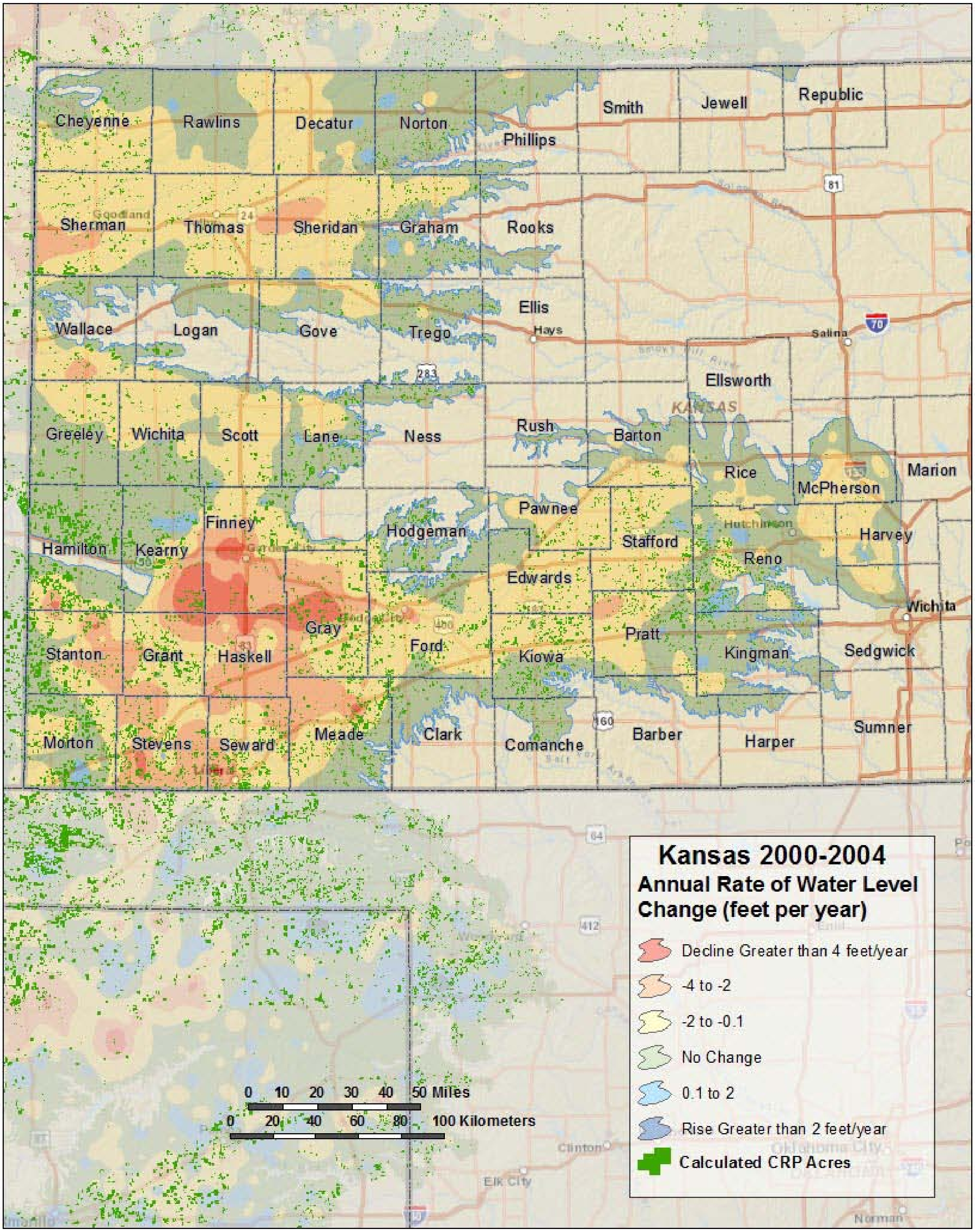

Figure 18. Kansas CRP polygons for 2004 over water-level change, 2000-2004.

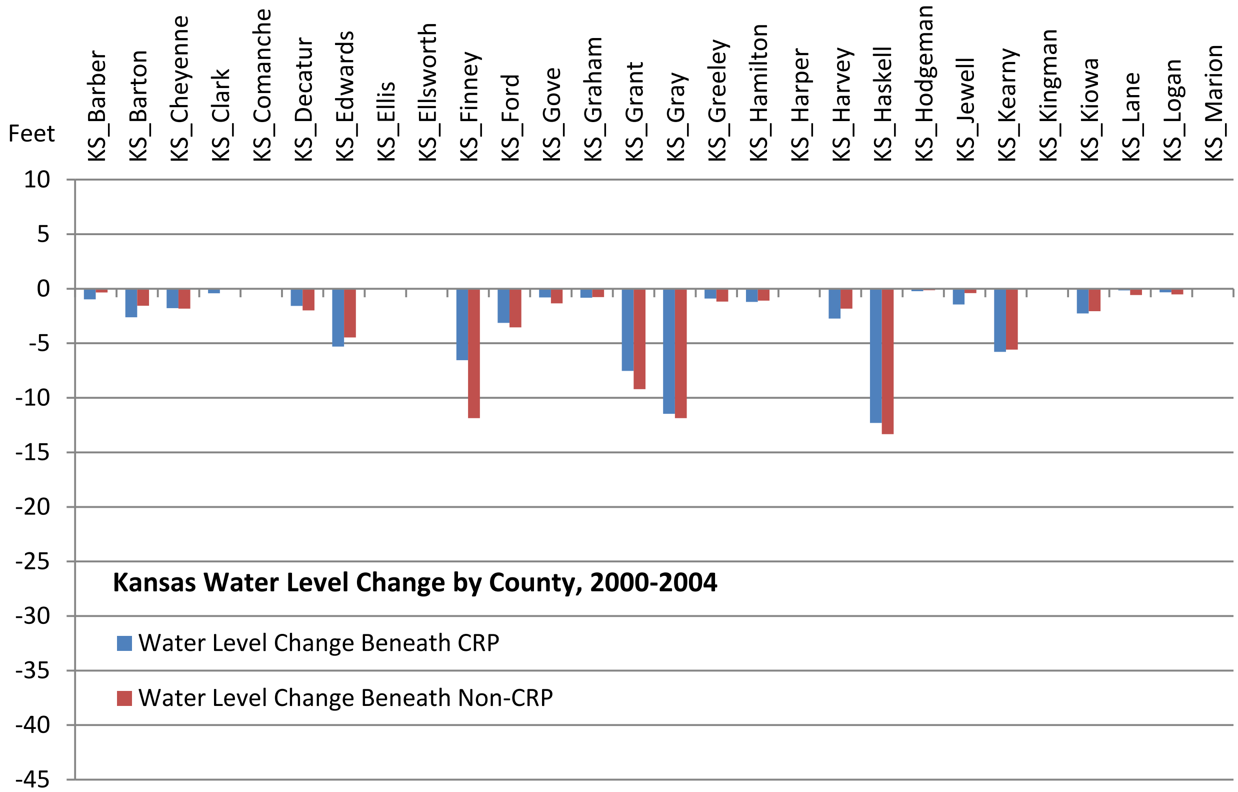

Figure 19. Comparison of water-level changes beneath CRP and non-CRP land, 2000-2004.

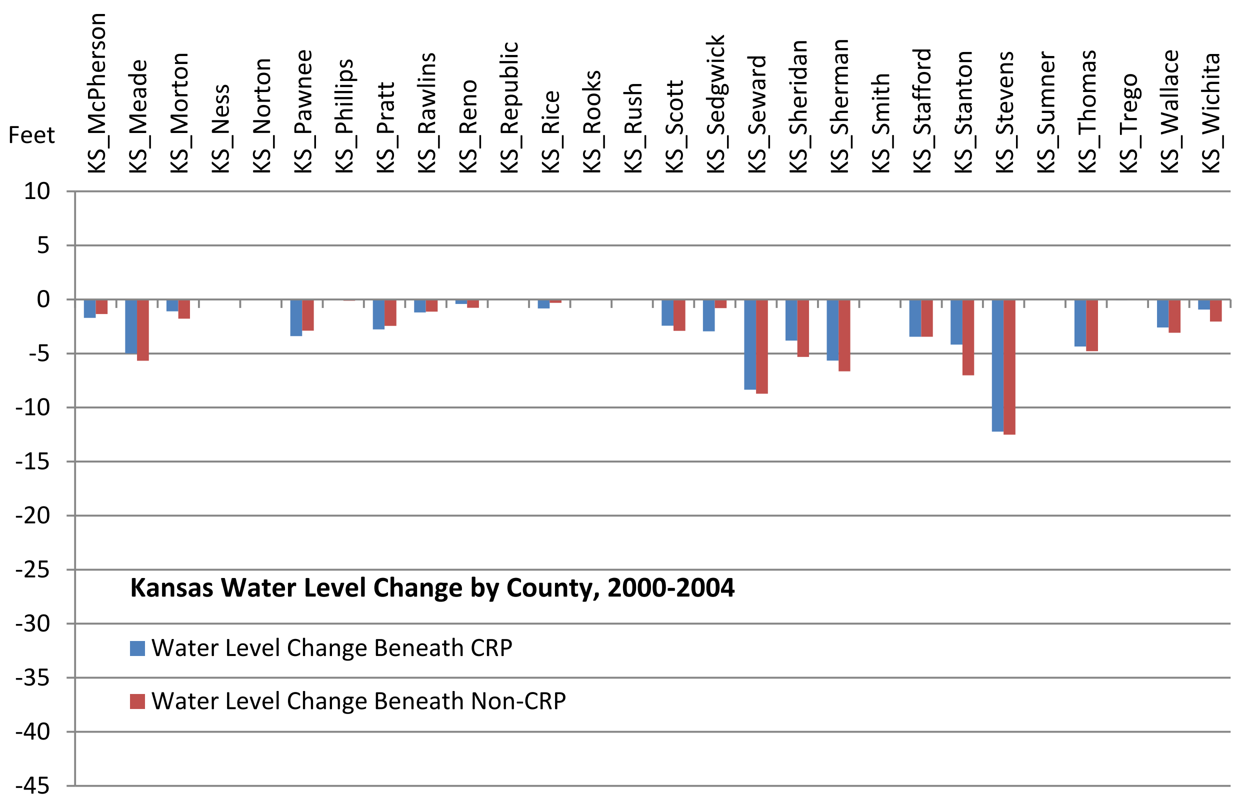

Figure 19 Continued. Comparison of water-level changes beneath CRP and non-CRP land 2000-2004.

2000-2004 Mean Water-level Change						
State_County	**County WLC (ft)**	**CRP WLC (ft)**	**Non-CRP WLC (ft)**	**Total County CRP Acres Over the Ogallala Aquifer**	**Total County Acres Over the Ogallala Aquifer**	**Percent of County Over the Ogallala Aquifer in CRP**
KS_Barber	-0.36	-0.97	-0.35	2,639	113,402	2.33
KS_Barton	-1.58	-2.62	-1.56	7,403	302,242	2.45
KS_Cheyenne	-1.82	-1.79	-1.83	40,281	592,596	6.80
KS_Clark	-0.07	-0.42	-0.05	10,744	210,858	5.10
KS_Comanche	0.00	0.00	0.00	10,433	123,516	8.45
KS_Decatur	-1.98	-1.58	-1.98	5,349	572,254	0.93
KS_Edwards	-4.52	-5.31	-4.47	22,879	396,116	5.78
KS_Ellis	0.00	0.00	0.00	1,317	19,042	6.92
KS_Ellsworth	0.00	0.00	0.00	379	31,112	1.22
KS_Finney	-11.57	-6.55	-11.86	35,140	643,130	5.46
KS_Ford	-3.51	-3.14	-3.54	56,260	677,287	8.31
KS_Gove	-1.33	-0.80	-1.35	8,414	287,900	2.92
KS_Graham	-0.78	-0.82	-0.78	21,425	407,892	5.25
KS_Grant	-9.01	-7.54	-9.21	45,240	368,092	12.29
KS_Gray	-11.82	-11.47	-11.86	57,091	556,350	10.26
KS_Greeley	-1.16	-0.90	-1.18	31,949	498,208	6.41
KS_Hamilton	-1.11	-1.20	-1.09	115,031	558,226	20.61
KS_Harper	0.00	0.00	0.00	1,685	59,249	2.84
KS_Harvey	-1.83	-2.74	-1.83	1,583	214,546	0.74
KS_Haskell	-13.30	-12.30	-13.33	10,667	369,839	2.88
KS_Hodgeman	-0.15	-0.22	-0.14	31,595	273,007	11.57
KS_Jewell	-0.40	-1.44	-0.40	5	11,100	0.04
KS_Kearny	-5.60	-5.78	-5.58	44,985	527,869	8.52
KS_Kingman	-0.05	0.04	-0.06	15,357	409,907	3.75
KS_Kiowa	-2.08	-2.26	-2.06	54,261	420,432	12.91
KS_Lane	-0.54	-0.15	-0.58	30,357	372,852	8.14
KS_Logan	-0.52	-0.32	-0.52	10,701	301,442	3.55
KS_Marion	0.00	0.00	0.00	4	7,676	0.05

Table 9. Kansas water-level change beneath CRP and non-CRP land by county, 2000-2004.

2000-2004 Mean Water-level Change						
State_County	County WLC (ft)	CRP WLC (ft)	Non-CRP WLC (ft)	Total County CRP Acres Over the Ogallala Aquifer	Total County Acres Over the Ogallala Aquifer	Percent of County Over the Ogallala Aquifer in CRP
KS_McPherson	-1.35	-1.71	-1.34	2,913	339,724	0.86
KS_Meade	-5.60	-4.99	-5.67	55,926	599,515	9.33
KS_Morton	-1.67	-1.09	-1.78	74,173	467,153	15.88
KS_Ness	0.00	0.00	0.00	12,532	118,891	10.54
KS_Norton	0.00	-0.01	0.00	16,744	501,102	3.34
KS_Pawnee	-2.91	-3.39	-2.89	12,662	303,100	4.18
KS_Phillips	-0.11	0.00	-0.12	3,554	244,095	1.46
KS_Pratt	-2.47	-2.77	-2.45	37,491	470,862	7.96
KS_Rawlins	-1.13	-1.20	-1.13	2,540	684,529	0.37
KS_Reno	-0.75	-0.42	-0.78	52,867	691,499	7.65
KS_Republic	0.00	0.00	0.00	25	11,663	0.22
KS_Rice	-0.33	-0.83	-0.32	5,551	334,974	1.66
KS_Rooks	0.00	0.00	0.00	2,206	100,026	2.21
KS_Rush	0.00	0.00	0.00	3,783	50,122	7.55
KS_Scott	-2.89	-2.43	-2.90	12,731	456,686	2.79
KS_Sedgwick	-0.81	-2.95	-0.80	532	143,014	0.37
KS_Seward	-8.68	-8.35	-8.72	50,016	409,912	12.20
KS_Sheridan	-5.29	-3.81	-5.31	10,518	567,053	1.85
KS_Sherman	-6.60	-5.66	-6.65	33,024	676,018	4.89
KS_Smith	0.00	0.00	0.00	168	19,035	0.88
KS_Stafford	-3.46	-3.45	-3.46	36,632	508,747	7.20
KS_Stanton	-6.58	-4.17	-7.01	66,374	435,466	15.24
KS_Stevens	-12.47	-12.22	-12.51	56,807	465,582	12.20
KS_Sumner	0.00	0.00	0.00	173	20,742	0.84
KS_Thomas	-4.77	-4.35	-4.78	20,076	687,871	2.92
KS_Trego	-0.04	-0.06	-0.04	10,447	248,663	4.20
KS_Wallace	-3.05	-2.59	-3.08	23,481	398,282	5.90
KS_Wichita	-1.99	-0.94	-2.04	20,759	459,899	4.51

Table 9 Continued. Kansas water-level change beneath CRP and non-CRP land by county, 2000-2004.

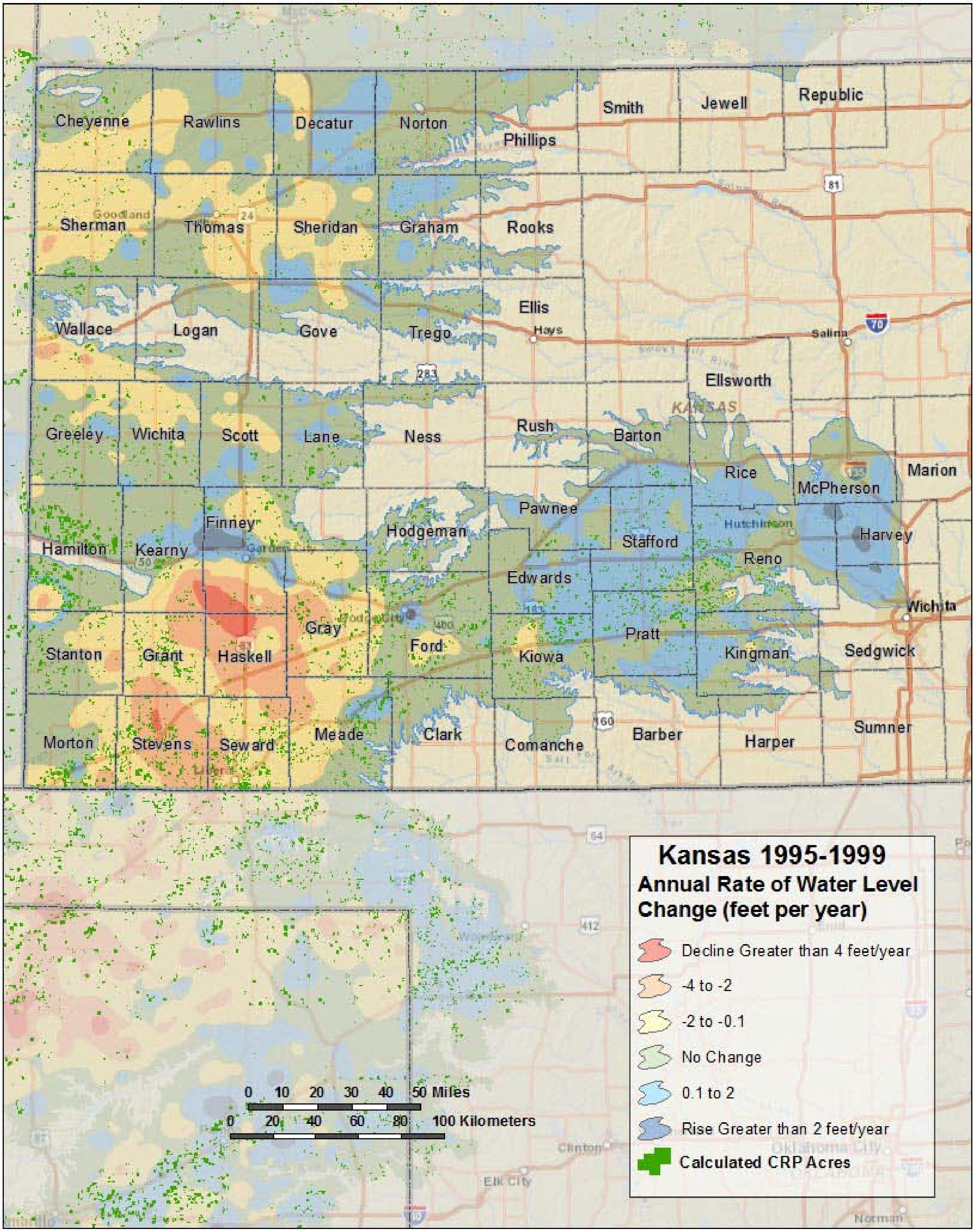

Figure 20. Kansas CRP polygons for 1999 over water-level change, 1995-1999.

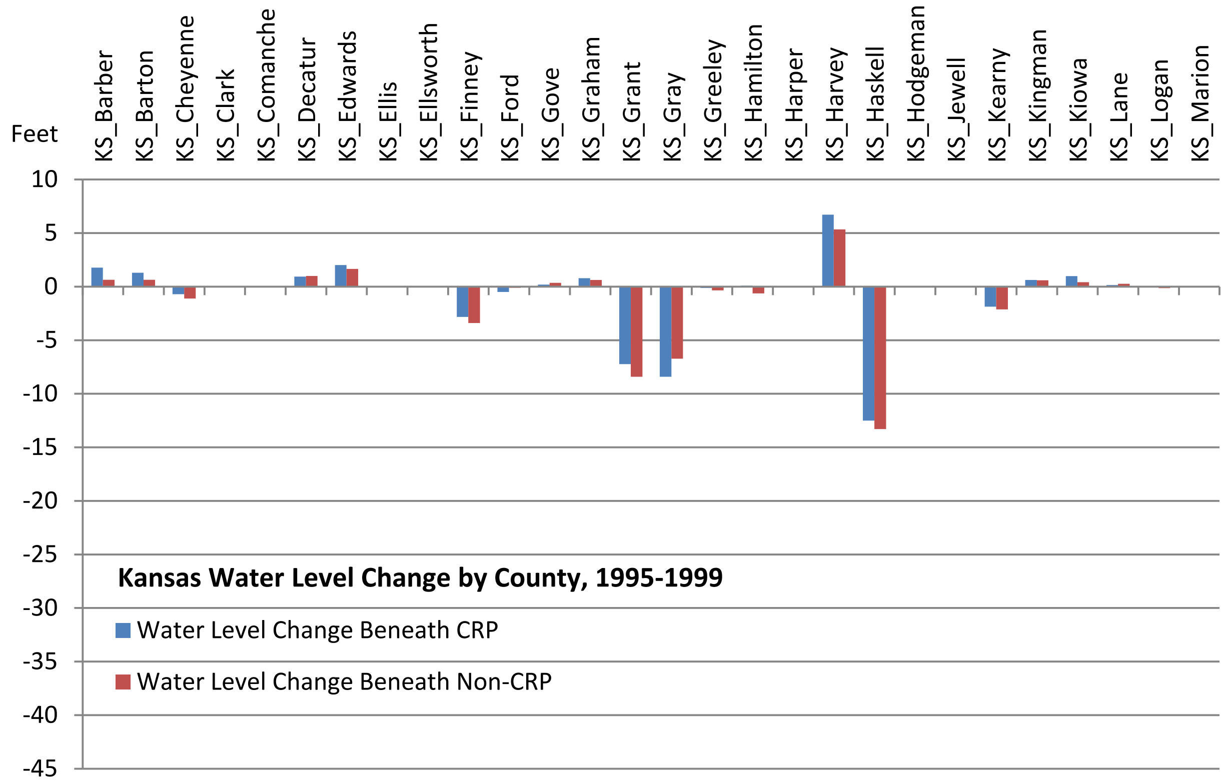

Figure 21. Comparison of water-level changes beneath CRP and non-CRP land, 1995-1999.

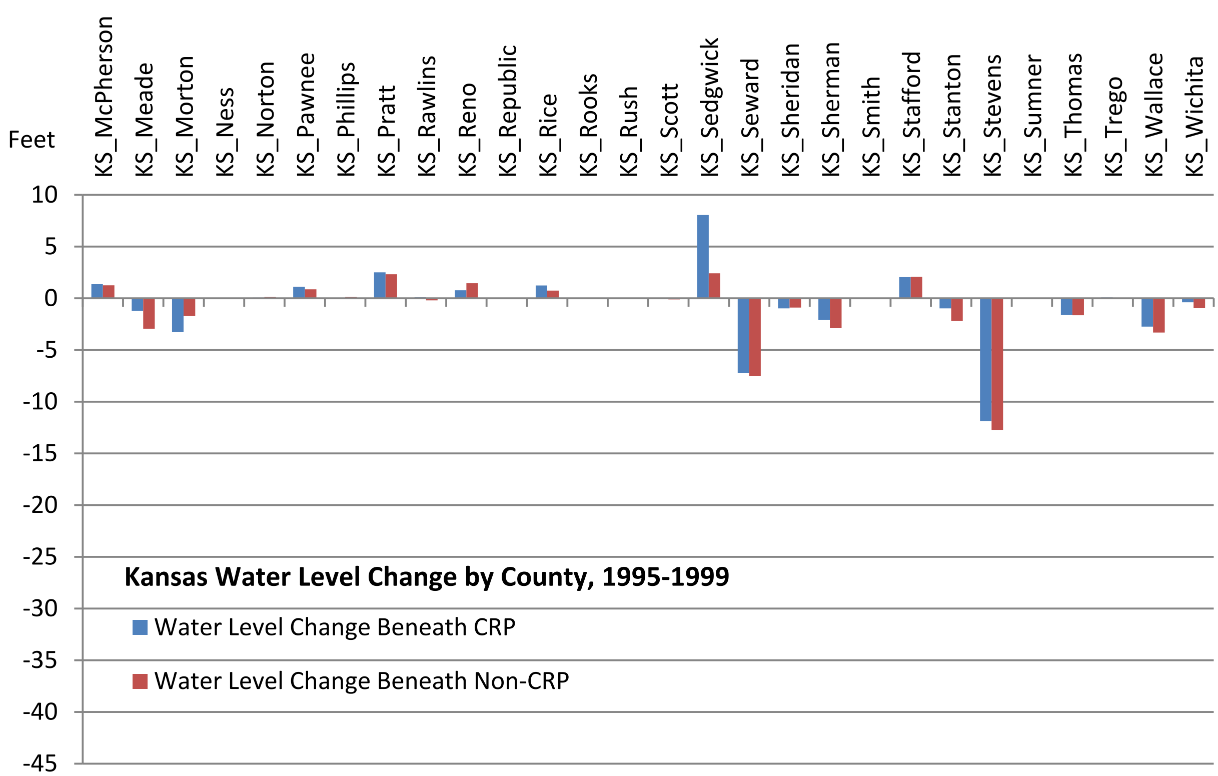

Figure 21 Continued. Comparison of water-level changes beneath CRP and non-CRP land, 1995-1999.

1995-1999 Mean Water-level Change						
State_County	**County WLC (ft)**	**CRP WLC (ft)**	**Non-CRP WLC (ft)**	**Total County CRP Acres Over the Ogallala Aquifer**	**Total County Acres Over the Ogallala Aquifer**	**Percent of County Over the Ogallala Aquifer in CRP**
KS_Barber	0.65	1.78	0.64	1,258	113,402	1.11
KS_Barton	0.65	1.30	0.64	5,933	302,242	1.96
KS_Cheyenne	-1.09	-0.71	-1.11	19,872	592,596	3.35
KS_Clark	0.01	0.02	0.01	7,079	210,858	3.36
KS_Comanche	0.00	0.00	0.00	3,234	123,516	2.62
KS_Decatur	0.99	0.94	0.99	3,606	572,254	0.63
KS_Edwards	1.66	2.01	1.65	12,227	396,116	3.09
KS_Ellis	0.00	0.00	0.00	291	19,042	1.53
KS_Ellsworth	0.00	0.00	0.00	365	31,112	1.17
KS_Finney	-3.38	-2.83	-3.40	23,904	643,130	3.72
KS_Ford	-0.14	-0.50	-0.11	50,345	677,287	7.43
KS_Gove	0.36	0.19	0.36	5,745	287,900	2.00
KS_Graham	0.63	0.78	0.62	5,647	407,892	1.38
KS_Grant	-8.31	-7.24	-8.41	32,993	368,092	8.96
KS_Gray	-6.82	-8.42	-6.72	33,480	556,350	6.02
KS_Greeley	-0.34	-0.12	-0.35	22,537	498,208	4.52
KS_Hamilton	-0.53	0.09	-0.63	78,171	558,226	14.01
KS_Harper	0.00	0.00	0.00	771	59,249	1.30
KS_Harvey	5.35	6.71	5.34	1,149	214,546	0.54
KS_Haskell	-13.28	-12.50	-13.30	6,247	369,839	1.69
KS_Hodgeman	0.02	0.00	0.02	19,715	273,007	7.22
KS_Jewell	0.00	0.00	0.00	4	11,100	0.03
KS_Kearny	-2.11	-1.87	-2.12	18,284	527,869	3.46
KS_Kingman	0.60	0.62	0.60	10,397	409,907	2.54
KS_Kiowa	0.46	0.98	0.41	35,498	420,432	8.44
KS_Lane	0.25	0.15	0.26	12,773	372,852	3.43
KS_Logan	-0.14	-0.03	-0.14	3,569	301,442	1.18
KS_Marion	0.00	0.00	0.00	2	7,676	0.02

Table 10. Kansas water-level change beneath CRP and non-CRP land by county, 1995-1999.

1995-1999 Mean Water-level Change						
State_County	**County WLC (ft)**	**CRP WLC (ft)**	**Non-CRP WLC (ft)**	**Total County CRP Acres Over the Ogallala Aquifer**	**Total County Acres Over the Ogallala Aquifer**	**Percent of County Over the Ogallala Aquifer in CRP**
KS_McPherson	1.26	1.37	1.26	1,743	339,724	0.51
KS_Meade	-2.82	-1.21	-2.94	39,610	599,515	6.61
KS_Morton	-1.80	-3.28	-1.71	28,599	467,153	6.12
KS_Ness	0.00	0.00	0.00	5,704	118,891	4.80
KS_Norton	0.13	0.06	0.13	8,196	501,102	1.64
KS_Pawnee	0.87	1.12	0.87	4,956	303,100	1.64
KS_Phillips	0.12	0.00	0.12	751	244,095	0.31
KS_Pratt	2.33	2.51	2.32	30,472	470,862	6.47
KS_Rawlins	-0.20	0.10	-0.20	1,003	684,529	0.15
KS_Reno	1.42	0.78	1.46	43,913	691,499	6.35
KS_Republic	0.00	0.00	0.00	0.000	11,663	0.00
KS_Rice	0.75	1.24	0.74	2,962	334,974	0.88
KS_Rooks	0.00	0.00	0.00	458	100,026	0.46
KS_Rush	0.00	0.00	0.00	1,945	50,122	3.88
KS_Scott	-0.11	-0.05	-0.11	5,992	456,686	1.31
KS_Sedgwick	2.44	8.06	2.42	489	143,014	0.34
KS_Seward	-7.48	-7.24	-7.51	47,817	409,912	11.67
KS_Sheridan	-0.90	-0.97	-0.90	5,763	567,053	1.02
KS_Sherman	-2.88	-2.10	-2.90	17,246	676,018	2.55
KS_Smith	0.00	0.00	0.00	19	19,035	0.10
KS_Stafford	2.08	2.04	2.08	23,776	508,747	4.67
KS_Stanton	-2.13	-0.97	-2.20	25,941	435,466	5.96
KS_Stevens	-12.63	-11.88	-12.72	49,297	465,582	10.59
KS_Sumner	0.00	0.00	0.00	49	20,742	0.24
KS_Thomas	-1.64	-1.62	-1.64	9,897	687,871	1.44
KS_Trego	0.04	0.07	0.03	3,401	248,663	1.37
KS_Wallace	-3.30	-2.74	-3.32	11,583	398,282	2.91
KS_Wichita	-0.94	-0.39	-0.96	13,246	459,899	2.88

Table 10 Continued. Kansas water-level change beneath CRP and non-CRP land by county, 1995-1999.

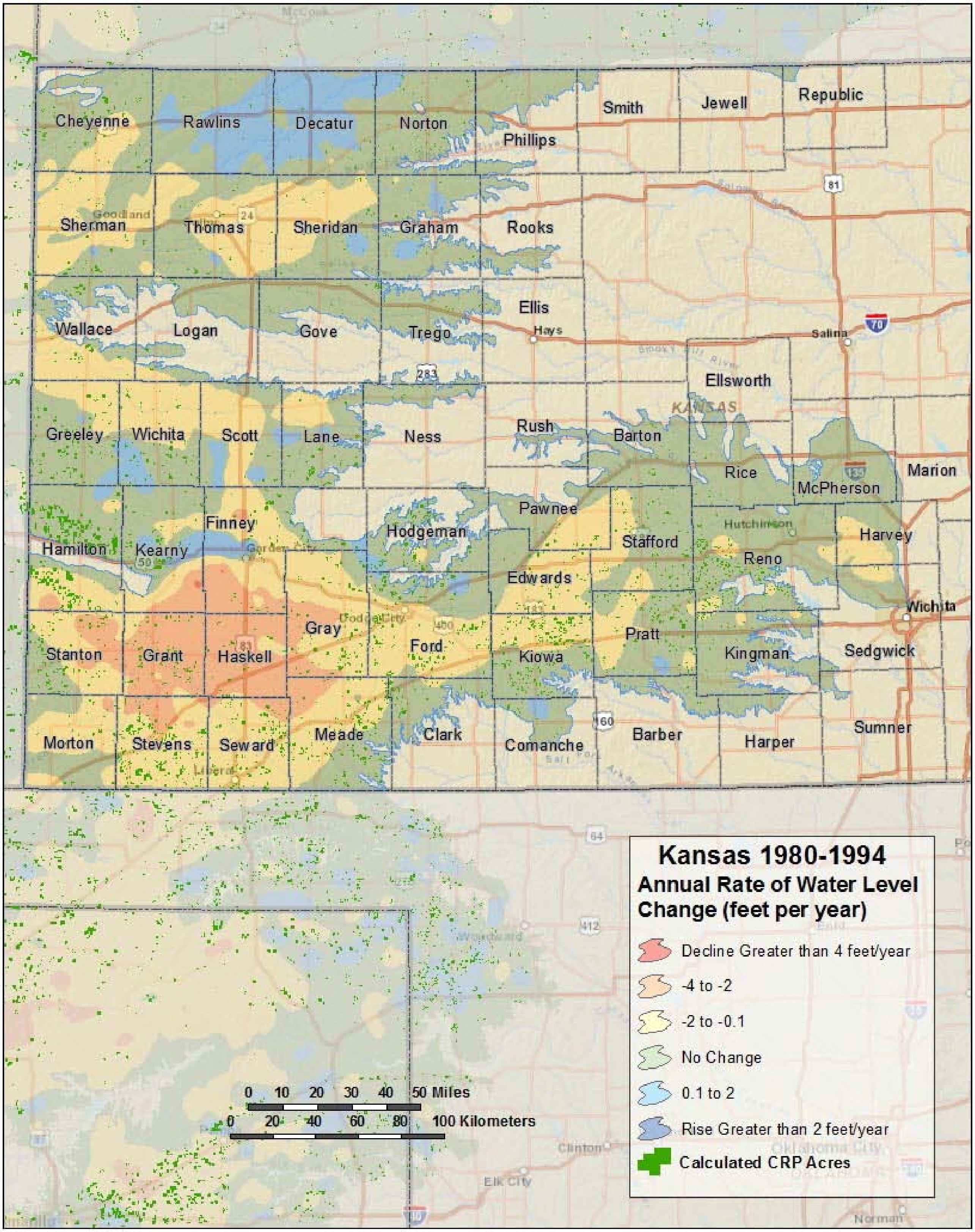

Figure 22. Kansas CRP polygons for 1994 over water-level change, 1980-1994.

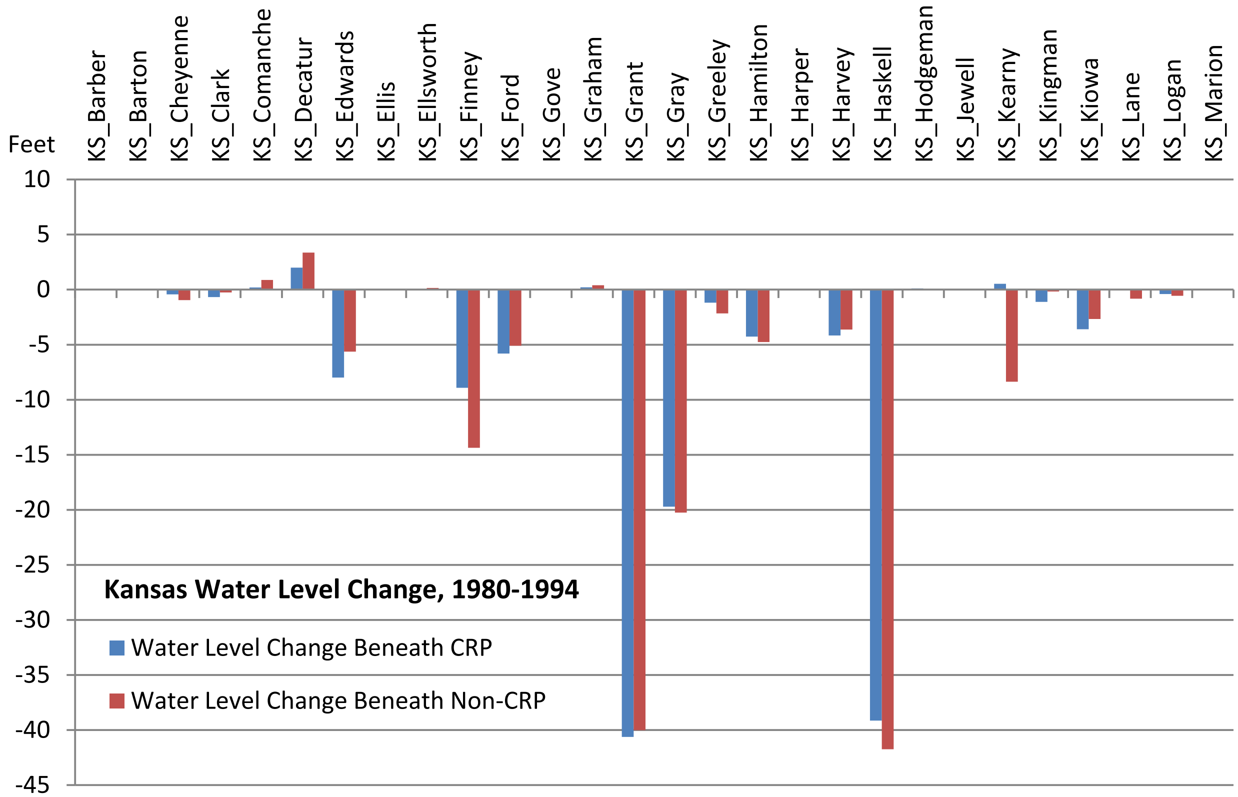

Figure 23. Comparison of water-level changes beneath CRP and non-CRP land, 1980-1994.

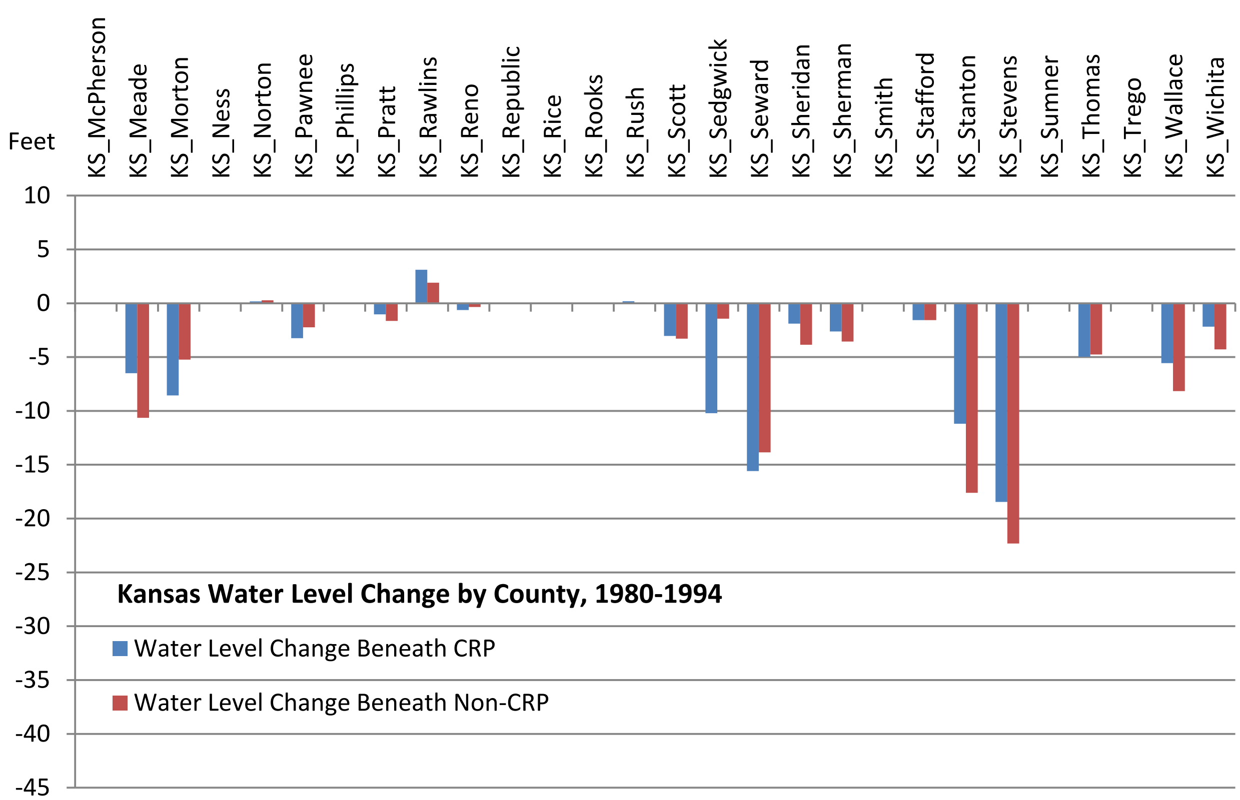

Figure 23 Continued. Comparison of water-level changes beneath CRP and non-CRP land, 1980-1994.

1980-1994 Mean Water-level Change						
State_County	County WLC (ft)	CRP WLC (ft)	Non-CRP WLC (ft)	Total County CRP Acres Over the Ogallala Aquifer	Total County Acres Over the Ogallala Aquifer	Percent of County Over the Ogallala Aquifer in CRP
KS_Barber	0.00	0.00	0.00	1,203	113,402	1.06
KS_Barton	0.03	0.02	0.03	2,452	302,242	0.81
KS_Cheyenne	-0.94	-0.43	-0.95	13,696	592,596	2.31
KS_Clark	-0.27	-0.68	-0.26	6,818	210,858	3.23
KS_Comanche	0.86	0.19	0.88	2,824	123,516	2.29
KS_Decatur	3.35	2.00	3.36	2,262	572,254	0.40
KS_Edwards	-5.69	-7.98	-5.63	10,183	396,116	2.57
KS_Ellis	0.00	0.00	0.00	296	19,042	1.55
KS_Ellsworth	0.15	0.00	0.15	243	31,112	0.78
KS_Finney	-14.25	-8.92	-14.36	13,647	643,130	2.12
KS_Ford	-5.13	-5.81	-5.10	34,240	677,287	5.06
KS_Gove	0.00	0.00	0.00	2,136	287,900	0.74
KS_Graham	0.40	0.21	0.40	2,858	407,892	0.70
KS_Grant	-40.04	-40.61	-40.01	14,651	368,092	3.98
KS_Gray	-20.24	-19.71	-20.25	19,116	556,350	3.44
KS_Greeley	-2.11	-1.18	-2.15	20,054	498,208	4.03
KS_Hamilton	-4.70	-4.26	-4.76	69,273	558,226	12.41
KS_Harper	0.00	0.00	0.00	234	59,249	0.39
KS_Harvey	-3.62	-4.16	-3.62	570	214,546	0.27
KS_Haskell	-41.71	-39.14	-41.74	5,175	369,839	1.40
KS_Hodgeman	0.04	0.11	0.04	16,917	273,007	6.20
KS_Jewell	0.00	0.00	0.00	0	11,100	0.00
KS_Kearny	-8.14	0.54	-8.36	13,027	527,869	2.47
KS_Kingman	-0.18	-1.11	-0.16	6,057	409,907	1.48
KS_Kiowa	-2.74	-3.60	-2.67	33,483	420,432	7.96
KS_Lane	-0.80	-0.01	-0.82	8,561	372,852	2.30
KS_Logan	-0.56	-0.39	-0.56	1,378	301,442	0.46
KS_Marion	0.00	0.00	0.00	0	7,676	0.00

Table 11. Kansas water-level change beneath CRP and non-CRP land by county, 1980-1994.

1980-1994 Mean Water-level Change						
State_County	**County WLC (ft)**	**CRP WLC (ft)**	**Non-CRP WLC (ft)**	**Total County CRP Acres Over the Ogallala Aquifer**	**Total County Acres Over the Ogallala Aquifer**	**Percent of County Over the Ogallala Aquifer in CRP**
KS_McPherson	0.00	0.00	0.00	687	339,724	0.20
KS_Meade	-10.46	-6.50	-10.65	26,671	599,515	4.45
KS_Morton	-5.28	-8.56	-5.23	5,702	467,153	1.22
KS_Ness	0.00	0.00	0.00	2,230	118,891	1.88
KS_Norton	0.27	0.18	0.27	6,320	501,102	1.26
KS_Pawnee	-2.24	-3.24	-2.23	3,574	303,100	1.18
KS_Phillips	0.04	0.00	0.04	304	244,095	0.12
KS_Pratt	-1.61	-1.03	-1.63	17,579	470,862	3.73
KS_Rawlins	1.92	3.12	1.91	793	684,529	0.12
KS_Reno	-0.36	-0.62	-0.35	30,523	691,499	4.41
KS_Republic	0.00	0.00	0.00	0	11,663	0.00
KS_Rice	0.00	0.00	0.00	2,168	334,974	0.65
KS_Rooks	0.00	0.00	0.00	353	100,026	0.35
KS_Rush	0.06	0.18	0.06	380	50,122	0.76
KS_Scott	-3.30	-3.04	-3.30	1,379	456,686	0.30
KS_Sedgwick	-1.45	-10.21	-1.43	319	143,014	0.22
KS_Seward	-13.95	-15.59	-13.85	23,108	409,912	5.64
KS_Sheridan	-3.84	-1.90	-3.85	3,136	567,053	0.55
KS_Sherman	-3.55	-2.62	-3.56	7,068	676,018	1.05
KS_Smith	0.00	0.00	0.00	0	19,035	0.00
KS_Stafford	-1.57	-1.56	-1.57	14,127	508,747	2.78
KS_Stanton	-17.28	-11.19	-17.61	22,540	435,466	5.18
KS_Stevens	-22.01	-18.46	-22.31	36,715	465,582	7.89
KS_Sumner	0.00	0.00	0.00	3	20,742	0.01
KS_Thomas	-4.77	-4.97	-4.77	5,565	687,871	0.81
KS_Trego	0.00	0.00	0.00	1,586	248,663	0.64
KS_Wallace	-8.10	-5.56	-8.17	9,547	398,282	2.40
KS_Wichita	-4.23	-2.18	-4.29	12,047	459,899	2.62

Table 11 Continued. Kansas water-level change beneath CRP and non-CRP land by county, 1980-1994.

Colorado

CRP Effects on Water-level Change by County

Summary Results: Colorado

In Colorado, the High Plains Aquifer underlies all of part of 15 counties on the eastern most side of the state – with an area covering approximately 13,300 square miles. In Colorado the greatest water-level declines have occurred in the eastern-central and northeastern parts of the state. Specifically, Yuma, Phillips, Kit Carson and Cheyenne counties have seen the greatest water-levels declines. In addition to these four counties, significant water-level declines have also occurred in Sedgwick, Logan and Washington counties during the two most recent time intervals, 2005-2008 and 2000-2004. In the southeastern part of the state there has been little water-level change in Baca, Prowers and Kiowa counties.

In the four counties with the greatest decline (Yuma, Phillips, Kit Carson and Cheyenne), the drawdown beneath CRP land was less than non-CRP land for all of the counties in all four of the time intervals. In Yuma County, the drawdown beneath CRP land was 5 percent less 2005-2008, 11 percent less in 2000-2004, 20 percent less in 1995-1999 and 32 percent less in 1980-1994. Over all four time intervals (1980 to 2008), the aquifer in Yuma County declined 18.5 feet beneath CRP land and 22.6 feet between non-CRP land and the total aquifer drawdown was 18 percent less beneath CRP land.

In Phillips County, the drawdown beneath CRP land was 10 percent less in 2005-2008, 21 percent less in 2000-2004, 46 percent less in 1995-1999 and 25 percent less in 1980-1994. Between 1980 and 2008 the drawdown beneath CRP land was 13.8 feet and the drawdown beneath non-CRP land was 18.0 feet. Over the four time intervals, the total drawdown beneath CRP land was less 23 percent less than the drawdown beneath non-CRP land.

Compared to Yuma and Phillips, the total drawdown between 1980 and 2008 was not quite as large in Kit Carson and Cheyenne counties. Both of these counties, however, showed a greater difference between CRP and non-CRP land. In Kit Carson County, the total drawdown beneath CRP land was 7.4 feet and the total drawdown beneath non-CRP land was 14.7 feet. Over the four time intervals, the drawdown beneath CRP was 50 percent less. Similarly, in Cheyenne County, the total drawdown beneath CRP land was 5.4 feet and the total drawdown beneath non-CRP land was 9.4 feet. For Cheyenne County, the drawdown beneath CRP was 42 percent less.

The other counties in Colorado showed mixed results. In the 2005-2008 and 2000-2004 time intervals both Sedgwick and Logan counties had a greater decline beneath CRP. In contrast the decline beneath CRP land in Washington County was 38 percent less in the 2005-2008 interval and 55 percent less in the 2000-2004 interval.

It is also of interest to note that several of these Colorado counties showed a rise in the water-level in the two earlier time intervals. Between 1995 and 2000 the water-level increase beneath CRP land was greater than non-CRP land in Sedgwick and Washington counties. In the 1980-1994 time interval, the rise in the water-level beneath CRP land was significantly greater than the rise beneath non-CRP land in Logan and Washington counties.

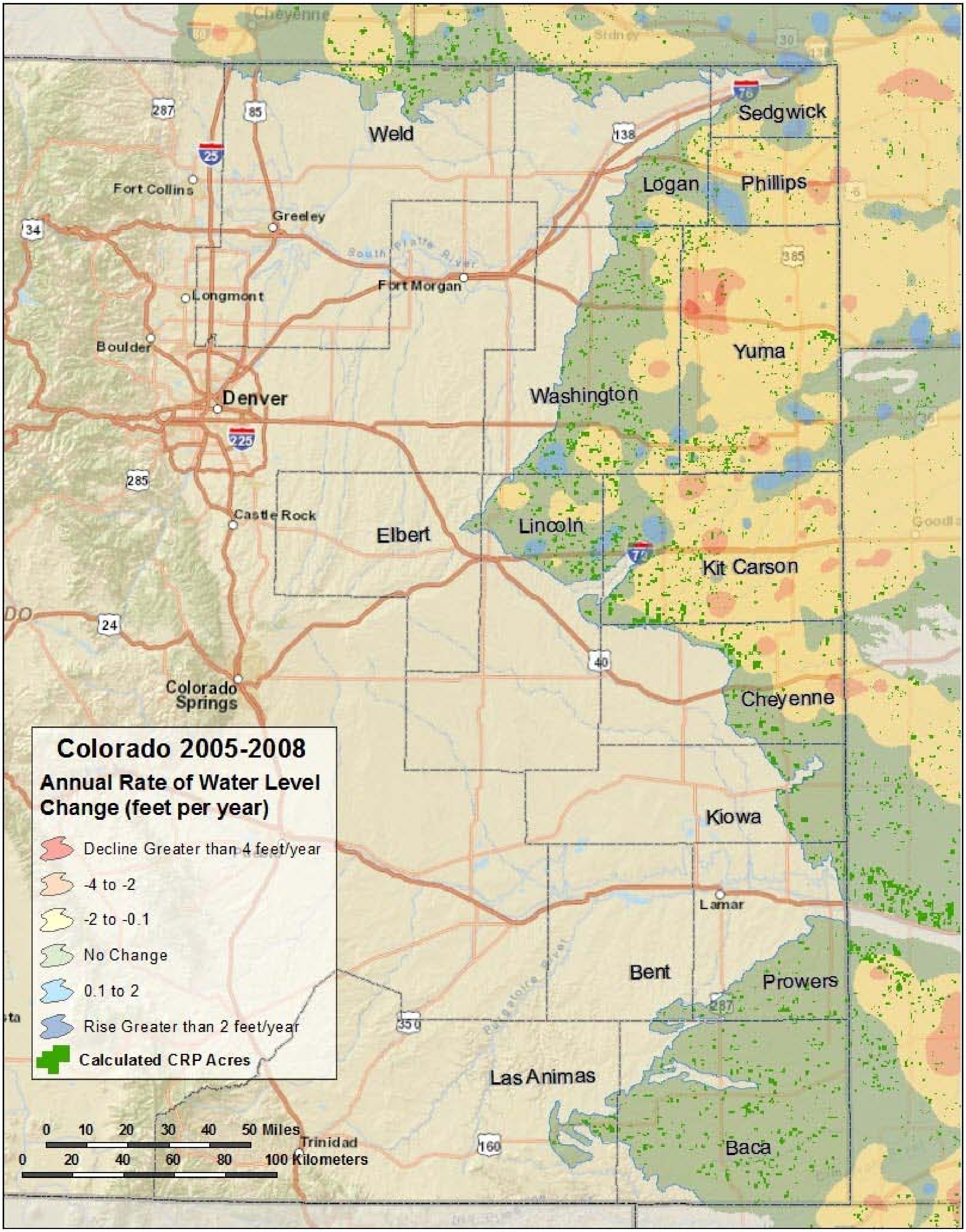

Figure 24. Colorado CRP polygons for 2008 over water-level change, 2005-2008.

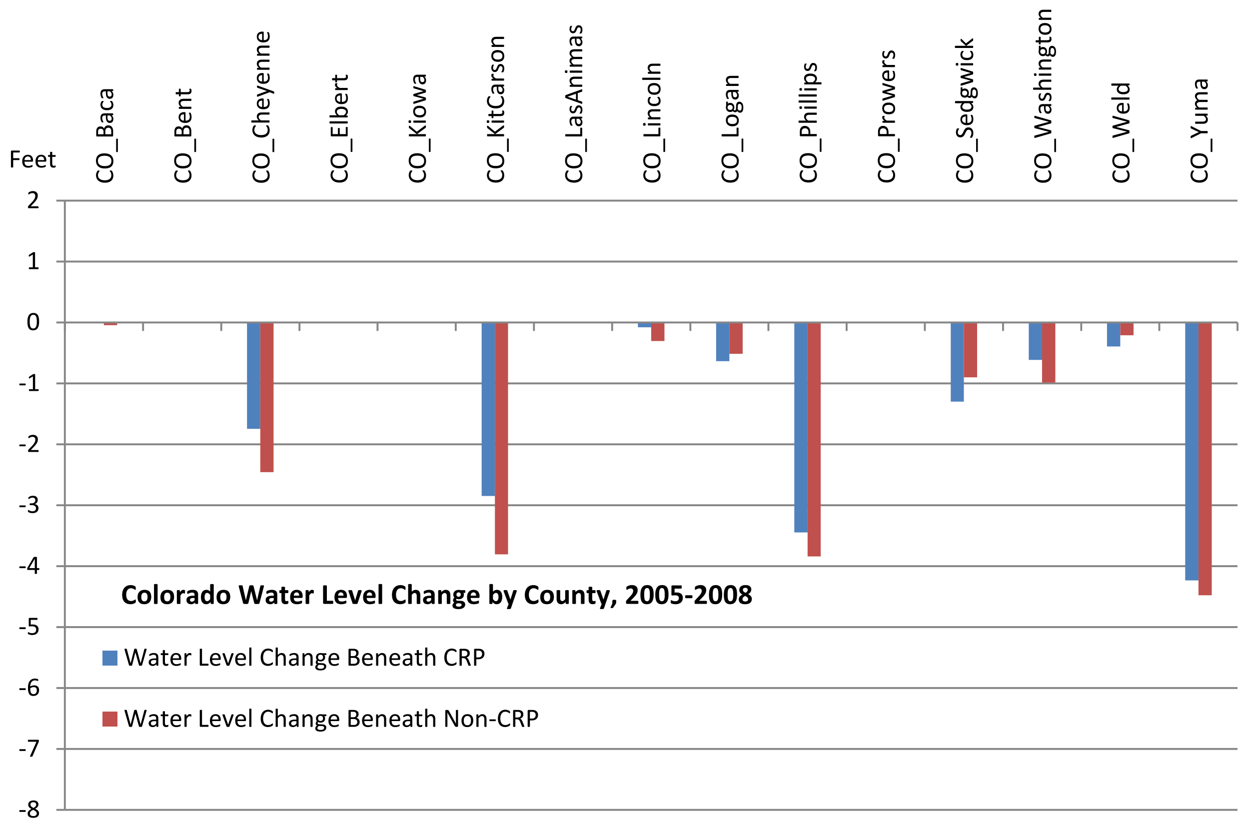

Figure 25. Comparison of water-level changes beneath CRP and non-CRP land, 2005-2008.

2005-2008 Mean Water-level Change						
State_County	**County WLC (ft)**	**CRP WLC (ft)**	**Non-CRP WLC (ft)**	**Total County CRP Acres Over the Ogallala Aquifer**	**Total County Acres Over the Ogallala Aquifer**	**Percent of County Over the Ogallala Aquifer in CRP**
CO_Baca	-0.04	0.00	-0.04	261,375	1,397,304	18.71
CO_Bent	0.00	0.00	0.00	1,664	19,987	8.32
CO_Cheyenne	-2.37	-1.75	-2.46	75,410	589,894	12.78
CO_Elbert	0.00	0.00	0.00	610	9,420	6.48
CO_Kiowa	0.00	0.00	0.00	21,554	236,555	9.11
CO_KitCarson	-3.70	-2.85	-3.80	151,535	1,347,438	11.25
CO_LasAnimas	0.00	0.00	0.00	8,756	83,056	10.54
CO_Lincoln	-0.28	-0.08	-0.30	55,242	424,618	13.01
CO_Logan	-0.53	-0.64	-0.51	61,100	434,205	14.07
CO_Phillips	-3.80	-3.45	-3.84	43,793	440,345	9.95
CO_Prowers	0.00	0.00	0.00	76,351	417,677	18.28
CO_Sedgwick	-0.92	-1.30	-0.90	12,849	290,538	4.42
CO_Washington	-0.94	-0.61	-0.99	128,464	1,047,657	12.26
CO_Weld	-0.24	-0.39	-0.21	44,801	261,767	17.11
CO_Yuma	-4.46	-4.23	-4.48	110,722	1,514,924	7.31

Table 2. Colorado water-level change beneath CRP and non-CRP land by county, 2005-2008.

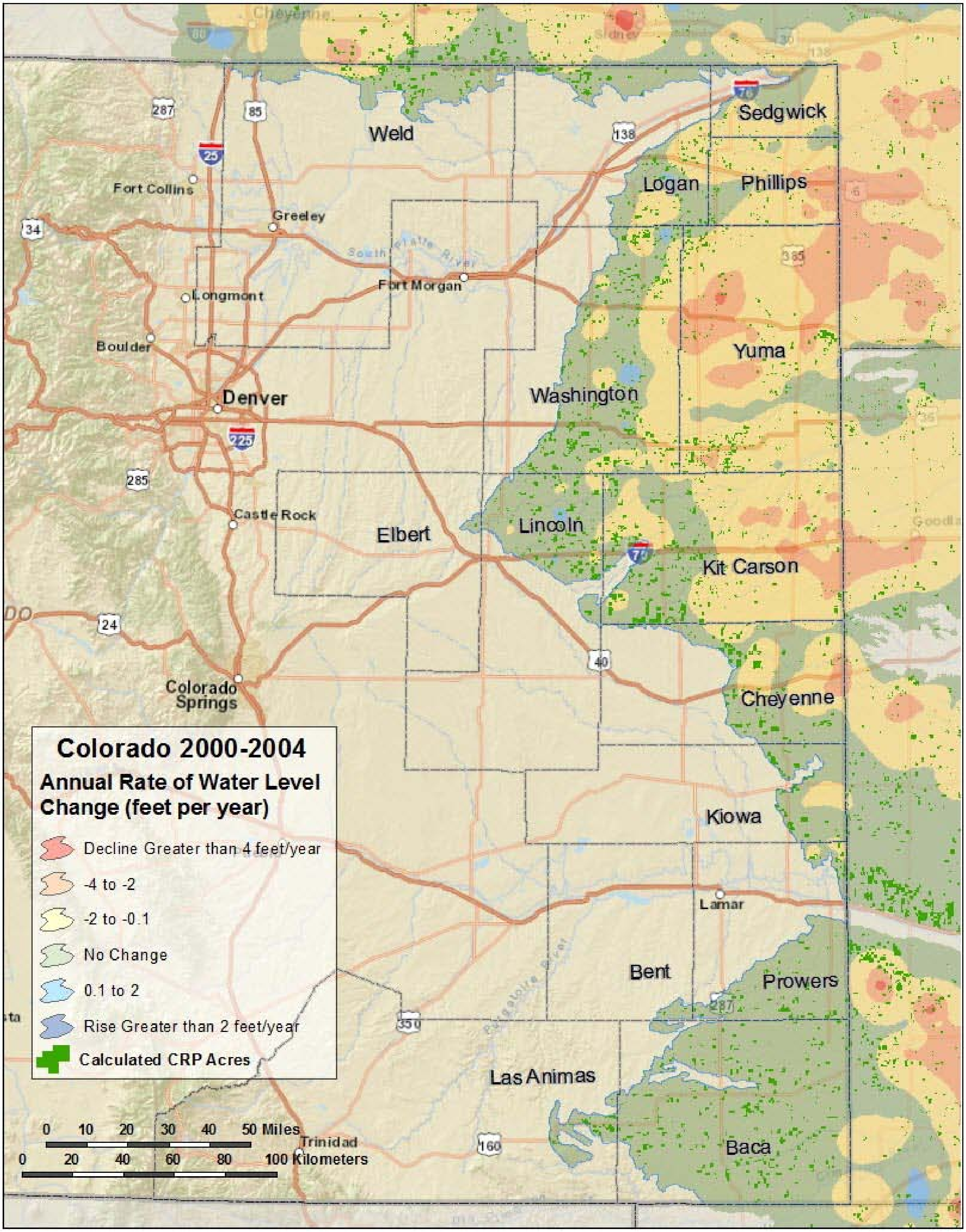

Figure 26. Colorado CRP polygons for 2004 over water-level change, 2000-2004.

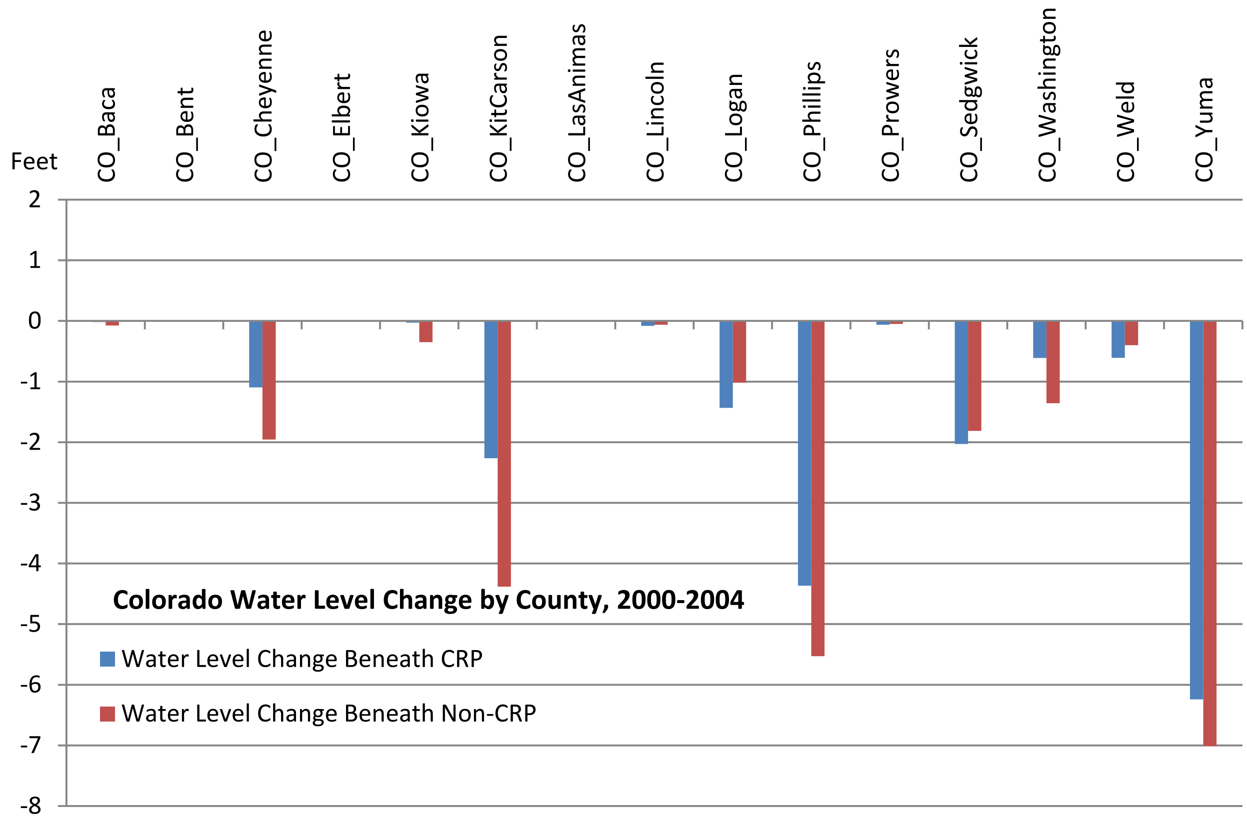

Figure 27. Comparison of water-level changes beneath CRP and non-CRP land, 2000-2004.

2000-2004 Mean Water-level Change						
State_County	**County WLC (ft)**	**CRP WLC (ft)**	**Non-CRP WLC (ft)**	**Total County CRP Acres Over the Ogallala Aquifer**	**Total County Acres Over the Ogallala Aquifer**	**Percent of County Over the Ogallala Aquifer in CRP**
CO_Baca	-0.06	-0.02	-0.07	261,218	1,397,304	18.69
CO_Bent	0.00	0.00	0.00	1,664	19,987	8.32
CO_Cheyenne	-1.85	-1.10	-1.96	75,410	589,894	12.78
CO_Elbert	0.00	0.00	0.00	610	9,420	6.48
CO_Kiowa	-0.32	-0.03	-0.35	21,554	236,555	9.11
CO_KitCarson	-4.14	-2.26	-4.38	151,095	1,347,438	11.21
CO_LasAnimas	0.00	0.00	0.00	8,756	83,056	10.54
CO_Lincoln	-0.06	-0.08	-0.06	55,242	424,618	13.01
CO_Logan	-1.07	-1.43	-1.02	61,100	434,205	14.07
CO_Phillips	-5.42	-4.36	-5.53	43,225	440,345	9.82
CO_Prowers	-0.05	-0.06	-0.05	76,351	417,677	18.28
CO_Sedgwick	-1.82	-2.03	-1.81	12,846	290,538	4.42
CO_Washington	-1.27	-0.61	-1.36	128,464	1,047,657	12.26
CO_Weld	-0.43	-0.61	-0.40	43,669	261,767	16.68
CO_Yuma	-6.95	-6.24	-7.01	110,345	1,514,924	7.28

Table 13. Colorado water-level change beneath CRP and non-CRP land by county, 2000-2004.

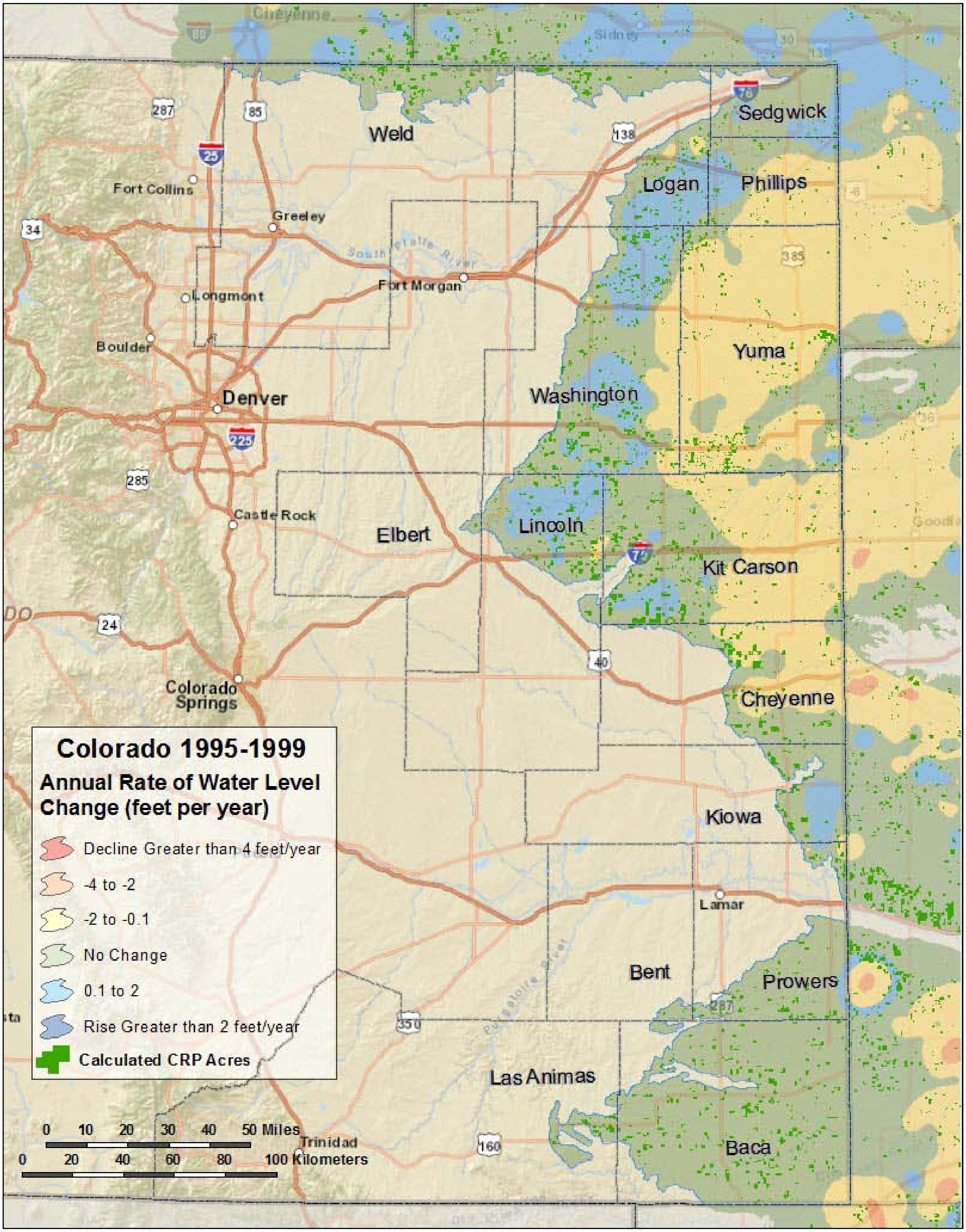

Figure 28. Colorado CRP polygons for 1999 over water-level change, 1995-1999.

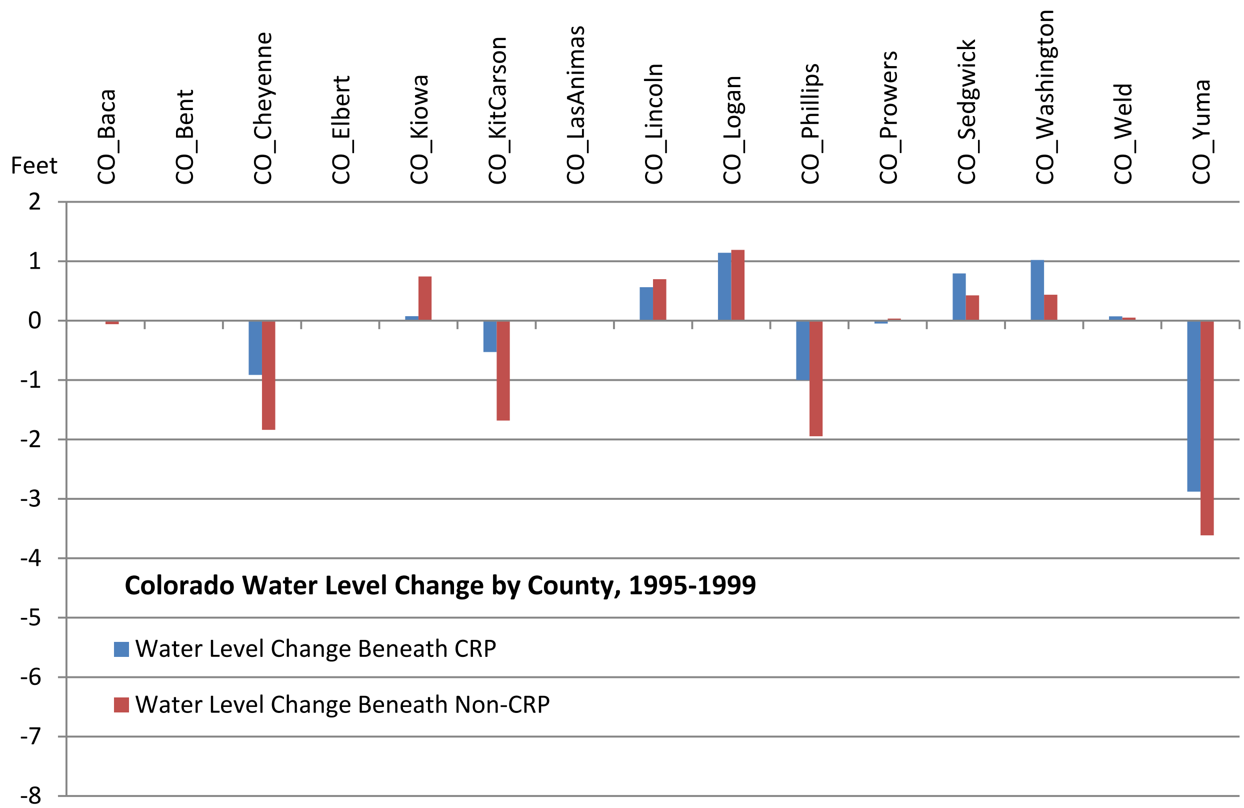

Figure 29. Comparison of water-level changes beneath CRP and non-CRP land, 1995-1999.

1995-1999 Mean Water-level Change						
State_County	**County WLC (ft)**	**CRP WLC (ft)**	**Non-CRP WLC (ft)**	**Total County CRP Acres Over the Ogallala Aquifer**	**Total County Acres Over the Ogallala Aquifer**	**Percent of County Over the Ogallala Aquifer in CRP**
CO_Baca	-0.06	0.00	-0.06	77,759	1,397,304	5.56
CO_Bent	0.00	0.00	0.00	691	19,987	3.46
CO_Cheyenne	-1.77	-0.91	-1.84	39,681	589,894	6.73
CO_Elbert	0.00	0.00	0.00	495	9,420	5.25
CO_Kiowa	0.70	0.08	0.74	13,908	236,555	5.88
CO_KitCarson	-1.59	-0.53	-1.68	109,911	1,347,438	8.16
CO_LasAnimas	0.00	0.00	0.00	7,100	83,056	8.55
CO_Lincoln	0.69	0.56	0.70	34,395	424,618	8.10
CO_Logan	1.19	1.15	1.19	50,371	434,205	11.60
CO_Phillips	-1.86	-1.00	-1.95	38,206	440,345	8.68
CO_Prowers	0.03	-0.05	0.04	24,018	417,677	5.75
CO_Sedgwick	0.44	0.80	0.43	9,889	290,538	3.40
CO_Washington	0.49	1.02	0.44	89,597	1,047,657	8.55
CO_Weld	0.06	0.07	0.05	27,230	261,767	10.40
CO_Yuma	-3.57	-2.88	-3.61	83,615	1,514,924	5.52

Table 14. Colorado water-level change beneath CRP and non-CRP land by county, 1995-1999.

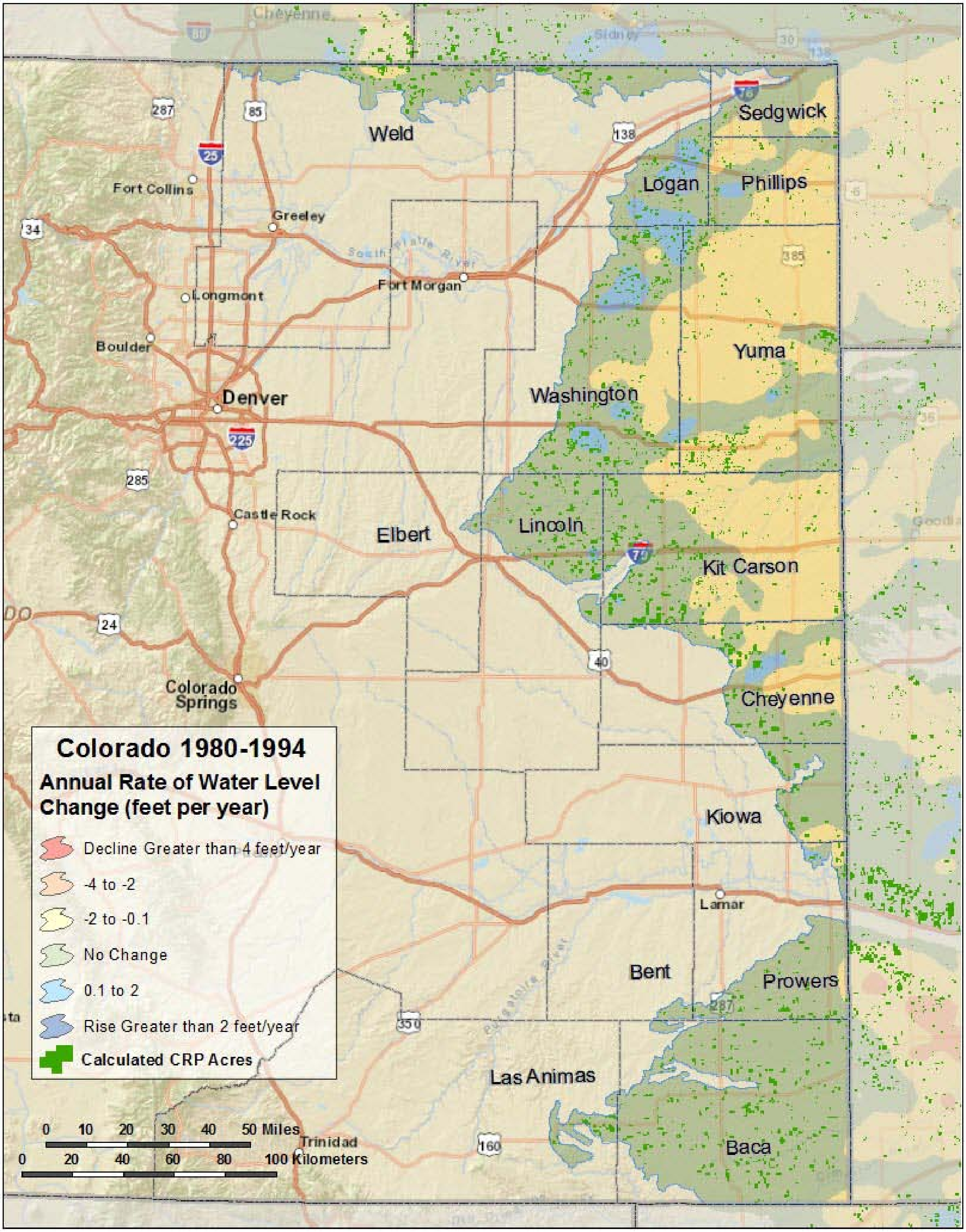

Figure 30. Colorado CRP polygons for 1994 over water-level change, 1980-1994.

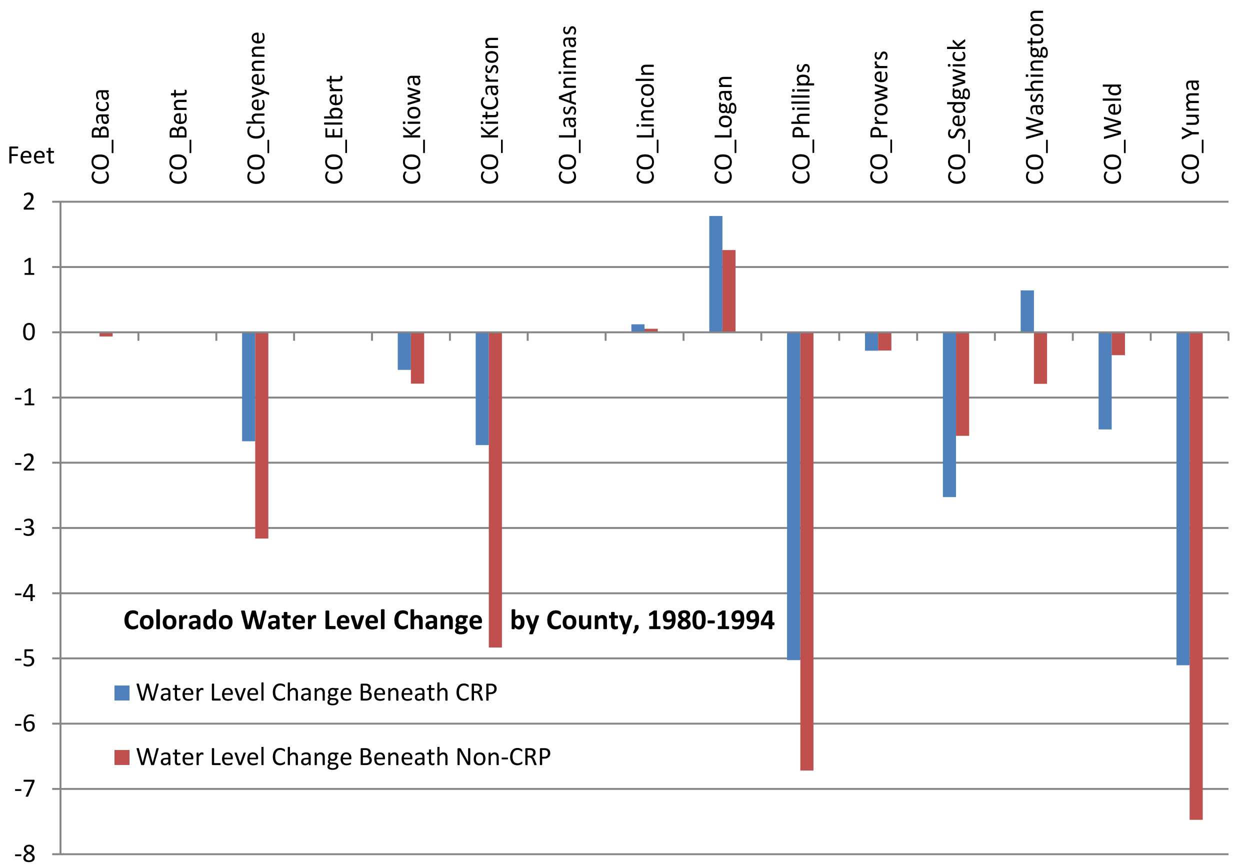

Figure 31. Comparison of water-level changes beneath CRP and non-CRP land, 1980-1994.

1980-1994 Mean Water-level Change						
State_County	**County WLC (ft)**	**CRP WLC (ft)**	**Non-CRP WLC (ft)**	**Total County CRP Acres Over the Ogallala Aquifer**	**Total County Acres Over the Ogallala Aquifer**	**Percent of County Over the Ogallala Aquifer in CRP**
CO_Baca	-0.06	0.00	-0.07	68,981	1,397,304	4.94
CO_Bent	0.00	0.00	0.00	692	19,987	3.46
CO_Cheyenne	-3.07	-1.67	-3.16	35,353	589,894	5.99
CO_Elbert	0.00	0.00	0.00	491	9,420	5.22
CO_Kiowa	-0.77	-0.58	-0.79	13,898	236,555	5.88
CO_KitCarson	-4.67	-1.73	-4.83	71,471	1,347,438	5.30
CO_LasAnimas	0.00	0.00	0.00	7,095	83,056	8.54
CO_Lincoln	0.06	0.12	0.05	33,902	424,618	7.98
CO_Logan	1.30	1.78	1.26	31,218	434,205	7.19
CO_Phillips	-6.67	-5.03	-6.72	12,093	440,345	2.75
CO_Prowers	-0.28	-0.28	-0.28	21,484	417,677	5.14
CO_Sedgwick	-1.60	-2.53	-1.59	4,130	290,538	1.42
CO_Washington	-0.69	0.64	-0.79	76,199	1,047,657	7.27
CO_Weld	-0.45	-1.49	-0.35	22,075	261,767	8.43
CO_Yuma	-7.40	-5.10	-7.47	49,303	1,514,924	3.25

Table 15. Colorado water-level change beneath CRP and non-CRP land by county, 1980-1994.

Discussion and Conclusion

Analysis of Water-Level Change by State and Region: Oklahoma, Kansas and Colorado

Table 16 shows the water-level change beneath CRP land and non-CRP land calculated as the mean for each state and the study region. When the water-level change is calculated on a state-wide basis, all of the water-level change values are negative beneath CRP and non-CRP land. As might be expected, this indicates that the net change in the water level in each state is negative and the state-wide average drawdown is greater than any rise in the water table.

Comparing the mean water-level decline beneath CRP and non-CRP land, the percent difference is a measure of the overall benefit of CRP land. In Table 16, positive values for Percent Difference indicate a positive benefit, where the decline beneath CRP is less than the decline beneath non-CRP land. Conversely, negative values indicate that the water-level decline beneath CRP land was greater than the decline beneath non-CRP land.

For Oklahoma, the data in Table 16 indicate that the CRP had a strong positive benefit in the three earlier time intervals, but not in the most recent time interval. For Kansas, the data show that the mean overall water-level decline was greater beneath CRP land in the three most recent time intervals. For Colorado, all four time intervals are positive, indicating a positive benefit.

WLC Time Interval	Percent CRP	Percent Non-CRP	Mean WLC Beneath CRP Land (feet)	Mean WLC Beneath Non-CRP Land (feet)	Percent Difference (Non-CRP - CRP)/ Non-CRP
OKLAHOMA					
2005-2008	11.2	88.8	-1.298	-1.193	-8.85
2000-2004	11.1	88.9	-0.370	-0.493	24.80
1995-1999	7.5	92.5	-1.582	-2.118	25.31
1980-1994	5.0	95.0	-2.090	-2.794	25.19
KANSAS					
2005-2008	7.2	92.8	-2.417	-2.043	-18.29
2000-2004	6.6	93.4	-3.729	-3.647	-2.25
1995-1999	6.2	93.8	-2.075	-2.013	-3.04
1980-1994	4.2	95.8	-6.980	-8.586	18.70
COLORADO					
2005-2008	12.4	87.6	-1.271	-2.034	37.53
2000-2004	12.3	87.7	-1.460	-2.774	47.38
1995-1999	12.8	87.2	-0.320	-2.073	84.56
1980-1994	9.6	90.4	-0.990	-5.468	81.90
STUDY REGION					
2005-2008	9.1	90.9	-1.817	-1.922	**5.44**
2000-2004	8.7	91.3	-2.284	-2.990	**23.62**
1995-1999	5.1	94.9	-1.359	-1.228	**-7.99**
1980-1994	3.5	96.5	-3.923	-4.455	**11.74**

Table 16. Comparison of mean water-level change (WLC) beneath calculated CRP and non-CRP land in Oklahoma, Kansas and Colorado and the study region as a whole.

The data in Table 16 also show the results for the entire study region as a whole. In this case, the two most recent time intervals show a positive benefit. In the 2000-2004 interval, the overall drawdown beneath CRP land is 5.4 percent less than non-CRP land. In the 2005-2008 interval, the overall drawdown beneath CRP land is 23.6 percent less. In the two earlier time intervals, the results are mixed. In the 1995-1999 interval, there is an 8 percent greater decline beneath CRP land. In the 1980-1995 time interval, the decline beneath CRP land is 11.7 percent less.

Analysis of Water-Level Change by State and Region: Aquifer Over 30 Feet

One issue with drawing broad conclusions from the data in Table 16 concerns the presence of CRP land in areas where the saturated thickness of the aquifer is relatively thin. In areas where the saturated thickness is 30 feet or less, there is generally insufficient groundwater available to support large-volume irrigation (Schloss and Buddemeier, 2000). Thus, if land in these areas is placed into a CRP contract, this land might benefit the aquifer through enhance recharge, but it is unlikely to have any direct effect on the drawdown of the aquifer.

To address this issue, the state-wide analysis of water-level change was repeated to include only those areas where the aquifer has the potential to be used for irrigation – those areas where the saturated thickness of the aquifer is more than 30 feet. Figure 32 shows the saturated thickness of the High Plains Aquifer in early 2009, highlighting those areas of the aquifer where the saturated thickness is less than 30 feet. In general, these areas on the fringe of the aquifer are not suitable for large-volume irrigation, although a large percent of the CRP land in the study region is located over the fringe area of the aquifer.

Table 17 compares the water-level change beneath CRP and non-CRP land based upon an analysis of water-level changes in only those areas where the saturated thickness of the aquifer is greater than 30 feet. Comparing these results with the data in Table 16, the data in Table 17 suggest that the effect of CRP on water-level decline is significantly less. As might be expected, the mean water-level decline beneath CRP land is greater that the corresponding values in Table 16. Thus, the data in Table 17 show that the percent difference in the drawdown beneath CRP and not-CRP land is less when measured as state-wide and regional averages. For example, in the 2005-2008 interval, the data for the entire aquifer area in Table 16 suggest that the mean water-level decline beneath CRP land is 5.4 less when compared to non-CRP land. When the analysis is restricted to only those areas with a saturated thickness of greater than 30 feet, the data in Table 17 suggest that the water-level decline beneath CRP is 3.4 percent greater than the decline beneath non-CRP land.

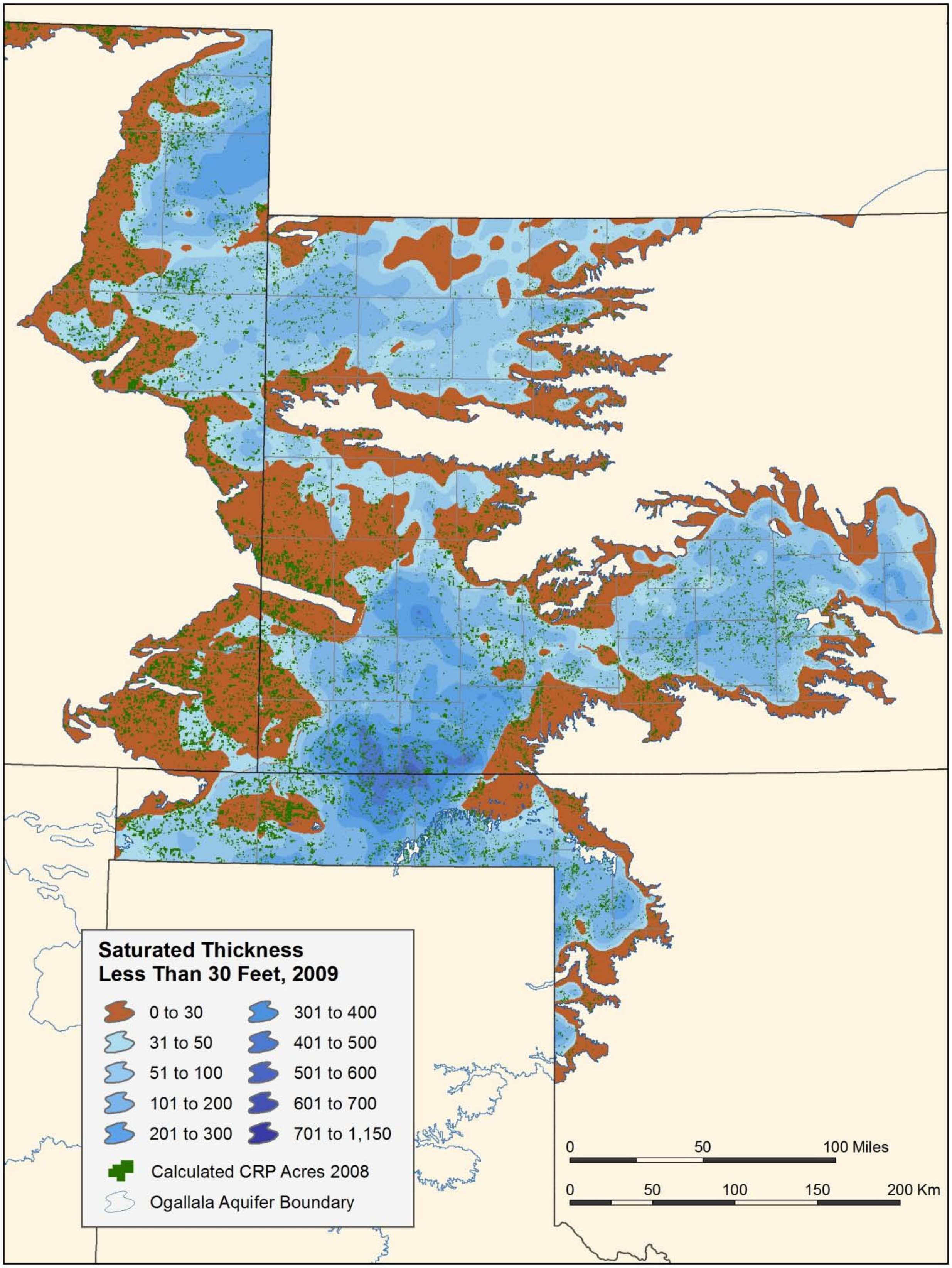

Figure 32. Saturated thickness of the aquifer in 2009 highlighting those areas where the saturated thickness is less than 30 feet.

WLC Time Interval	Percent CRP	Percent Non-CRP	Mean WLC Beneath CRP Land (feet)	Mean WLC Beneath Non-CRP Land (feet)	Percent Difference (Non-CRP - CRP)/ Non-CRP
OKLAHOMA					
2005-2008	11.8	88.2	-1.609	-1.609	-1.81
2000-2004	11.7	88.3	-0.538	-0.717	24.91
1995-2999	5.9	94.1	-1.778	-2.118	16.06
1980-1994	3.9	96.1	-2.824	-2.794	-1.10
KANSAS					
2005-2008	6.6	93.4	-3.891	-3.095	-25.72
2000-2004	6.1	93.9	-5.933	-5.406	-9.76
1995-2999	4.1	95.9	-3.179	-2.013	-57.89
1980-1994	2.5	97.5	-10.665	-8.586	-24.23
COLORADO					
2005-2008	9.3	90.7	-2.702	-3.508	22.97
2000-2004	9.3	90.7	-3.326	-4.933	32.57
1995-2999	6.4	93.6	-1.130	-2.073	45.50
1980-1994	4.0	96.0	-2.852	-5.468	47.84
STUDY REGION					
2005-2008	8.0	92.0	-3.038	-2.939	**-3.36**
2000-2004	7.7	92.3	-3.875	-4.547	**14.78**
1995-2999	4.9	95.1	-2.321	-2.043	**-13.58**
1980-1994	3.1	96.9	-6.790	-6.955	**2.38**

Table 17. Comparison of mean water-level change (WLC) beneath CRP and non-CRP land overlying the High Plains Aquifer in areas where the saturated thickness is greater than 30 feet.

Analysis of Water-Level Change in 16 Critical Counties

While the forgoing comparison of water-level change beneath CRP and non-CRP for each state is of interest, the results presented in Tables 21 and 22 mask the inherent spatial variability in water-level change. To better understand the effects of CRP land on the aquifer, it is important to recognize that there is a strong spatial relationship between the saturated thickness of the aquifer and water-level change. In counties where the saturated thickness of the aquifer is greatest, producers will certainly take advantage of the groundwater resource and a decline in the overall water-level should be expected. Conversely, in counties where the aquifer is thin, there might be insufficient groundwater to support large-scale irrigated agriculture. In these counties, the water table will tend to be much more stable – with either small declines or small rises.

Figures 33 and 34 show the water-level change for the entire study area, highlighting those counties with the greatest water-level decline. In both time intervals, the greatest water-level decline was focused in 16 critical counties. In Oklahoma, the greatest water-level decline occurred in Texas County. In Kansas, the greatest water-level decline was focused in the far southwestern part of the state – in Finney, Kearny, Gray, Haskell, Grant, Stanton, Stevens, Seward and Meade counties. In northwestern Kansas, the greatest drawdown occurred in Sherman, Thomas and Sheridan counties. In northeastern Colorado, the greatest water-level decline occurred in Phillips, Yuma and Kit Carson counties.

While the general pattern of water-level change in the 2005-2008 and 2000-2004 time intervals is similar in Oklahoma, western Kansas and Colorado, there is a very obvious difference in central Kansas. During the period from 2005 to 2008 (Figure 33), the map shows a noteworthy rise in the water table. During the period from 2000 to 2004 (Figure 34), the water-level declined. To explain this marked difference in water-level change, precipitation data were analyzed for the two time intervals (PRISM Climate Group, 2012). The results of this analysis showed that eastern Nebraska and central Kansas received precipitation during the 2005-2008 time interval that was well above normal.

In Oklahoma, western Kansas and eastern Colorado, the annual precipitation during both time periods was similar. Comparing Figure 33 and 34, there appears to be slightly more drawdown in the earlier 2000-2004 time period, but this is largely the result of the different years of record. The 2000-2004 time interval covers five years of record, whereas the 2005-2009 time interval covers only four years. Thus, the water-level decline for the 2000-2004 interval is somewhat greater.

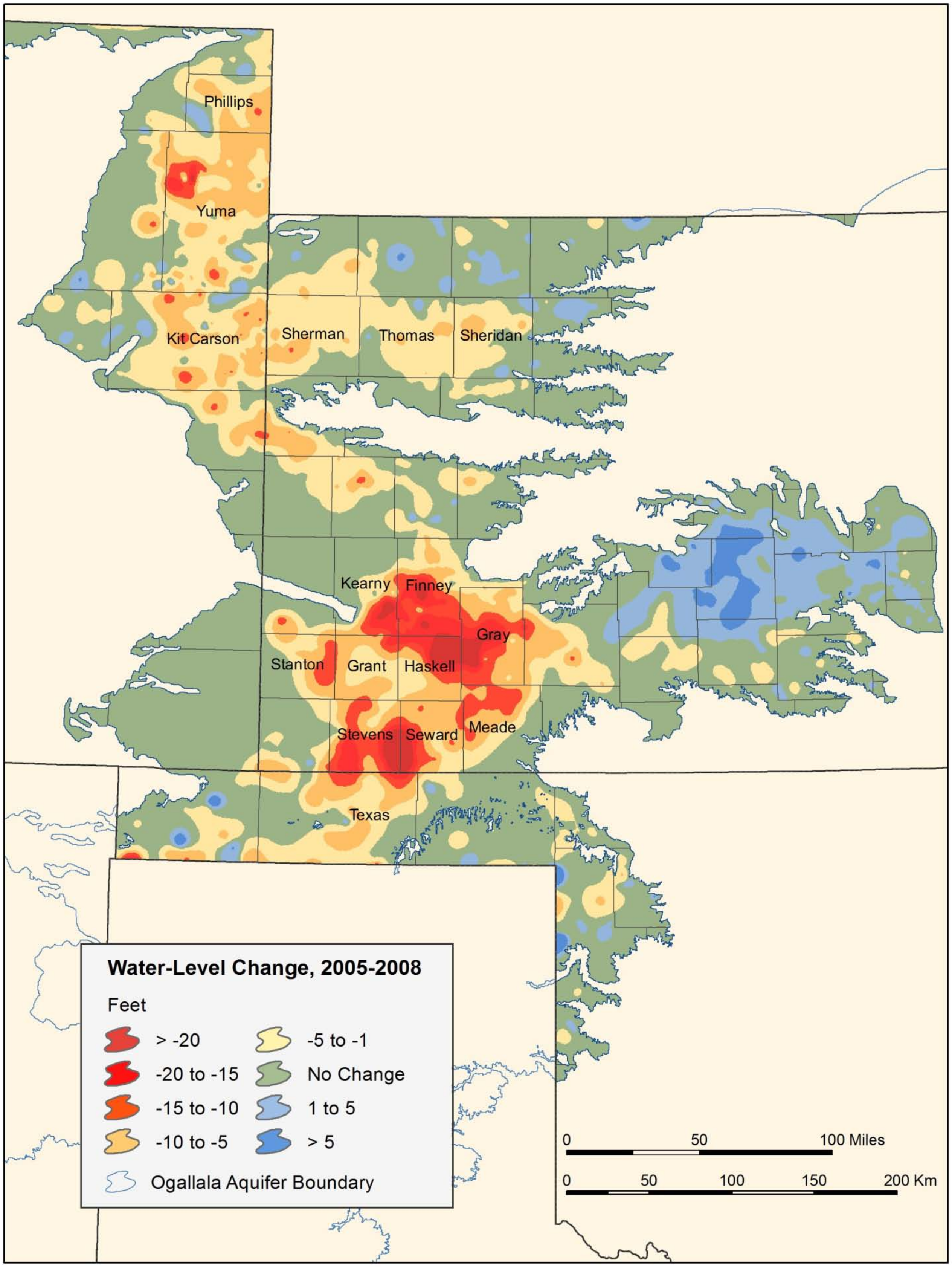

Figure 33. Water-level change, 2005-2008.

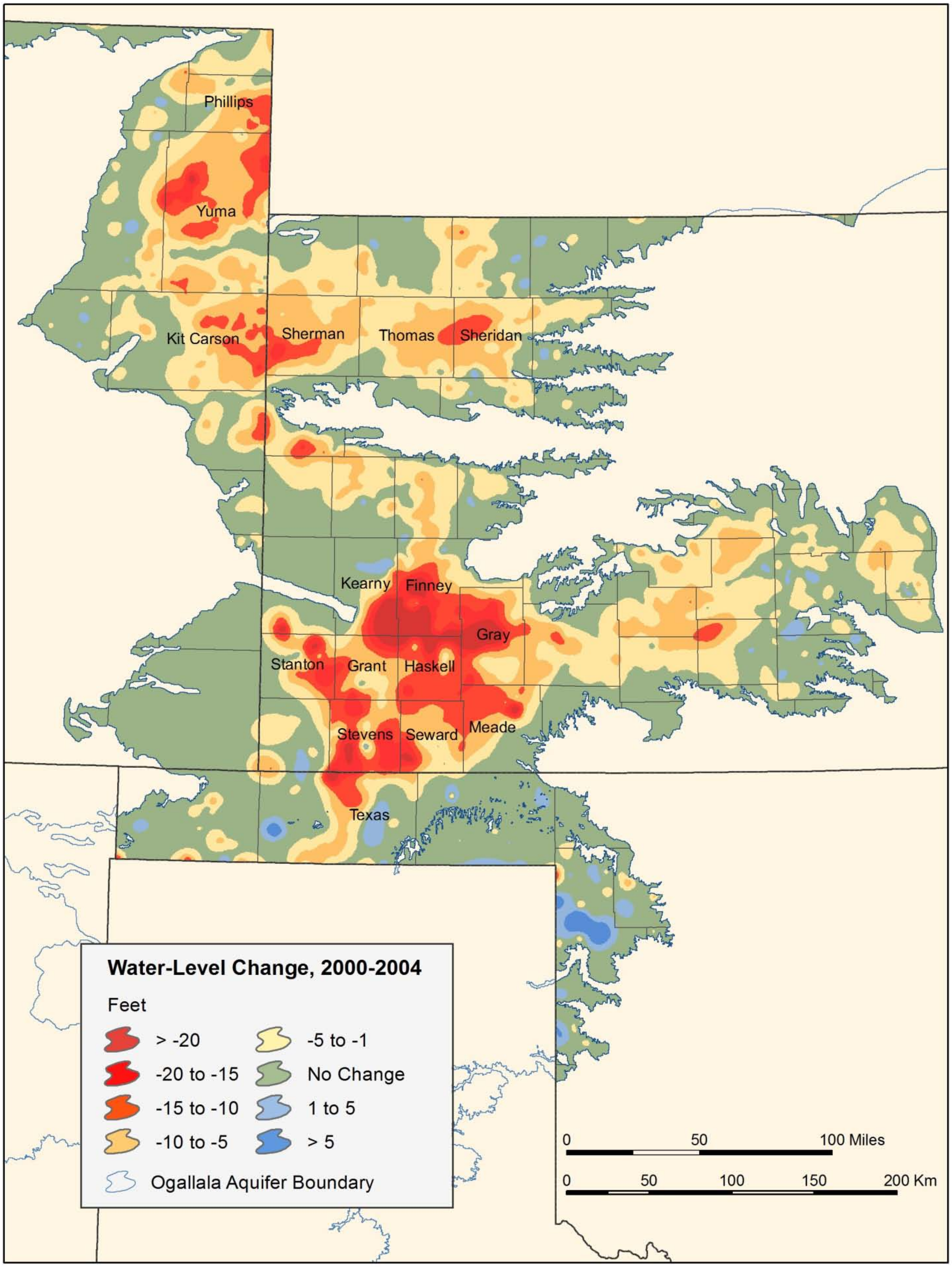

Figure 34. Water-level change, 2000-2004.

To assess the effects of CRP land on the aquifer in these 16 critical counties, the difference in the water-level change beneath CRP land and non-CRP land was used to calculate the net benefit of CRP land. Using this difference, a positive net benefit can occur under two different scenarios.

1) First, when the water-level decline beneath CRP was less than the water-level decline beneath non-CRP land, the difference between these two values is calculated as a positive net benefit attributed to the presence of CRP land.

2) Conversely, if the water-level rise beneath CRP land was greater than the water-level rise beneath non-CRP land, this difference can also be calculated a positive net benefit.

Figure 35 shows (a) the water-level change during the 2005-2008 time interval, (b) the net benefit of CRP land, and (c) the percent of the county area that lies over the aquifer that was enrolled in CRP in 2008. In 13 of the 16 counties, the water-level decline beneath CRP land was less than the water-level decline beneath non-CRP land. Consequently, this difference results in a positive net benefit for the 13 counties. Of these, the greatest benefit was calculated for Finney, Haskell and Stanton counties in southwestern Kansas. While there was also a large drawdown in Stevens, Gray and Seward counties, the water-level decline beneath CRP land in these Kansas counties was slightly greater than the decline beneath non-CRP land In Colorado, the greatest benefit was in Kit Carson County. In Oklahoma, Texas County also showed a positive net benefit.

In a similar manner, Figure 36a-c provides the same data for the 2000-2004 time interval. During this period the drawdown beneath CRP land was less than the drawdown beneath non-CRP land in 15 of the 16 counties. Once again, Finney and Stanton counties in Kansas were among the top several counties in terms of greatest positive benefit. Moreover, the three Kansas counties that showed no benefit in 2005-2009 (Stevens, Gray and Seward), all show a slight benefit in this earlier time interval. Of the 12 Kansas counties identified as critical counties, only Kearny County showed no benefit. In Colorado, all three counties showed a positive benefit with Kit Carson County having the second highest benefit of all 16 counties. In Oklahoma, Texas County also showed a positive net benefit.

It is also of interest to note that the net benefit was not directly related to the amount of land enrolled in CRP. For example, in 2004 and 2008 Finney County had approximately 5-6 percent of the county enrolled in CRP and Stanton County had approximately 15-16 percent of the county enrolled. While this difference in the percent of CRP land over the aquifer might partly explain the difference in water-level decline, the net benefit in Finney County was notably larger than the net benefit in Stanton County.

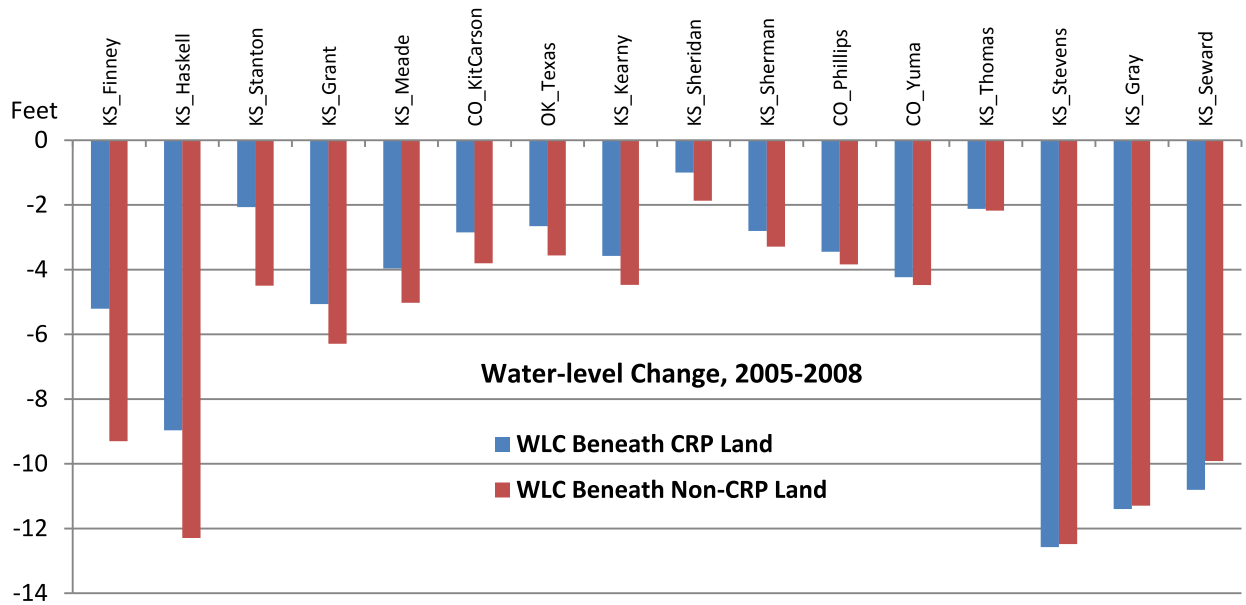

Figure 35a. Comparison of water-level change for critical counties, 2005-2008.

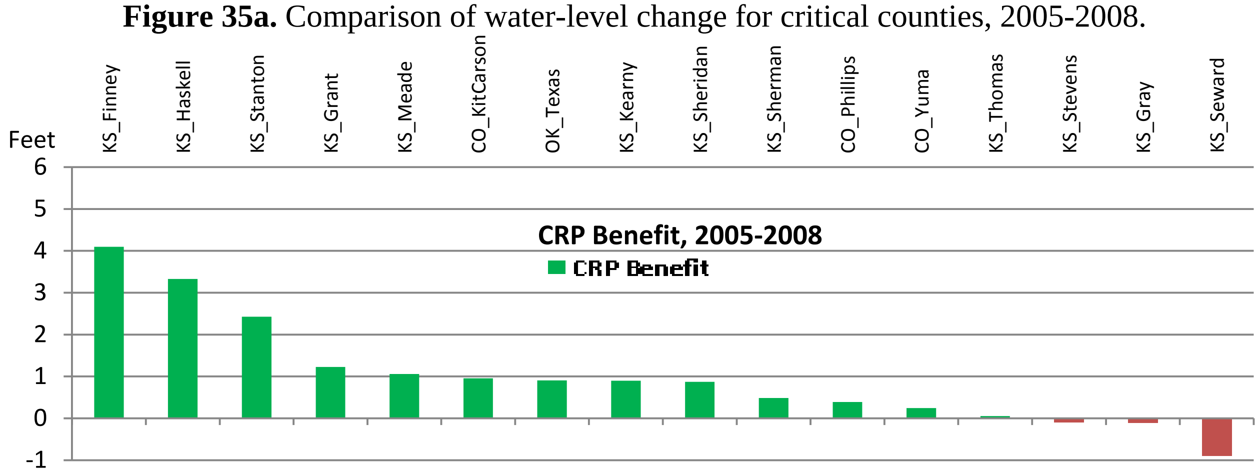

Figure 35b. CRP benefit in critical counties, 2005-2008.

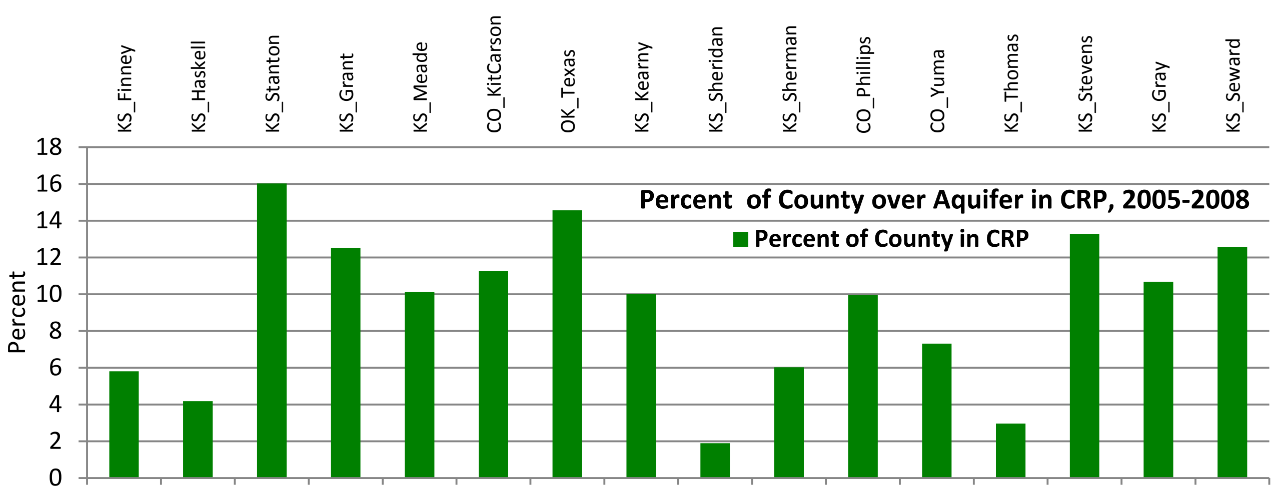

Figure 35c. Water-level change, CRP benefit, and percent of the county over the aquifer in CRP (2005-2008)

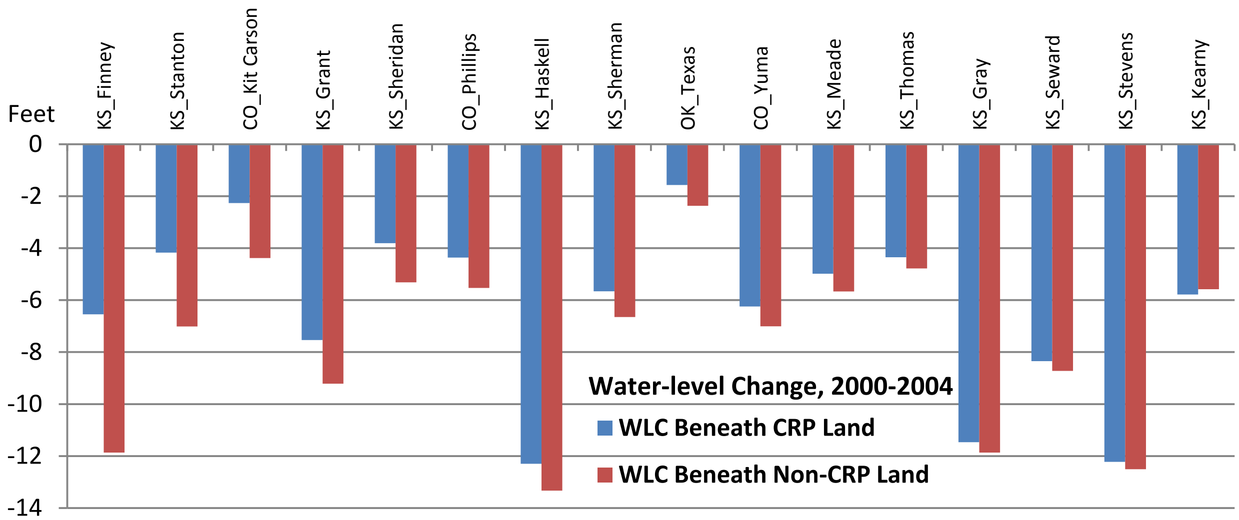

Figure 36a. Comparison of water-level changes for critical counties, 2000-2004.

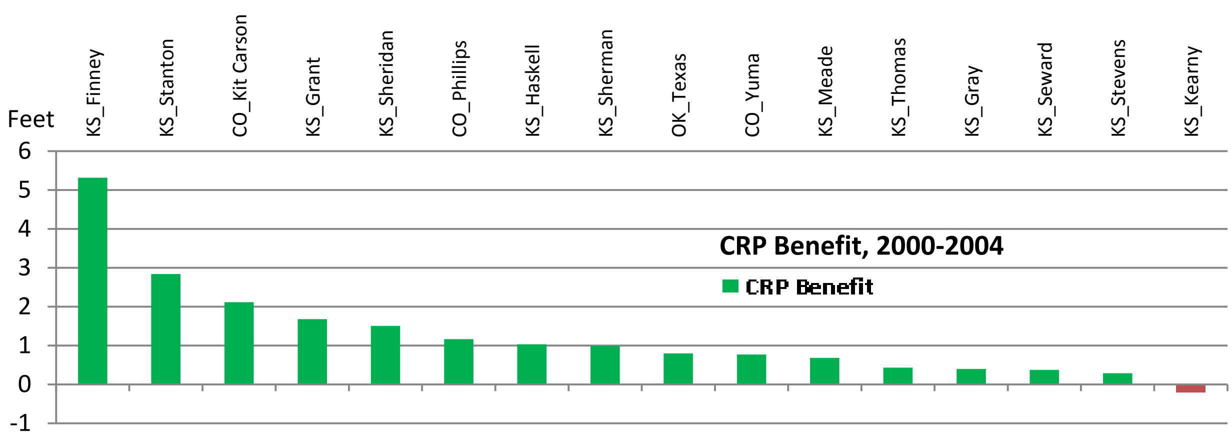

Figure 36b. CRP benefit in critical counties for critical counties, 2000-2004.

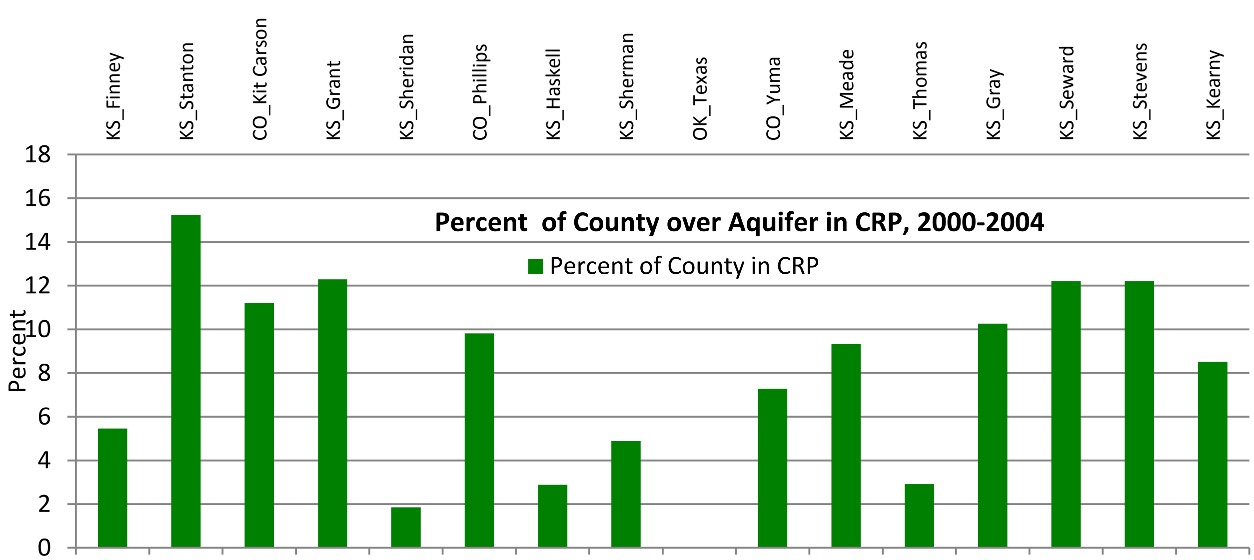

Figure 36c. Percent of the county over the aquifer in CRP, 2000-2004.

To assess the effect of CRP land on water-level change it is also important to differentiate those counties where the benefit is derived from reduced drawdown and those areas where the benefit is derived by a greater rise in the water table. Figures 37 and 38 show the counties in the study area classified by the type of benefit The counties in dark green are those counties where the benefit was derived from less drawdown beneath CRP land compared to non-CRP land. The counties in light green are those counties where the benefit was derived from a greater rise in the water table beneath CRP land. The counties mapped in the two shades of red are those counties where there was no net benefit. The darker red color corresponds to counties where the drawdown beneath CRP was greater than the drawdown beneath non-CRP land. The lighter red color indicates that the water-level rise was greater beneath non-CRP land.

For the 2005-2008 time interval, Figure 37 shows that most of the counties in western Kansas were counties with a net benefit derived from less drawdown beneath CRP land. Of particular interest are those critical counties in the southwestern corner of the state that coincide with the greatest decline in the aquifer. Of these nine counties, the data show a positive result for Finney, Kearny, Stanton, Grant, Haskell and Meade counties and no net benefit in Stevens, Seward and Gray counties. In northwestern Kansas, Sherman, Thomas and Sheridan counties also had a positive result. In the Oklahoma Panhandle, Texas County had a net benefit; as did Phillips, Yuma and Kit Carson in Colorado.

For the 2000-2004 time interval, the county data mapped in Figure 38 follow a very similar pattern. In this case, eight of the nine critical counties in southwestern Kansas had a net benefit – with lower drawdown beneath CRP land. The only exception was Kearny County. In northwestern Kansas, a positive result was obtained for Sherman, Thomas and Sheridan counties. In Oklahoma, Texas County also had a positive result. In northeastern Colorado, as before, all three of the critical counties show a net benefit as a result of the lower drawdown beneath CRP land.

It is also of interest to note that none of the critical counties in either time period had a positive benefit as a result of a greater water-level rise beneath CRP land. In the 2005-2008 time interval, several counties in central and northern Kansas had a net benefit as a result of water-table rise, but the pattern was not repeated in the previous 2000-2004 time interval. In this earlier time interval all of the counties that had a greater rise beneath CRP land were located in Oklahoma.

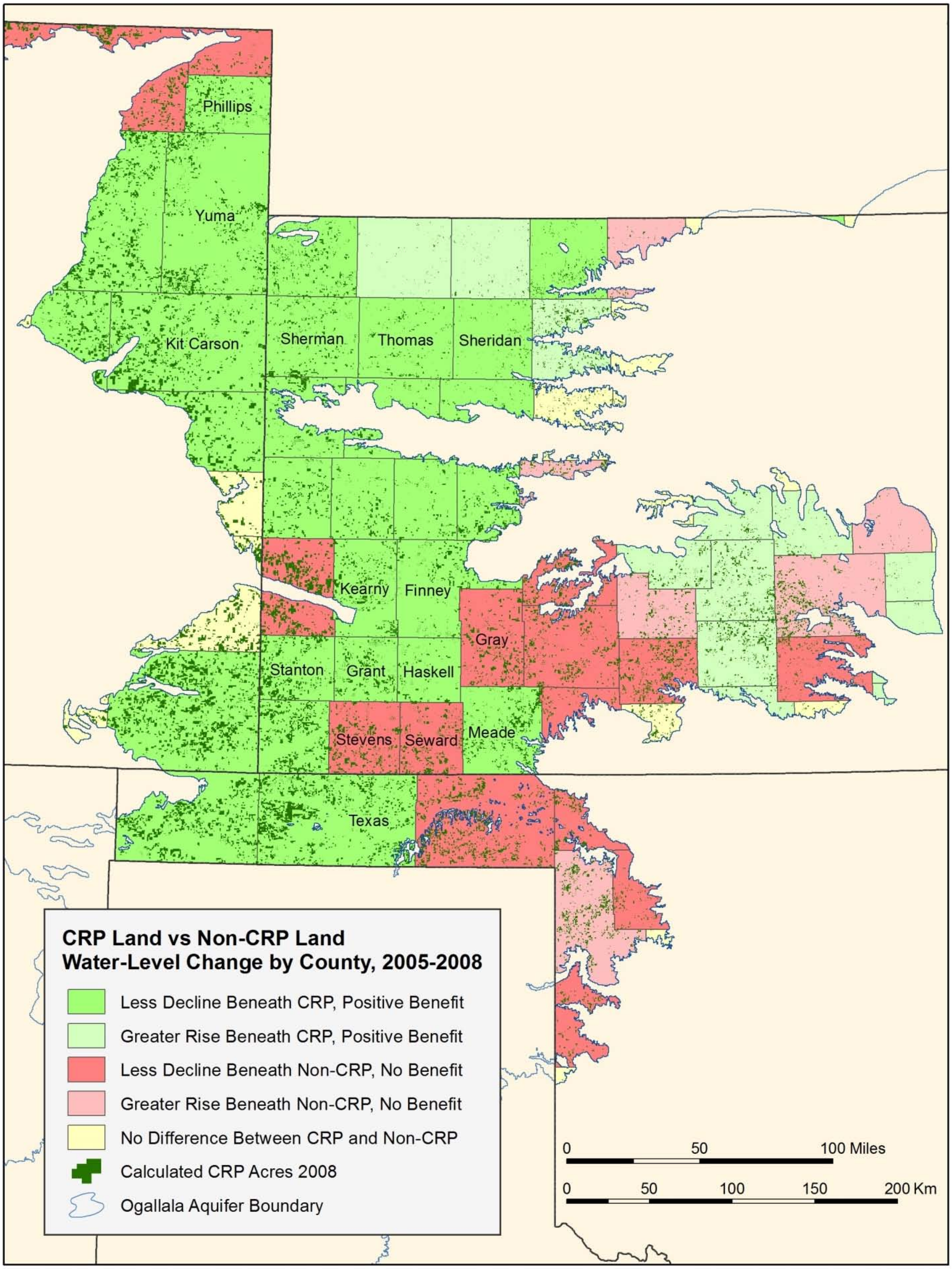

Figure 37. Counties classified by type of water-level change, 2005-2008.

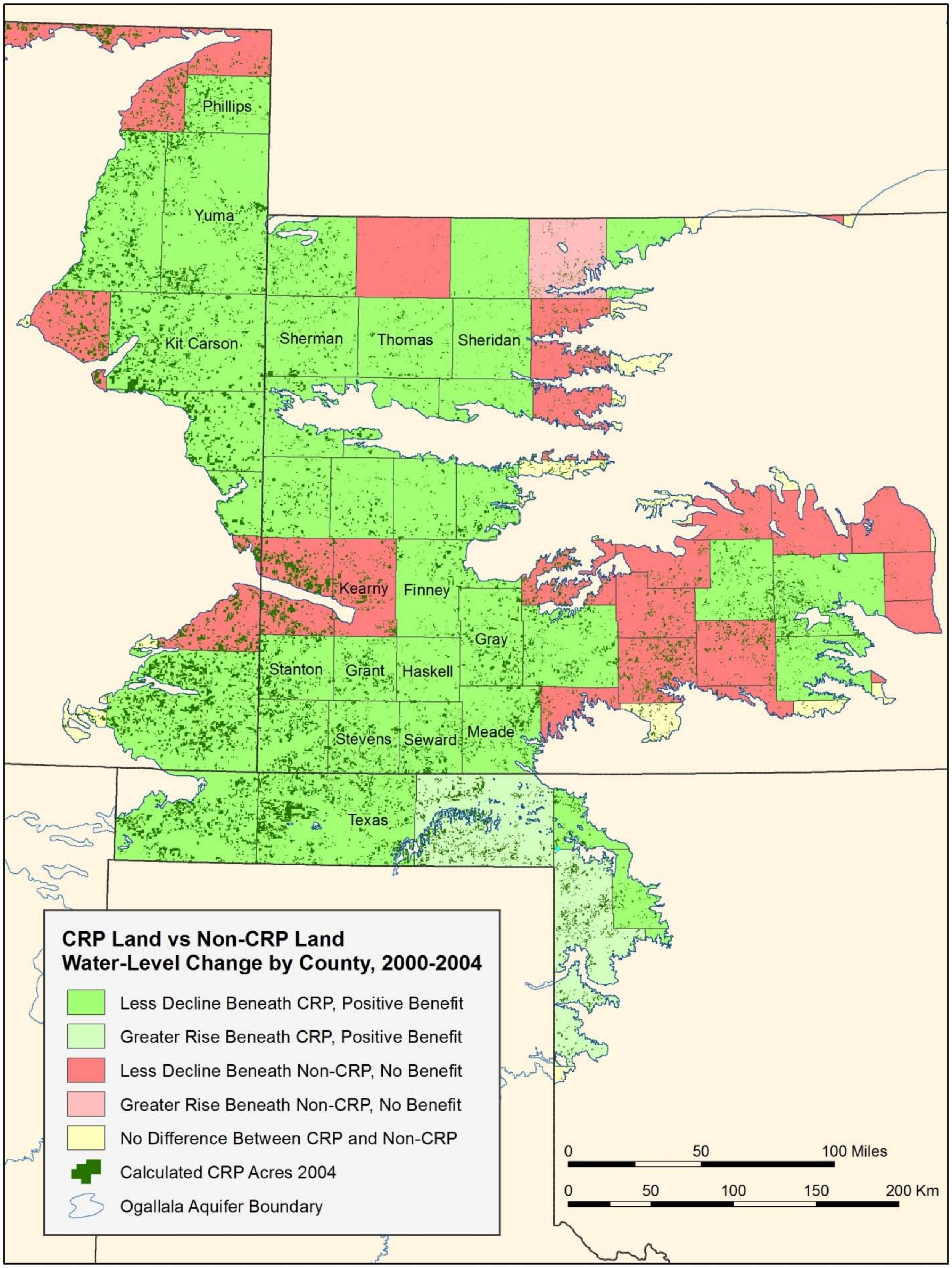

Figure 38. Counties classified by type of water-level change, 2000-2004.

Conclusion

The purpose of this study was to conduct a county-level analysis to assess the effects of the Conservation Reserve Program on the Ogallala (High Plains) Aquifer in Oklahoma, Kansas and Colorado. To assess these effects, it was necessary to estimate the presence of CRP land assuming a 20 year contract length and working backward from the expiration date of the CRP contract. Using this approach the total calculated CRP acreage for each county was compared to the CRP acreage reported by the FSA. Using this approach, a reasonable estimate of the presence of CRP land was derived for the two most recent time intervals in the study, 2000-2005 and 2005-2009. For the two earlier time periods, 1980-1994 and 1995-1999, it was only possible to estimate the presence of a small percentage of the actual CRP acreage.

After the CRP data were assembled, a geographic information system (GIS) was used to overlay the CRP polygons on raster grids representing water-level change in the four time intervals. Zonal statistics were then run to extract the mean water-level change beneath the CRP and non-CRP polygons for each county and for each time interval. These data were then used to assess the effect of CRP land on the aquifer. A net benefit accrues when the drawdown beneath CRP land is less than the drawdown beneath non-CRP land or when the water-level rise beneath CRP land is greater than the rise beneath non-CRP land.

For each state and the study region as a whole, the results of the analysis were encouraging but also mixed. In some cases the state-wide averages showed less drawdown beneath CRP, but in other cases they did not. Moreover, the state-wide results were not as promising when the analysis was performed only on those areas where the saturated thickness of the aquifer is more than 30 feet.

To better assess the effect of CRP land on the aquifer, the results of the analysis were reported for each of the 80 counties that overlie the aquifer in the three states. These county-level data, however, are often difficult to interpret for several reasons.

1) First, many of the counties in this study are found on the fringe of the aquifer with a small land area over the aquifer itself and thus very little land enrolled in CRP. In these counties it is difficult to draw any conclusions simply because the data are sparse.

2) Secondly, in some counties, the percent difference between CRP and non-CRP might be very large, but the actual rise or decline in the water-level is very small. In these counties it is difficult to assess the effect of CRP because any interpretation of the percent difference is suspect.

3) Thirdly, the analysis of the county-level data is complicated by the fact that the time intervals under study vary in length. Moreover, in some time intervals the water-level change in a county might suggest a benefit, but in other time intervals it might not.

4) Fourthly, the limitations of the original CRP database make it impossible to know exactly how much land was in enrolled in CRP at any given time. As discussed earlier, it was necessary to assume a 20-year contract length and work backward from the CRP contract expiration date. While this approach certainly underestimates the land enrolled in CRP, especially during the 1980-1995 and 1995-2000 time intervals, this should lead to a conservative estimate of the observed differences in water-level change. Nevertheless, the underestimate of CRP land also

makes it difficult to interpret results. For example, in counties showing a positive net benefit, it is assumed that the result represents a minimum net benefit. In situations where a county shows no net benefit, however, there is some uncertainty. In this case the result might be real or it might be an artifact of the data under representing the presence of CRP land.

5) Lastly, it was assumed that a CRP contract in place for at least one year of a WLC time interval was sufficient to influence water-level change and the polygon was counted as land in CRP. Again, this assumption should produce a conservative estimate of the difference in water-level change beneath CRP and non-CRP land, but it also adds some uncertainty to the interpretation of results.

While it is important to recognize these limitations, when the best data are used (the two most recent time intervals) to assess the water-level change in the most critical counties (those with the largest drawdown), the results from this analysis strongly suggest that the Conservation Reserve Program has a positive benefit on the aquifer. When the analysis focused on the 16 counties with the greatest drawdown, 13 counties showed a net benefit in the 2005-2008 time interval and 15 counties showed a net benefit in the 2000-2004 time interval. Based on these results, the analysis shows that the benefits of CRP are greatest in those critical areas with the greatest water-level decline. Targeting land in these areas for increased CRP enrollment or re-enrollment is likely to be beneficial to the aquifer.

References

Esri. 2012. ArcGIS for Desktop 10.1. SP1, Redlands, California.

McGuire, V.L., Lund, K.D., and Densmore, B.K., 2012, Saturated thickness and water in storage in the High Plains aquifer, 2009, and water-level changes and changes in water in storage in the High Plains aquifer, 1980 to 1995, 1995 to 2000, 2000 to 2005, and 2005 to 2009: U.S. Geological Survey Scientific Investigations Report 2012–5177, 28 p.
Spatial data available at http://pubs.usgs.gov/sir/2012/5177/.

PRISM Climate Group, 2012, U.S. precipitation, 2000-2008 2.5 arc-minute annual grids: Oregon State University, PRISM Climate Group Products, (accessed December, 2012).
Spatial data available at http://www.prism.oregonstate.edu/products/.

Schloss, J.A., and Buddemeier, R,W., 2000, Estimated Usable Lifetime, in *An Atlas of the Kansas High Plains Aquifer*, http://www.kgs.ku.edu/HighPlains/atlas/ateul.htm (accessed April, 2013).