CRP Effects on the Ogallala Aquifer

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Introduction

To support the Conservation Effects Assessment Program-Wetland Components (CEAP-Wetlands) regional assessment for The High Plains (THP), the purpose of this study, funded by the USDA Farm Services Administration (FSA), was to examine the influence of the 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) CRP to conserve groundwater.

In particular, this research aimed to identify the consequences of enrolling lands into the CRP based on groundwater levels. By better identifying land for water savings and groundwater recharge, USDA 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 Ogallala Aquifer in Texas. For this report the Ogallala Aquifer is referred to as the High Plains Aquifer in which the Ogallala Formation is the principle geologic unit.

Map layers developed during this study of the 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 beneath CRP and areas not beneath CRP were extracted from the regional dataset. This approach 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 study suggested CRP benefitted groundwater levels, especially in those counties with the most intensive irrigation and highest water use. For example, Table 1 compared 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 than those observed in 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, results from the original Texas study were promising insofar as they suggested that land enrolled in the CRP provided a significant ecosystem service beyond soil conservation and biodiversity provisioning (Smith et al. 2011). These results suggested that land enrolled in the CRP also had the added benefit of reducing the rate of groundwater depletion.

While these results suggested 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 was 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 grazing 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 was unclear whether or not the results from the original Texas study are unique – and whether or not these results would hold true if they were extrapolated to the other states that overlie the aquifer.

This important research question must be addressed because it has important policy implications for agriculture and conservation in 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. A previous report (Mulligan et al., 2013) described the results of the research conducted for the first phase of the study covering Oklahoma, Kansas and Colorado. This report describes the results of the second phase of the study covering Texas, New Mexico, Nebraska, South Dakota and Wyoming.

Study Area

The spatial extent of the study area overlying the High Plains Aquifer on the Great Plains is shown in Figure 1. In the second phase of this study, the analysis focused on the areas overlying the aquifer in Texas, New Mexico, Nebraska, South Dakota and Wyoming.

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

Methodology

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. Non-CRP land was cropland, native grassland, or urban areas. The analysis was predicated on the hypothesis 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 CRP is having a positive effect on the aquifer by reducing the rate of aquifer decline. This conclusion, however, is based 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 water-level change 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 completed, the CRP and non-CRP polygon layers were overlaid on the corresponding water-level change 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 water-level change rasters within the zones of the CRP polygons.

Naming Conventions for Time Intervals

To assess effects of the CRP on aquifer levels, the USGS provided aquifer data in five raster datasets (McGuire et al., 2012). These data included one saturated thickness layer for 2009 and four water-level change rasters for the time intervals used in this study.

Water level measurements are typically made at the beginning of a calendar year well after the growing season and harvest when most wells have not been actively pumped for a few months. Measuring water levels at this time allows aquifer levels to re-equilibrate for reliable comparisons over time.

It is customary to name water-level measurement data using the calendar year in which the well data were measured. Therefore water level data named 1980 reflect changes that occurred the previous year (McGuire, pers. comm). For example, a water-level change raster dataset named wlc80_95 represents changes over a 15-year period while the measurements made in early 1980 represent water levels at the end of the 1979 growing season. Similarly, the measurements made in early 1995 represent the water levels at the end of the 1994 growing season.

The sequential dataset named wlc95_00 represents the water-level changes that were measured for the 5-year period, while the measurements made in early 1995 represent the water levels at the end of the 1994 growing season. The measurements made in early 2000 represent the water levels at the end of the 1999 growing season.

Similarly, the wlc00_05 raster dataset represents the 5-year time interval from the end of the 1999 growing season to the end of the 2004 growing season. Finally, the wlc05_09 raster dataset represents the 4-year time interval from the end of the 2004 growing season to the end of the 2009 growing season.

Water level measurement times do not correspond with CRP expiration dates that are typically set to September 30 (see Table 5). Therefore the wlc05_09 raster corresponds to CRP contracts active between October 1, 2004 and September 30, 2008 and were assigned to the 2005 to 2009 time interval (Figure 2).

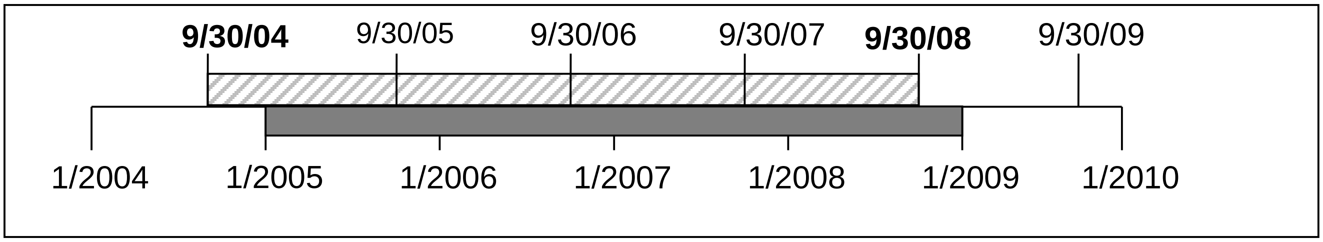

Figure 2. Time interval for the wlc05_09 named raster showing the 4-year period for calendar years 2005 to the beginning of 2009 (solid bar), and the associated period representing CRP contracts present from 9/30/2004 to 9/30/2008 (hatched bar).

Estimating the Presence of CRP Contracts in each Time Interval

In addition to the USGS raster data layers, the FSA provided a GIS polygon layer of CRP contracts present in 2011. This layer represented the best available CRP spatial data. Unfortunately CRP data were not available for the time intervals specified for this study; therefore, it was necessary to develop a methodology to estimate which contracts were present in each time interval (Barbato et al. 2012) using attributes present in the 2011 CRP polygon layer. Ideally, if each CRP contract had an associated start date, then each record could be assigned to the time interval in which the contract was initiated. An evaluation of the data, however, revealed that contract start dates were not available for CRP data.

Two attributes in the CRP database proved useful to calculate a contract start date from which contracts could be assigned to one or more of the four time intervals in this study. These attributes included a Conservation Practice Code (CP Code) and a Contract Expiration Date. The CP code was present for each contract record and described the type of agricultural activity on the land. Each code also had an associated minimum and maximum contract length (Appendices I, II and III). The Contract Expiration Date stored date values representing the expiration date in effect for each contract in the 2011 dataset. Contract expiration dates ranged from 9/30/2000 at the earliest to 9/30/2029 at the latest[1]. While the 2011 layer did not contain CRP contracts present for the time intervals required for this study, it was the best and only available CRP data for this analysis.

In this study four time intervals were established to analyze areas with and without CRP contracts in relation to water-level change (Tables 2 and 3). It is important to remember that CRP contracts in the FSA database are assigned an expiration date, but no start date. This fact created a challenge for creation of spatial layers of CRP lands to coincide with each time interval of the study.

For each of the four time intervals, it was necessary to estimate the presence of CRP polygons using the 2011 CRP layer and an assumed contract length. While the CRP database was current for 2011, the database contained only a few thousand records with contract dates that expired prior to 2011. These contracts were present mostly in 2007, 2008, 2009 and 2010 (Table 5). In fact, there were only 21 records that predated 9/30/2007, and no records predated 2000. Obviously, there were many more CRP contracts that expired prior to 2011, but those contract data were not available to include in the analysis.

[1] 2029 is most likely an error given that contracts are for a maximum of 15 years. Similarly contract expiration dates beyond 2022 in the database are suspect and should be examined to make sure that they are for practices with 15-year contracts as opposed to a 10-year contract.

To map acreage in CRP present during a time interval, it was necessary to calculate a contract start date. This calculation required assigning an appropriate contract length[2] to each contract and then subtracting contract length from contract expiration date to obtain a start date.

Contract lengths are typically assigned 10, 15 or 20 years and vary according to CP code and individual contract. The total contract length of 20 years was certain for only two CP codes; CP10 and CP11. Communication with the FSA (Hyberg, pers. comm.) indicated that practice codes CP10 and CP11 are "at least 10 years old at the start of the current contract". Assuming the current contracts are set for 10 years, the maximum contract length for these codes is 20 years. The CP codes and contract lengths for the 2011 dataset are presented in Appendices I, II and III).

Tables 2 and 3 show the relationship between the time intervals, the range of years that CRP contracts expire for 10- and 20-year contract lengths, the total number of CRP polygons over the aquifer for that time interval, and the GIS-calculated CRP acreage over the aquifer.

Period	Time Interval to Analyze CRP Contracts & Water Level	Year of CRP Contract Expiration for 10-year Contract	CRP Polygons (database records)	GIS Calculated CRP Acres
4	2005-2009	2005 – 2019	113,760	6,730,970
3	2000-2005	2000 – 2015	40,696	2,869,897
2	1995-2000	2000 – 2010	2042	211,840
1	1980-1995	2000 – 2005	6	71

Table 2. Estimated presence of CRP land in each study period time interval assuming 10-year contracts.

Period	Time Interval to Analyze CRP Contracts & Water Level	Year of CRP Contract Expiration for 20-year Contract	CRP Polygons (database records)	GIS Calculated CRP Acres
4	2005-2009	2005 – 2029	113,759	6,730,963
3	2000-2005	2000 – 2025	109,153	6,522,345
2	1995-2000	2000 – 2020	72,599	4,020,954
1	1980-1995	2000 – 2015	40,683	2,869,863

Table 3. Estimated presence of CRP land in each study period time interval assuming 10-year contract with one 10-year renewal for a total of 20 years in CRP.

Comparing the data in Tables 2 and 3, for the most recent 2005-2009 time interval the number of polygons and calculated acreage was virtually the same assuming either a 10-year or 20-year contract length. For the 2000-2005 time interval, the calculated acreage assuming a 10-year contract underestimated the acreage for 20-year contracts by about 55 percent. For the 1995-2000 time interval, the underestimate was nearly 95 percent for 10-year contracts. The 1980-1995 time interval was assigned only 6 contracts, or 71 acres, from the 2011 dataset for 10-year contracts compared to 40,683 contracts or over 2.8 million acres for 20-year contracts.

Given that there were only a few thousand expired contracts in the FSA CRP database that were not renewed prior to 2011, it is likely that the methodology for estimating the presence of CRP land in any time interval underestimated the number of CRP polygons and CRP acreage as one went farther back in time. This underestimation occurred regardless of whether the contract length used to

[2] Each CP code has a predetermined contract length and contract renewal characteristics.

calculate start dates was 10 years or 20 years. While either contract length provided a reasonable estimate of CRP acreage for the 2005-2009 interval, it seemed that using a 10-year contract and assuming a one 10-year renewal (for a total of 20 years) provided a much better estimate for the second 5-year time interval (2000-2004).

For the 1995-2000 and 1980-1995 time intervals, it became obvious that using a 10-year contract length was unrealistic. Assuming a 20-year contract period provided a better estimate of CRP acreage for these two time intervals. Recall while the aquifer data for the first time interval began in 1980, CRP did not commence until 1986.

To calculate the start dates for the CRP contracts, the following assumptions were made: 1) the contract length was 10 years for all CRP records and 2) each contract had one 10 year contract renewal (for a total of 20 years). These assumptions provided a conservative, yet realistic, set of data for analysis. Furthermore, since the CRP data and water-level change rasters were not available on an annual basis, any contract regardless of how long it was present within a time period was included in the analysis for that time period because it had the potential to affect water levels during that time.

After the contract length was assigned to each CRP contract, values were converted to Julian format to facilitate date subtraction. The start date of each contract was calculated by subtracting total contract length from the expiration date.

Assigning CRP Contracts to Appropriate Time Intervals

After the start date was calculated, each contract was assigned to the appropriate time interval(s) in which it was present. To track presence or absence of CRP contracts in each time interval, four fields (representing each time period) were created in the CRP layer. Table 4 shows the queries used to select CRP records. Once a set of records was selected for a query, the appropriate time interval fields were assigned a value of “1” to signify that the contract was active during that time period. A value of “0” was assigned to signify that the contract was not active during that time period.

Contract Start Date is	AND Expiration Date is	Assigned to Period 1 1980-1994	Assigned to Period 2 1995-1999	Assigned to Period 3 2000-2004	Assigned to Period 4 2005-2008
> 10/1/2004 AND <= 10/1/2008	> 9/30/2004	0	0	0	1
> 10/1/1999 AND <= 10/1/2004	> 9/30/1999 AND <= 9/30/2004	0	0	1	0
> 10/1/1999 AND <= 10/1/2004	> 9/30/2004	0	0	1	1
> 10/1/1994 AND <= 10/1/1999	> 9/30/1994 AND <= 9/30/1999	0	1	0	0
> 10/1/1994 AND <= 10/1/1999	> 9/30/1999 AND <= 9/30/2004	0	1	1	0
> 10/1/1994 AND <= 10/1/1999	> 9/30/2004	0	1	1	1
<= 10/1/1994	<= 9/30/1994	1	0	0	0
<= 10/1/1994	> 9/30/1994 AND <= 9/30/1999	1	1	0	0
<= 10/1/1994	> 9/30/1999 AND <= 9/30/2004	1	1	1	0
<= 10/1/1994	> 9/30/2004	1	1	1	1

Table 4. Date ranges for queries used to assign CRP contracts to a time interval. A “1” signifies a contract was active during the time period and a “0” signifies contract was not active during the time period.

Since the CRP was initiated in 1986, some water levels measured in the1980-1995 raster preceded the program. However, contracts with start dates prior to 10/1/1994 could be included in the analysis for Period 1 provided a sufficient number of CRP polygons were available for analysis. Assuming 20-year contracts, this period included 40,683 records with expiration dates of 9/30/2014 or earlier. These contracts had calculated start dates of 10/1/1994 or earlier and covered approximately 2.8M acres of CRP. In this case, it was determined that there was a sufficient number of contracts to assign to the first time period and include in the analysis.

A frequency analysis (Esri, 2012) was performed on unique expiration date values to calculate the number of contract records that expired on each date and to obtain the number of contracts active within each time period. Table 5 shows the number of records present for each unique expiration date as a result of the frequency analysis.

Expiration Date	Frequency	Expiration Date	Frequency	Expiration Date	Frequency
NULL	29	9/20/2013	3	9/3/2018	2
9/30/2000	1	9/27/2013	1	9/8/2018	1
9/30/2001	2	9/28/2013	2	9/20/2018	1
9/30/2003	1	9/29/2013	1	9/23/2018	3
9/30/2004	1	9/30/2013	10610	9/28/2018	2
9/26/2005	1	10/1/2013	8	9/30/2018	6244
9/30/2005	7	10/7/2013	1	10/1/2018	1
9/30/2006	8	1/1/2014	2	12/30/2018	1
9/7/2007	3	6/30/2014	1	9/9/2019	1
9/30/2007	863	9/3/2014	1	9/29/2019	1
10/1/2007	1	9/5/2014	1	9/30/2019	3734
3/30/2008	1	9/20/2014	1	4/12/2020	1
9/3/2008	1	9/23/2014	2	9/1/2020	1
9/29/2008	6	9/24/2014	1	9/3/2020	1
9/30/2008	1116	9/30/2014	6066	9/10/2020	1
9/3/2009	1	1/26/2015	1	9/15/2020	1
9/30/2009	954	3/30/2015	1	9/20/2020	2
9/3/2010	1	5/1/2015	1	9/23/2020	3
9/28/2010	2	9/3/2015	4	9/28/2020	1
9/30/2010	849	9/8/2015	1	9/30/2020	20884
7/30/2011	1	9/15/2015	3	10/13/2020	1
9/22/2011	1	9/24/2015	1	11/30/2020	1
9/28/2011	10	9/26/2015	1	5/28/2021	1
9/30/2011	2079	9/27/2015	1	7/30/2021	1
10/30/2011	2	9/30/2015	6952	9/3/2021	1
2/1/2012	1	10/30/2015	4	9/6/2021	1
8/30/2012	1	11/1/2015	1	9/20/2021	3
8/31/2012	1	2/6/2016	1	9/21/2021	1
9/3/2012	2	9/3/2016	1	9/22/2021	1
9/8/2012	1	9/18/2016	1	9/23/2021	3
9/12/2012	3	9/30/2016	6442	9/28/2021	1
9/13/2012	1	10/1/2016	2	9/29/2021	2
9/20/2012	3	1/1/2017	1	9/30/2021	13073
9/22/2012	2	3/30/2017	1	10/1/2021	1
9/23/2012	4	6/30/2017	1	10/30/2021	1
9/28/2012	7	9/11/2017	1	9/30/2022	667
9/29/2012	1	9/20/2017	2	9/30/2023	968
9/30/2012	18031	9/23/2017	5	9/30/2024	932
10/1/2012	2	9/30/2017	8490	9/30/2025	3325
10/30/2012	4	10/1/2017	2	9/30/2026	1270
2/10/2013	1	12/30/2017	1	9/30/2027	15
9/1/2013	1	3/30/2018	1	9/30/2029	1
9/8/2013	1	4/28/2018	1		
9/13/2013	3	8/30/2018	1		

Table 5. Frequency analysis of unique expiration dates. Assuming a constant contract length of 20 years, the bold lines separate the four time intervals to which a contract was assigned (see Tables 2 and 3).

Analysis of GIS and FSA Reported CRP acres

While grouping contracts in 15-, 5- and 4-year time intervals might have impacted the analysis, if water-level change was shown to be less beneath CRP than for areas not beneath CRP, then the result represented a conservative estimate. For example, if an area beneath CRP showed less aquifer decline than an area not beneath CRP, then it can be assumed that this difference represented a minimum savings because there might have been some CRP land classified as non-CRP during the time period. It is also important to remember that as contracts went progressively further back in time, the calculated acreage likely underestimated actual acreage.

To assess the effect of expired contracts not present in the 2011 FSA CRP database, calculated CRP acres derived from the database were compared to CRP acres published in the FSA CRP Annual Summary reports for each water-level change end-year. Table 5 presents the frequency of occurrence of CRP contracts summed for counties that are completely within or a significant area overlies the High Plains Aquifer boundary of Nebraska, New Mexico, South Dakota, Texas and Wyoming. For these 107 counties, the GIS-calculated CRP acres underestimated the reported FSA CRP acres by 19.4 percent for the interval ending 2008, 14.6 percent ending 2004, 26.4 percent ending 1999 and 67.4 percent in 1994 (Table 6). Similar results were found for comparing GIS-calculated versus FSA reported CRP acres for Oklahoma, Kansas and Colorado (Mulligan et al. 2013).

Water-level change Period/ Year ending	GIS Calculated CRP Acres	FSA Reported CRP Acres	GIS Acres / FSA Acres (Percent)	GIS Calculated Acres Underestimate (Percent)
2005-2008	3,434,238	4,088,038	80.6	19.4
2000-2004	3,353,180	4,095,580	85.4	14.6
1995-1999	2,139,362	3,951,391	73.6	26.4
1980-1994	1,559,718	3,937,944	32.6	67.4

Table 6. Comparison of GIS-calculated CRP acres and FSA reported CRP acres for 107 counties that lie completely within the boundary of the aquifer in NE, NM, SD, TX and WY.

Based on results in Table 6, the GIS-calculated CRP acreage (derived assuming a 20-year contract length) provided a reasonable estimate of the reported CRP acreage for the two most recent water-level change time intervals (2005-2009 and 2000-2005), but strongly underestimated actual CRP acreage for the 1995-2000 and 1980-1995 water-level change time intervals. To better understand this relationship between calculated and published CRP acres, Figures 3 to 6 compare calculated and reported acres in the form of scatter plots. For each plot a best-fit line (shown in gray) was placed through the data to illustrate how the underestimate deviates from an ideal 1:1 relationship.

For time intervals ending 2009 and 2005 the R^2 value was good (Figures 3 and 4). While these R^2 values are not meaningful in this context because no causal relationship was implied, they are reported to illustrate the strength of the relationship. More importantly, the slope of the best-fit line illustrated how the GIS-calculated CRP acres compared to the FSA-published acres. Based on these scatter plots, the data once again suggested that the calculated CRP acres (derived assuming a 20-year contract length) provided a reasonable estimate of actual acreage in the two more recent time intervals, but progressively underestimated actual CRP acreage for the two earlier water-level change time periods.

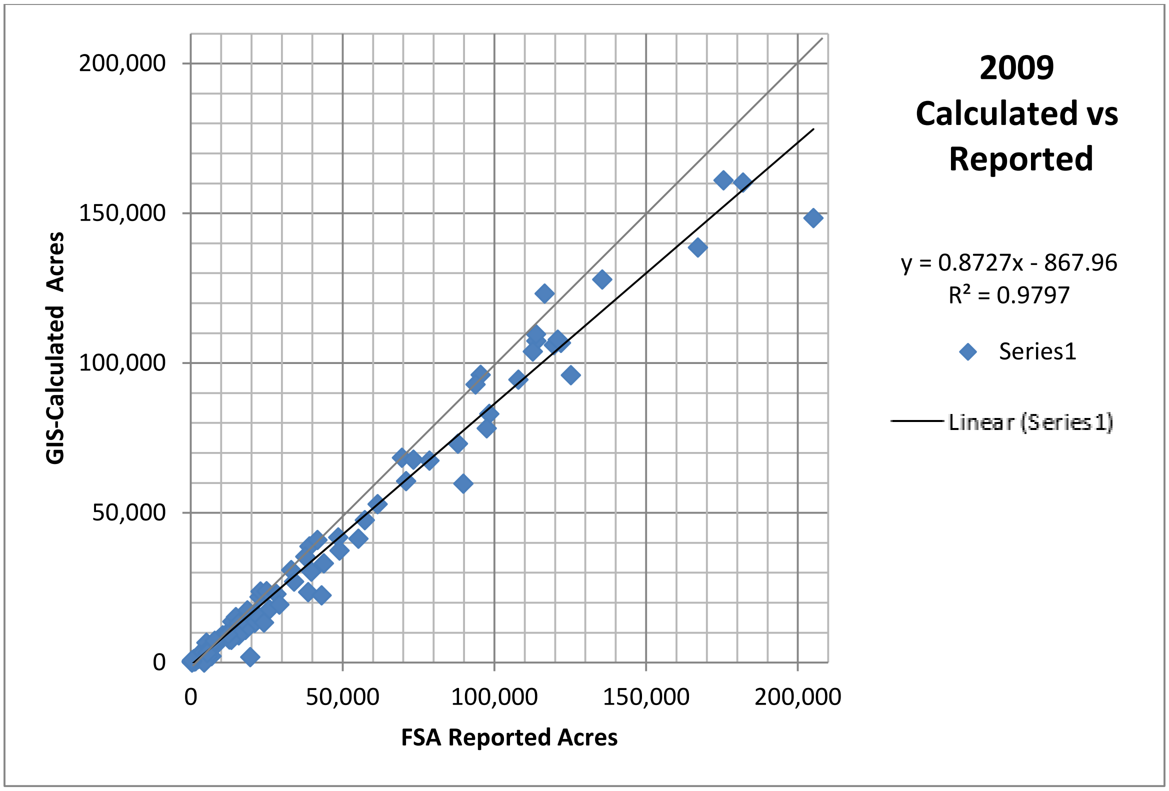

Figure 3. Comparison of total GIS-calculated acres and total FSA reported CRP acres for counties completely contained within the boundary of the High Plains Aquifer for 2009.

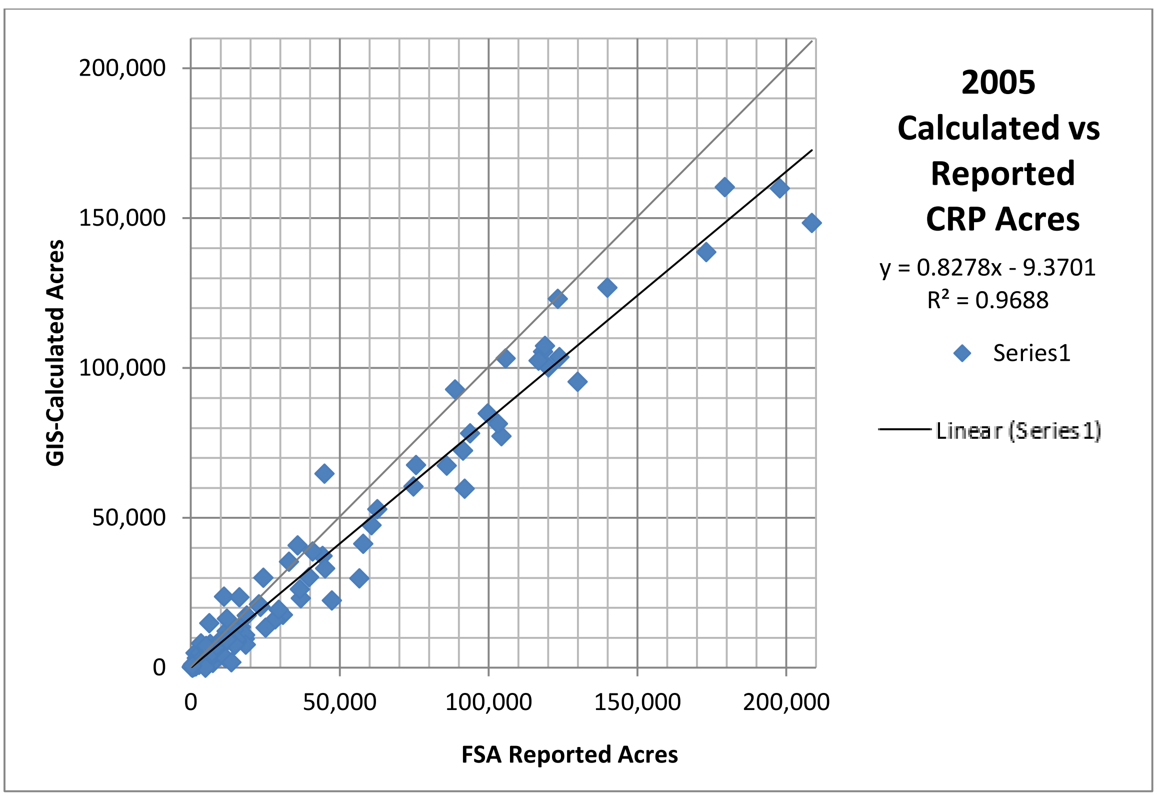

Figure 4. Comparison of total GIS-calculated acres and total FSA reported CRP acres for counties completely contained within the boundary of the High Plains Aquifer for 2005.

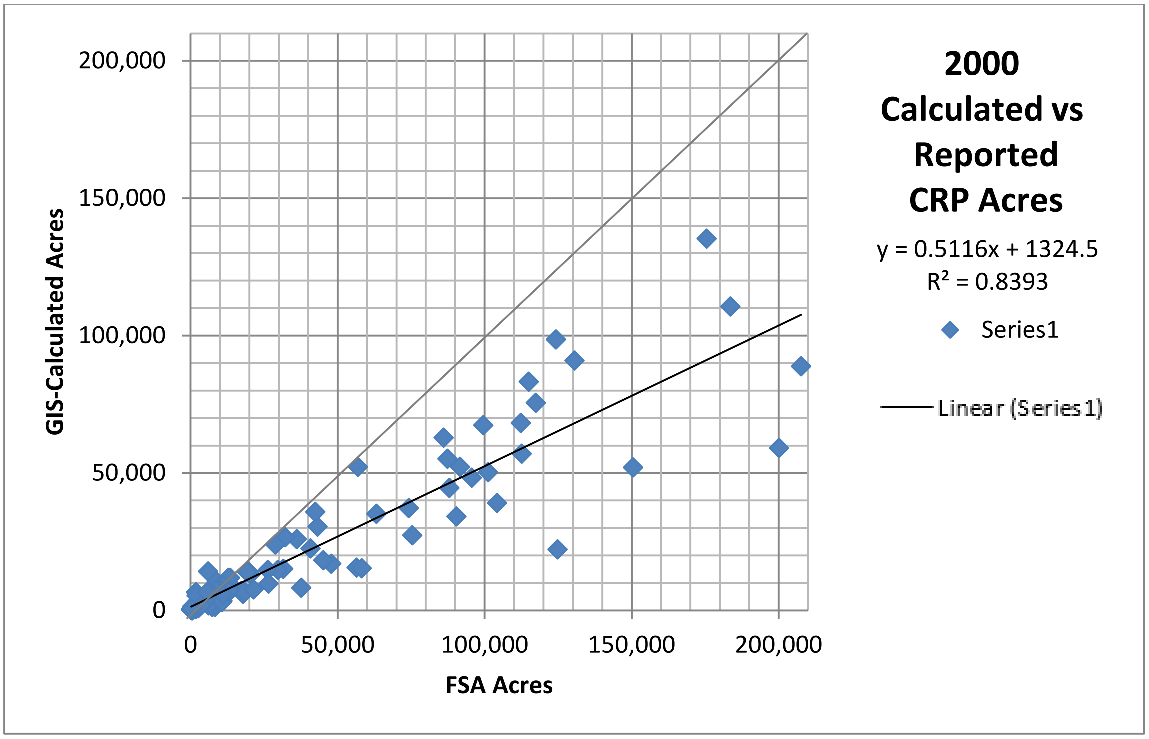

Figure 5. Comparison of total GIS-calculated acres and total FSA reported CRP acres for counties completely contained within the boundary of the High Plains Aquifer for 2000.

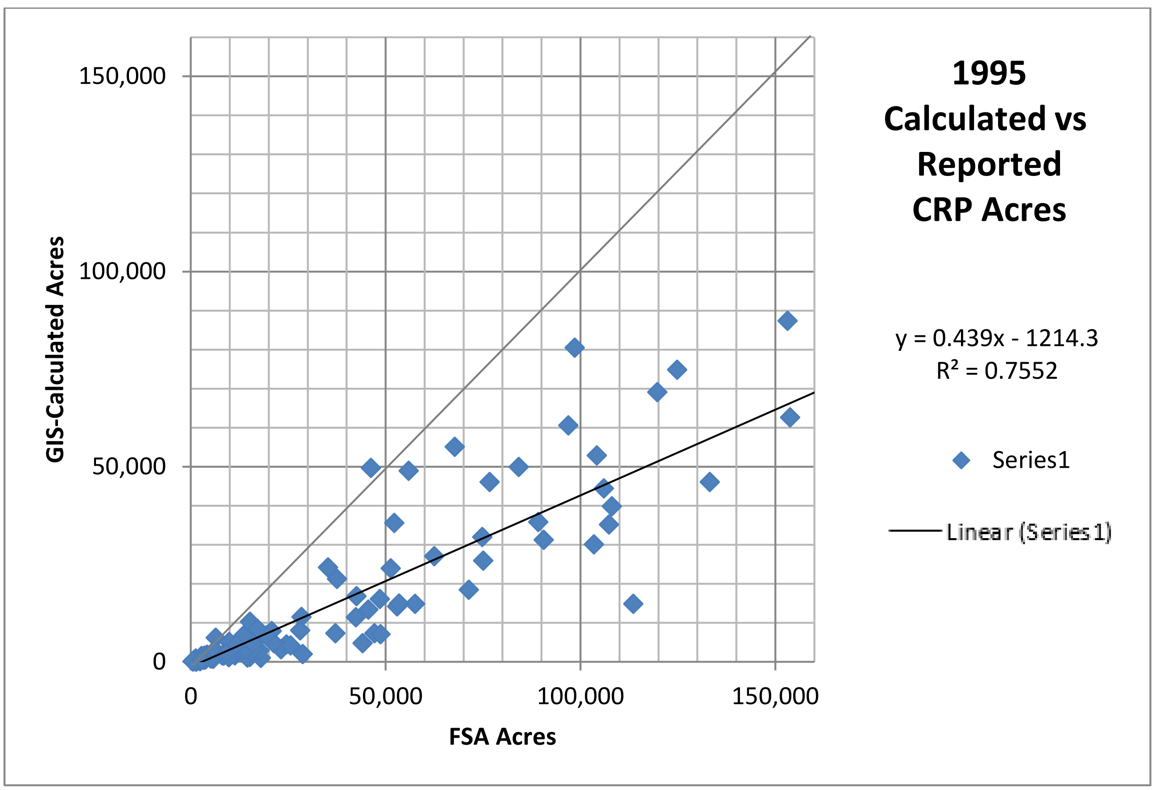

Figure 6. Comparison of total GIS-calculated acres and total FSA reported CRP acres for counties completely contained within the boundary of the High Plains Aquifer for 1995.

The Conservative Nature of Analytical Results

From Figures 3 through 6, it became apparent that any maps of CRP land created from the FSA CRP database (assuming a 20-year contract length) under-reported actual CRP area present during any water-level change time interval. While there was risk 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 was much more likely that a significant amount of CRP land was being mapped as non-CRP. In this case, CRP polygons were mapped as non-CRP because the CRP record was not present in the 2011 CRP database and expired before 2011. While these data were not ideal, it does not rule out an analysis of the effects of CRP land on water-level change. If calculated CRP acreage was an underestimate of actual CRP acreage (Table 6), this approach implied that some CRP polygons were mapped as non-CRP. In this situation, the results of any analysis simply provided conservative estimates of the effects of CRP land on water-level change – and the conservative nature of this estimate increased for the earlier water-level change time intervals. Inclusion of native grassland in non-CRP acreage should increase the conservative nature of these results because this land was never irrigated.

To illustrate the classification 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 was reducing the rate at which the aquifer declined, 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 had the consequence of assigning CRP to locations where they might not have been present. This decision 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 was 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 was being used for irrigated agriculture. If the results of an analysis showed that the rise beneath CRP land was 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 were obtained with CRP land mapped as non-CRP, then the greater rise in the water table beneath CRP land was 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.

Remember this analysis assumed that land enrolled in CRP for at least one year during a time interval had the potential to affect 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 was still attributed to land in CRP. Once again, this assumption produced 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 tended to be a conservative estimate – and, again, the conservative nature of this estimate increased for the earlier time periods.

Comparing Water-level Change beneath CRP and non-CRP Lands

To evaluate effects of the CRP on groundwater levels in the aquifer, the water-level change beneath CRP land was compared to water-level change beneath non-CRP land for each county. To perform this analysis, CRP and non-CRP areas were overlaid on the water-level change raster datasets provided by the USGS. The four water-level change raster datasets were projected to an Albers Equal Area projection – which was necessary to generate area calculations. Once again, these raster datasets covered the water-level change for four time intervals: 2005-2009, 2000-2005, 1995-2000, and 1980-1995.

The method used to determine water-level change involved summarizing cell values of the water-level change raster located within the zones of the CRP and non-CRP areas on a county basis. Specifically, a zonal statistic process (Esri, 2012) was applied to compute the water-level change values and output the results for CRP and non-CRP lands to separate tables. The spatial resolution (grid cell size) of the water-level change rasters, however, was 500 m. For the zonal statistics process to output a result, at least one grid cell must be completely contained within each CRP polygon. Many of the CRP polygons, however, were much smaller than the 500 m cell resolution of the USGS water-level change rasters, which precluded generating a water-level change calculation.

To capture water-level change beneath these smaller CRP polygons, it was necessary to resample the USGS water-level change rasters to create new datasets at a higher spatial resolution (smaller grid cell size). The nearest neighbor sampling technique was used for the resampling. 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 water-level change rasters were created without changing the underlying data.

To find the appropriate grid cell size, the 2005-2009 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 that output a record for each CRP features. In the end, the raster's resolution was re-sampled down to 25 m. At this spatial resolution, the input CRP layer contained 79,615 individual CRP records, and the output zonal statistics table contained 79,126 CRP records for one time interval. In this test case (using CRP polygons), the 489 polygons that did not output a result were smaller than the 25 m resolution. This number represented less than 1 percent of the polygons in the input CRP layer – which was deemed to have only a minor effect on the final results. Resampling the water-level change rasters to a 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. The non-CRP areas were created using the CRP polygons and several geoprocessing steps. The zonal statistics tables output a record for each county with the name, total number of raster cells, and the mean water-level change in feet for all cells in that county. These results were included in charts presented for each state in this report.

Mapping Saturated Thickness and Water-level Change

Figure 7 shows the spatial variability in saturated thickness of the High Plains Aquifer in 2009. Clearly, the aquifer is thickest in the area underlying the Sandhills in Nebraska. In other parts of the Great Plains, the thickness of the aquifer varies – with relatively greater amounts of groundwater in northeastern Colorado, southwestern Kansas, the Oklahoma panhandle, and northern Texas.

Of particular concern in this study are those areas of the aquifer with significant declines. Figure 8 shows the cumulative water-level change measured between 2000 and 2009. This map was created by summing the USGS water-level change rasters for 2000-2005 and 2000-2009. Over this nine-year period, the greatest declines occurred in the Rainwater Basin south of the Platte River in Nebraska that is dominated by corn crop, parts of northeastern Colorado, southwestern Kansas, and three separate areas in Texas. In general, these areas of decline correspond to regions of greater aquifer saturated thickness.

The next sections of this report describe the groundwater-level changes for Texas, New Mexico, Nebraska, South Dakota and Wyoming. Each section contains maps, tables and graphs depicting groundwater levels of CRP and non-CRP lands for each county. It is 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 can be masked in the county-wide average. For example in Floyd County, Texas, the west half is on the aquifer and east half is off the caprock.

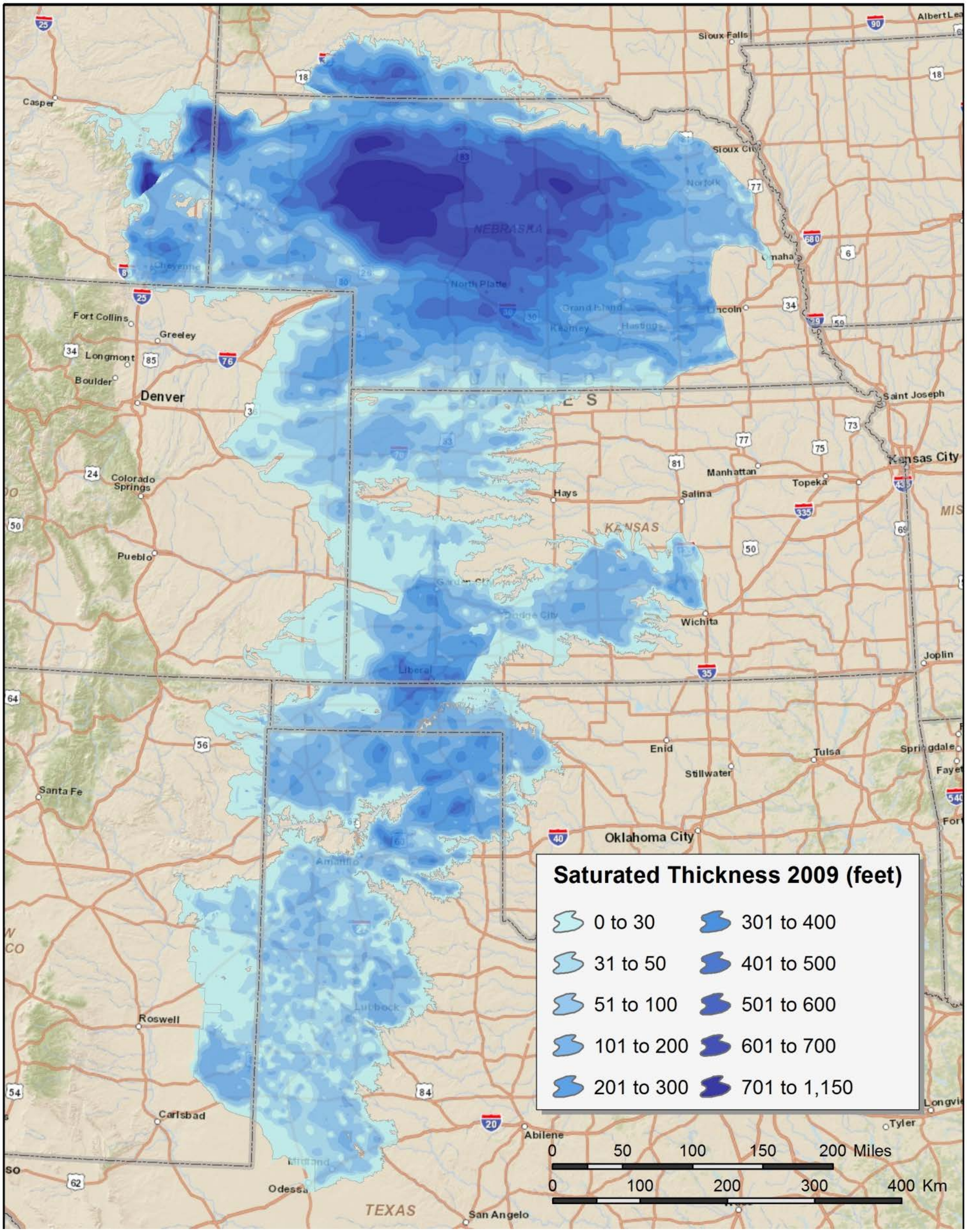

Figure 7. Saturated thickness of the High Plains Aquifer, 2009. Map created from saturated thickness data developed by the USGS (McGuire et al., 2012).

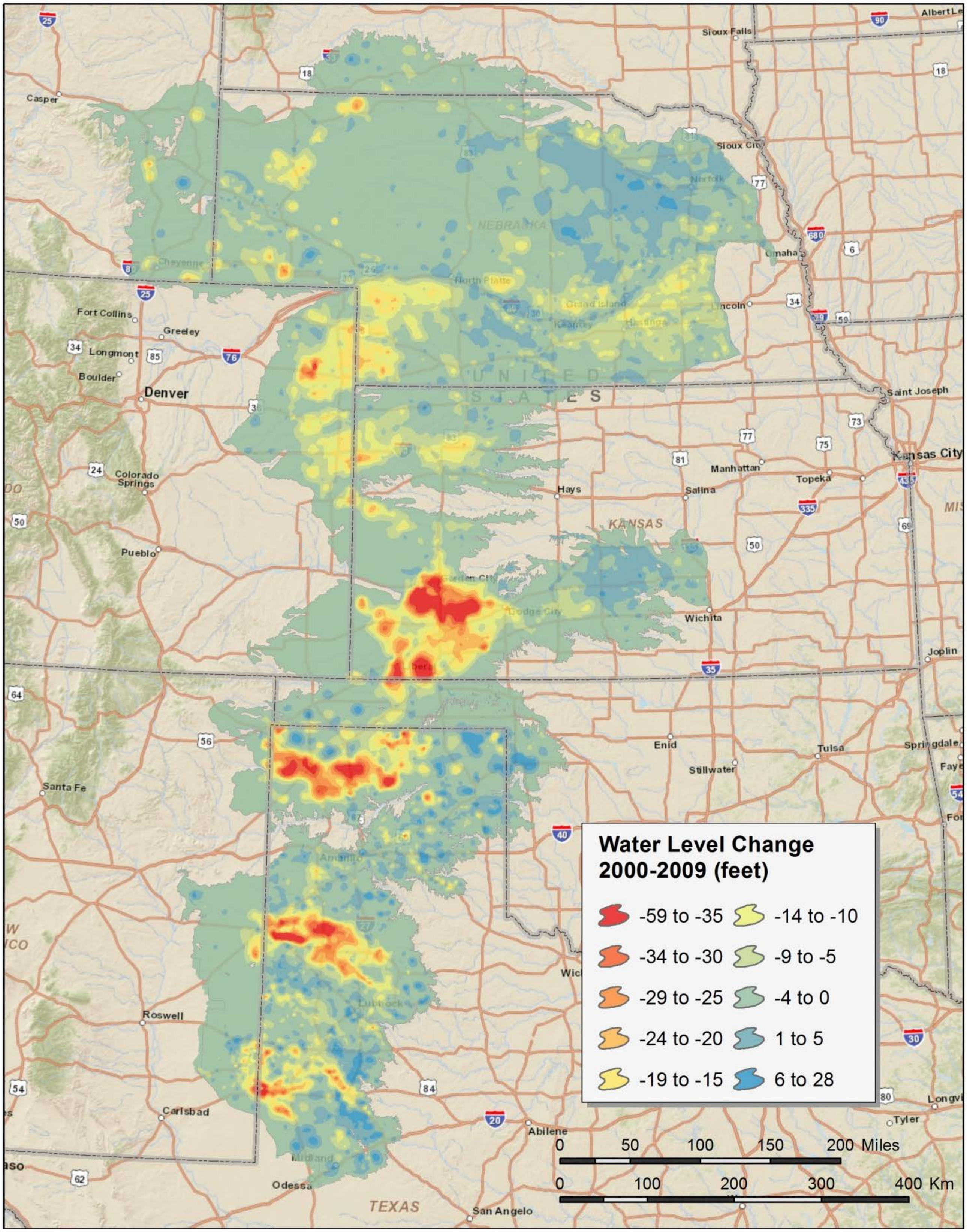

Figure 8. Water-level change in the High Plains Aquifer, 2000-2009. Map created from water-level change data developed by the USGS (McGuire et al., 2012).

Texas

CRP Effects on Water-level Change by County

Summary Results: Texas

In Texas, the High Plains Aquifer underlies all of part of 46 counties – covering an area of approximately 36,060 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 total contract length) were overlaid on each of the four water-level change rasters and the zonal statistics process run to determine the change under each type of land use.

Given the large number of counties in Texas for this discussion, the state was divided into three analysis regions: north, central and south (Figure 9). The Prairie Dog Town Fork of the Red River was used as the dividing line to describe changes in water level between counties to the north and central regions. This river also divides two distinctly different geologic formations that control the characteristics of the High Plains Aquifer in Texas. The southern boundary of Lubbock County at about 33°24’ N was the dividing line between counties in the central and south analysis regions.

Figures 10, 12, 14 and 16 show the rate of water-level change during each of the four time intervals for Texas. To create these maps, the water-level change data in each USGS raster were 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 time intervals.

Three areas in Texas have displayed consistent and significant declines throughout all four time intervals. The first area of consistent drawdown was represented in six counties in the northwestern part of Texas. The second area of consistent drawdown was located in the central part of the Texas High Plains Aquifer and affected the counties along a southeastern trend from Parmer to Floyd County. The third and southernmost area of significant decline affected areas of Gaines, Terry, and Yoakum counties.

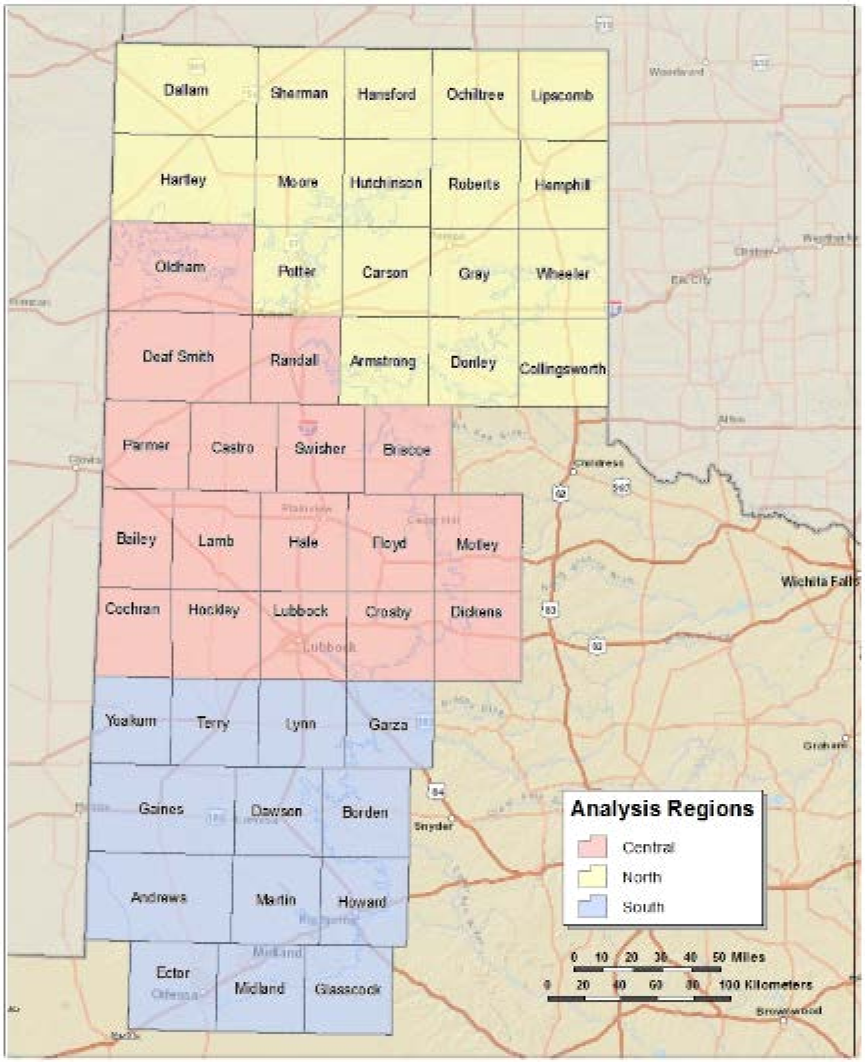

Figure 9. Texas analysis regions.

Counties North of the Prairie Dog Town Fork of the Red River

Counties with Significant Change (greater than 1 foot change per year)

For all four time intervals, Sherman County experienced significant aquifer decline of 1 foot or more per year. The decline was greater beneath non-CRP land for all but the 1995-2000 time interval, when there was significant decline of 13 feet beneath CRP and about 12.3 feet beneath non-CRP, or a 0.7 foot greater decline beneath CRP.

Dallam, Hansford, Hartley and Moore counties also experienced significant aquifer decline of over 1 foot per year in three time intervals. Only Dallam County experienced greater decline beneath non-CRP lands for the 2005-2009, 2000-2005 and 1995-2000 time intervals.

Counties with Moderate Change (between 0.5 and 1 foot change per year)

Hutchinson County experienced moderate decline of about 0.5 to 0.9 feet per year for three time intervals: 1980-1995, 1995-2000 and 2000-2005. CRP land accounted for only 0.2% to 0.6% of the area over the High Plains Aquifer with only about a dozen CRP contracts. In each case there was significantly greater decline beneath CRP than non-CRP. It is important to note that several contracts were in areas of significant decline with some contracts located in the center of the largest declines in the county.

Ochiltree and Roberts counties showed moderate and mixed changes between 0.5 and 1.0 foot per year in the 2005-2009 and 1995-2000 time intervals. For the 2005-2009 time interval, Ochiltree County declined 0.6 feet more beneath CRP, while Roberts declined 1.8 feet more beneath non-CRP. However, in the 1995-2000 interval, Ochiltree declined 1.7 feet more beneath non-CRP, while Roberts showed a rise of 3.2 feet beneath CRP, which was 0.6 feet more than for non-CRP.

In the 2000-2005 time interval, Hansford and Moore counties experienced declines of about 0.7 and 0.9 feet per year respectively with greater declines beneath non-CRP. Lipscomb County showed about a 0.8 decline per year during the 1995-2000 with about 1.2 feet greater decline beneath CRP. During the 1980-1995 time interval Carson, Dallam and Hartley counties had declines ranging from about 0.6 to 0.8 feet per year. Carson and Dallam showed greater declines beneath non-CRP, while Hartley was the opposite.

Counties with Little Change (less than 0.5 foot change per year)

These counties with little change beneath CRP and non-CRP lands might be due to the abundant native grassland which is similar to CRP. Counties located to the north of the Prairie Dog Town Fork of the Red River that experienced little or no change for all four time intervals included Armstrong, Collingsworth, Donley, Gray, Hemphill, Potter and Wheeler. These counties experienced mixed rise-and-decline results beneath CRP and non-CRP lands.

Carson and Lipscomb counties showed little change for three intervals. Both counties favored either less decline or greater rise beneath CRP for the 2005-2009 and 2000-2005 time intervals. Carson County also experienced little change during the 1995-2000 interval with about a 2 foot greater rise beneath CRP. Lipscomb had little change during the 1980-1995 interval with about a 1.1 foot greater rise beneath CRP.

Both Ochiltree and Roberts counties showed little change for the 2000-2005 time interval. Ochiltree had slightly more decline beneath non-CRP, while Roberts had about a 0.8 foot greater rise over CRP.

Counties South of the Prairie Dog Town Fork Red River and north of 33°24’ N

Counties with Significant Change (greater than 1 foot change per year)

For all four time intervals, the counties with the most significant and consistent aquifer decline of 1 foot or more per year occurred in Castro, Hale, Lamb, and Parmer counties. In the 2005-2009 time interval, Castro and Parmer counties had the greatest decline of over 8 feet beneath non-CRP lands, while declines beneath CRP were 2.3 and 3.1 feet, respectively. For this same time interval, Hale and Lamb counties experienced declines beneath non-CRP of 6.1 and 5.8 feet but only 3.9 and 1.7 feet, respectively, of decline beneath CRP.

Counties with Moderate Change (between 0.5 and 1 foot change per year)

Deaf Smith County showed a decline of about 0.5 feet per year in all but the 2000-2005 time interval with more decline occurring beneath non-CRP land.

During the 1980-1995 interval Floyd County was the only one that showed a moderate amount of change of about 0.7 feet per year.

Counties with Little Change (less than 0.5 foot change per year)

For all four time intervals, Briscoe, Crosby, Dickens, Motley, Oldham and Randall counties had little to no change in groundwater level south of the Prairie Dog Fork of the Red River. Except for Crosby and Randall these counties are on the edge of and have less than half of their areas over the High Plains Aquifer.

For the 1980-1995, 2000-2005 and2005-2009 time intervals Bailey, Cochran, Hockley, Lubbock and Swisher counties recorded less than 0.5 foot per year change. In general, Bailey County had much lower declines beneath CRP during the 1980-1995 interval and showed a 1.7 foot rise beneath CRP and about a 6 foot decline beneath non-CRP. Cochran County had similar declines beneath CRP and non-CRP for the 2000-2005 and 2005-2009 intervals, and about a 2-foot greater rise beneath CRP during the 1980-1995 interval. Hockley County experienced either greater rise or less decline beneath CRP. Lubbock County showed similar declines beneath CRP and non-CRP for the 2000-2005 and 2005-2009 time intervals, and greater decline beneath CRP for the 1980-1995 interval. Swisher County showed greater declines beneath non-CRP for the three intervals.

For the 2000-2005 and 2005-2009 intervals, Floyd County showed greater decline beneath non-CRP of up to 1 foot, while Martin County had a greater rise of about 1 foot beneath CRP. For the 1980-1995 interval, Terry County showed nearly 2.8 feet greater rise over CRP.

During the 2000-2005 interval, Deaf Smith County showed a rise of about 0.6 feet over CRP and decline of about 0.7 feet beneath non-CRP. Finally, during the 1980-1995 interval, Gaines and Yoakum Counties showed greater rises of about 4 feet each beneath CRP lands.

Counties South of 33°24’ N

Counties with Significant Change (greater than 1 foot change per year)

For all four time intervals, Gaines County experienced significant and consistent aquifer decline of 1 foot or more per year, with declines beneath CRP about a foot less than beneath non-CRP for the three most recent time intervals.

Counties with Moderate Change (between 0.5 and 1 foot change per year)

Yoakum County experienced moderate declines between 0.5 and 1 foot per year for the 2000-2005 and 2005-2009 time intervals, with about 0.4 foot greater decline beneath CRP in 2005-2009 and slightly more decline beneath non-CRP during the 2000-2005 interval. Lynn and Martin counties had about 0.6 foot decline per year during the 1995-2000 interval with 0.5 to 0.9 foot greater decline beneath CRP. During the 1980-1995 interval, these counties had between about 0.6 and 0.8 foot rise per year, with Lynn County having about 0.3 foot greater rise beneath non-CRP while Martin County had about 1.8 foot greater rise beneath CRP.

Dawson County was the only one with a moderate amount of change of about 0.6 foot decline per year during the 2000-2005 interval with slightly greater decline beneath non-CRP land.

Counties with Little Change (less than 0.5 foot change per year)

For all four time intervals Andrews, Borden, Garza and Glasscock counties had little to no change in groundwater level. Except for Andrews, which has abundant native grassland, these counties are on the edge of the aquifer and have less than one fourth of their area over the aquifer.

For the 1980-1995, 2000-2005, and 2005-2009 time intervals, Howard and Midland counties recorded less than 0.5 foot per year change. Midland County experienced greater rises beneath CRP for the 1980-1995 and 2005-2009 intervals but greater decline beneath CRP for the 2000-2005 interval.

For the 2005-2009 interval, Martin and Terry Counties showed greater declines beneath non-CRP of up to 1 foot, while Lynn showed a similar increase beneath both CRP and non-CRP. During the 2000-2005 interval, Lynn County showed greater declines of up to 1 foot beneath non-CRP, while Martin County had a greater rise of about 1 foot beneath CRP. For the 1980-1995 interval, Terry County showed greater rise over CRP of nearly 2.8 feet.

Dawson County showed greater decline beneath CRP of about 0.8 feet for the 2005-2009 interval. Finally, during the 1980-1995 interval, Gaines and Yoakum counties showed greater rises of about 4 feet each beneath CRP lands.

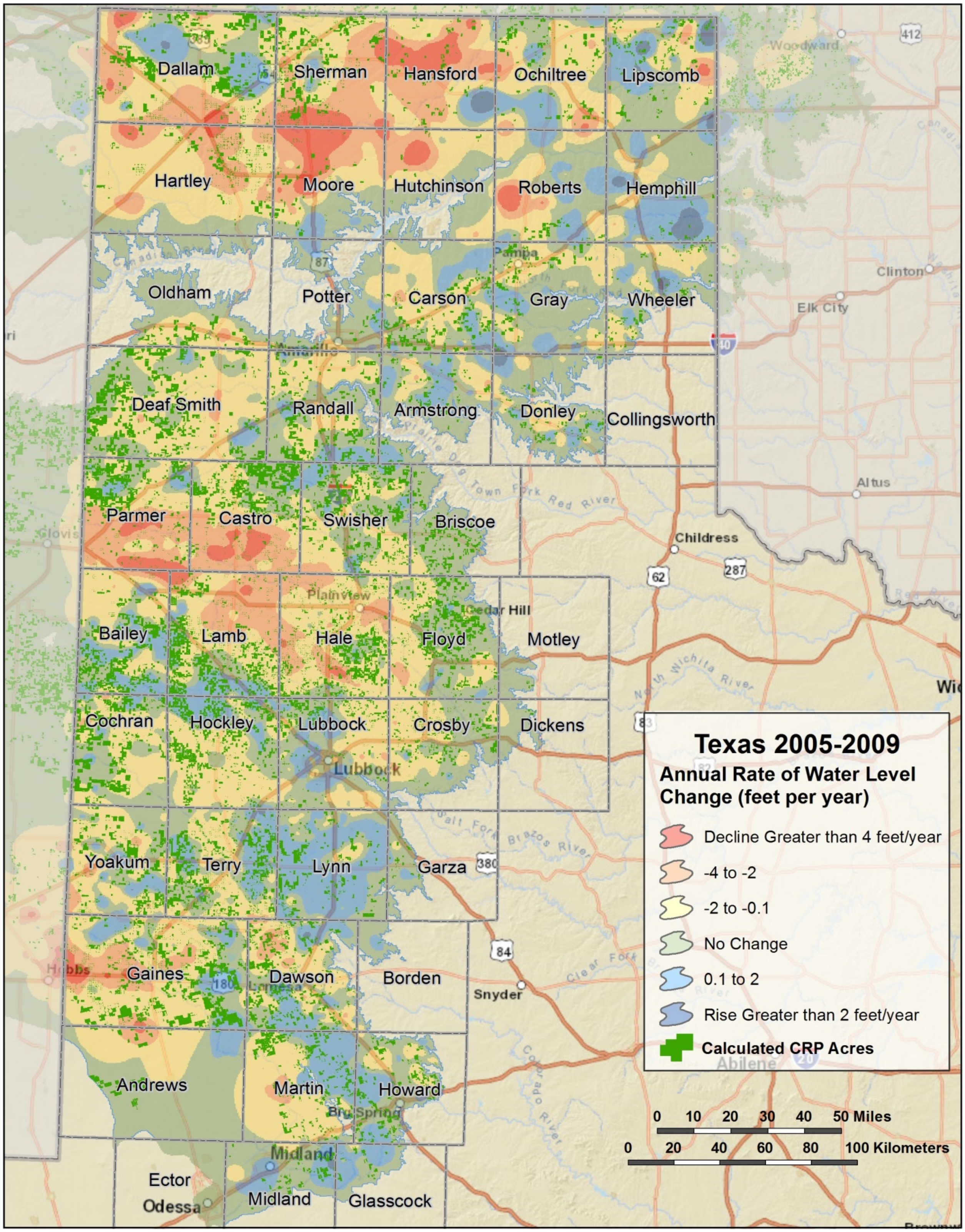

Figure 10. Texas CRP polygons for 2009 overlaid on water-level change, 2005-2009.

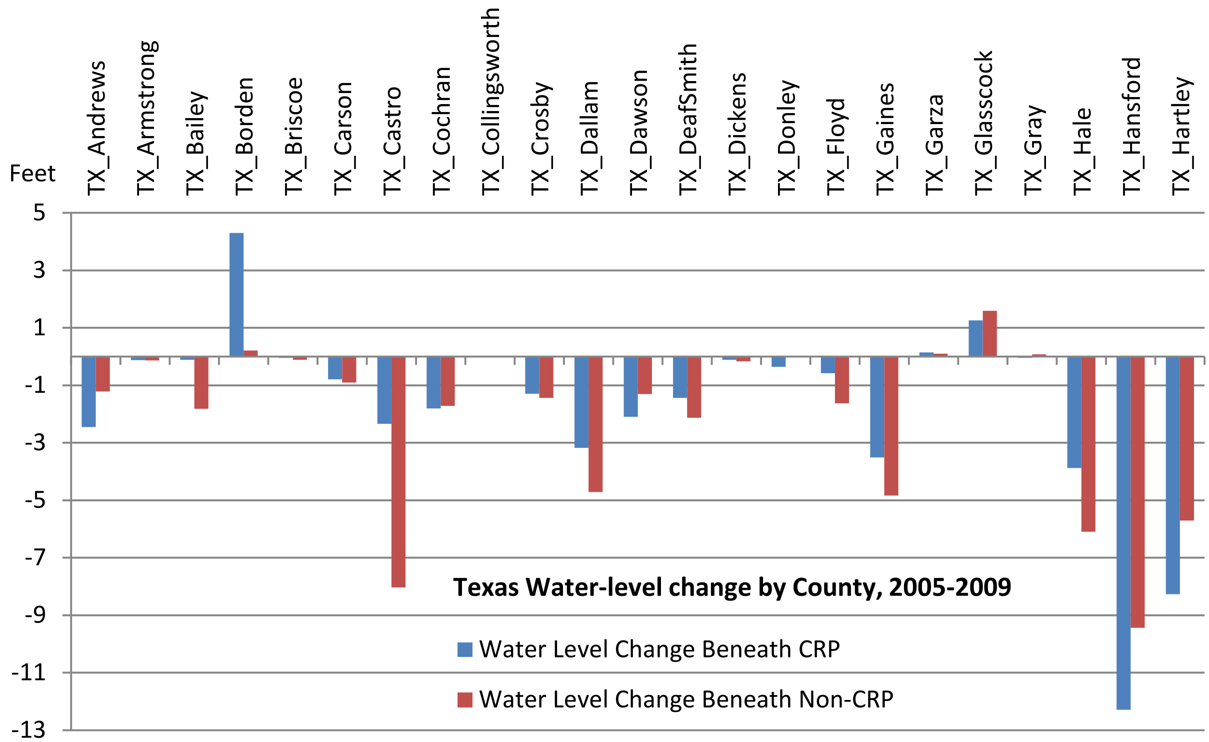

Figure 11. Comparison of water-level changes beneath CRP and non-CRP land, 2005-2009.

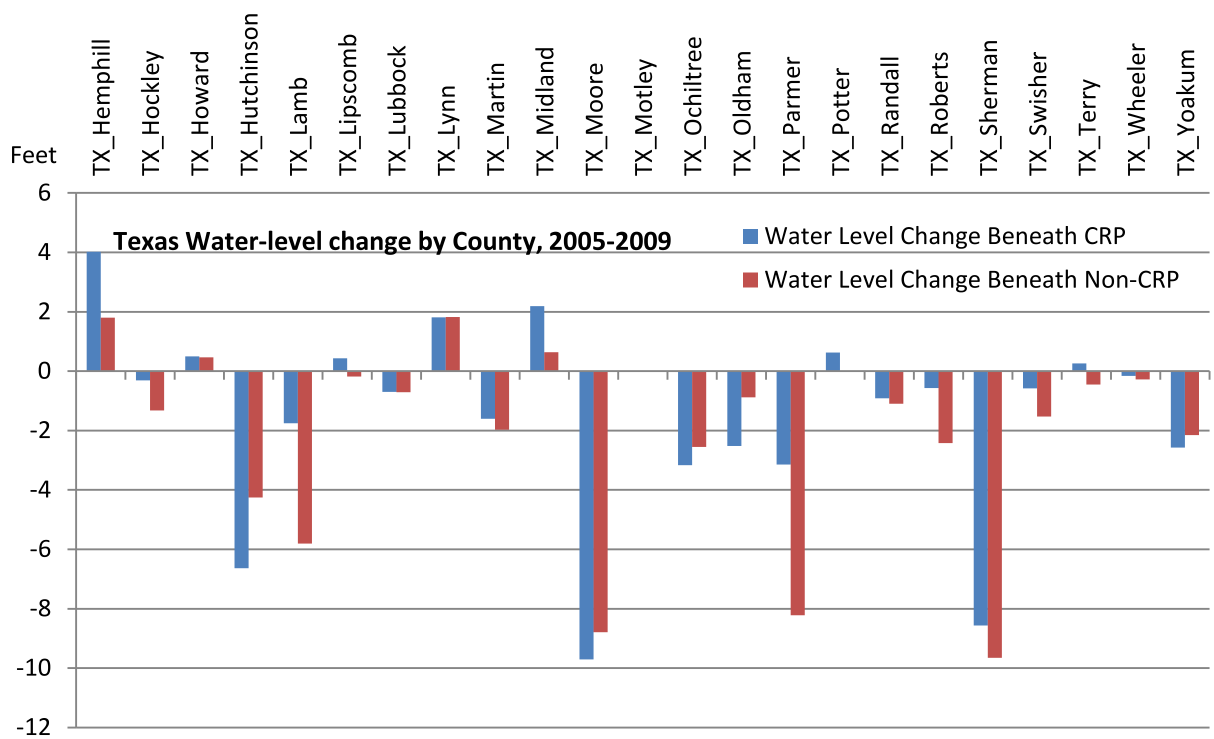

Figure 11 Continued. Comparison of water-level changes beneath CRP and non-CRP land, 2005-2009.

2005-2009 Mean Water-level Change						
State_County	**County water-level change (ft)**	**CRP water-level change (ft)**	**Non-CRP water-level change (ft)**	**Total County CRP Acres over the Aquifer**	**Total County Acres over the Aquifer**	**Percent of County over the Aquifer in CRP**
TX_Andrews	-1.25	-2.45	-1.21	23,427	777,346	3.0
TX_Armstrong	-0.14	-0.13	-0.14	22,454	397,000	5.7
TX_Bailey	-1.50	-0.11	-1.82	96,001	529,586	18.1
TX_Borden	0.22	4.30	0.21	155	66,996	0.2
TX_Briscoe	-0.11	-0.05	-0.12	37,682	258,532	14.6
TX_Carson	-0.89	-0.79	-0.90	52,935	583,986	9.1
TX_Castro	-6.98	-2.34	-8.04	107,360	575,547	18.7
TX_Cochran	-1.74	-1.80	-1.72	96,088	496,150	19.4
TX_Collingsworth	0.00	0.00	0.00	64	10,400	0.6
TX_Crosby	-1.43	-1.29	-1.44	37,381	445,769	8.4
TX_Dallam	-4.52	-3.17	-4.72	123,155	963,362	12.8
TX_Dawson	-1.42	-2.10	-1.30	82,988	541,326	15.3
TX_DeafSmith	-2.01	-1.44	-2.14	161,015	921,697	17.5
TX_Dickens	-0.16	-0.11	-0.16	850	78,012	1.1
TX_Donley	-0.04	-0.36	-0.03	19,069	396,832	4.8
TX_Floyd	-1.44	-0.58	-1.62	106,011	591,283	17.9
TX_Gaines	-4.62	-3.51	-4.84	160,320	961,829	16.7
TX_Garza	0.10	0.14	0.10	4,565	100,930	4.5
TX_Glasscock	1.58	1.26	1.59	5,164	126,564	4.1
TX_Gray	0.07	-0.05	0.08	30,330	576,083	5.3
TX_Hale	-5.73	-3.87	-6.10	106,769	643,053	16.6
TX_Hansford	-9.54	-12.29	-9.44	19,382	588,151	3.3
TX_Hartley	-5.82	-8.27	-5.71	38,778	911,952	4.3

Table 7. Texas water-level change beneath CRP and non-CRP land by county, 2005-2009.

2005-2009 Mean Water-level Change						
State_County	County water-level change (ft)	CRP water-level change (ft)	Non-CRP water-level change (ft)	Total County CRP Acres over the Aquifer	Total County Acres over the Aquifer	Percent of County over the Aquifer in CRP
TX_Hemphill	1.83	4.02	1.80	7,580	576,369	1.3
TX_Hockley	-1.15	-0.31	-1.33	103,890	581,481	17.9
TX_Howard	0.47	0.49	0.47	41,255	350,959	11.8
TX_Hutchinson	-4.27	-6.64	-4.25	2,822	458,467	0.6
TX_Lamb	-5.02	-1.75	-5.81	127,862	651,339	19.6
TX_Lipscomb	-0.15	0.43	-0.18	33,139	596,668	5.6
TX_Lubbock	-0.71	-0.70	-0.71	40,903	571,132	7.2
TX_Lynn	1.82	1.81	1.82	47,560	569,320	8.4
TX_Martin	-1.94	-1.61	-1.98	60,553	566,314	10.7
TX_Midland	0.73	2.19	0.64	17,430	317,182	5.5
TX_Moore	-8.82	-9.70	-8.79	13,427	538,593	2.5
TX_Motley	0.00	0.00	0.00	709	64,659	1.1
TX_Ochiltree	-2.59	-3.17	-2.56	35,385	586,128	6.0
TX_Oldham	-0.98	-2.53	-0.89	25,195	460,563	5.5
TX_Parmer	-7.39	-3.15	-8.22	92,874	566,500	16.4
TX_Potter	0.01	0.62	0.00	7,061	302,486	2.3
TX_Randall	-1.08	-0.91	-1.10	73,116	569,553	12.8
TX_Roberts	-2.39	-0.57	-2.43	9,420	587,413	1.6
TX_Sherman	-9.51	-8.57	-9.65	78,254	590,848	13.2
TX_Swisher	-1.36	-0.58	-1.53	107,790	575,702	18.7
TX_Terry	-0.32	0.26	-0.46	109,657	570,202	19.2
TX_Wheeler	-0.28	-0.16	-0.28	17,508	372,472	4.7
TX_Yoakum	-2.21	-2.58	-2.15	67,715	511,831	13.2

Table 7 Continued. Texas water-level change beneath CRP and non-CRP land by county, 2005-2009.

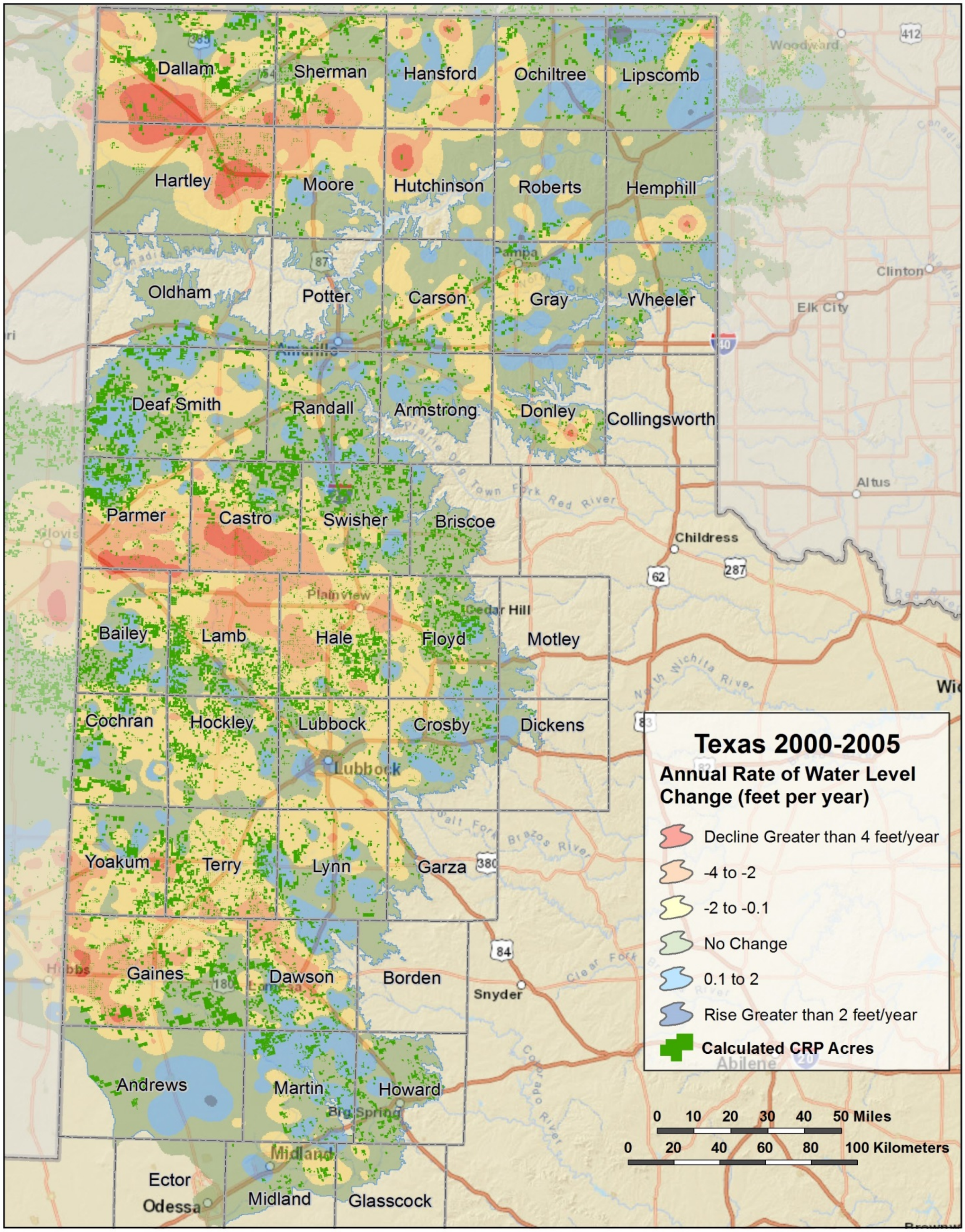

Figure 12. Texas CRP polygons for 2005 overlaid on water-level change, 2000-2005.

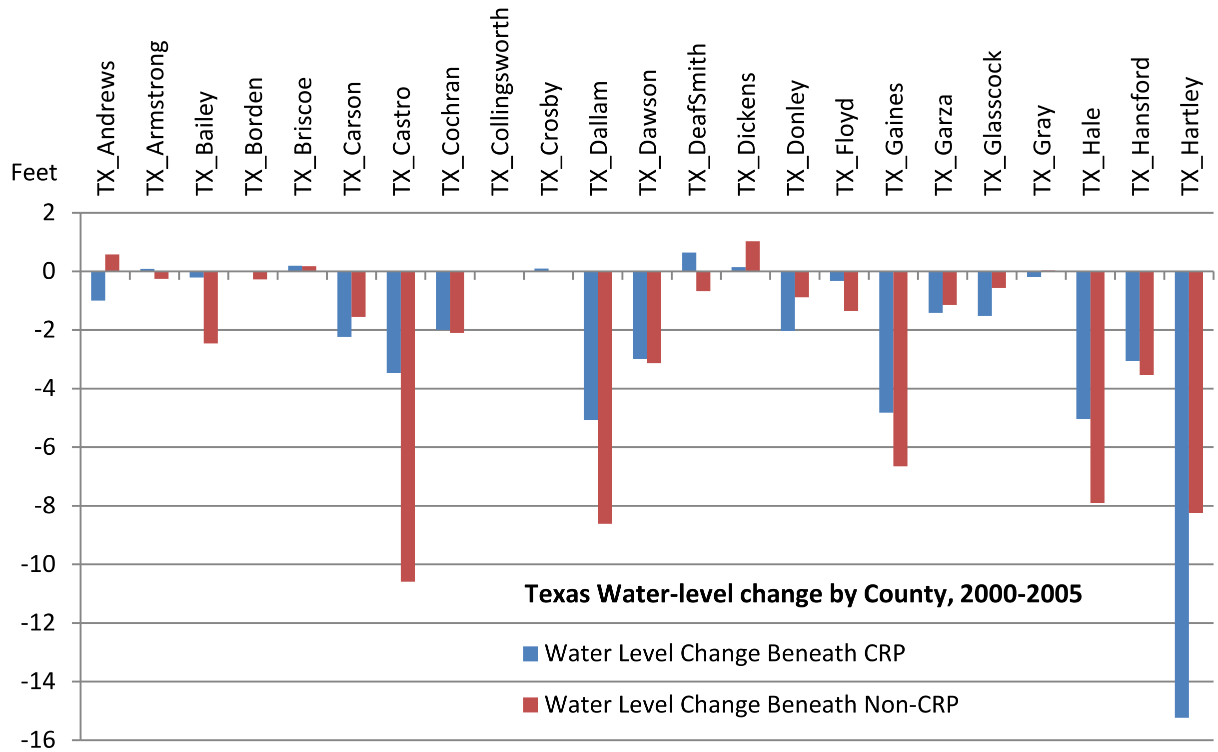

Figure 13. Comparison of water-level changes beneath CRP and non-CRP land, 2000-2005.

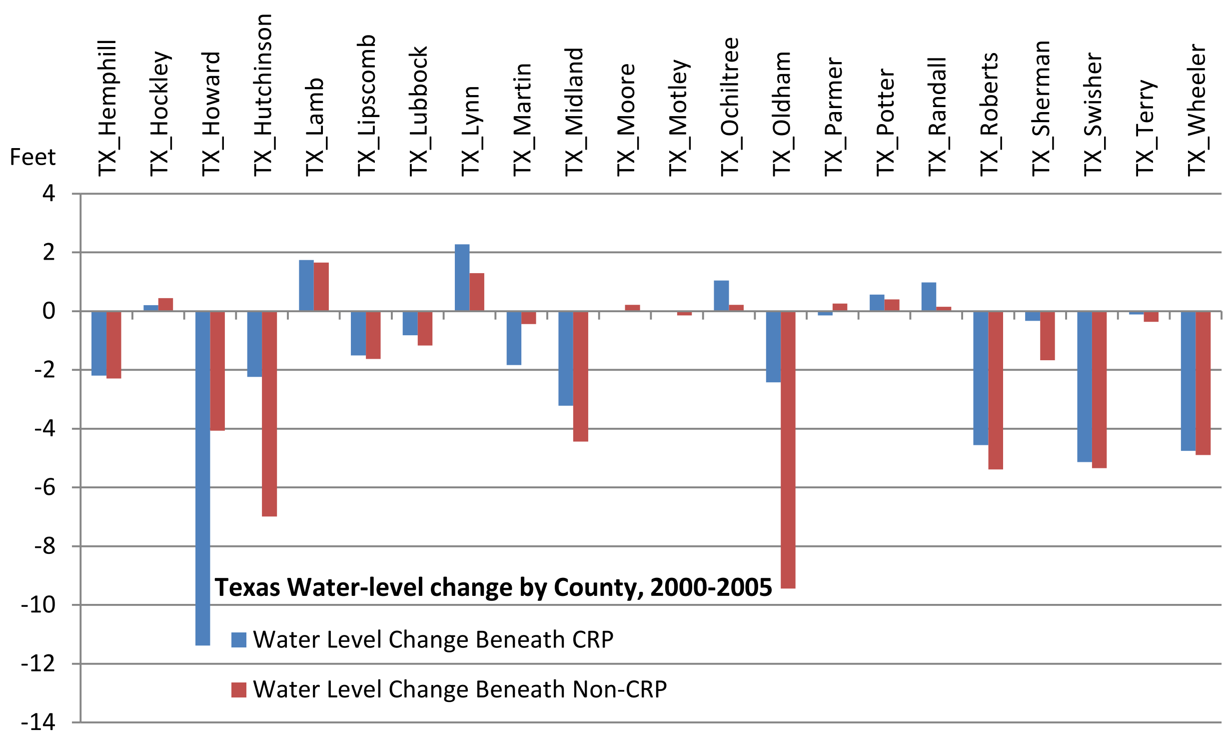

Figure 13 Continued. Comparison of water-level changes beneath CRP and non-CRP land, 2000-2005.

2000-2005 Mean Water-level Change						
State_County	**County water-level change (ft)**	**CRP water-level change (ft)**	**Non-CRP water-level change (ft)**	**Total County CRP Acres over the Aquifer**	**Total County Acres over the Aquifer**	**Percent of County over the Aquifer in CRP**
TX_Andrews	0.53	-0.99	0.58	23,427	777,346	3.0
TX_Armstrong	-0.23	0.09	-0.25	22,454	397,000	5.7
TX_Bailey	-2.05	-0.20	-2.46	95,392	529,586	18.0
TX_Borden	-0.27	0.00	-0.27	155	66,996	0.2
TX_Briscoe	0.18	0.20	0.17	37,659	258,532	14.6
TX_Carson	-1.61	-2.22	-1.55	52,935	583,986	9.1
TX_Castro	-9.32	-3.47	-10.59	103,242	575,547	17.9
TX_Cochran	-2.08	-1.99	-2.10	84,835	496,150	17.1
TX_Collingsworth	0.01	0.00	0.01	64	10,400	0.6
TX_Crosby	0.00	0.10	-0.01	37,381	445,769	8.4
TX_Dallam	-8.16	-5.07	-8.61	123,155	963,362	12.8
TX_Dawson	-3.11	-2.98	-3.14	81,457	541,326	15.0
TX_DeafSmith	-0.44	0.65	-0.67	160,392	921,697	17.4
TX_Dickens	1.02	0.14	1.03	850	78,012	1.1
TX_Donley	-0.93	-2.03	-0.88	19,069	396,832	4.8
TX_Floyd	-1.18	-0.33	-1.36	100,261	591,283	17.0
TX_Gaines	-6.36	-4.82	-6.66	159,985	961,829	16.6
TX_Garza	-1.15	-1.41	-1.15	4,565	100,930	4.5
TX_Glasscock	-0.61	-1.52	-0.57	5,164	126,564	4.1
TX_Gray	0.02	-0.19	0.03	30,330	576,083	5.3
TX_Hale	-7.43	-5.03	-7.90	105,450	643,053	16.4
TX_Hansford	-3.53	-3.06	-3.54	19,382	588,151	3.3
TX_Hartley	-8.54	-15.23	-8.24	38,778	911,952	4.3

Table 8. Texas water-level change beneath CRP and non-CRP land by county, 2000-2005.

2000-2005 Mean Water-level Change						
State_County	**County water-level change (ft)**	**CRP water-level change (ft)**	**Non-CRP water-level change (ft)**	**Total County CRP Acres over the Aquifer**	**Total County Acres over the Aquifer**	**Percent of County over the Aquifer in CRP**
TX_Hemphill	-0.70	-0.77	-0.70	7,580	576,369	1.3
TX_Hockley	-2.28	-2.20	-2.29	102,478	581,481	17.6
TX_Howard	0.41	0.20	0.44	41,255	350,959	11.8
TX_Hutchinson	-4.12	-11.38	-4.07	2,822	458,467	0.6
TX_Lamb	-6.07	-2.24	-6.99	126,821	651,339	19.5
TX_Lipscomb	1.66	1.74	1.66	33,139	596,668	5.6
TX_Lubbock	-1.62	-1.50	-1.62	40,871	571,132	7.2
TX_Lynn	-1.13	-0.82	-1.17	47,560	569,320	8.4
TX_Martin	1.40	2.28	1.30	60,553	566,314	10.7
TX_Midland	-0.52	-1.83	-0.45	17,430	317,182	5.5
TX_Moore	-4.41	-3.22	-4.44	13,427	538,593	2.5
TX_Motley	0.21	0.00	0.21	709	64,659	1.1
TX_Ochiltree	-0.14	-0.04	-0.15	35,385	586,128	6.0
TX_Oldham	0.26	1.05	0.21	25,195	460,563	5.5
TX_Parmer	-8.30	-2.42	-9.44	92,874	566,500	16.4
TX_Potter	0.25	-0.15	0.26	7,061	302,486	2.3
TX_Randall	0.42	0.56	0.40	72,483	569,553	12.7
TX_Roberts	0.16	0.98	0.14	9,420	587,413	1.6
TX_Sherman	-5.28	-4.56	-5.39	78,254	590,848	13.2
TX_Swisher	-1.43	-0.33	-1.67	103,617	575,702	18.0
TX_Terry	-5.32	-5.13	-5.35	107,404	570,202	18.8
TX_Wheeler	-0.36	-0.11	-0.37	17,056	372,472	4.6
TX_Yoakum	-4.87	-4.75	-4.89	67,715	511,831	13.2

Table 8 Continued. Texas water-level change beneath CRP and non-CRP land by county, 2000-2005.

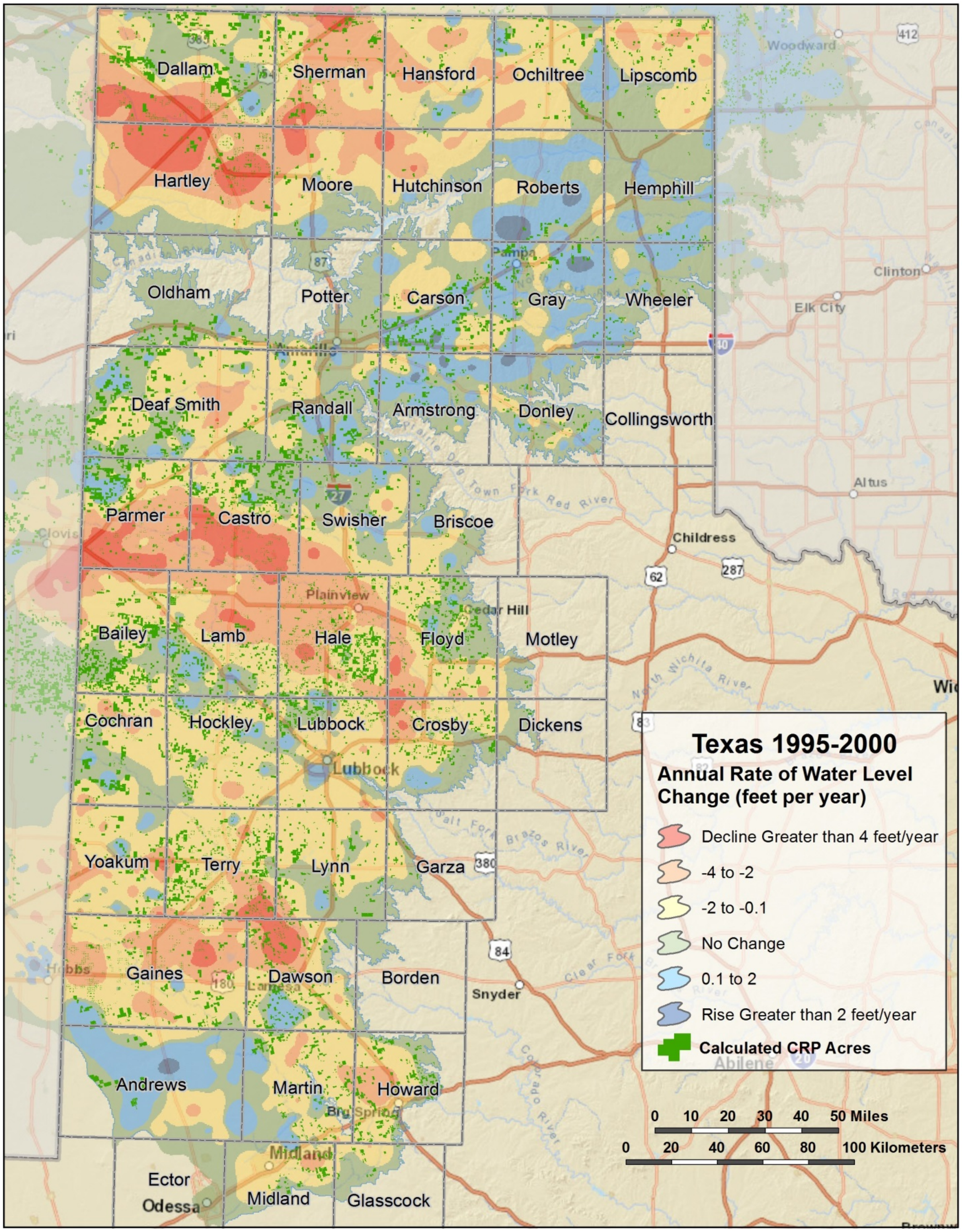

Figure 14. Texas CRP polygons for 2000 overlaid on water-level change, 1995-2000.

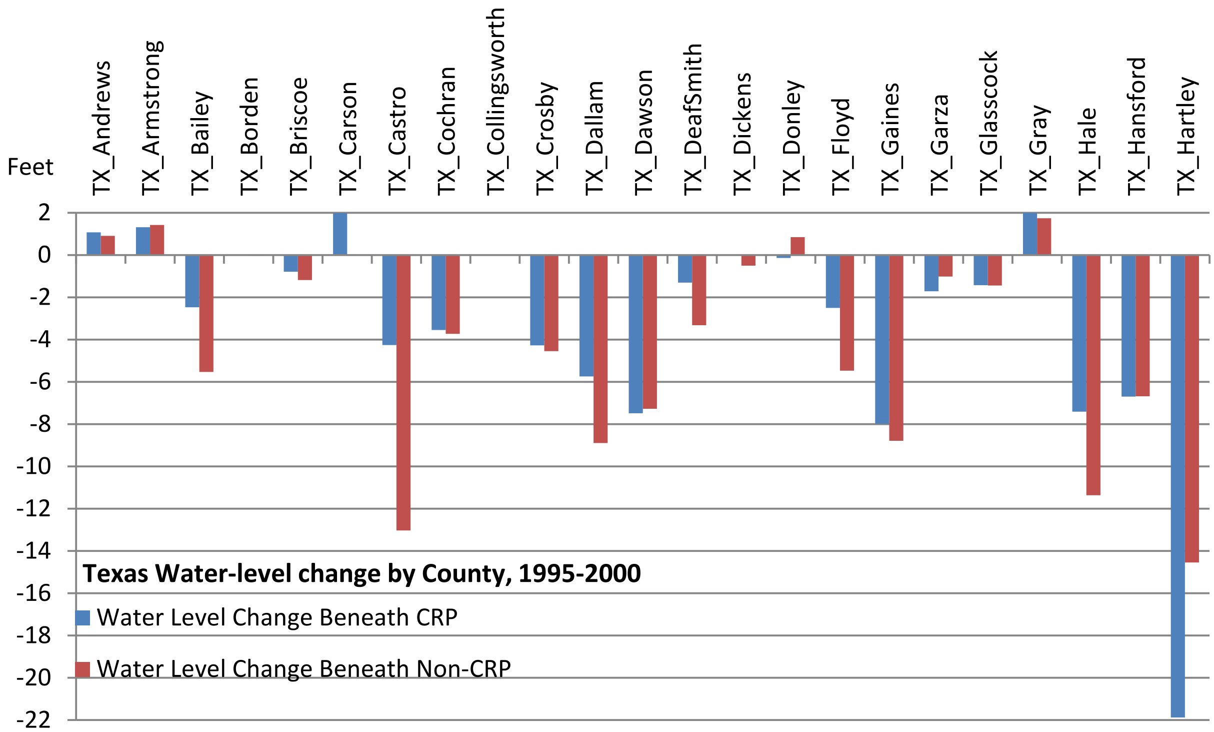

Figure 15. Comparison of water-level changes beneath CRP and non-CRP land, 1995-2000.

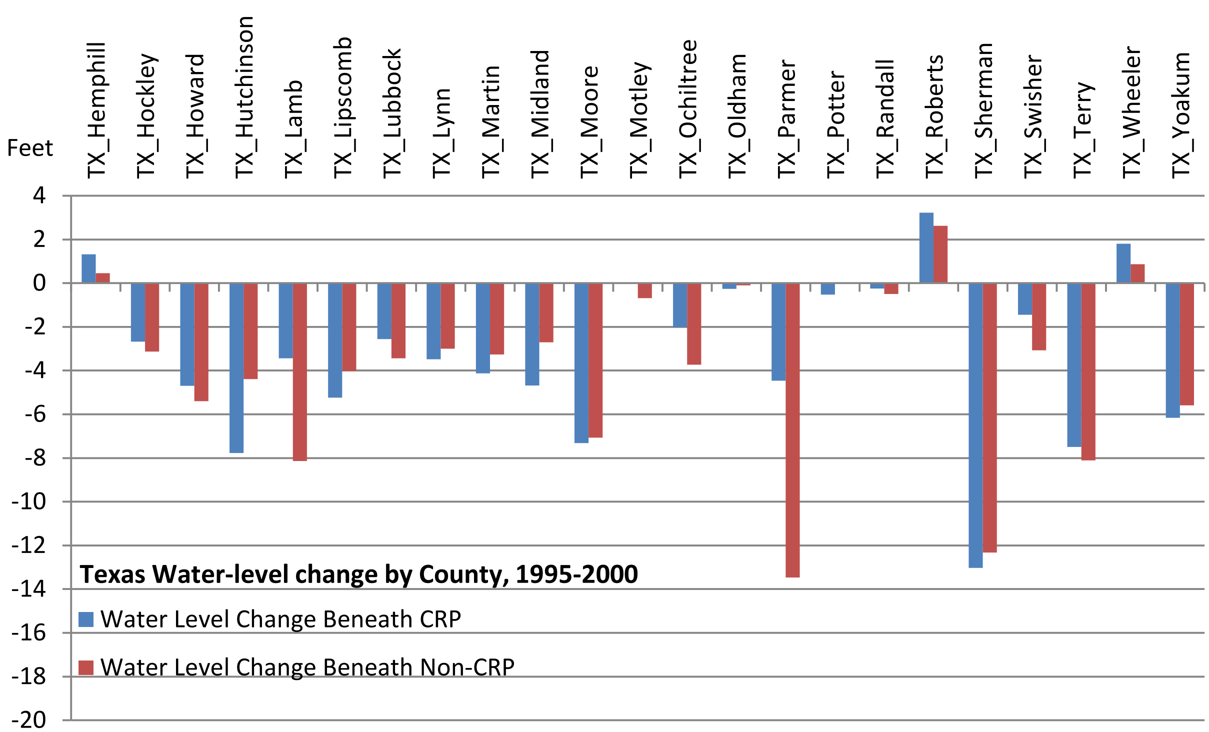

Figure 15 Continued. Comparison of water-level changes beneath CRP and non-CRP land, 1995-2000.

1995-2000 Mean Water-level Change						
State_County	**County water-level change (ft)**	**CRP water-level change (ft)**	**Non-CRP water-level change (ft)**	**Total County CRP Acres over the Aquifer**	**Total County Acres over the Aquifer**	**Percent of County over the Aquifer in CRP**
TX_Andrews	0.91	1.07	0.90	14,698	777,346	1.9
TX_Armstrong	1.41	1.32	1.42	16,939	397,000	4.3
TX_Bailey	-5.00	-2.46	-5.53	90,971	529,586	17.2
TX_Borden	-0.02	0.00	-0.02	154	66,996	0.2
TX_Briscoe	-1.16	-0.79	-1.17	7,281	258,532	2.8
TX_Carson	0.19	1.98	0.01	52,257	583,986	8.9
TX_Castro	-12.00	-4.25	-13.02	67,396	575,547	11.7
TX_Cochran	-3.70	-3.54	-3.72	50,334	496,150	10.1
TX_Collingsworth	0.00	0.00	0.00	11	10,400	0.1
TX_Crosby	-4.53	-4.28	-4.54	30,504	445,769	6.8
TX_Dallam	-8.57	-5.74	-8.89	98,581	963,362	10.2
TX_Dawson	-7.28	-7.48	-7.26	48,270	541,326	8.9
TX_DeafSmith	-3.07	-1.30	-3.31	110,643	921,697	12.0
TX_Dickens	-0.49	0.00	-0.50	782	78,012	1.0
TX_Donley	0.83	-0.13	0.86	10,532	396,832	2.7
TX_Floyd	-5.12	-2.49	-5.47	68,187	591,283	11.5
TX_Gaines	-8.73	-7.98	-8.78	59,094	961,829	6.1
TX_Garza	-1.04	-1.71	-1.01	4,193	100,930	4.2
TX_Glasscock	-1.44	-1.43	-1.44	3,764	126,564	3.0
TX_Gray	1.76	2.01	1.75	26,686	576,083	4.6
TX_Hale	-10.85	-7.41	-11.36	83,225	643,053	12.9
TX_Hansford	-6.68	-6.70	-6.68	9,779	588,151	1.7
TX_Hartley	-14.72	-21.87	-14.55	22,514	911,952	2.5

Table 9. Texas water-level change beneath CRP and non-CRP land by county, 1995-2000.

1995-2000 Mean Water-level Change						
State_County	County water-level change (ft)	CRP water-level change (ft)	Non-CRP water-level change (ft)	Total County CRP Acres over the Aquifer	Total County Acres over the Aquifer	Percent of County over the Aquifer in CRP
TX_Hemphill	0.47	1.33	0.45	7,353	576,369	1.3
TX_Hockley	-3.08	-2.68	-3.13	57,003	581,481	9.8
TX_Howard	-5.32	-4.69	-5.40	37,618	350,959	10.7
TX_Hutchinson	-4.40	-7.78	-4.39	1,651	458,467	0.4
TX_Lamb	-7.77	-3.44	-8.14	52,075	651,339	8.0
TX_Lipscomb	-4.05	-5.23	-4.02	18,296	596,668	3.1
TX_Lubbock	-3.38	-2.55	-3.44	35,894	571,132	6.3
TX_Lynn	-3.03	-3.48	-2.99	35,090	569,320	6.2
TX_Martin	-3.32	-4.13	-3.26	37,188	566,314	6.6
TX_Midland	-2.79	-4.68	-2.70	13,954	317,182	4.4
TX_Moore	-7.08	-7.31	-7.07	7,666	538,593	1.4
TX_Motley	-0.67	0.00	-0.68	625	64,659	1.0
TX_Ochiltree	-3.66	-2.02	-3.73	23,952	586,128	4.1
TX_Oldham	-0.11	-0.26	-0.11	24,433	460,563	5.3
TX_Parmer	-12.46	-4.46	-13.46	62,833	566,500	11.1
TX_Potter	-0.03	-0.52	-0.03	6,206	302,486	2.1
TX_Randall	-0.47	-0.24	-0.49	52,317	569,553	9.2
TX_Roberts	2.63	3.22	2.62	6,024	587,413	1.0
TX_Sherman	-12.38	-13.03	-12.32	44,534	590,848	7.5
TX_Swisher	-3.01	-1.44	-3.08	22,162	575,702	3.8
TX_Terry	-8.03	-7.49	-8.11	75,612	570,202	13.3
TX_Wheeler	0.89	1.80	0.87	9,752	372,472	2.6
TX_Yoakum	-5.62	-6.16	-5.59	27,362	511,831	5.3

Table 9 Continued. Texas water-level change beneath CRP and non-CRP land by county, 1995-2000.

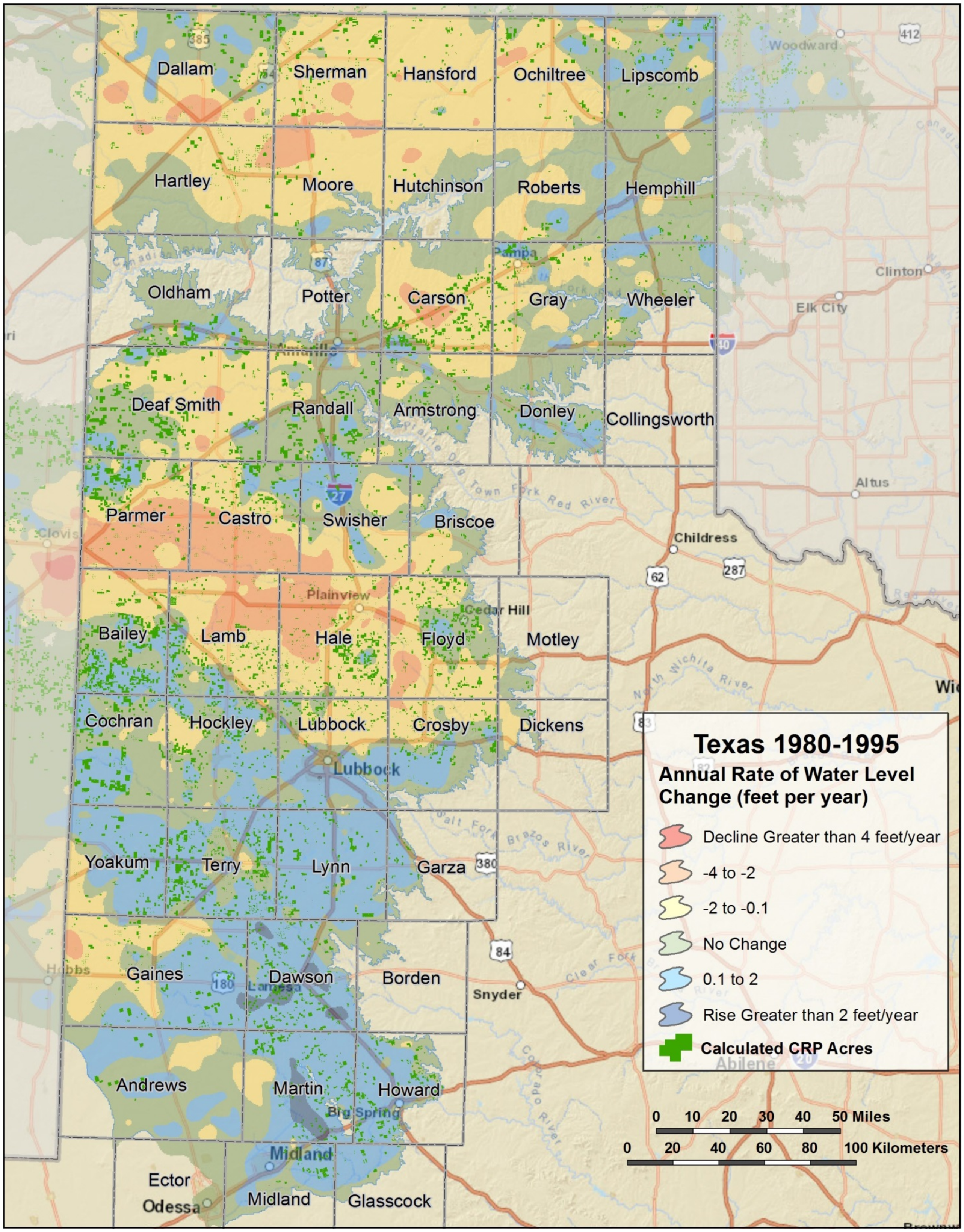

Figure 16. Texas CRP polygons for 1995 overlaid on water-level change, 1980-1995.

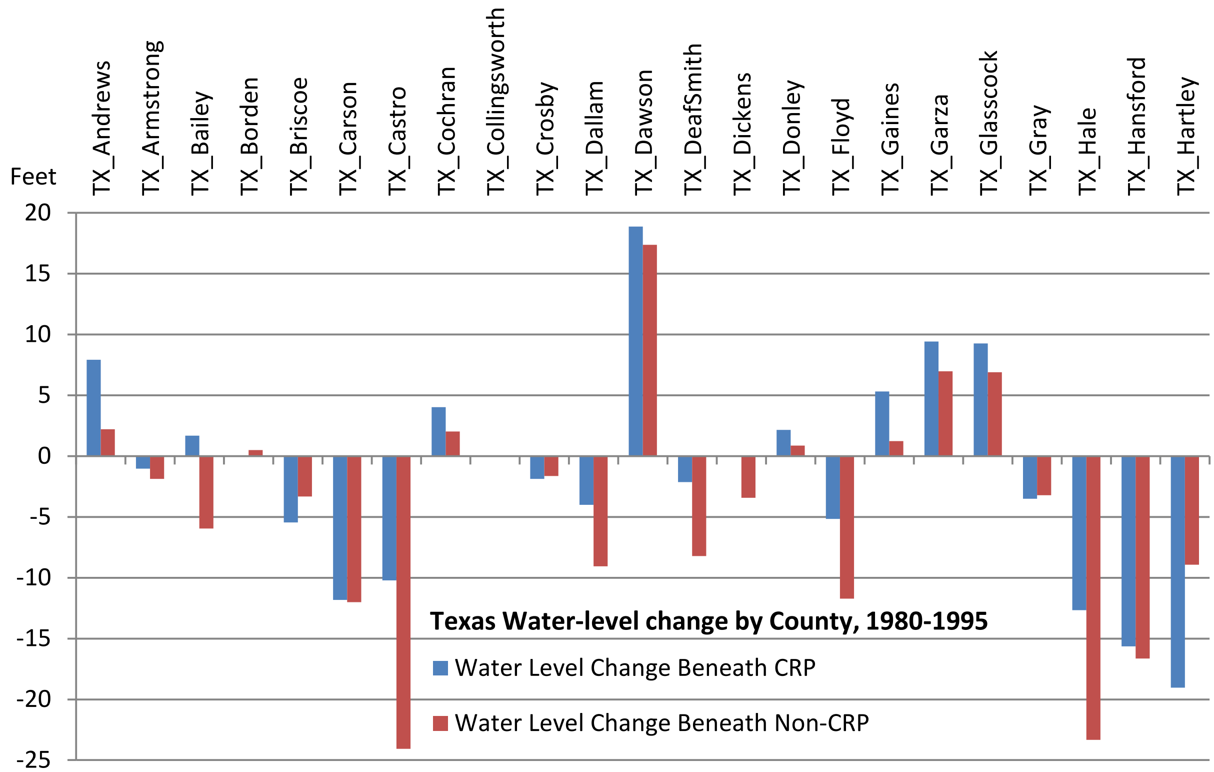

Figure 17. Comparison of water-level changes beneath CRP and non-CRP land, 1980-1995.

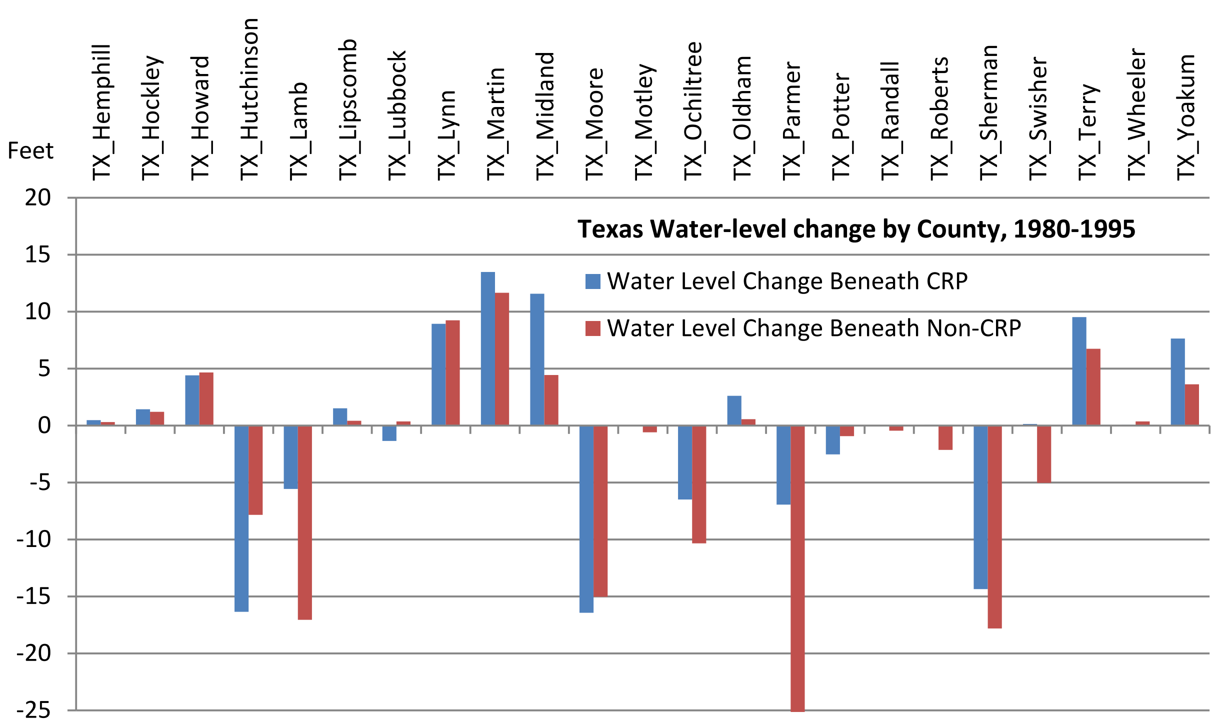

Figure 17 Continued. Comparison of water-level changes beneath CRP and non-CRP land, 1980-1995.

1980-1995 Mean Water-level Change						
State_County	**County water-level change (ft)**	**CRP water-level change (ft)**	**Non-CRP water-level change (ft)**	**Total County CRP Acres over the Aquifer**	**Total County Acres over the Aquifer**	**Percent of County over the Aquifer in CRP**
TX_Andrews	2.24	7.91	2.19	6,590	777,346	0.8
TX_Armstrong	-1.85	-1.02	-1.88	16,847	397,000	4.2
TX_Bailey	-4.79	1.68	-5.96	80,496	529,586	15.2
TX_Borden	0.48	0.00	0.48	154	66,996	0.2
TX_Briscoe	-3.39	-5.46	-3.33	6,246	258,532	2.4
TX_Carson	-12.00	-11.84	-12.02	49,642	583,986	8.5
TX_Castro	-23.21	-10.21	-24.07	35,609	575,547	6.2
TX_Cochran	2.21	4.04	2.01	49,919	496,150	10.1
TX_Collingsworth	0.00	0.00	0.00	12	10,400	0.1
TX_Crosby	-1.66	-1.87	-1.64	24,193	445,769	5.4
TX_Dallam	-8.89	-4.02	-9.06	30,115	963,362	3.1
TX_Dawson	17.48	18.87	17.37	39,877	541,326	7.4
TX_DeafSmith	-7.65	-2.13	-8.23	87,363	921,697	9.5
TX_Dickens	-3.40	0.00	-3.43	787	78,012	1.0
TX_Donley	0.89	2.14	0.86	9,699	396,832	2.4
TX_Floyd	-11.05	-5.16	-11.72	60,599	591,283	10.2
TX_Gaines	1.37	5.32	1.24	30,968	961,829	3.2
TX_Garza	7.04	9.43	6.96	3,520	100,930	3.5
TX_Glasscock	6.93	9.26	6.88	2,499	126,564	2.0
TX_Gray	-3.24	-3.51	-3.22	21,249	576,083	3.7
TX_Hale	-22.46	-12.68	-23.33	52,872	643,053	8.2
TX_Hansford	-16.63	-15.63	-16.63	7,333	588,151	1.2
TX_Hartley	-9.08	-19.03	-8.92	14,828	911,952	1.6

Table 10. Texas water-level change beneath CRP and non-CRP land by county, 1980-1995.

1980-1995 Mean Water-level Change						
State_County	County water-level change (ft)	CRP water-level change (ft)	Non-CRP water-level change (ft)	Total County CRP Acres over the Aquifer	Total County Acres over the Aquifer	Percent of County over the Aquifer in CRP
TX_Hemphill	0.31	0.47	0.30	6,750	576,369	1.2
TX_Hockley	1.24	1.43	1.22	44,397	581,481	7.6
TX_Howard	4.65	4.42	4.67	28,031	350,959	8.0
TX_Hutchinson	-7.85	-16.35	-7.83	1,085	458,467	0.2
TX_Lamb	-16.25	-5.57	-17.05	46,038	651,339	7.1
TX_Lipscomb	0.44	1.52	0.41	16,062	596,668	2.7
TX_Lubbock	0.29	-1.36	0.37	23,994	571,132	4.2
TX_Lynn	9.23	8.93	9.25	27,037	569,320	4.7
TX_Martin	11.76	13.49	11.65	31,956	566,314	5.6
TX_Midland	4.63	11.57	4.44	8,475	317,182	2.7
TX_Moore	-15.04	-16.44	-15.02	7,041	538,593	1.3
TX_Motley	-0.59	0.00	-0.59	552	64,659	0.9
TX_Ochiltree	-10.22	-6.50	-10.34	18,439	586,128	3.1
TX_Oldham	0.67	2.62	0.56	23,820	460,563	5.2
TX_Parmer	-23.70	-6.94	-25.28	48,920	566,500	8.6
TX_Potter	-0.96	-2.52	-0.93	5,932	302,486	2.0
TX_Randall	-0.42	0.01	-0.46	46,092	569,553	8.1
TX_Roberts	-2.11	0.06	-2.13	4,328	587,413	0.7
TX_Sherman	-17.64	-14.37	-17.82	35,846	590,848	6.1
TX_Swisher	-4.90	0.13	-5.03	14,820	575,702	2.6
TX_Terry	7.07	9.53	6.73	69,126	570,202	12.1
TX_Wheeler	0.35	0.04	0.36	9,264	372,472	2.5
TX_Yoakum	3.84	7.64	3.63	25,921	511,831	5.1

Table 10 Continued. Texas water-level change beneath CRP and non-CRP land by county, 1980-1995.

New Mexico

CRP Effects on Water-level Change by County

Summary Results: New Mexico

Eastern New Mexico has eight counties over the aquifer covering a little over 5.7 million acres (9,000 square miles). These counties are located along the eastern border with Texas. The largest part of the aquifer extended into Curry, Quay, Roosevelt and Lea counties, and small parts of De Baca and Guadalupe counties. The northern section of the aquifer extended into Union, Harding and the northernmost part of Quay County.

Curry County had the most land in CRP at about 148,500 acres (232 square miles) for the two most recent time intervals. In the 2005-2009 interval, Curry County experienced low decline of less than 0.1 foot per year with 0.35 foot greater decline beneath non-CRP. For the 2000-2005 and 1995-2000 intervals, Curry County experienced moderate declines of about 0.4 foot per year with greater declines beneath non-CRP. Curry County exhibited decline of about 0.4 foot per year in the 1980-1995 interval with almost all of the decline beneath non-CRP lands.

Roosevelt County had about 138,000 acres (216 square miles) in CRP and experienced low average declines of 0.0 to 0.3 foot per year for the 2005-2009 and 2000-2005 intervals, with greater declines beneath non-CRP. There were moderate declines of 0.4 foot per year in 1995-2000, with 1.6 foot greater decline beneath non-CRP. In the 1980-1995 interval there was also an average decline of 0.2 foot per year, with 3.2 feet greater decline beneath non-CRP.

Quay County had about 54,400 acres (85 square miles) in CRP and experienced low mean change of 0.0 to -0.1 feet per year decline in aquifer levels for all intervals. There was a slightly greater rise over CRP for the 2005-2009 interval and slightly greater decline beneath non-CRP for the 2000-2005 interval, with no change in aquifer levels in the earlier time intervals.

Lea County had about 26,880 acres (42 square miles) in CRP and experienced moderate decline in the 2005-2009 interval, with greater decline of 1.2 feet beneath CRP. For the remaining three periods,Lea County experienced low mean change in aquifer levels of 0.2 to 0.3 feet, with greater declines beneath CRP lands.

For all other counties, the percent CRP area over the aquifer was small, from about 320 to 830 acres (0.5 to 1.3 square miles), and the change in aquifer levels was low or less than 0.3 feet per year. For Union County, the 2005-2009 interval showed a slightly greater decline beneath non-CRP of 0.2 feet. The 2000-2005 interval, however, showed a much greater drawdown of 2.9 feet beneath CRP. For the remaining intervals Union County exhibited no change in aquifer level, as did DeBaca, Guadalupe and Harding Counties for all four periods.

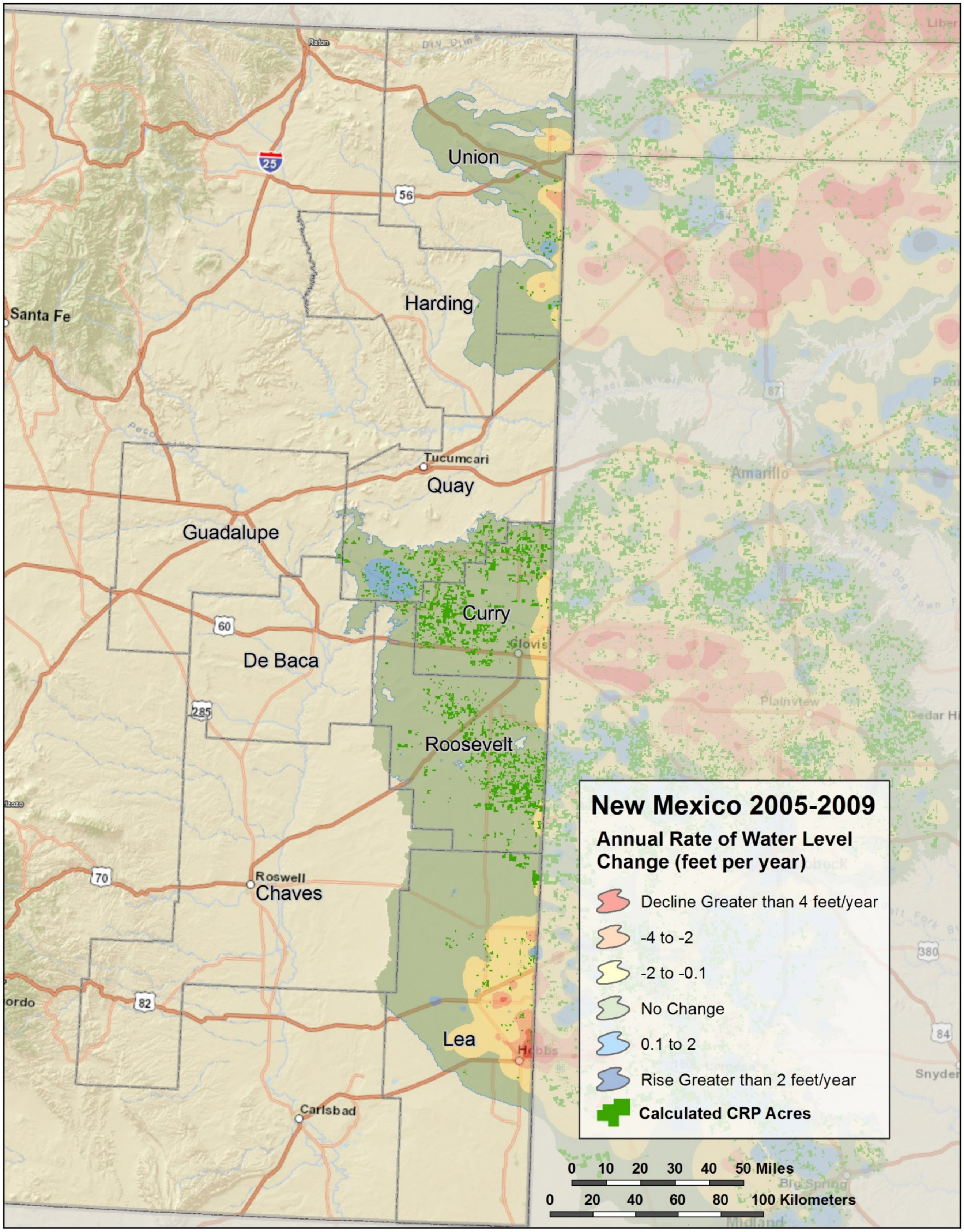

Figure 18. New Mexico CRP polygons for 2009 overlaid on water-level change, 2005-2009.

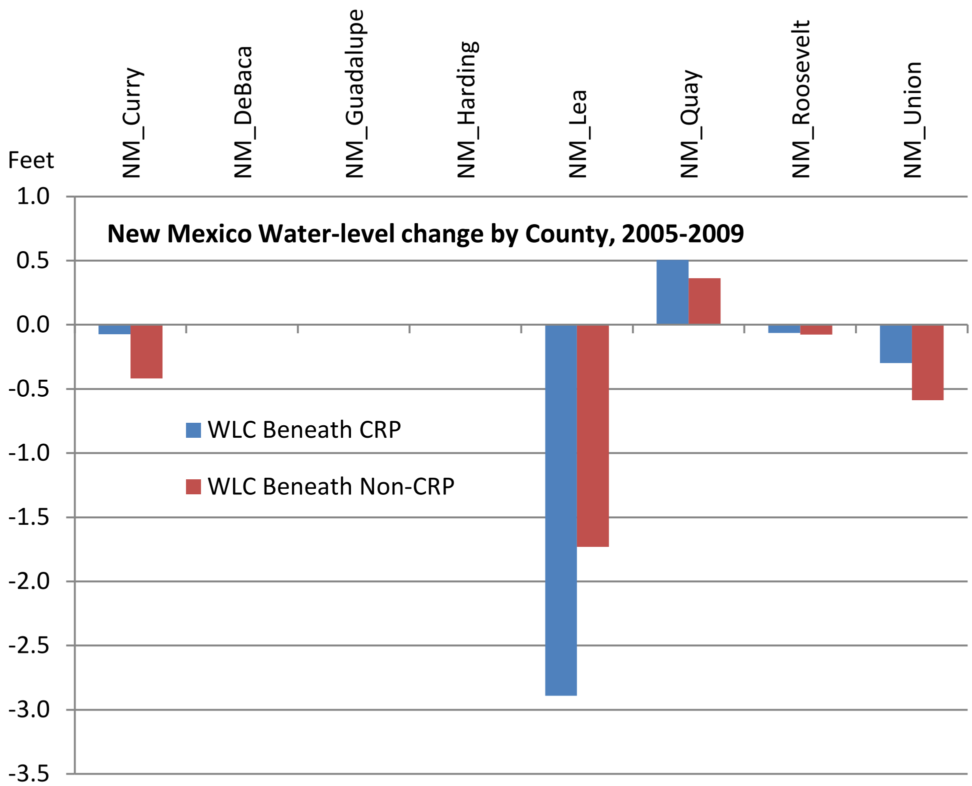

Figure 19. Comparison of water-level changes beneath CRP and non-CRP land, 2005-2009.

2005-2009 Mean Water-level Change						
State_County	**County water-level change (ft)**	**CRP water-level change (ft)**	**Non-CRP water-level change (ft)**	**Total County CRP Acres over the Aquifer**	**Total County Acres over the Aquifer**	**Percent of County over the Aquifer in CRP**
NM_Curry	-0.36	-0.07	-0.42	148,453.11	898,180.32	16.5
NM_DeBaca	0.00	0.00	0.00	844.94	34,129.99	2.5
NM_Guadalupe	0.00	0.00	0.00	834.29	7,002.34	11.9
NM_Harding	0.00	0.00	0.00	316.45	128,703.25	0.2
NM_Lea	-1.75	-2.89	-1.73	27,016.76	1,680,152.18	1.6
NM_Quay	0.38	0.50	0.36	54,948.12	542,917.95	10.1
NM_Roosevelt	-0.07	-0.06	-0.08	138,622.05	1,493,026.47	9.3
NM_Union	-0.58	-0.30	-0.59	14,431.55	994,782.33	1.5

Table 11. New Mexico water-level change beneath CRP and non-CRP land by county, 2005-2009.

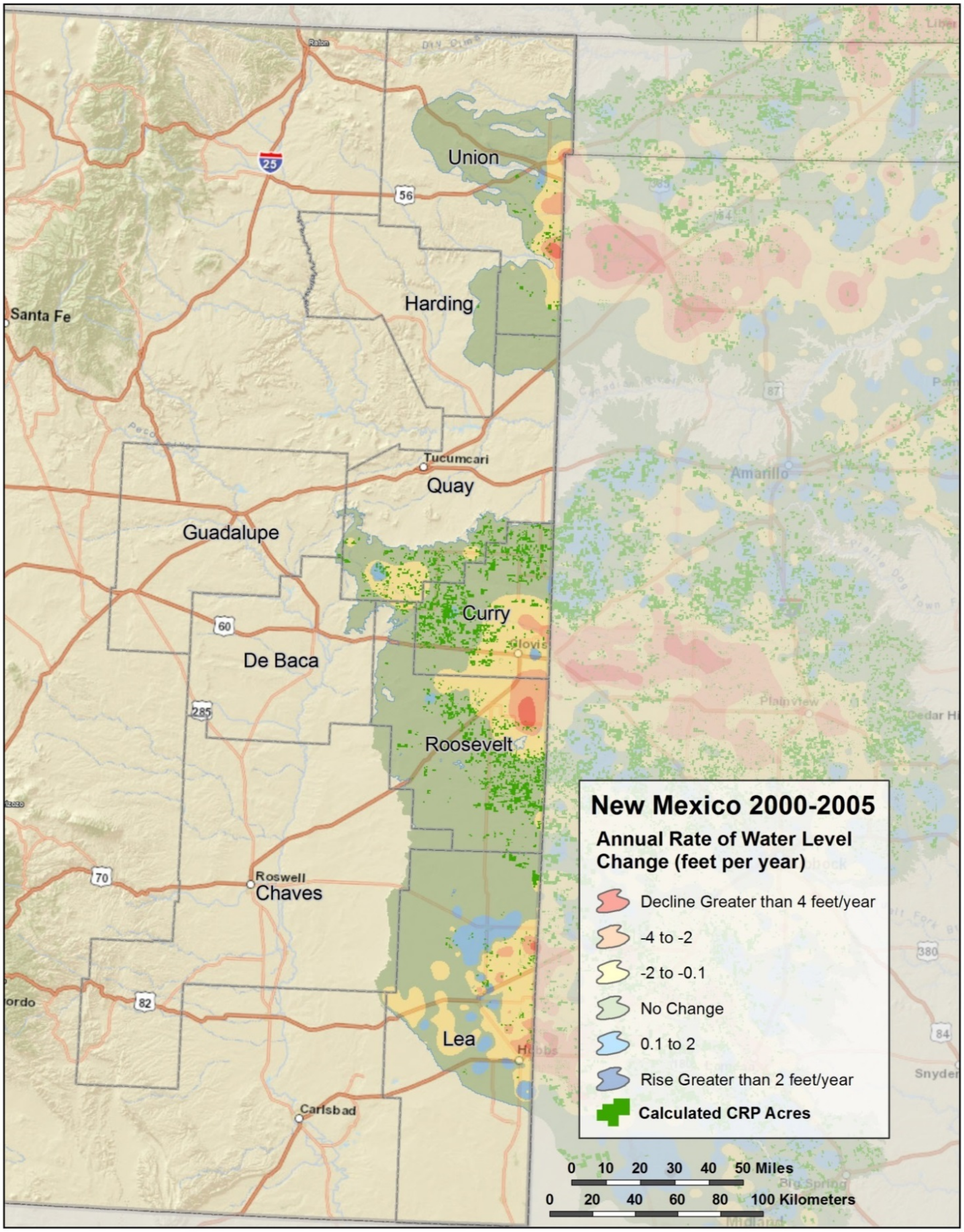

Figure 20. New Mexico CRP polygons for 2005 overlaid on water-level change, 2000-2005.

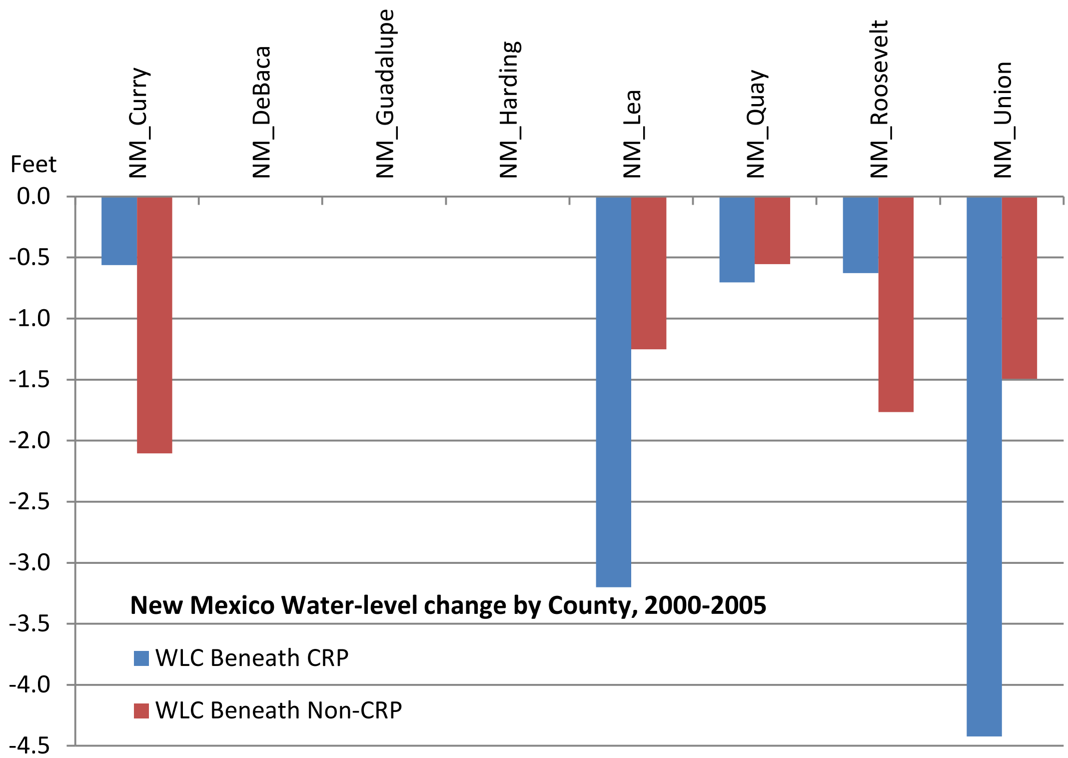

Figure 21. Comparison of water-level changes beneath CRP and non-CRP land, 2000-2005.

2000-2005 Mean Water-level Change						
State_County	County water-level change (ft)	CRP water-level change (ft)	Non-CRP water-level change (ft)	Total County CRP Acres over the Aquifer	Total County Acres over the Aquifer	Percent of County over the Aquifer in CRP
NM_Curry	-1.85	-0.56	-2.10	148,453.11	898,180.32	16.5
NM_DeBaca	0.00	0.00	0.00	844.94	34,129.99	2.5
NM_Guadalupe	0.00	0.00	0.00	834.29	7,002.34	11.9
NM_Harding	0.00	0.00	0.00	316.45	128,703.25	0.2
NM_Lea	-1.28	-3.20	-1.25	26,193.13	1,680,152.18	1.6
NM_Quay	-0.57	-0.70	-0.56	54,948.12	542,917.95	10.1
NM_Roosevelt	-1.66	-0.63	-1.77	138,686.44	1,493,026.47	9.3
NM_Union	-1.54	-4.42	-1.49	14,431.55	994,782.33	1.5

Table 12. New Mexico water-level change beneath CRP and non-CRP land by county, 2000-2005.

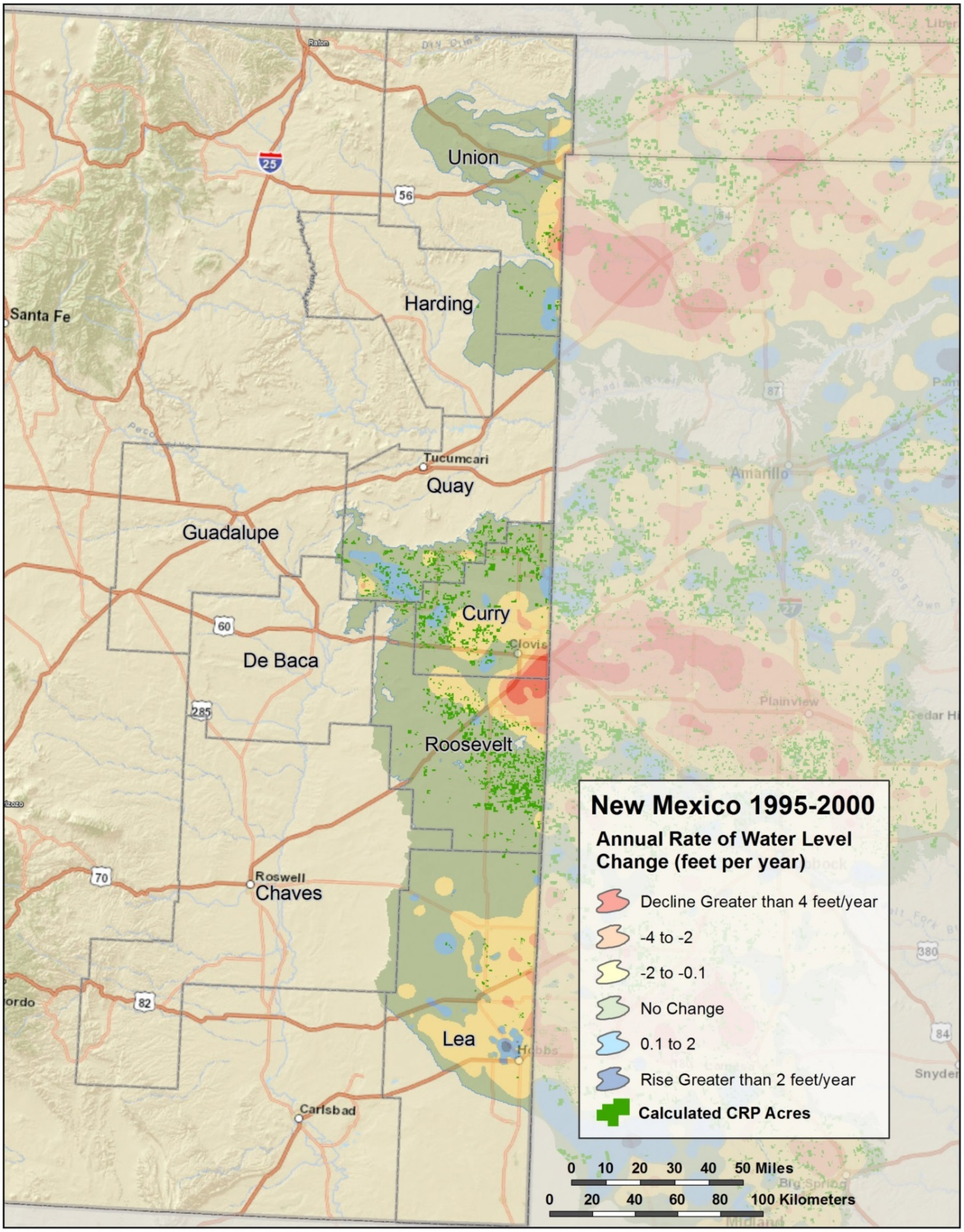

Figure 22. New Mexico CRP polygons for 2000 overlaid on water-level change, 1995-2000.

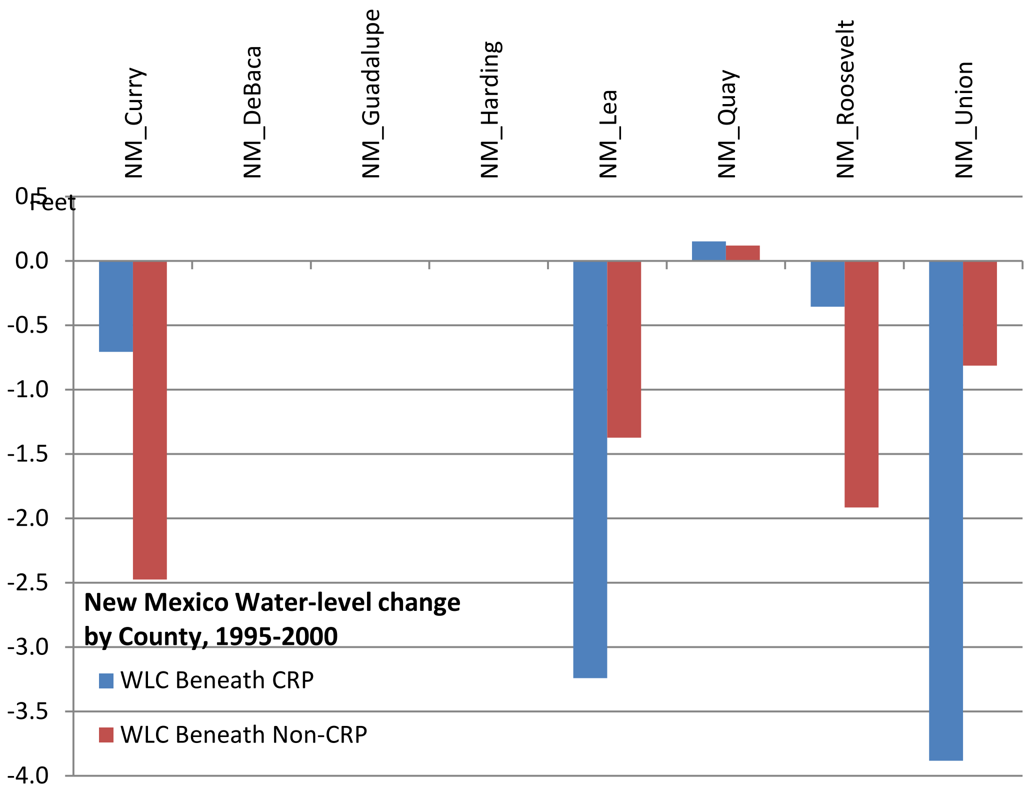

Figure 23. Comparison of water-level changes beneath CRP and non-CRP land, 1995-2000.

1995-2000 Mean Water-level Change						
State_County	**County water-level change (ft)**	**CRP water-level change (ft)**	**Non-CRP water-level change (ft)**	**Total County CRP Acres over the Aquifer**	**Total County Acres over the Aquifer**	**Percent of County over the Aquifer in CRP**
NM_Curry	-2.30	-0.71	-2.47	88,840.58	898,180.32	9.9
NM_DeBaca	0.00	0.00	0.00	844.02	34,129.99	2.5
NM_Guadalupe	0.00	0.00	0.00	832.13	7,002.34	11.9
NM_Harding	0.00	0.00	0.00	316.29	128,703.25	0.2
NM_Lea	-1.38	-3.24	-1.37	8,208.06	1,680,152.18	0.5
NM_Quay	0.12	0.15	0.12	54,925.73	542,917.95	10.1
NM_Roosevelt	-1.77	-0.36	-1.91	135,251.99	1,493,026.47	9.1
NM_Union	-0.86	-3.88	-0.81	13,334.87	994,782.33	1.3

Table 13. New Mexico water-level change beneath CRP and non-CRP land by county, 1995-2000.

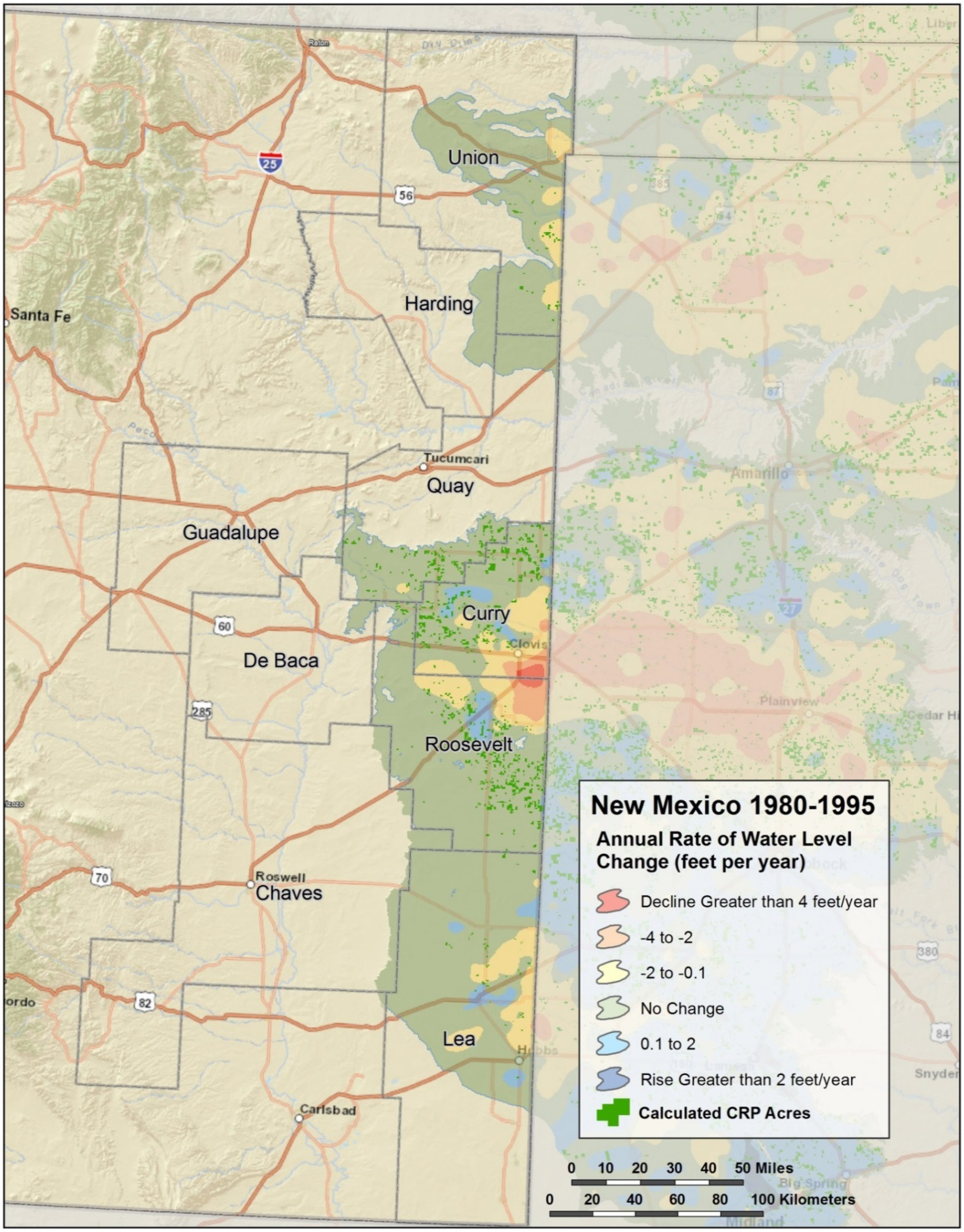

Figure 24. New Mexico CRP polygons for 1995 overlaid on water-level change, 1980-1995.

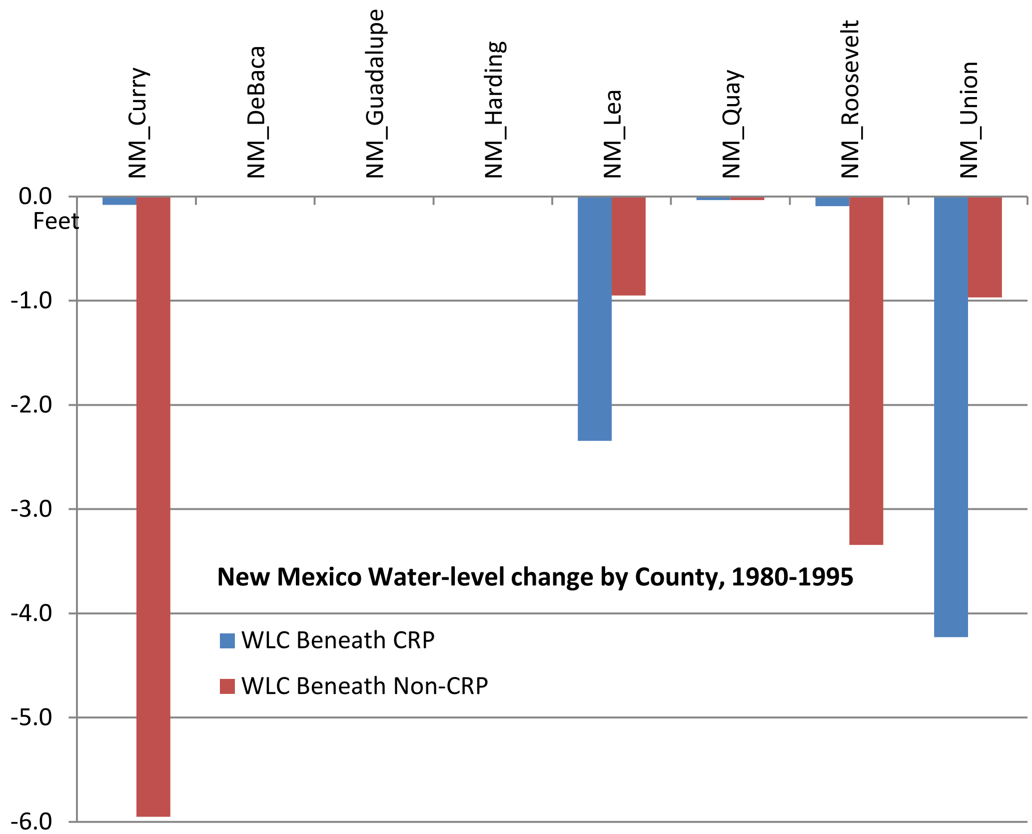

Figure 25. Comparison of water-level changes beneath CRP and non-CRP land, 1980-1995.

1980-1995 Mean Water-level Change						
State_County	**County water-level change (ft)**	**CRP water-level change (ft)**	**Non-CRP water-level change (ft)**	**Total County CRP Acres over the Aquifer**	**Total County Acres over the Aquifer**	**Percent of County over the Aquifer in CRP**
NM_Curry	-5.54	-0.08	-5.95	62,645.44	898,180.32	7.0
NM_DeBaca	0.00	0.00	0.00	317.53	34,129.99	0.9
NM_Guadalupe	0.00	Null	0.00	Null	7,002.34	
NM_Harding	0.00	Null	0.00	Null	128,703.25	
NM_Lea	-0.96	-2.35	-0.95	7,355.08	1,680,152.18	0.4
NM_Quay	-0.03	-0.03	-0.03	28,170.59	542,917.95	5.2
NM_Roosevelt	-3.18	-0.09	-3.34	74,785.87	1,493,026.47	5.0
NM_Union	-1.00	-4.23	-0.97	8,725.43	994,782.33	0.9

Table 14. New Mexico water-level change beneath CRP and non-CRP land by county, 1980-1995.

Nebraska

CRP Effects on Water-level Change by County

Summary Results: Nebraska

In Nebraska, the High Plains Aquifer underlies all of part of 82 counties covering approximately 40.8 million acres (63,800 square miles) throughout most of the state. In general the CRP land distribution appeared to form an oval around the Nebraska Sandhills region, with contracts more prevalent along the outer edge of the Sandhills and largely absent in the center. Since the Sandhills region is dominated by sand dunes, the interior region was not cultivated. This pattern also coincided with the thicker aquifer saturated thickness (Figure 7) in the center portion of the Sandhills where thickness values ranged up to 1,150 feet. At the outer edge of the Sandhills, the thickness of the aquifer was about 100 feet or less.

Given the large number of counties in Nebraska, for this discussion the state was divided into four analysis regions: northeast, north central, northwest and south (Figure 26). The line separating the northeast and north central regions was the boundary between Keya Paha and Boyd Counties and continuing down to Dawson and Buffalo Counties. The line separating the northwest region from the north central and south regions was the boundary between Sheridan and Cherry Counties continuing down to Deuel and Keith Counties. In general, the Platte River was the dividing line to describe changes in water level for counties in the south region.

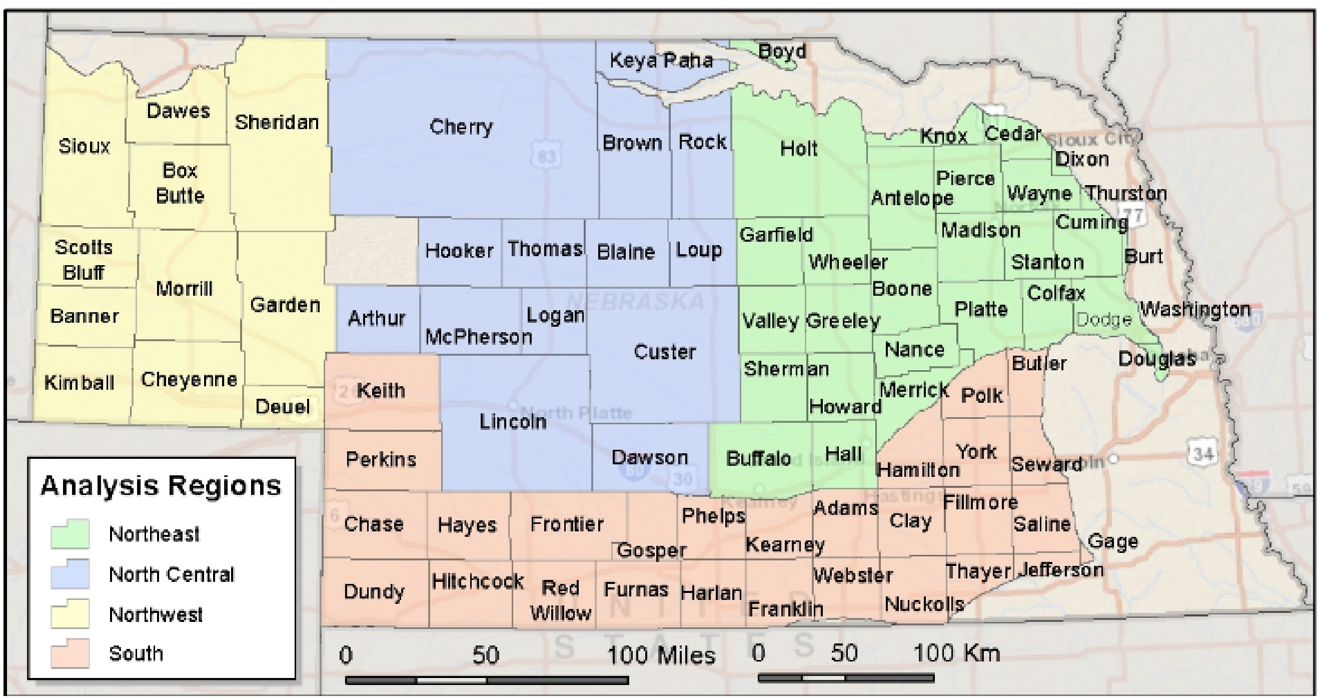

Figure 26. Nebraska analysis regions. Grant County is omitted from the analysis in the north central region because no CRP contracts are present.

Comparing the Nebraska maps of water-level change for each of the four time intervals, the most consistent and significant declines occurred during the 2000-2005 time interval with little change or rises in groundwater occurring during the other three intervals for many counties. The most consistent declines for all time intervals occurred in Perkins, Chase and Dundy counties in the south region. These declines might be due to recent widespread irrigation in this region. In general, water-level decline was also relatively significant in the region south of the Platte River.

The north central analysis region was in the central Sandhills where agricultural land use was limited and there were few or no CRP contracts. In this region there were generally more moderate to small changes in groundwater levels. In contrast, counties in the northeastern region tended to show far less decline and, in many cases, a small to moderate rise. Changes in the northwestern region were relatively modest compared to changes in other parts of the state. The westernmost part of region (such as Banner, Kimball, and Cheyenne) had significant acreage in CRP and showed greater changes in groundwater levels than those in the northwest corner.

Many counties showed either a small overall decline or a small overall rise. With these small changes in water level, it was difficult to assess the effects of the CRP land, and the results are mixed depending on time interval. In some cases the water-level decline beneath CRP was less than non-CRP land, in other cases it was more. This finding might be due to the more isolated nature of CRP contracts in Nebraska compared to the denser arrangement of contracts in Texas and New Mexico. As before, the maps of water-level change were expressed as the average rate over each time interval.

As previously stated, it is important to recognize that these data represented county-wide averages, and there can be considerable difference in the water-level changes that can be masked in the county-wide average. For example, in Keith County the rate of water-level decline in the southern part of the county south of the Platte River far exceeded the rate of water-level decline in the northern part of the county. In fact, in the two most recent time intervals, 2000-2005 and 2005-2009, there was a significant decline in the water level in the southern part of the county, but much less or no decline to the north. 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 or no change in the water level in the north part of the county. Despite these marked differences in water-level change, Keith County had slightly less water-level decline beneath CRP than non-CRP for the 2005-2009 interval, slightly more decline beneath CRP for the 2000-2005 interval, and about the same amount or rise or decline for the remaining intervals.

In the following section, counties that had significant (1 foot per year or greater) or moderate change (between 0.5 and 1 foot per year) in groundwater levels are described. All other counties in each analysis region had less than 0.5 foot per year change in groundwater level.

Northwest Region

Counties with Significant Change (greater than 1 foot change per year)

During the 2000-2005 time interval, only Box Butte County in the northwest region experienced significant change of 1 foot or more per year at about -1.1 foot per year, and showed roughly the same amount of decline beneath CRP as non-CRP.

Counties with Moderate Change (between 0.5 and 1 foot change per year)

Box Butte County experienced moderate decline of about 0.5 foot per year for the 2005-2009 time interval with about the same amount of decline of -2 feet beneath CRP and non-CRP. Banner, Cheyenne and Scotts Bluff counties also had moderate declines of about 0.5 to 0.6 foot per year for the 2000-2005 interval.

North Central Region

Counties with Significant Change (greater than 1 foot change per year)

During the 2000-2005 time interval, only Dawson County in the north central analysis region experienced significant change of 1 foot per year, with about 1.5 more feet of decline beneath non-CRP.

Counties with Moderate Change (between 0.5 and 1 foot change per year)

Custer County experienced moderate decline of about 0.7 foot per year for the 2005-2009 time interval, with about the same amount of decline of -3.5 feet beneath CRP as non-CRP. During the 2000-2005 interval, Lincoln and Rock counties had about 0.6 foot per year decline for the same period with greater declines beneath CRP.

Northeast Region

Counties with Significant Change (greater than 1 foot change per year)

During the 2005-2009 time interval Antelope, Boone, Madison and Wheeler counties experienced significant changes of 1 foot per year, with about 1.0 to 1.2 foot per year of groundwater rise and roughly the same amount of rise beneath CRP as non-CRP.

In the 2000-2005 interval, Buffalo and Hall counties had about 1.6 foot per year declines, with nearly 8 feet of overall decline during the period. Merrick and Platte counties each had about 1 foot per year decline, with about 5 feet of overall decline during the interval.

Counties with Moderate Change (between 0.5 and 1 foot change per year)

Custer County experienced moderate decline of about 0.7 foot per year for the 2005-2009 time interval, with about the same amount of decline of -3.5 feet beneath CRP as non-CRP. During the 2000-2005 interval Lincoln and Rock counties had about 0.6 foot per year decline for the same period, with greater declines beneath CRP.

South Region

Counties with Significant Change (greater than 1 foot change per year)

During the 2000-2005 and 2005-2009 time interval, Perkins County experienced significant changes of about 1.2 and about 1.6 feet of decline per year, respectively, with about 0.5 less feet of decline beneath CRP.

In the 2000-2005 interval Adams, Butler, Chase, Clay, Dundy, Fillmore, Hamilton, Kearney, Perkins, Phelps, Polk, Saline, Seward and York Counties all experienced significant declines from about 1.0 to 2.1 foot per year. Hamilton and York Counties had the greatest declines of about 10.6 feet for the period. In these counties the dominant crop was corn that requires large amounts of irrigation water.

In the 1995-2000 interval both Clay and Hamilton Counties had groundwater rises of about 1.0 foot per year, with slightly less rise under CRP.

Counties with Moderate Change (between 0.5 and 1 foot change per year)

York County experienced moderate change of about 0.5 foot rise or greater per year for the three time intervals 1980-1995, 1995-2000 and 2005-2009, with slightly greater rise beneath non-CRP.

Butler, Chase, Dundy, Frontier, Hamilton and York counties experienced moderate changes during the 2005-2009 interval. It is interesting to note that Butler, Frontier, Hamilton and York Counties experienced moderate rises in groundwater while, Chase and Dundy counties experienced moderate declines.

During the 2000-2005 interval, Frontier, Gage, Gosper, Harlan, Jefferson, Red Willow and Webster counties had moderate declines of about 0.5 foot per year. Hayes and Thayer counties experienced slightly greater declines of 0.8 to 0.7 foot per year, respectively.

In the 1995-2005 interval, Dundy County showed an average decline of 0.5 foot per year and about 0.4 foot greater decline beneath CRP. In contrast, Fillmore, Gosper, Phelps and York counties showed rises in groundwater from about 0.5 to 0.9 foot per year, with slightly greater rises occurring under non-CRP.

Finally during the 1980-1995 interval, Gosper, Hamilton, Phelps and York counties showed moderate rises in groundwater from 0.5 to about 0.8 foot per year, with mixed results of greater rise over CRP or non-CRP.

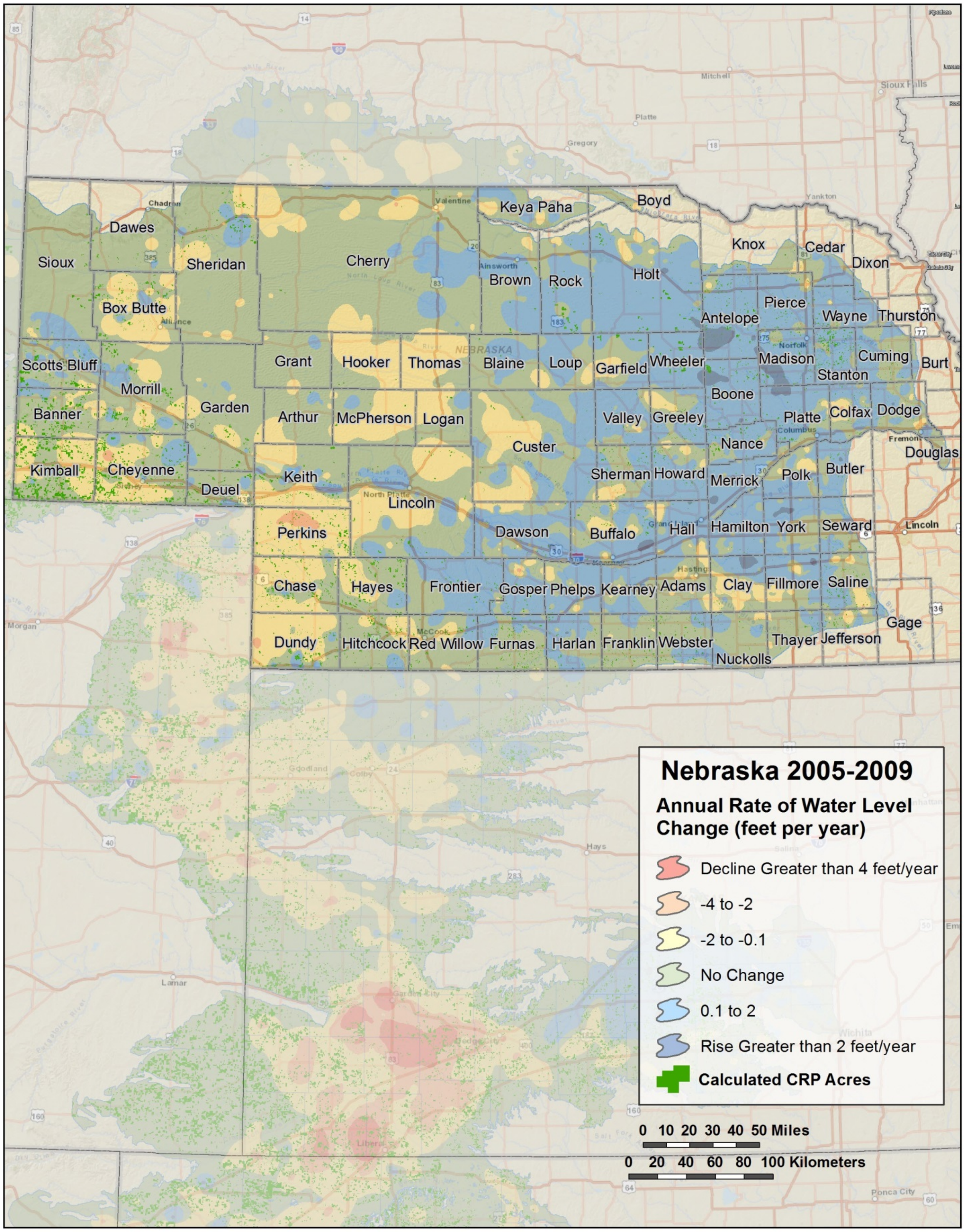

Figure 27. Nebraska CRP polygons for 2009 overlaid on water-level change, 2005-2009.

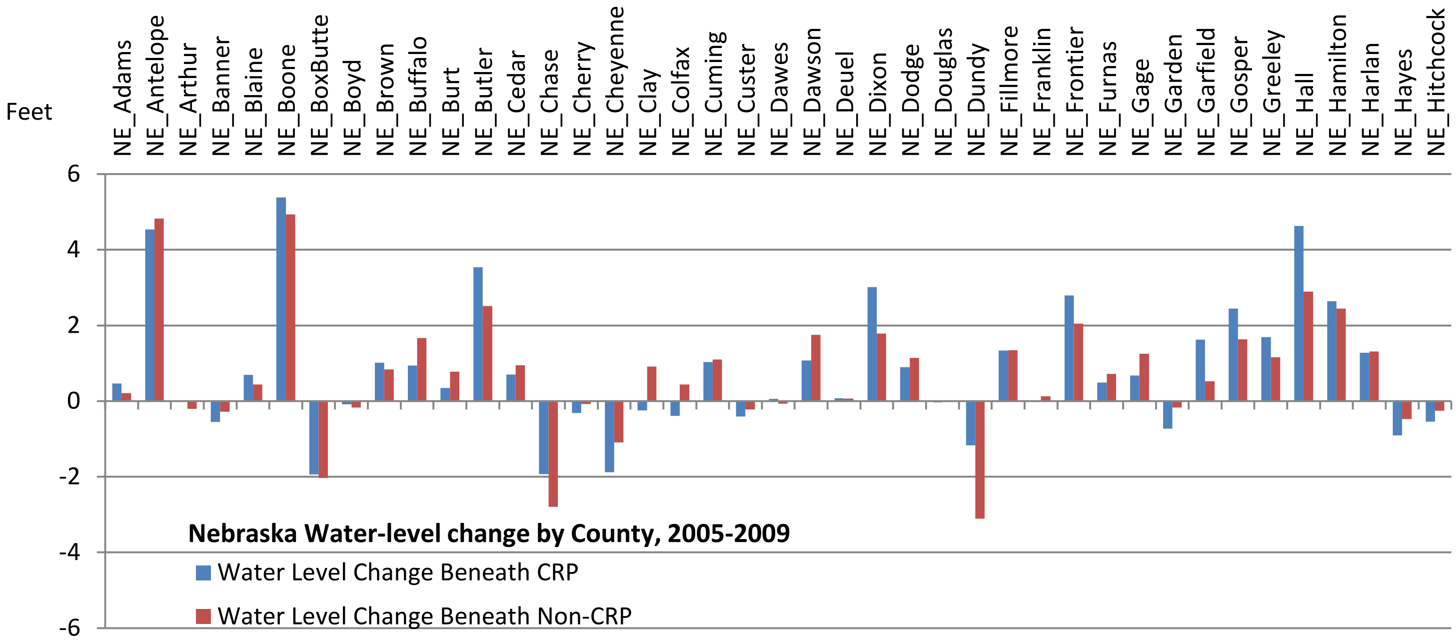

Figure 28. Comparison of water-level changes beneath CRP and non-CRP land, 2005-2009.

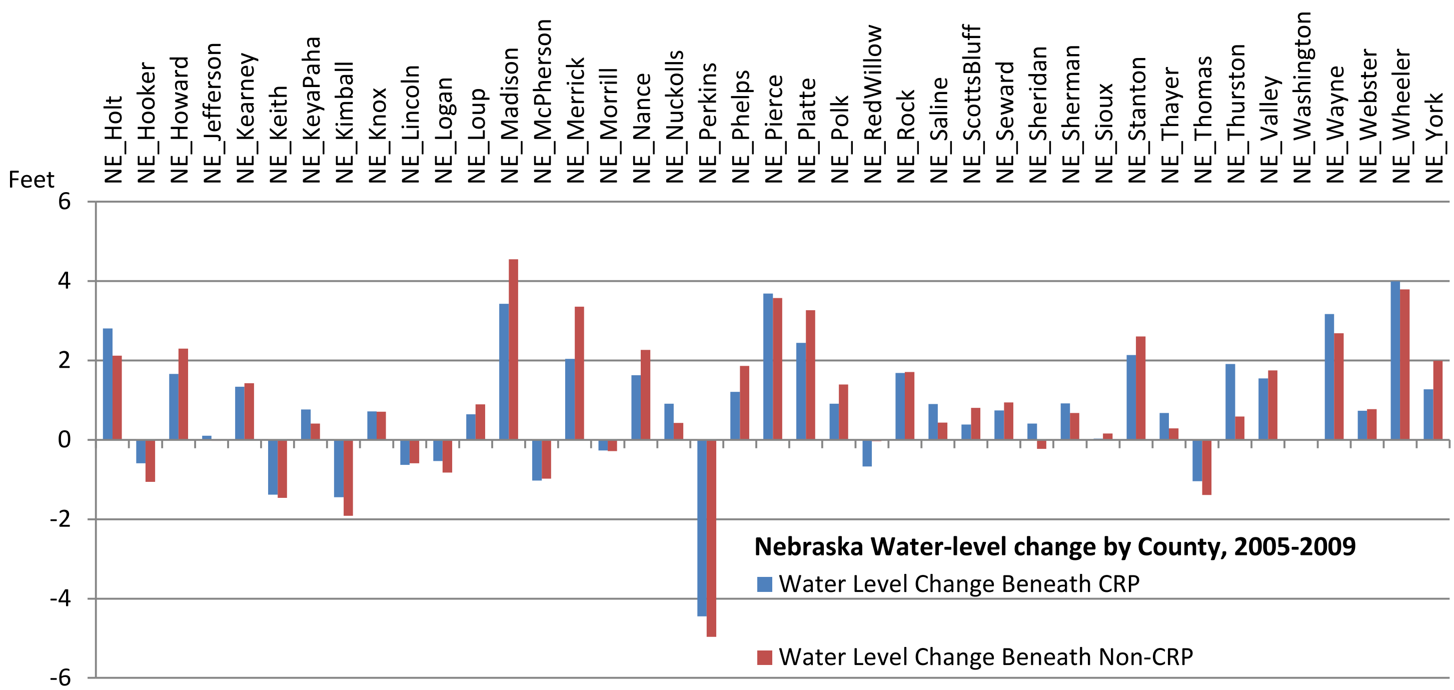

Figure 28 Continued. Comparison of water-level changes beneath CRP and non-CRP land, 2005-2009.

2005-2009 Mean Water-level Change						
State_County	County water-level change (ft)	CRP water-level change (ft)	Non-CRP water-level change (ft)	Total County CRP Acres over the Aquifer	Total County Acres over the Aquifer	Percent of County over the Aquifer in CRP
NE_Adams	0.21	0.47	0.21	1,478	361,110	0.4
NE_Antelope	4.82	4.54	4.83	13,949	549,504	2.5
NE_Arthur	-0.20	0.00	-0.20	191	459,714	0.0
NE_Banner	-0.31	-0.55	-0.28	41,811	477,671	8.8
NE_Blaine	0.44	0.70	0.44	755	457,188	0.2
NE_Boone	4.95	5.39	4.94	9,659	439,831	2.2
NE_BoxButte	-2.03	-1.93	-2.03	21,981	689,812	3.2
NE_Boyd	-0.17	-0.08	-0.17	355	65,803	0.5
NE_Brown	0.83	1.01	0.83	2,150	755,101	0.3
NE_Buffalo	1.66	0.94	1.67	5,792	624,252	0.9
NE_Burt	0.77	0.35	0.78	200	27,261	0.7
NE_Butler	2.53	3.54	2.51	2,107	196,589	1.1
NE_Cedar	0.95	0.70	0.95	684	181,752	0.4
NE_Chase	-2.76	-1.93	-2.80	23,799	574,403	4.1
NE_Cherry	-0.08	-0.32	-0.08	1,637	3,846,032	0.0
NE_Cheyenne	-1.16	-1.88	-1.09	68,388	765,695	8.9
NE_Clay	0.91	-0.25	0.91	1,238	367,061	0.3
NE_Colfax	0.43	-0.39	0.44	3,786	265,895	1.4
NE_Cuming	1.10	1.03	1.10	5,079	356,804	1.4
NE_Custer	-0.22	-0.41	-0.22	4,091	1,648,603	0.2
NE_Dawes	-0.07	0.06	-0.07	3,061	511,040	0.6
NE_Dawson	1.75	1.07	1.75	2,442	652,438	0.4
NE_Deuel	0.07	0.08	0.07	13,749	282,056	4.9
NE_Dixon	1.81	3.01	1.79	400	26,309	1.5
NE_Dodge	1.14	0.89	1.14	2,585	314,493	0.8
NE_Douglas	0.00	-0.03	0.00	60	44,726	0.1
NE_Dundy	-3.06	-1.17	-3.11	16,359	588,183	2.8
NE_Fillmore	1.34	1.34	1.34	1,126	368,976	0.3
NE_Franklin	0.13	0.01	0.13	8,353	356,042	2.3
NE_Frontier	2.06	2.79	2.05	4,932	627,244	0.8
NE_Furnas	0.71	0.49	0.72	13,318	461,211	2.9
NE_Gage	1.24	0.68	1.25	244	15,367	1.6
NE_Garden	-0.18	-0.73	-0.17	9,127	1,107,757	0.8
NE_Garfield	0.53	1.62	0.52	3,055	365,690	0.8
NE_Gosper	1.65	2.45	1.64	3,236	296,140	1.1
NE_Greeley	1.17	1.69	1.16	4,310	365,217	1.2
NE_Hall	2.90	4.63	2.90	437	353,371	0.1
NE_Hamilton	2.44	2.64	2.44	669	350,100	0.2
NE_Harlan	1.31	1.28	1.32	5,312	367,400	1.4
NE_Hayes	-0.49	-0.91	-0.47	23,892	456,499	5.2
NE_Hitchcock	-0.26	-0.54	-0.25	15,251	459,826	3.3

Table 15. Nebraska water-level change beneath CRP and non-CRP land by county, 2005-2009.

2005-2009 Mean Water-level Change						
State_County	**County water-level change (ft)**	**CRP water-level change (ft)**	**Non-CRP water-level change (ft)**	**Total County CRP Acres over the Aquifer**	**Total County Acres over the Aquifer**	**Percent of County over the Aquifer in CRP**
NE_Holt	2.13	2.81	2.12	10,978	1,274,936	0.9
NE_Hooker	-1.06	-0.59	-1.06	543	461,757	0.1
NE_Howard	2.29	1.66	2.29	4,499	368,378	1.2
NE_Jefferson	-0.02	0.10	-0.03	3,444	113,141	3.0
NE_Kearney	1.42	1.34	1.42	359	330,464	0.1
NE_Keith	-1.46	-1.38	-1.46	13,170	710,234	1.9
NE_KeyaPaha	0.41	0.77	0.41	143	339,476	0.0
NE_Kimball	-1.84	-1.45	-1.91	94,468	609,540	15.5
NE_Knox	0.71	0.72	0.71	2,086	172,586	1.2
NE_Lincoln	-0.59	-0.63	-0.59	8,767	1,648,072	0.5
NE_Logan	-0.82	-0.53	-0.82	956	365,522	0.3
NE_Loup	0.90	0.64	0.90	405	365,488	0.1
NE_Madison	4.53	3.43	4.55	7,584	368,286	2.1
NE_McPherson	-0.98	-1.03	-0.98	1,179	550,403	0.2
NE_Merrick	3.35	2.04	3.36	1,197	316,483	0.4
NE_Morrill	-0.28	-0.27	-0.28	30,871	915,112	3.4
NE_Nance	2.24	1.63	2.26	8,239	286,854	2.9
NE_Perkins	-4.94	-4.45	-4.96	23,549	566,033	4.2
NE_Phelps	1.86	1.20	1.86	753	345,871	0.2
NE_Pierce	3.57	3.68	3.57	5,560	367,738	1.5
NE_Platte	3.25	2.44	3.26	6,179	438,130	1.4
NE_Polk	1.39	0.91	1.39	564	282,005	0.2
NE_RedWillow	-0.05	-0.67	-0.04	8,223	459,524	1.8
NE_Rock	1.71	1.68	1.71	7,761	596,582	1.3
NE_Saline	0.45	0.90	0.43	9,094	340,969	2.7
NE_ScottsBluff	0.78	0.39	0.80	22,860	477,031	4.8
NE_Seward	0.94	0.74	0.95	2,353	231,597	1.0
NE_Sheridan	-0.22	0.41	-0.22	17,727	1,552,260	1.1
NE_Sherman	0.68	0.92	0.68	6,647	365,855	1.8
NE_Sioux	0.16	0.03	0.16	4,964	1,114,340	0.4
NE_Stanton	2.58	2.14	2.61	16,260	275,842	5.9
NE_Thayer	0.29	0.68	0.28	2,996	225,695	1.3
NE_Thomas	-1.39	-1.04	-1.39	10	456,747	0.0
NE_Thurston	0.61	1.91	0.59	316	21,138	1.5
NE_Valley	1.75	1.54	1.75	2,047	365,093	0.6
NE_Washington	0.00	0.00	0.00	11	1,353	0.8
NE_Wayne	2.69	3.17	2.68	3,246	280,883	1.2
NE_Webster	0.77	0.73	0.77	9,155	331,721	2.8
NE_Wheeler	3.79	3.99	3.79	9,463	368,374	2.6
NE_York	1.99	1.27	1.99	272	368,529	0.1

Table 15 Continued. Nebraska water-level change beneath CRP and non-CRP land by county, 2005-2009.

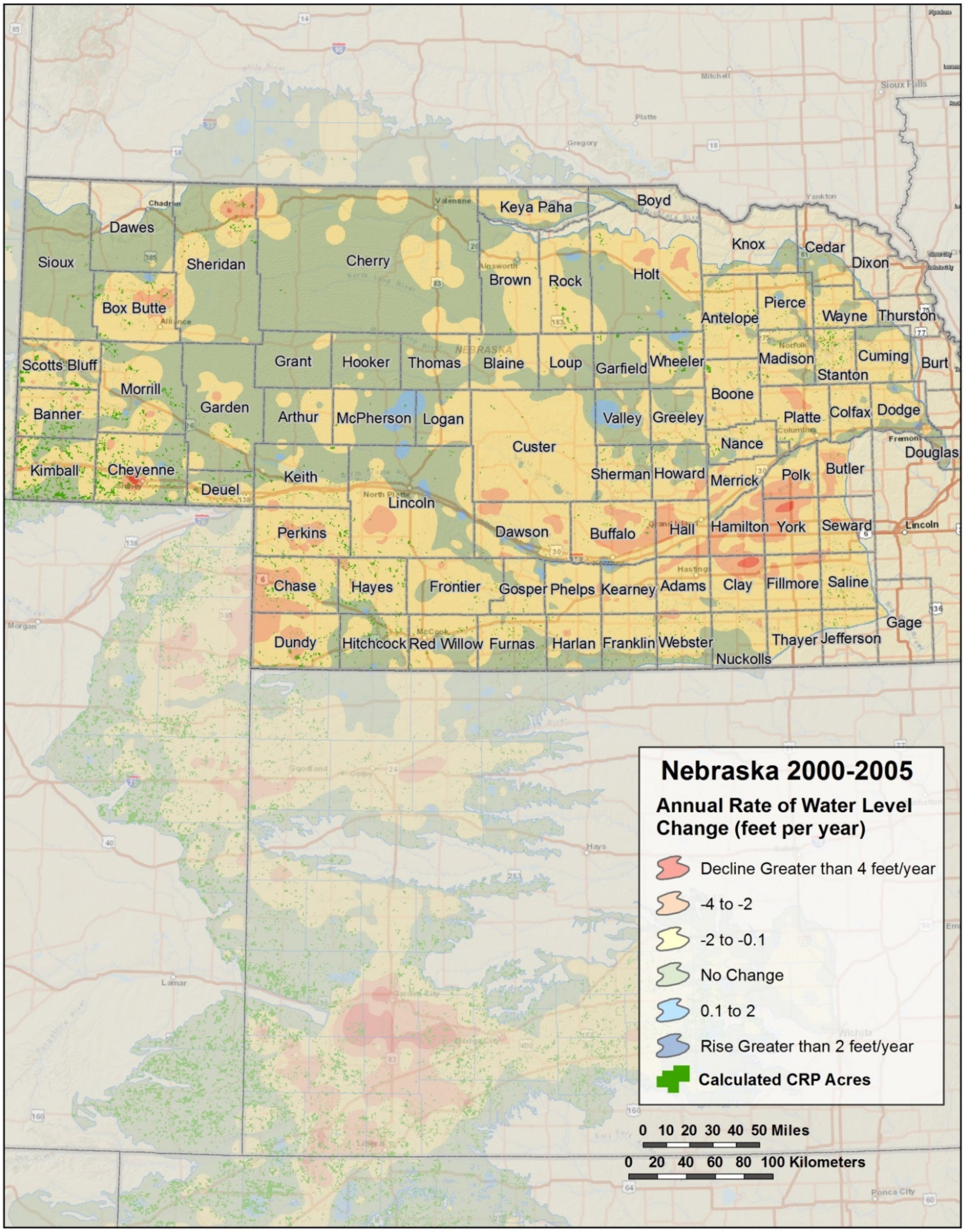

Figure 29. Nebraska CRP polygons for 2005 overlaid on water-level change, 2000-2005.

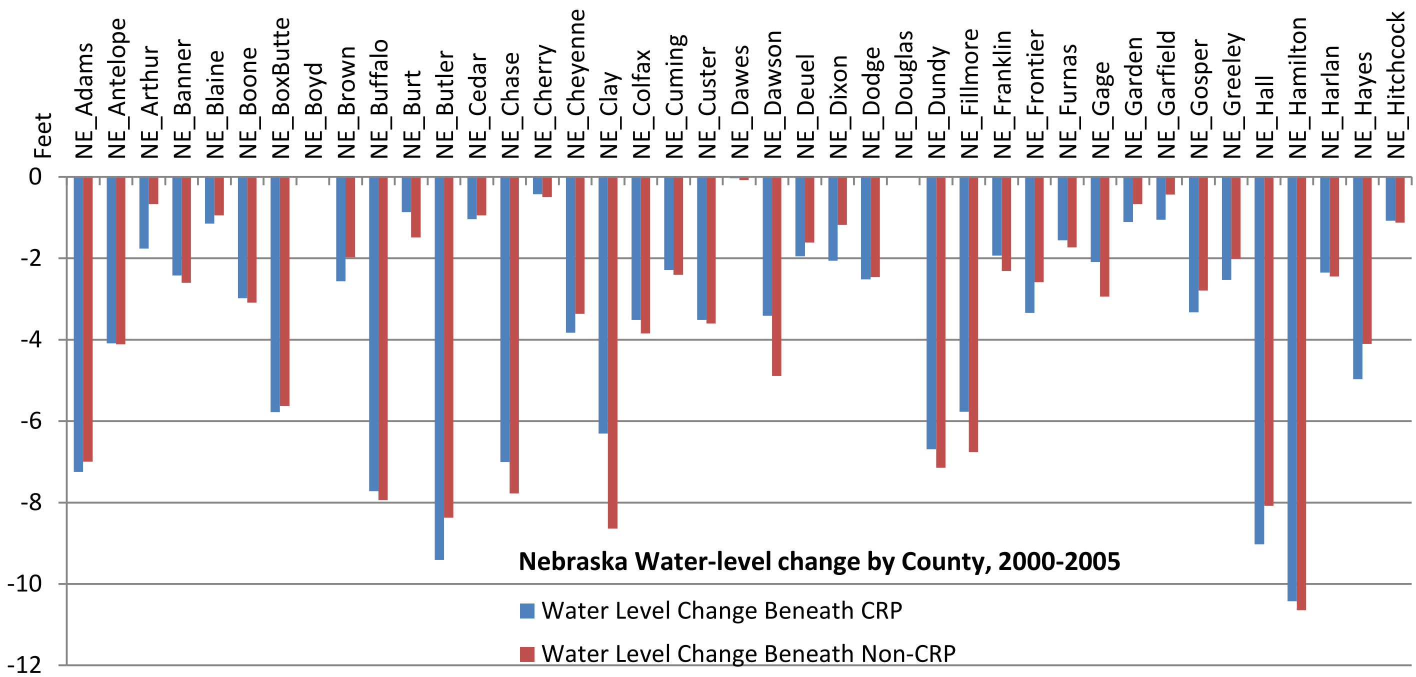

Figure 30. Comparison of water-level changes beneath CRP and non-CRP land, 2000-2005.

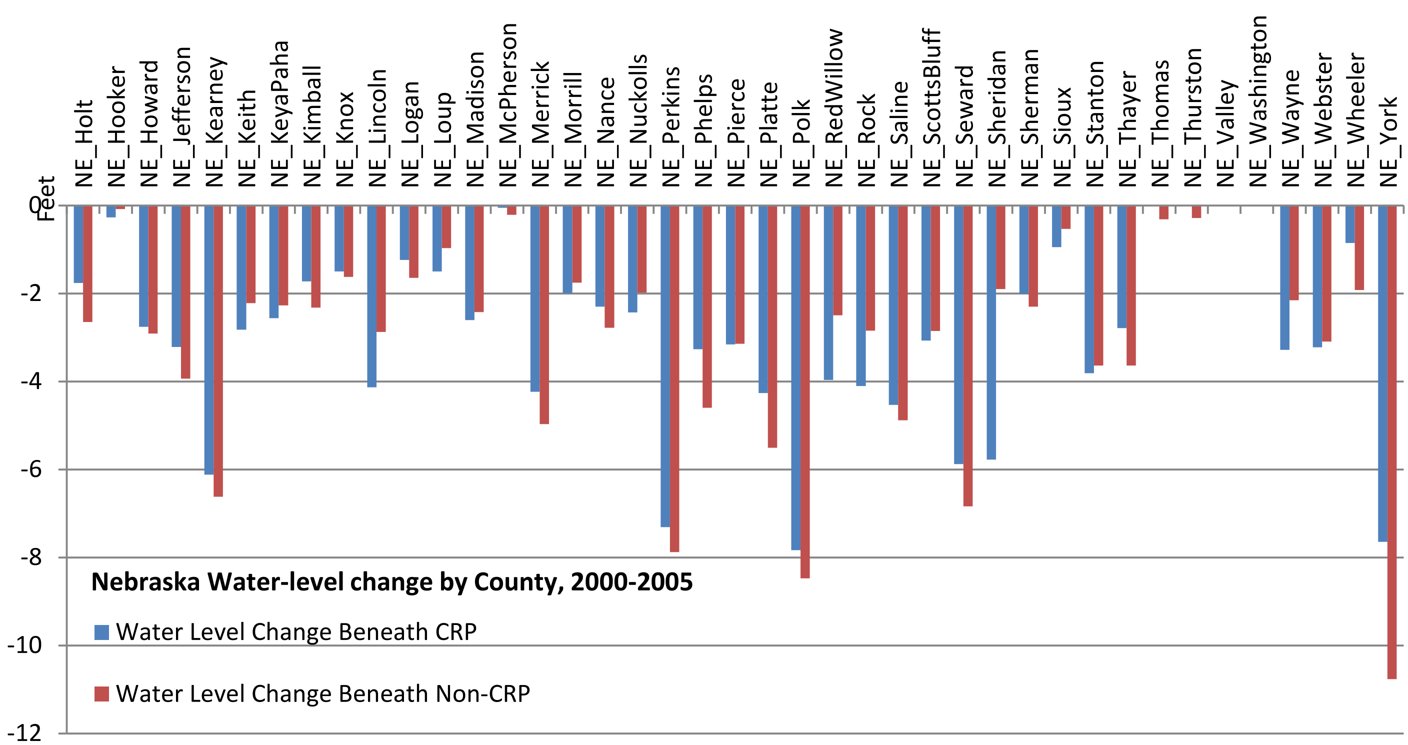

Figure 30 Continued. Comparison of water-level changes beneath CRP and non-CRP land, 2000-2005.

2000-2005 Mean Water-level Change						
State_County	County water-level change (ft)	CRP water-level change (ft)	Non-CRP water-level change (ft)	Total County CRP Acres over the Aquifer	Total County Acres over the Aquifer	Percent of County over the Aquifer in CRP
NE_Adams	-7.00	-7.24	-6.99	1,450	361,110	0.4
NE_Antelope	-4.11	-4.09	-4.11	13,560	549,504	2.5
NE_Arthur	-0.67	-1.76	-0.67	191	459,714	0.0
NE_Banner	-2.59	-2.42	-2.60	29,856	477,671	6.3
NE_Blaine	-0.95	-1.15	-0.95	755	457,188	0.2
NE_Boone	-3.09	-2.98	-3.09	9,618	439,831	2.2
NE_BoxButte	-5.63	-5.78	-5.63	21,222	689,812	3.1
NE_Boyd	-0.01	0.00	-0.01	355	65,803	0.5
NE_Brown	-1.98	-2.56	-1.98	2,115	755,101	0.3
NE_Buffalo	-7.94	-7.72	-7.94	5,788	624,252	0.9
NE_Burt	-1.48	-0.87	-1.48	200	27,261	0.7
NE_Butler	-8.39	-9.41	-8.38	2,102	196,589	1.1
NE_Cedar	-0.95	-1.04	-0.95	670	181,752	0.4
NE_Chase	-7.74	-7.00	-7.78	23,799	574,403	4.1
NE_Cherry	-0.50	-0.43	-0.50	1,606	3,846,032	0.0
NE_Cheyenne	-3.40	-3.83	-3.36	64,737	765,695	8.5
NE_Clay	-8.63	-6.30	-8.64	1,240	367,061	0.3
NE_Colfax	-3.84	-3.52	-3.85	3,769	265,895	1.4
NE_Cuming	-2.40	-2.29	-2.40	4,764	356,804	1.3
NE_Custer	-3.60	-3.51	-3.60	4,049	1,648,603	0.2
NE_Dawes	-0.08	-0.03	-0.08	1,840	511,040	0.4
NE_Dawson	-4.88	-3.42	-4.89	2,442	652,438	0.4
NE_Deuel	-1.63	-1.95	-1.61	12,187	282,056	4.3
NE_Dixon	-1.19	-2.06	-1.18	400	26,309	1.5
NE_Dodge	-2.46	-2.52	-2.46	2,564	314,493	0.8
NE_Douglas	0.00	0.00	0.00	60	44,726	0.1
NE_Dundy	-7.13	-6.69	-7.15	16,359	588,183	2.8
NE_Fillmore	-6.76	-5.77	-6.76	1,126	368,976	0.3
NE_Franklin	-2.30	-1.94	-2.31	7,965	356,042	2.2
NE_Frontier	-2.59	-3.34	-2.59	4,932	627,244	0.8
NE_Furnas	-1.72	-1.56	-1.73	12,659	461,211	2.7
NE_Gage	-2.93	-2.09	-2.94	244	15,367	1.6
NE_Garden	-0.68	-1.11	-0.67	9,045	1,107,757	0.8
NE_Garfield	-0.44	-1.05	-0.44	2,925	365,690	0.8
NE_Gosper	-2.80	-3.32	-2.79	3,197	296,140	1.1
NE_Greeley	-2.02	-2.53	-2.02	4,182	365,217	1.1
NE_Hall	-8.08	-9.03	-8.08	436	353,371	0.1
NE_Hamilton	-10.65	-10.43	-10.65	666	350,100	0.2
NE_Harlan	-2.44	-2.35	-2.45	5,005	367,400	1.4
NE_Hayes	-4.15	-4.96	-4.10	23,536	456,499	5.2
NE_Hitchcock	-1.13	-1.08	-1.13	14,883	459,826	3.2

Table 16. Nebraska water-level change beneath CRP and non-CRP land by county, 2000-2005.

2000-2005 Mean Water-level Change						
State_County	County water-level change (ft)	CRP water-level change (ft)	Non-CRP water-level change (ft)	Total County CRP Acres over the Aquifer	Total County Acres over the Aquifer	Percent of County over the Aquifer in CRP
NE_Holt	-2.64	-1.76	-2.65	10,907	1,274,936	0.9
NE_Hooker	-0.08	-0.27	-0.08	543	461,757	0.1
NE_Howard	-2.91	-2.76	-2.91	4,473	368,378	1.2
NE_Jefferson	-3.92	-3.22	-3.94	3,427	113,141	3.0
NE_Kearney	-6.62	-6.12	-6.62	354	330,464	0.1
NE_Keith	-2.23	-2.83	-2.22	12,664	710,234	1.8
NE_KeyaPaha	-2.27	-2.56	-2.27	143	339,476	0.0
NE_Kimball	-2.25	-1.73	-2.32	77,284	609,540	12.7
NE_Knox	-1.62	-1.50	-1.62	1,786	172,586	1.0
NE_Lincoln	-2.88	-4.14	-2.88	8,758	1,648,072	0.5
NE_Logan	-1.65	-1.24	-1.65	956	365,522	0.3
NE_Loup	-0.97	-1.50	-0.97	403	365,488	0.1
NE_Madison	-2.43	-2.61	-2.42	7,584	368,286	2.1
NE_McPherson	-0.21	-0.05	-0.21	1,179	550,403	0.2
NE_Merrick	-4.96	-4.24	-4.97	1,197	316,483	0.4
NE_Morrill	-1.76	-1.99	-1.76	30,046	915,112	3.3
NE_Nance	-2.77	-2.30	-2.78	8,238	286,854	2.9
NE_Nuckolls	-1.98	-2.43	-1.98	2,154	364,093	0.6
NE_Perkins	-7.85	-7.31	-7.88	23,252	566,033	4.1
NE_Phelps	-4.60	-3.27	-4.60	753	345,871	0.2
NE_Pierce	-3.15	-3.16	-3.15	5,302	367,738	1.4
NE_Platte	-5.49	-4.26	-5.51	6,030	438,130	1.4
NE_Polk	-8.48	-7.83	-8.48	564	282,005	0.2
NE_RedWillow	-2.52	-3.97	-2.50	8,167	459,524	1.8
NE_Rock	-2.86	-4.11	-2.85	7,693	596,582	1.3
NE_Saline	-4.88	-4.53	-4.88	8,961	340,969	2.6
NE_ScottsBluff	-2.86	-3.07	-2.85	20,297	477,031	4.3
NE_Seward	-6.83	-5.88	-6.84	2,353	231,597	1.0
NE_Sheridan	-1.94	-5.78	-1.90	17,721	1,552,260	1.1
NE_Sherman	-2.30	-2.01	-2.30	6,640	365,855	1.8
NE_Sioux	-0.54	-0.94	-0.54	3,927	1,114,340	0.4
NE_Stanton	-3.65	-3.81	-3.64	16,171	275,842	5.9
NE_Thayer	-3.63	-2.79	-3.64	2,903	225,695	1.3
NE_Thomas	-0.32	0.00	-0.32	10	456,747	0.0
NE_Thurston	-0.29	0.00	-0.29	316	21,138	1.5
NE_Valley	0.26	0.15	0.27	2,044	365,093	0.6
NE_Washington	0.00	0.00	0.00	11	1,353	0.8
NE_Wayne	-2.17	-3.28	-2.15	3,236	280,883	1.2
NE_Webster	-3.10	-3.22	-3.10	8,748	331,721	2.6
NE_Wheeler	-1.90	-0.85	-1.92	9,460	368,374	2.6

Table 16 Continued. Nebraska water-level change beneath CRP and non-CRP land by county, 2000-2005.

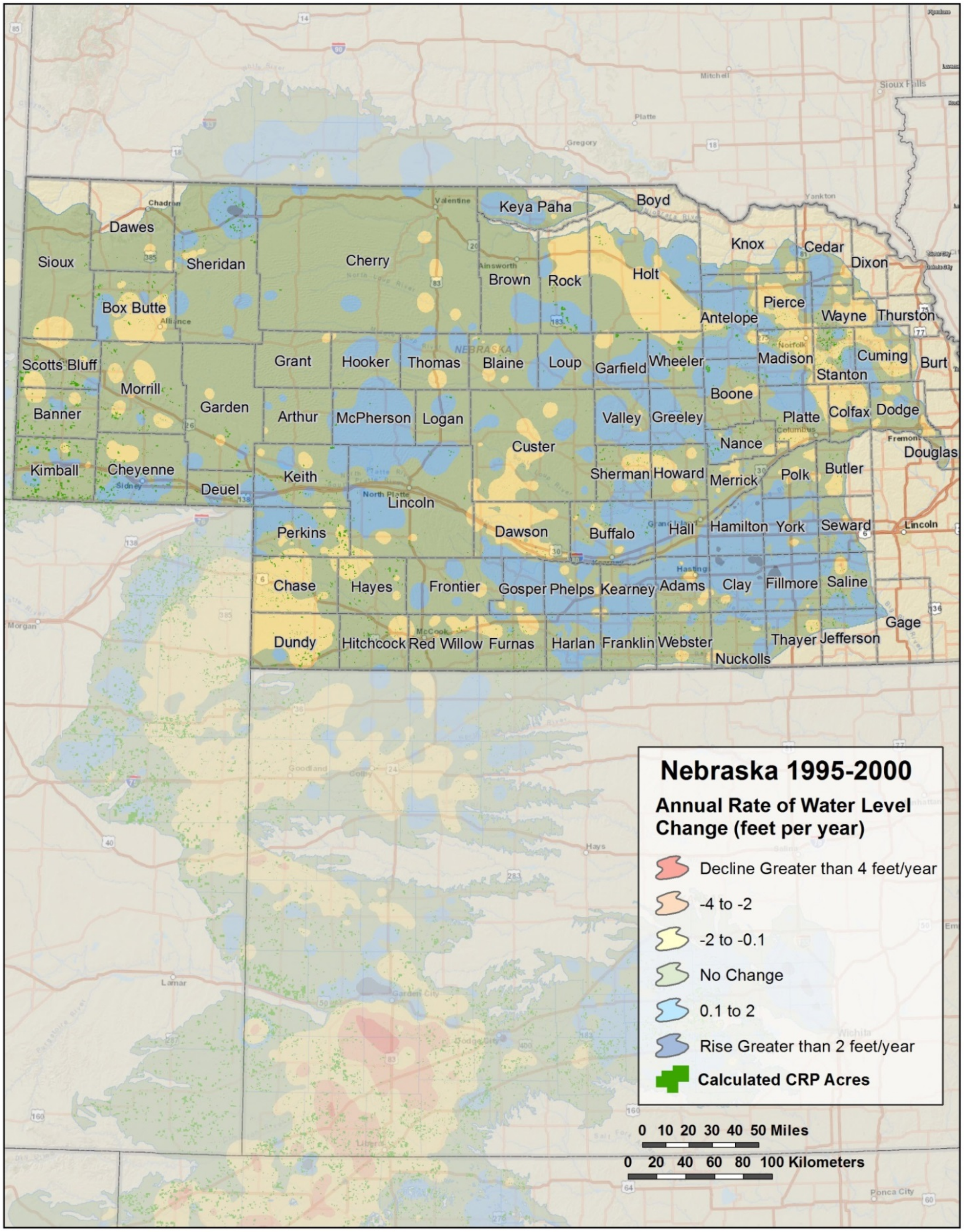

Figure 31. Nebraska CRP polygons for 2000 overlaid on water-level change, 1995-2000.

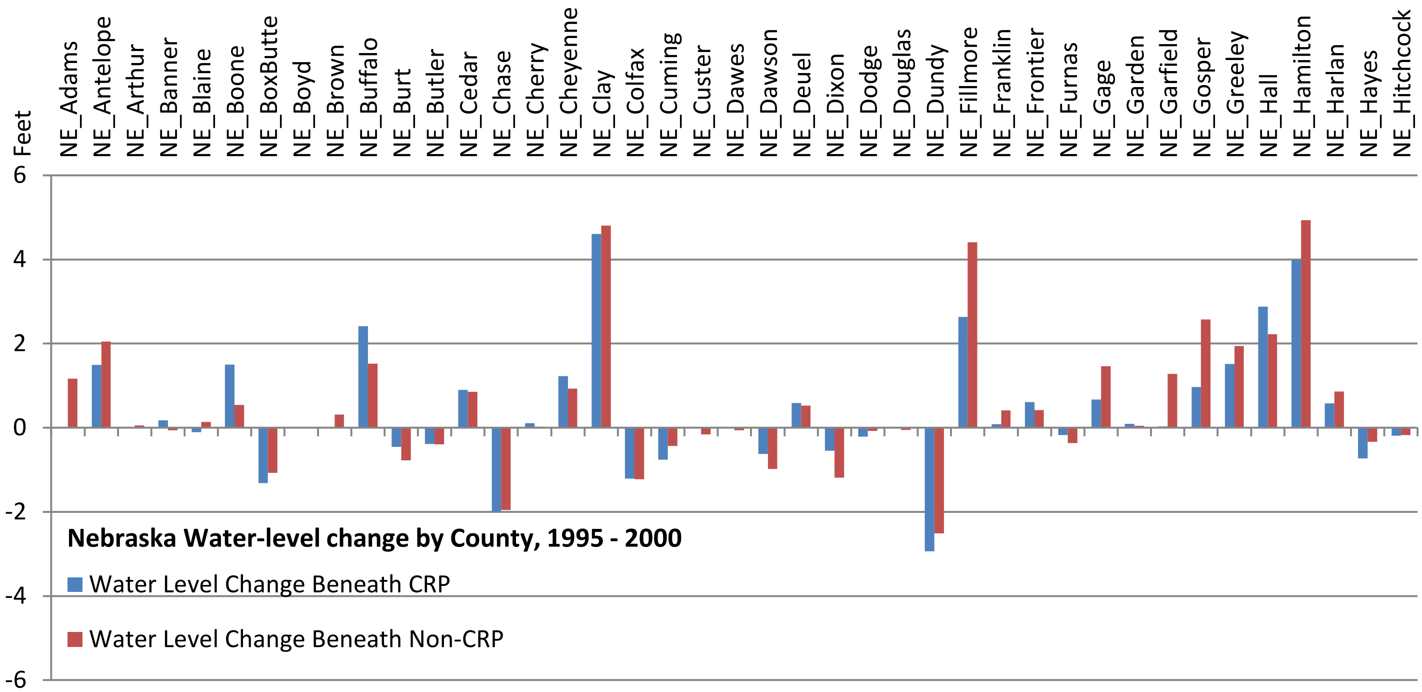

Figure 32. Comparison of water-level changes beneath CRP and non-CRP land, 1995-2000.

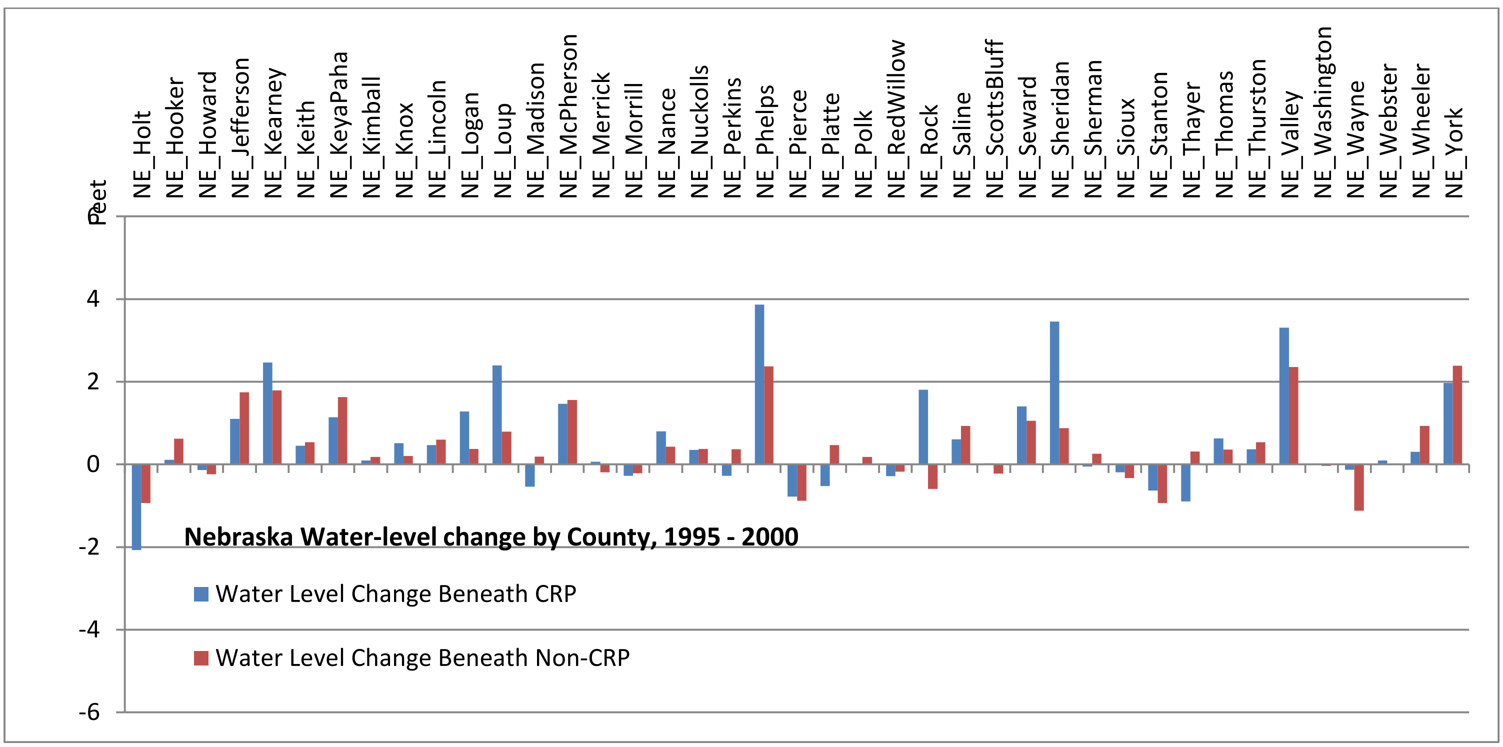

Figure 32 Continued. Comparison of water-level changes beneath CRP and non-CRP land, 1995-2000.

1995-2000 Mean Water-level Change						
State_County	**County water-level change (ft)**	**CRP water-level change (ft)**	**Non-CRP water-level change (ft)**	**Total County CRP Acres Over the Aquifer**	**Total County Acres Over the Aquifer**	**Percent of County over the Aquifer in CRP**
NE_Adams	1.16	-0.01	1.17	1,262	361,110	0.3
NE_Antelope	2.04	1.50	2.05	8,260	549,504	1.5
NE_Arthur	0.06	0.00	0.06	192	459,714	0.0
NE_Banner	-0.05	0.17	-0.06	15,597	477,671	3.3
NE_Blaine	0.14	-0.10	0.14	750	457,188	0.2
NE_Boone	0.56	1.50	0.54	7,097	439,831	1.6
NE_BoxButte	-1.08	-1.31	-1.07	11,887	689,812	1.7
NE_Boyd	0.00	0.00	0.00	360	65,803	0.5
NE_Brown	0.31	0.00	0.31	1,266	755,101	0.2
NE_Buffalo	1.53	2.42	1.53	5,156	624,252	0.8
NE_Burt	-0.77	-0.46	-0.77	181	27,261	0.7
NE_Butler	-0.40	-0.39	-0.40	1,963	196,589	1.0
NE_Cedar	0.85	0.90	0.85	612	181,752	0.3
NE_Chase	-1.96	-1.99	-1.96	14,233	574,403	2.5
NE_Cherry	0.02	0.11	0.02	1,276	3,846,032	0.0
NE_Cheyenne	0.94	1.23	0.93	25,959	765,695	3.4
NE_Clay	4.81	4.60	4.81	1,004	367,061	0.3
NE_Colfax	-1.23	-1.21	-1.23	3,337	265,895	1.3
NE_Cuming	-0.44	-0.76	-0.43	4,118	356,804	1.2
NE_Custer	-0.16	0.00	-0.16	1,894	1,648,603	0.1
NE_Dawes	-0.06	0.00	-0.06	1,536	511,040	0.3
NE_Dawson	-0.98	-0.63	-0.98	1,368	652,438	0.2
NE_Deuel	0.53	0.59	0.53	3,437	282,056	1.2
NE_Dixon	-1.18	-0.55	-1.19	395	26,309	1.5
NE_Dodge	-0.08	-0.21	-0.07	2,098	314,493	0.7
NE_Douglas	-0.05	0.00	-0.05	51	44,726	0.1
NE_Dundy	-2.52	-2.93	-2.51	10,431	588,183	1.8
NE_Fillmore	4.40	2.64	4.41	981	368,976	0.3
NE_Franklin	0.41	0.09	0.41	3,932	356,042	1.1
NE_Frontier	0.42	0.61	0.42	1,474	627,244	0.2
NE_Furnas	-0.36	-0.18	-0.36	7,285	461,211	1.6
NE_Gage	1.45	0.67	1.47	240	15,367	1.6
NE_Garden	0.05	0.09	0.05	4,416	1,107,757	0.4
NE_Garfield	1.27	0.03	1.28	2,054	365,690	0.6
NE_Gosper	2.57	0.97	2.58	1,329	296,140	0.4
NE_Greeley	1.94	1.52	1.94	2,259	365,217	0.6
NE_Hall	2.22	2.88	2.22	386	353,371	0.1
NE_Hamilton	4.93	3.99	4.93	539	350,100	0.2
NE_Harlan	0.86	0.58	0.86	3,090	367,400	0.8
NE_Hayes	-0.35	-0.73	-0.34	11,802	456,499	2.6
NE_Hitchcock	-0.17	-0.19	-0.17	6,617	459,826	1.4

Table 17. Nebraska water-level change beneath CRP and non-CRP land by county, 1995-2000.

1995-2000 Mean Water-level Change						
State_County	County water-level change (ft)	CRP water-level change (ft)	Non-CRP water-level change (ft)	Total County CRP Acres Over the Aquifer	Total County Acres Over the Aquifer	Percent of County over the Aquifer in CRP
NE_Holt	-0.94	-2.07	-0.94	5,994	1,274,936	0.5
NE_Hooker	0.62	0.11	0.62	544	461,757	0.1
NE_Howard	-0.24	-0.13	-0.24	3,046	368,378	0.8
NE_Jefferson	1.73	1.10	1.74	2,849	113,141	2.5
NE_Kearney	1.79	2.47	1.79	317	330,464	0.1
NE_Keith	0.54	0.45	0.54	9,151	710,234	1.3
NE_KeyaPaha	1.63	1.14	1.63	131	339,476	0.0
NE_Kimball	0.18	0.09	0.18	39,128	609,540	6.4
NE_Knox	0.20	0.51	0.20	950	172,586	0.6
NE_Lincoln	0.60	0.47	0.60	6,028	1,648,072	0.4
NE_Logan	0.37	1.28	0.37	776	365,522	0.2
NE_Loup	0.79	2.40	0.79	197	365,488	0.1
NE_Madison	0.18	-0.54	0.19	6,582	368,286	1.8
NE_McPherson	1.56	1.47	1.56	880	550,403	0.2
NE_Merrick	-0.19	0.06	-0.19	814	316,483	0.3
NE_Morrill	-0.22	-0.27	-0.22	13,138	915,112	1.4
NE_Nance	0.44	0.80	0.43	7,278	286,854	2.5
NE_Nuckolls	0.37	0.35	0.37	1,642	364,093	0.5
NE_Perkins	0.35	-0.28	0.37	15,166	566,033	2.7
NE_Phelps	2.38	3.87	2.37	469	345,871	0.1
NE_Pierce	-0.88	-0.78	-0.88	4,354	367,738	1.2
NE_Platte	0.46	-0.52	0.47	4,910	438,130	1.1
NE_Polk	0.18	0.01	0.18	485	282,005	0.2
NE_RedWillow	-0.18	-0.28	-0.18	5,363	459,524	1.2
NE_Rock	-0.56	1.81	-0.59	6,679	596,582	1.1
NE_Saline	0.93	0.61	0.94	7,617	340,969	2.2
NE_ScottsBluff	-0.22	0.03	-0.22	14,221	477,031	3.0
NE_Seward	1.06	1.41	1.06	2,134	231,597	0.9
NE_Sheridan	0.91	3.45	0.88	14,722	1,552,260	0.9
NE_Sherman	0.26	-0.05	0.26	5,849	365,855	1.6
NE_Sioux	-0.33	-0.19	-0.33	3,300	1,114,340	0.3
NE_Stanton	-0.92	-0.64	-0.93	14,769	275,842	5.4
NE_Thayer	0.30	-0.90	0.31	2,497	225,695	1.1
NE_Thomas	0.36	0.63	0.36	10	456,747	0.0
NE_Thurston	0.54	0.37	0.54	206	21,138	1.0
NE_Valley	2.36	3.31	2.36	1,809	365,093	0.5
NE_Washington	-0.03	0.00	-0.03	8	1,353	0.6
NE_Wayne	-1.11	-0.13	-1.12	3,014	280,883	1.1
NE_Webster	0.00	0.10	0.00	6,662	331,721	2.0
NE_Wheeler	0.92	0.31	0.94	7,345	368,374	2.0

Table 17 Continued. Nebraska water-level change beneath CRP and non-CRP land by county, 1995-2000.

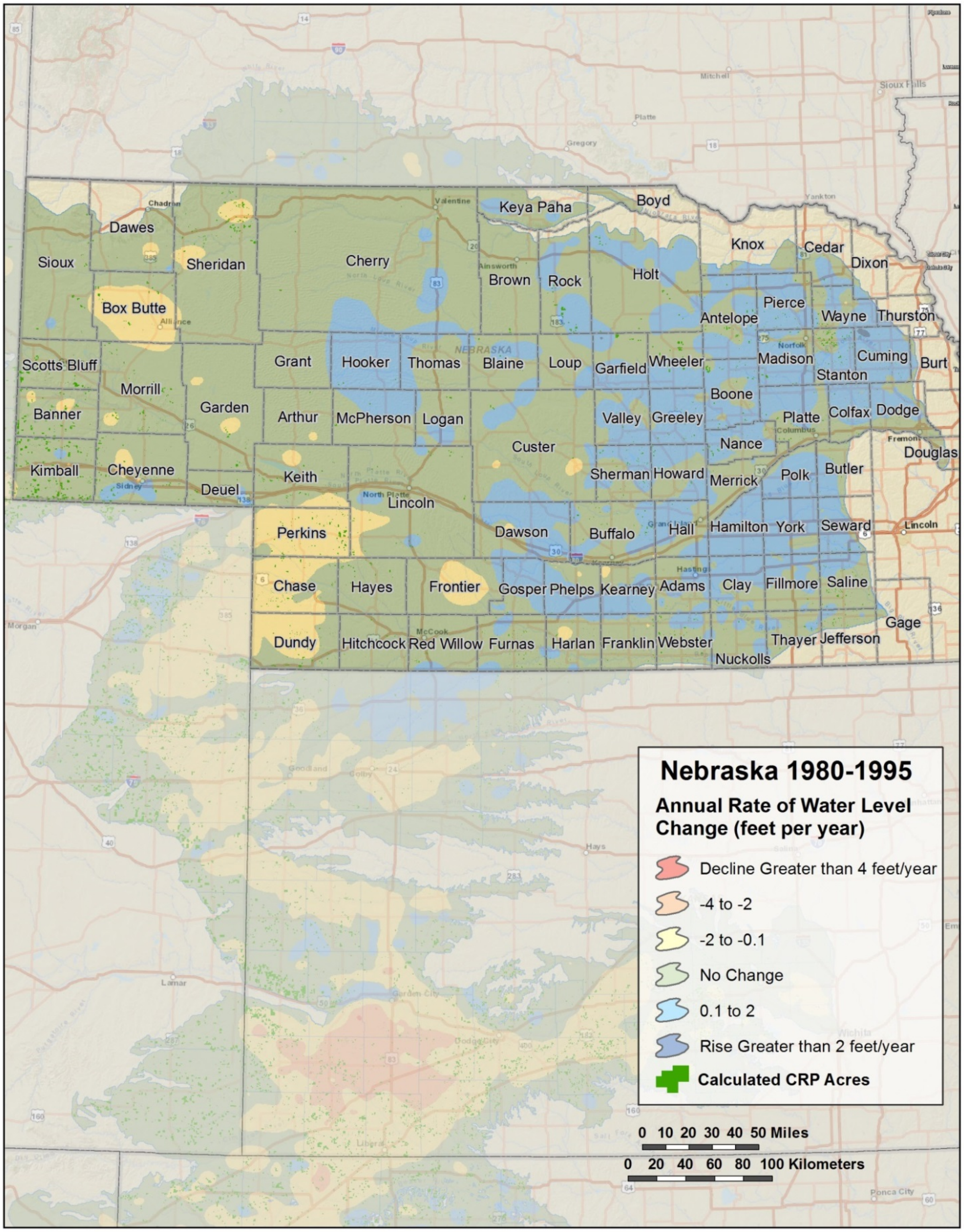

Figure 33. Nebraska CRP polygons for 1995 overlaid on water-level change, 1980-1995.

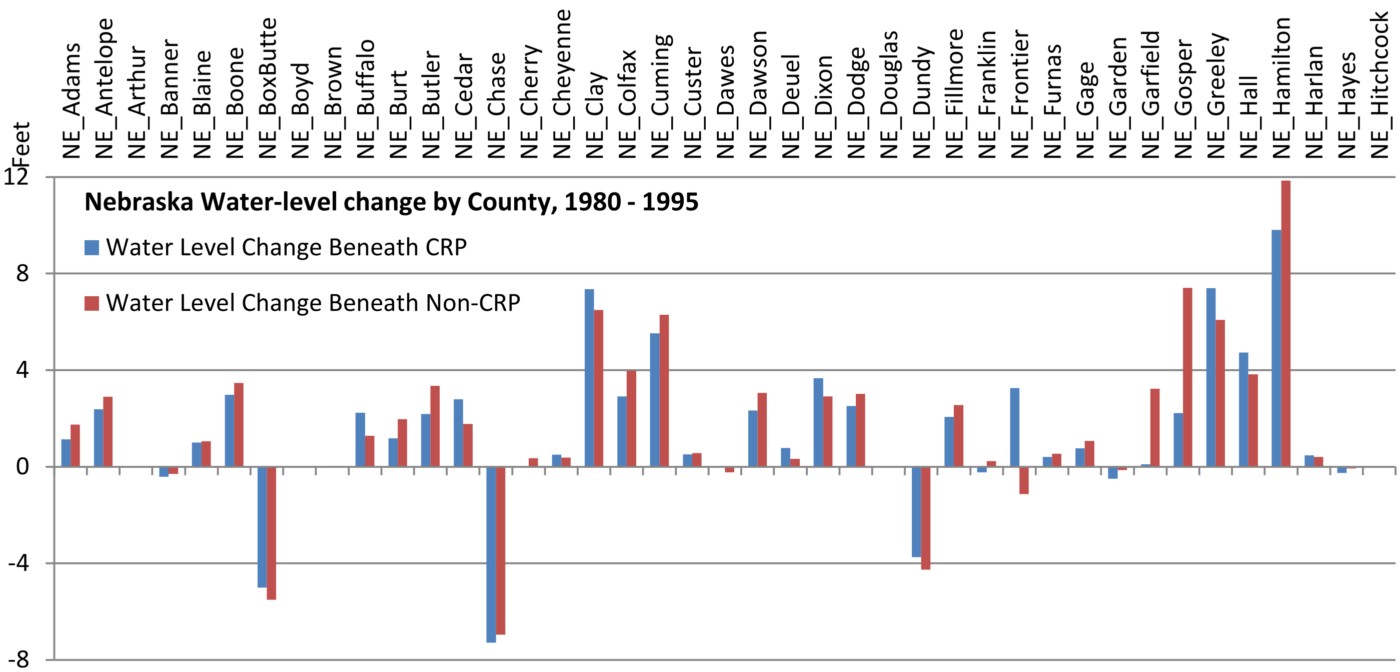

Figure 34. Comparison of water-level changes beneath CRP and non-CRP land, 1980-1995.

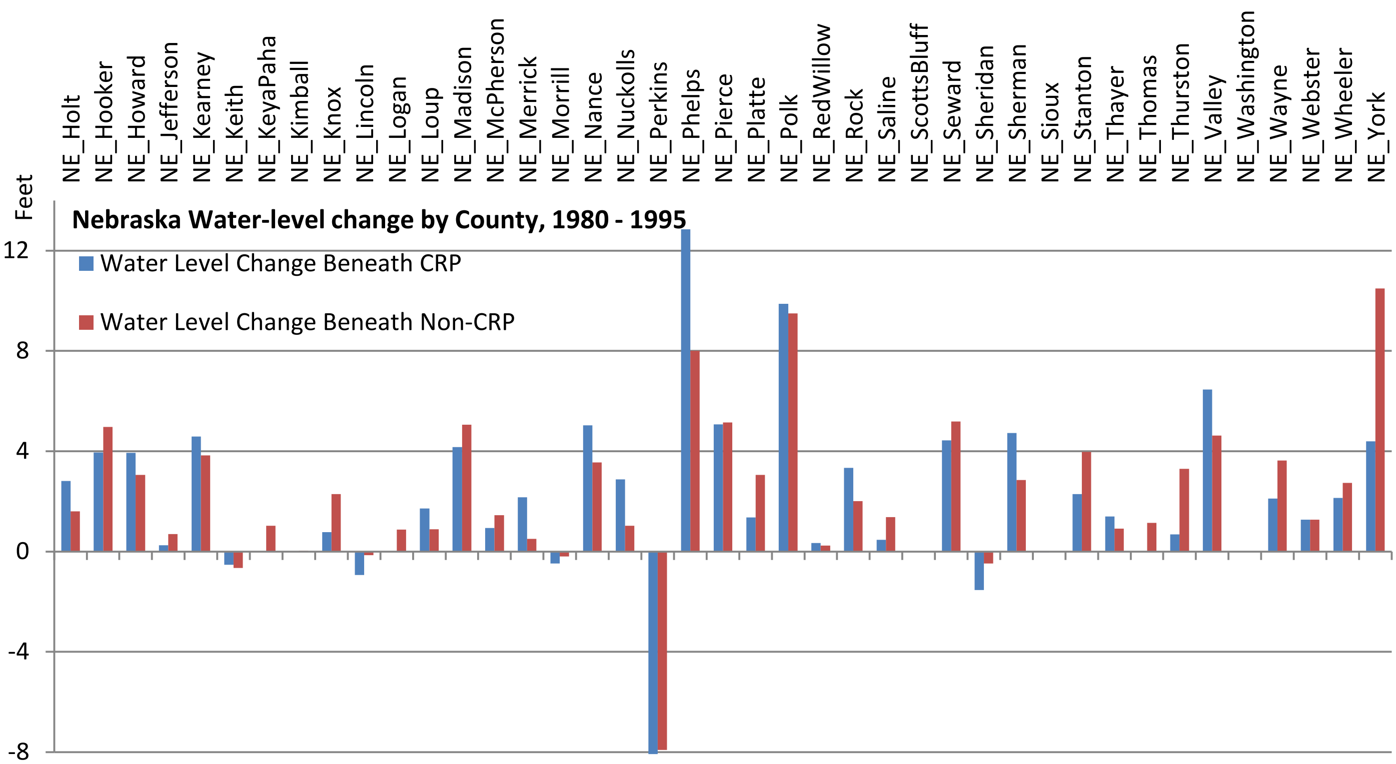

Figure 34 Continued. Comparison of water-level changes beneath CRP and non-CRP land, 1980-1995.

1980-1995 Mean Water-level Change						
State_County	**County water-level change (ft)**	**CRP water-level change (ft)**	**Non-CRP water-level change (ft)**	**Total County CRP Acres over the Aquifer**	**Total County Acres over the Aquifer**	**Percent of County over the Aquifer in CRP**
NE_Adams	1.74	1.13	1.74	646	361,110	0.2
NE_Antelope	2.90	2.38	2.90	5,238	549,504	1.0
NE_Arthur	-0.05	0.00	-0.05	191	459,714	0.0
NE_Banner	-0.30	-0.41	-0.29	14,179	477,671	3.0
NE_Blaine	1.06	1.00	1.06	579	457,188	0.1
NE_Boone	3.46	2.97	3.47	4,488	439,831	1.0
NE_BoxButte	-5.50	-5.00	-5.51	4,806	689,812	0.7
NE_Boyd	0.00	0.00	0.00	34	65,803	0.1
NE_Brown	0.03	0.00	0.03	1,006	755,101	0.1
NE_Buffalo	1.29	2.24	1.29	3,576	624,252	0.6
NE_Burt	1.97	1.18	1.98	141	27,261	0.5
NE_Butler	3.34	2.18	3.34	787	196,589	0.4
NE_Cedar	1.77	2.79	1.77	334	181,752	0.2
NE_Chase	-6.96	-7.28	-6.96	6,175	574,403	1.1
NE_Cherry	0.36	0.00	0.36	1,267	3,846,032	0.0
NE_Cheyenne	0.38	0.50	0.38	11,493	765,695	1.5
NE_Clay	6.50	7.36	6.50	397	367,061	0.1
NE_Colfax	3.96	2.91	3.97	1,506	265,895	0.6
NE_Cuming	6.29	5.53	6.30	1,862	356,804	0.5
NE_Custer	0.57	0.51	0.57	1,128	1,648,603	0.1
NE_Dawes	-0.23	0.00	-0.24	910	511,040	0.2
NE_Dawson	3.06	2.33	3.06	433	652,438	0.1
NE_Deuel	0.33	0.78	0.33	1,677	282,056	0.6
NE_Dixon	2.92	3.67	2.91	222	26,309	0.8
NE_Dodge	3.02	2.51	3.02	881	314,493	0.3
NE_Douglas	0.00	0.00	0.00	13	44,726	0.0
NE_Dundy	-4.26	-3.75	-4.27	5,641	588,183	1.0
NE_Fillmore	2.55	2.06	2.56	514	368,976	0.1
NE_Franklin	0.23	-0.23	0.23	1,644	356,042	0.5
NE_Frontier	-1.12	3.26	-1.13	413	627,244	0.1
NE_Furnas	0.53	0.40	0.53	3,353	461,211	0.7
NE_Gage	1.06	0.77	1.07	161	15,367	1.0
NE_Garden	-0.14	-0.49	-0.13	2,623	1,107,757	0.2
NE_Garfield	3.22	0.10	3.23	1,914	365,690	0.5
NE_Gosper	7.39	2.22	7.40	698	296,140	0.2
NE_Greeley	6.08	7.40	6.08	1,793	365,217	0.5
NE_Hall	3.82	4.73	3.82	242	353,371	0.1
NE_Hamilton	11.85	9.81	11.85	94	350,100	0.0
NE_Harlan	0.41	0.47	0.41	1,552	367,400	0.4
NE_Hayes	-0.07	-0.26	-0.07	3,897	456,499	0.9
NE_Hitchcock	0.00	0.00	0.00	758	459,826	0.2

Table 18. Nebraska water-level change beneath CRP and non-CRP land by county, 1980-1995.

1980-1995 Mean Water-level Change						
State_County	**County water-level change (ft)**	**CRP water-level change (ft)**	**Non-CRP water-level change (ft)**	**Total County CRP Acres over the Aquifer**	**Total County Acres over the Aquifer**	**Percent of County over the Aquifer in CRP**
NE_Holt	1.61	2.81	1.60	3,223	1,274,936	0.3
NE_Hooker	4.97	3.95	4.97	412	461,757	0.1
NE_Howard	3.06	3.94	3.06	1,580	368,378	0.4
NE_Jefferson	0.69	0.25	0.70	1,862	113,141	1.6
NE_Kearney	3.83	4.58	3.83	185	330,464	0.1
NE_Keith	-0.66	-0.53	-0.66	4,586	710,234	0.6
NE_KeyaPaha	1.02	Null	1.02	Null	339,476	
NE_Kimball	0.03	-0.03	0.04	35,157	609,540	5.8
NE_Knox	2.29	0.77	2.30	482	172,586	0.3
NE_Lincoln	-0.14	-0.94	-0.14	4,234	1,648,072	0.3
NE_Logan	0.87	0.00	0.87	548	365,522	0.1
NE_Loup	0.89	1.71	0.89	56	365,488	0.0
NE_Madison	5.05	4.17	5.06	2,230	368,286	0.6
NE_McPherson	1.45	0.93	1.45	738	550,403	0.1
NE_Merrick	0.50	2.17	0.50	423	316,483	0.1
NE_Morrill	-0.20	-0.47	-0.20	7,928	915,112	0.9
NE_Nance	3.57	5.03	3.55	3,028	286,854	1.1
NE_Nuckolls	1.04	2.87	1.03	852	364,093	0.2
NE_Perkins	-7.92	-8.54	-7.91	11,428	566,033	2.0
NE_Phelps	8.01	12.85	8.00	422	345,871	0.1
NE_Pierce	5.15	5.07	5.15	2,864	367,738	0.8
NE_Platte	3.05	1.36	3.06	2,946	438,130	0.7
NE_Polk	9.50	9.88	9.50	219	282,005	0.1
NE_RedWillow	0.23	0.34	0.23	1,027	459,524	0.2
NE_Rock	2.03	3.34	2.02	4,748	596,582	0.8
NE_Saline	1.36	0.46	1.38	5,124	340,969	1.5
NE_ScottsBluff	0.00	0.00	0.00	10,298	477,031	2.2
NE_Seward	5.19	4.44	5.19	1,067	231,597	0.5
NE_Sheridan	-0.49	-1.54	-0.48	13,390	1,552,260	0.9
NE_Sherman	2.87	4.73	2.85	3,271	365,855	0.9
NE_Sioux	0.00	-0.04	0.00	2,988	1,114,340	0.3
NE_Stanton	3.92	2.29	3.97	8,022	275,842	2.9
NE_Thayer	0.91	1.40	0.91	1,590	225,695	0.7
NE_Thomas	1.14	Null	1.14	Null	456,747	
NE_Thurston	3.29	0.69	3.29	13	21,138	0.1
NE_Valley	4.63	6.46	4.62	1,170	365,093	0.3
NE_Washington	0.00	0.00	0.00	0	1,353	0.0
NE_Wayne	3.62	2.12	3.63	2,002	280,883	0.7
NE_Webster	1.27	1.27	1.27	4,653	331,721	1.4
NE_Wheeler	2.73	2.14	2.74	6,737	368,374	1.8

Table 18 Continued. Nebraska water-level change beneath CRP and non-CRP land by county, 1980-1995.

South Dakota

CRP Effects on Water-level Change by County

Summary Results: South Dakota

In South Dakota, the High Plains Aquifer underlies all of part of seven counties in the south central part of the state mainly south of the White River. The aquifer area covers approximately 15,500 square miles with 100% in Bennett County, 91% in Todd County, 48% in Shannon County, 33% in Jackson County and 31% in Tripp County. The aquifer pinches out in Gregory and Mellette counties with 11 and less than 9 percent of the county over the aquifer, respectively.

Bennett County had the greatest amount of CRP of any county about 7,040 acres (11 square miles) for the three most recent time intervals. Aquifer change results for CRP versus non-CRP were mixed for Bennett County. For the most recent time interval (2005-2009), the aquifer had a 0.30 foot greater decline over CRP than non-CRP with a low mean annual decline of 0.1 feet. In the 2000-2005 interval, there was a moderate mean annual decline of 0.3 feet per year, with about 0.5 foot greater decline beneath non-CRP. For the 1995-2000 interval, there was a moderate annual rise in aquifer level of about 0.4 feet per year, with 0.5 foot greater rise over CRP. The 15-year interval 1980 to 1995 showed a slight rise of about 0.1 foot in CRP and slightly greater rise of about 0.3 foot beneath non-CRP.

Todd County had about 640 acres (1 square mile) of land in CRP and low mean annual changes in water level of about 0.1 feet per year. For the most recent time interval (2005-2009), land beneath both CRP and non-CRP declined about 0.6 foot. The results were variable for the remaining intervals ,with less decline beneath CRP for 2000-2005, greater rise beneath CRP for 1995-2000 and virtually no difference in the 1980-1995 interval. The mixed results might be due to the small amount of land in CRP.

With just under half of the county over the aquifer, Shannon County lies in the northwestern most part of the High Plains Aquifer. A little over 640 acres (1 square mile) of the county was in CRP, and it experienced low mean annual changes in water level from 0 to about 0.1 feet per year. There were very little or no changes in aquifer levels for the 2005-2009, 2000-2005 and 1980-1995 time intervals. The 1995-2000 interval however showed a rise of 3.2 feet for CRP and 0.43 feet over non-CRP. The reliability of these results might be compromised by the small amount of land in CRP.

The aquifer underlies less than half of both Jackson and Tripp counties and are located in the northern most edge of the aquifer. Jackson County had about 768 acres (1.2 square miles) in CRP land and Tripp just under 3 square miles in CRP. Both counties experienced low mean annual changes in water level from 0 to about 0.2 feet per year. These counties behaved oppositely in the 2005-2009 time interval, with Jackson County showing a greater decline of -0.2 feet over non-CRP and Tripp County greater decline of -0.3 feet over CRP. Once again in the 2000-2005 time interval, these counties behaved oppositely with Jackson County showing a greater decline of -0.8 feet over non-CRP and Tripp County greater decline of -0.2 feet over CRP. For the 1995-2000 and 1980-1995 time intervals, there were little or no changes in aquifer levels for these counties. The mixed results in these counties might be due to the small amount of land in CRP.

Gregory and Mellette counties had the least amount of area over the aquifer of about 11 and 8.6 square miles, respectively. Both counties experienced low mean annual changes in water level from 0 to about 0.2 feet per year. Gregory County had about 1.6 square miles enrolled in CRP for the two most recent time intervals and less area shown the older time intervals as a reflection of the contract start date calculation from the 2011 FSA data. Results were variable for these counties, with Gregory

County showing no change in aquifer level for the 2005-2009 intervals, while Mellette showed a slightly greater rises of 0.1 feet over CRP. In the 2000-2005 time interval, Gregory declined 0.63 feet more over non-CRP, but Mellette declined 0.8 feet more over CRP. The 1995-2000 period reflected a greater rise of 0.8 feet over non-CRP for Gregory County and a 1.2 foot greater rise over CRP for Mellette County. The 1980-1995 interval showed no change in aquifer level for Gregory County, while Mellette showed a 0.3 foot rise over non-CRP. These counties had both little area over the aquifer and in CRP.

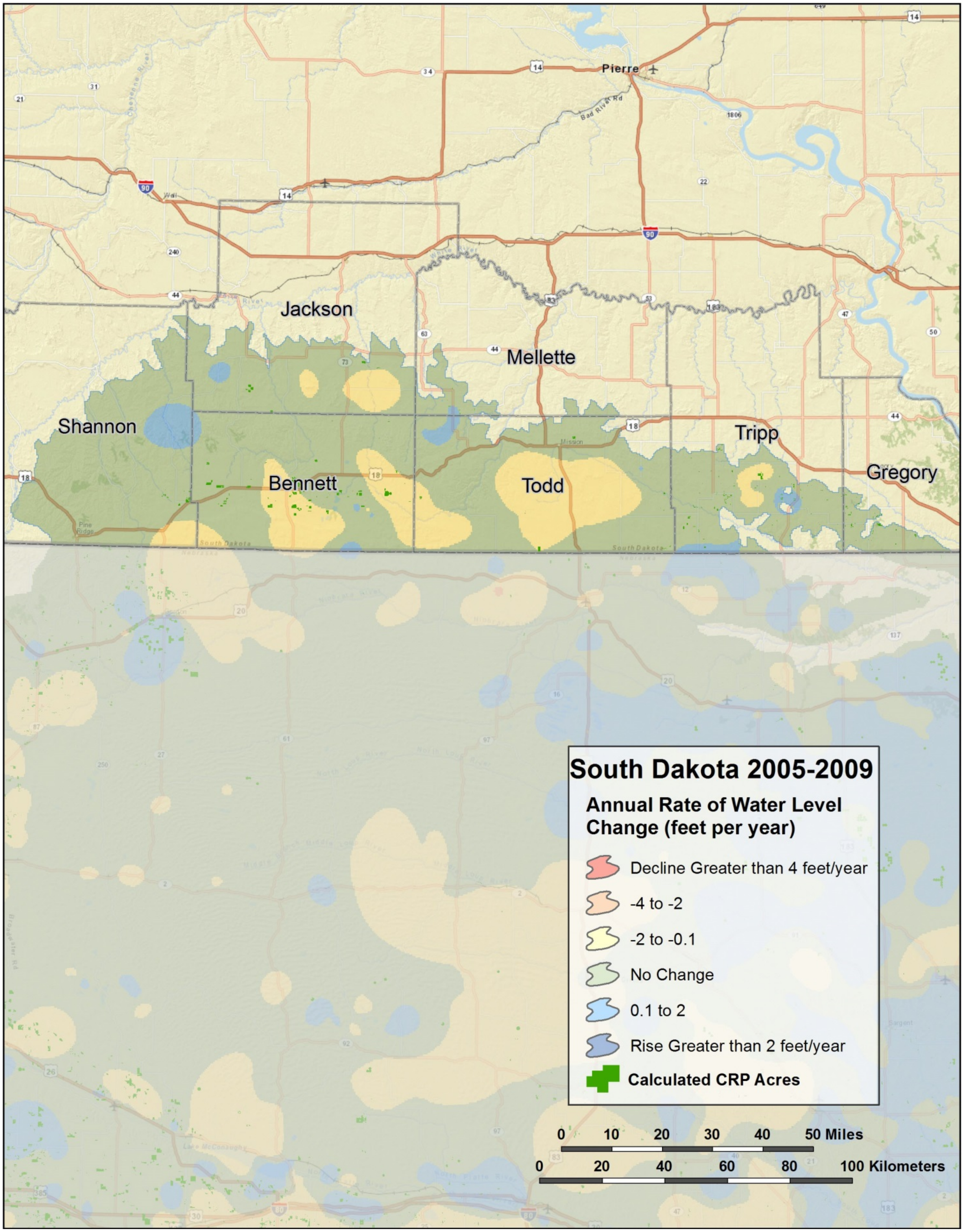

Figure 35. South Dakota CRP polygons for 2009 overlaid on water-level change, 2005-2009.

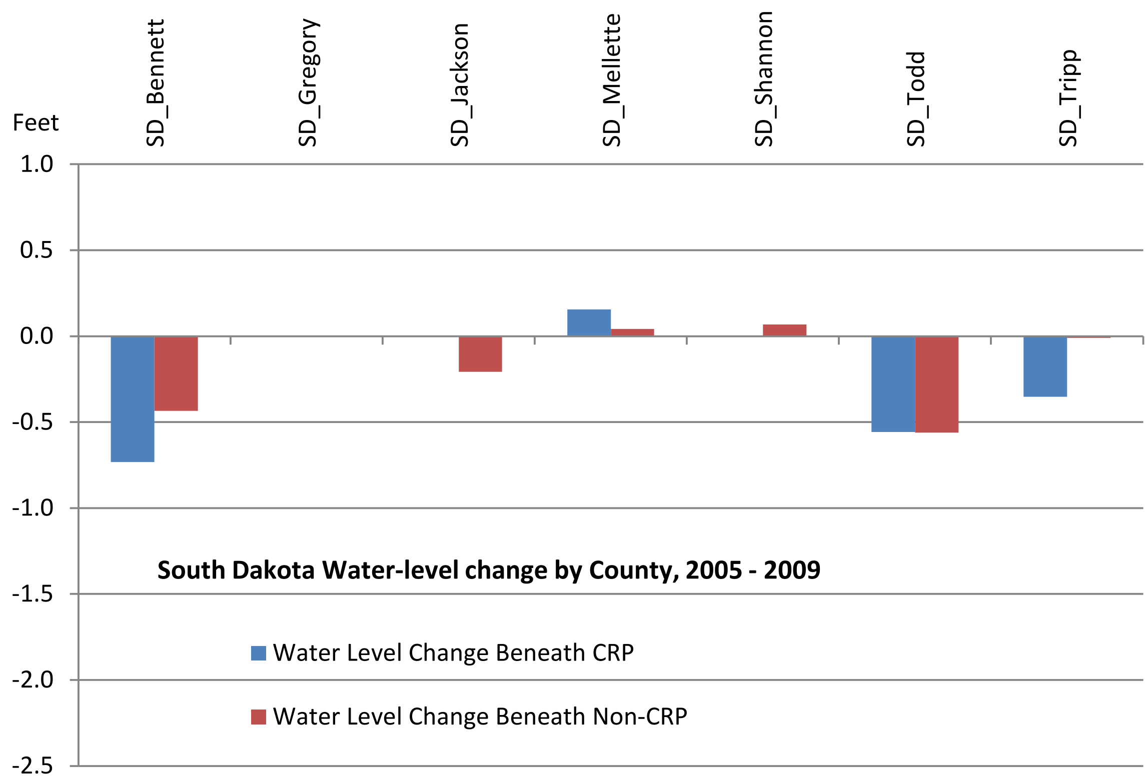

Figure 36. Comparison of water-level changes beneath CRP and non-CRP land, 2005-2009.

2005-2009 Mean Water-level Change						
State_County	**County water-level change (ft)**	**CRP water-level change (ft)**	**Non-CRP water-level change (ft)**	**Total County CRP Acres over the Aquifer**	**Total County Acres over the Aquifer**	**Percent of County over the Aquifer in CRP**
SD_Bennett	-0.44	-0.73	-0.43	7,277	761,921	1.0
SD_Gregory	0.00	0.00	0.00	1,087	74,879	1.5
SD_Jackson	-0.21	0.00	-0.21	799	403,591	0.2
SD_Mellette	0.04	0.16	0.04	97	72,251	0.1
SD_Shannon	0.07	0.00	0.07	729	647,202	0.1
SD_Todd	-0.56	-0.56	-0.56	823	815,267	0.1
SD_Tripp	-0.01	-0.35	-0.01	1,874	325,210	0.6

Table 19. South Dakota water-level change beneath CRP and non-CRP land by county, 2005-2009.

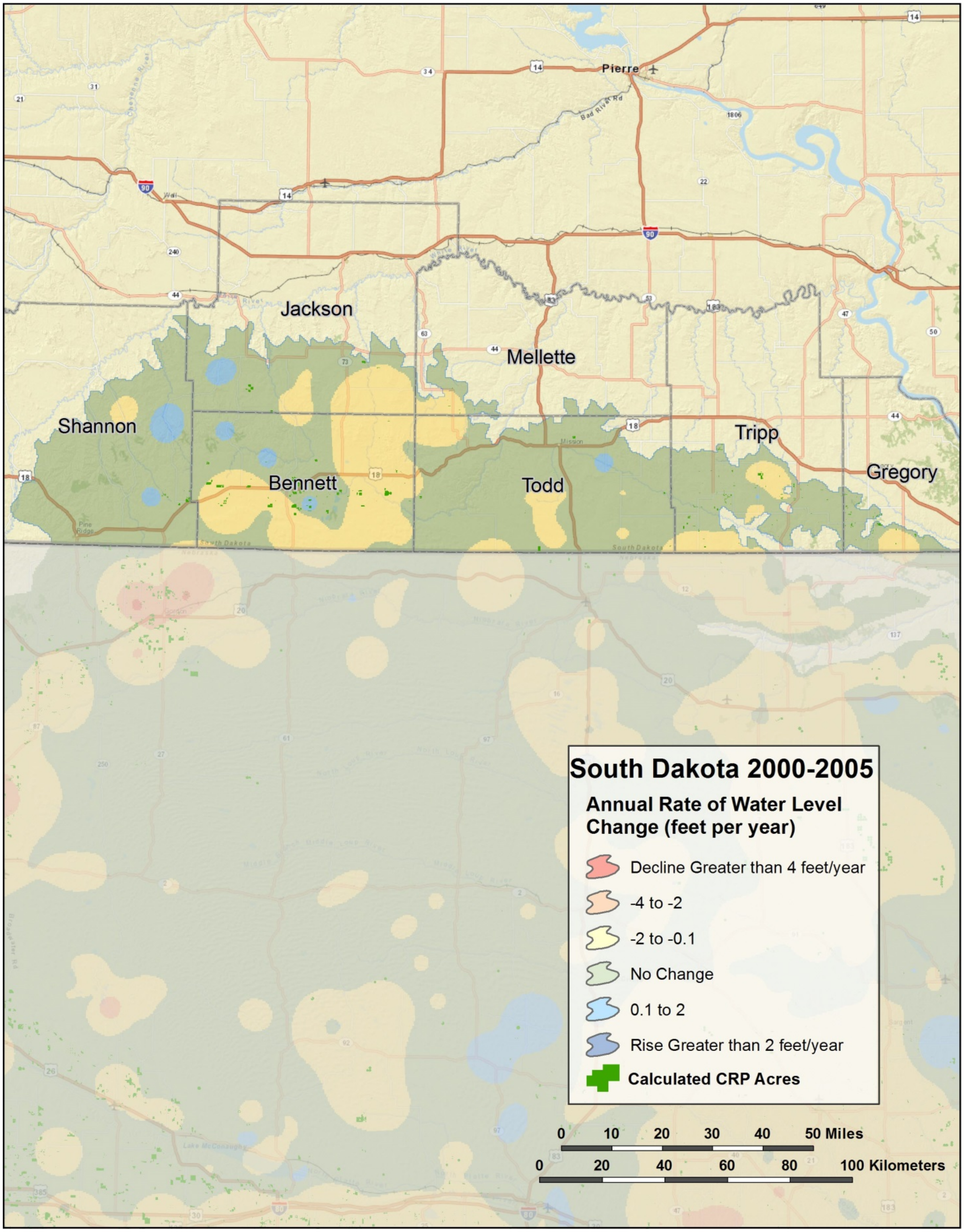

Figure 37. South Dakota CRP polygons for 2005 overlaid on water-level change, 2000-2005.

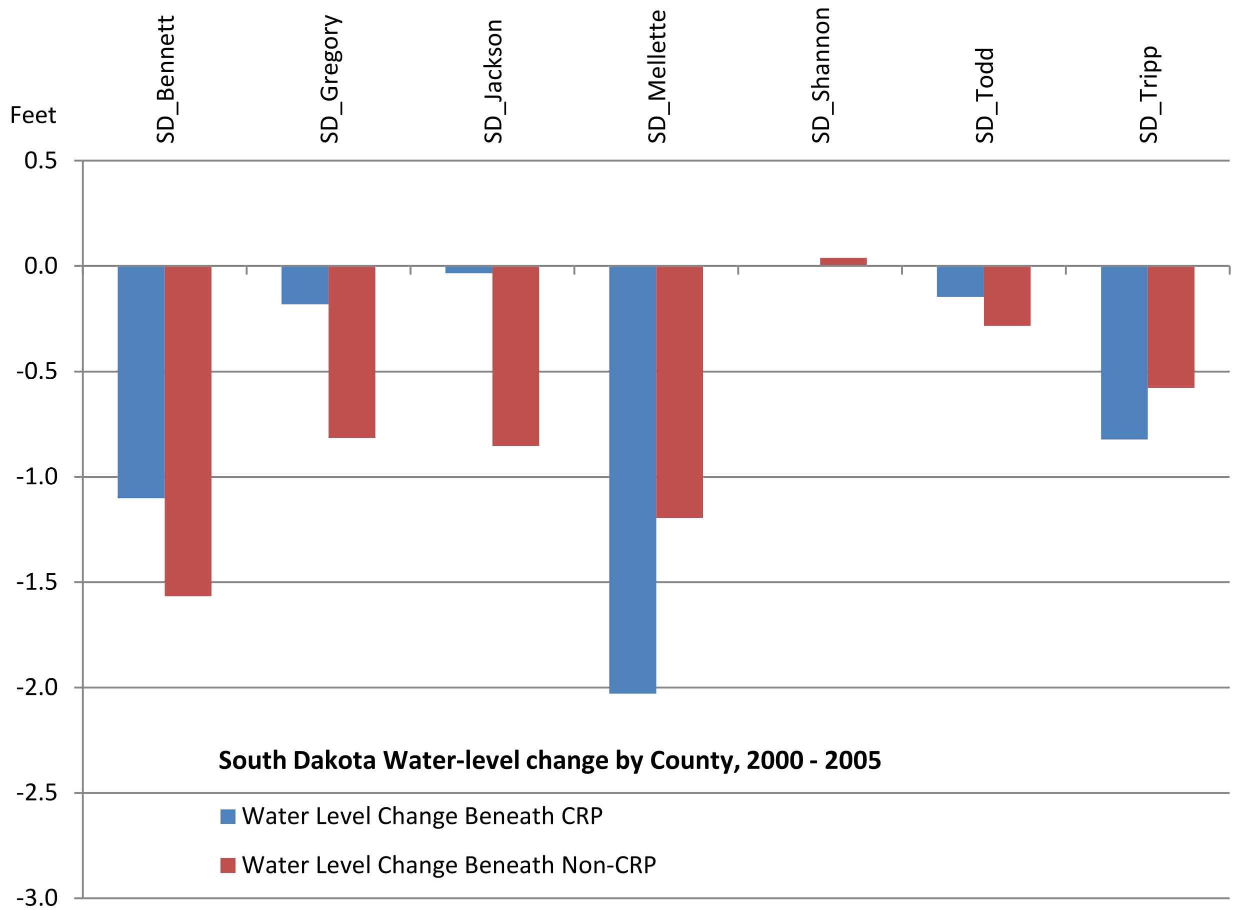

Figure 38. Comparison of water-level changes beneath CRP and non-CRP land, 2000-2005.

2000-2005 Mean Water-level Change						
State_County	**County water-level change (ft)**	**CRP water-level change (ft)**	**Non-CRP water-level change (ft)**	**Total County CRP Acres over the Aquifer**	**Total County Acres over the Aquifer**	**Percent of County over the Aquifer in CRP**
SD_Bennett	-1.56	-1.10	-1.57	7,275	761,921	1.0
SD_Gregory	-0.81	-0.18	-0.82	1,067	74,879	1.4
SD_Jackson	-0.85	-0.03	-0.85	799	403,591	0.2
SD_Mellette	-1.20	-2.03	-1.20	97	72,251	0.1
SD_Shannon	0.04	0.00	0.04	729	647,202	0.1
SD_Todd	-0.28	-0.15	-0.28	735	815,267	0.1
SD_Tripp	-0.58	-0.82	-0.58	1,850	325,210	0.6

Table 20. South Dakota water-level change beneath CRP and non-CRP land by county, 2000-2005.

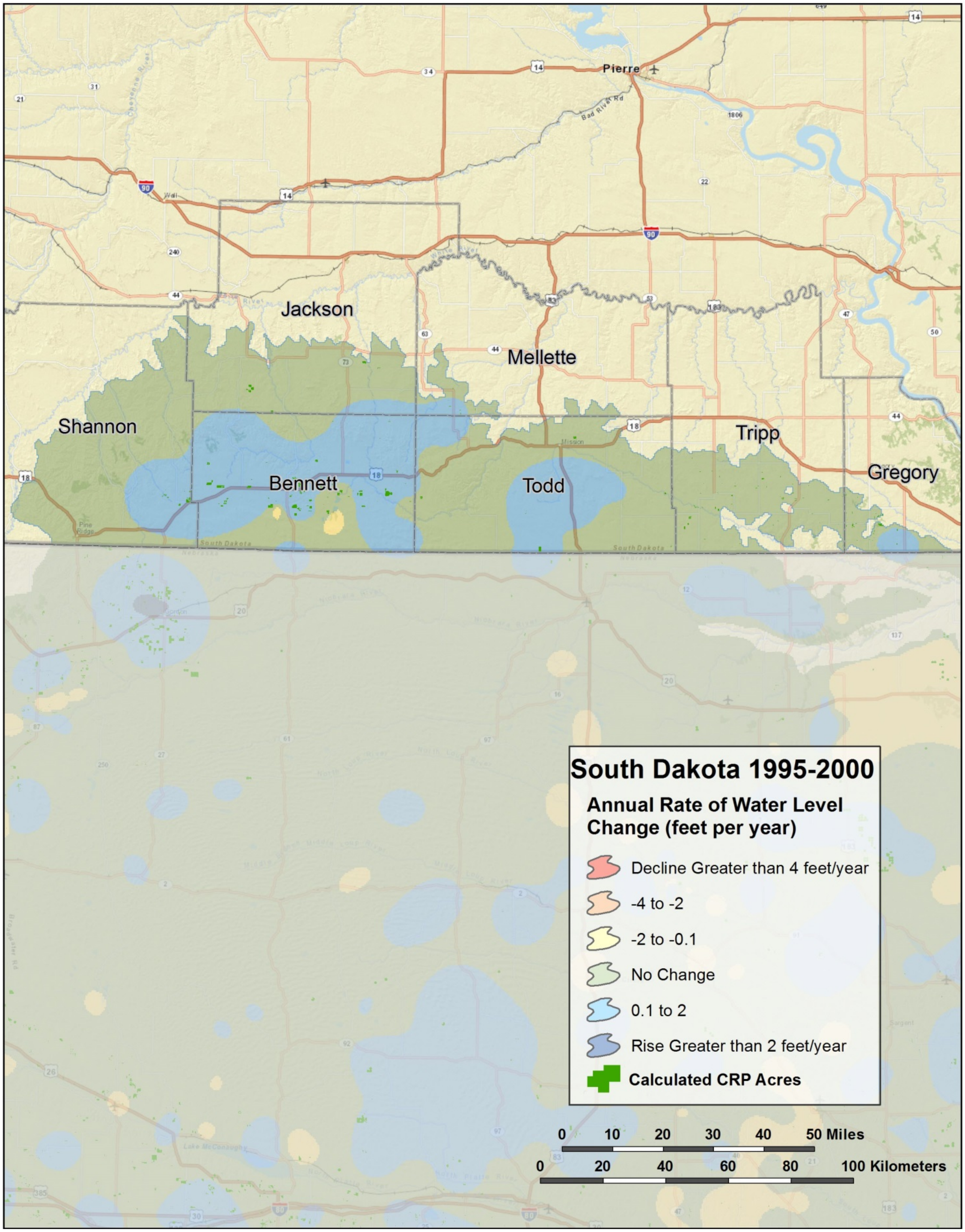

Figure 39. South Dakota CRP polygons for 2000 overlaid on water-level change, 1995-2000.

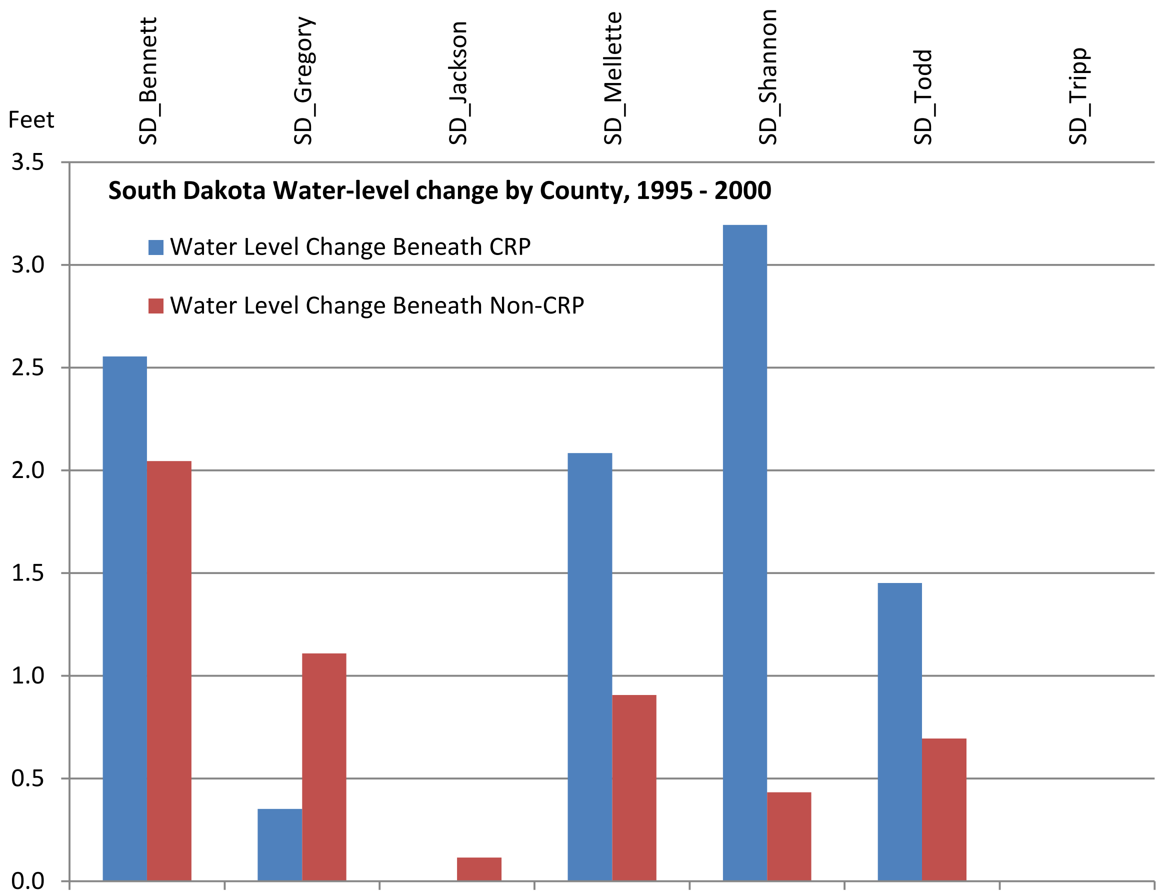

Figure 40. Comparison of water-level changes beneath CRP and non-CRP land, 1995-2000.

1995-2000 Mean Water-level Change						
State_County	**County water-level change (ft)**	**CRP water-level change (ft)**	**Non-CRP water-level change (ft)**	**Total County CRP Acres over the Aquifer**	**Total County Acres over the Aquifer**	**Percent of County over the Aquifer in CRP**
SD_Bennett	2.05	2.55	2.05	6,518	761,921	0.9
SD_Gregory	1.10	0.35	1.11	834	74,879	1.1
SD_Jackson	0.12	0.00	0.12	802	403,591	0.2
SD_Mellette	0.91	2.09	0.91	92	72,251	0.1
SD_Shannon	0.44	3.20	0.43	725	647,202	0.1
SD_Todd	0.70	1.45	0.69	697	815,267	0.1
SD_Tripp	0.00	0.00	0.00	892	325,210	0.3

Table 21. South Dakota water-level change beneath CRP and non-CRP land by county, 1995-2000.

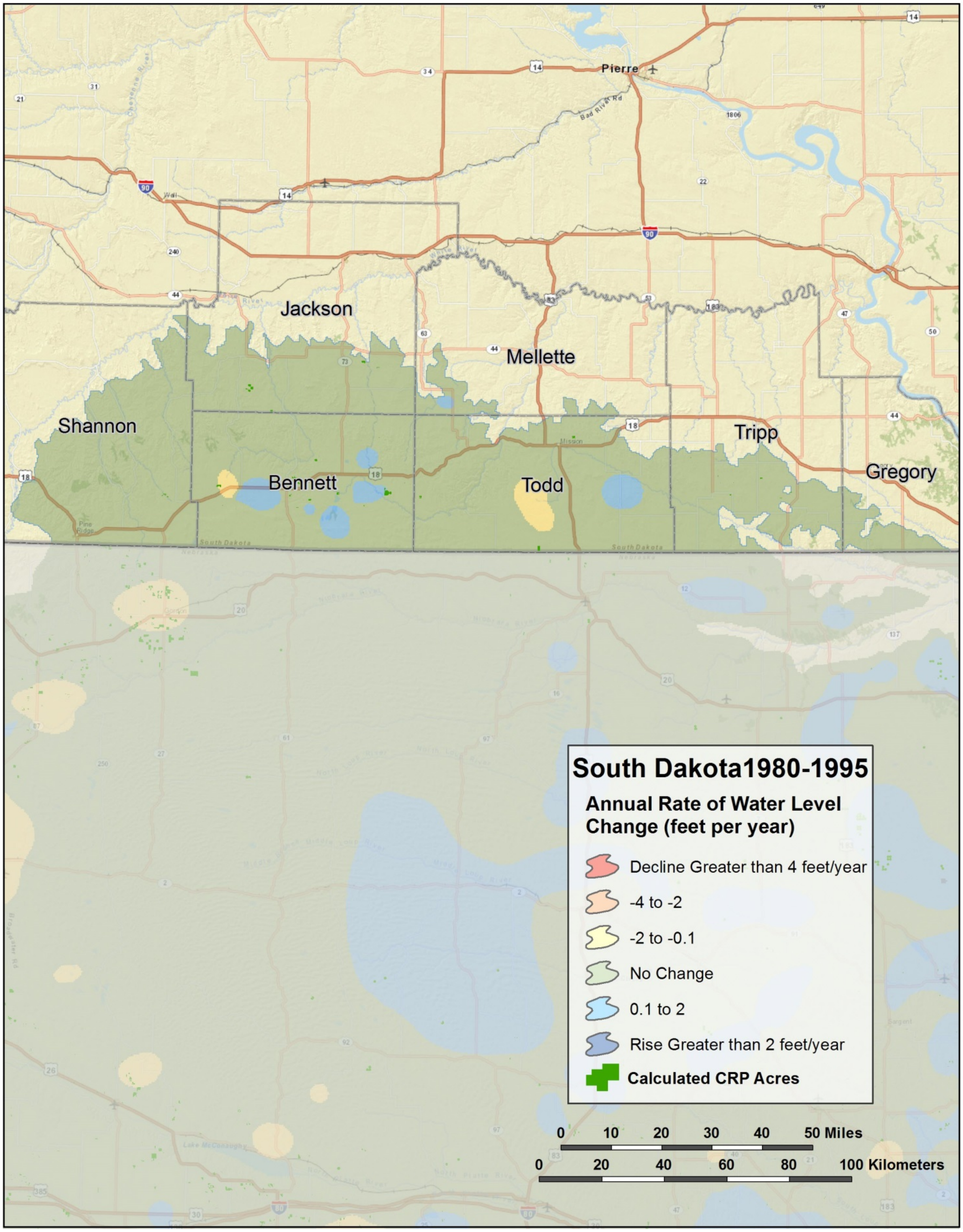

Figure 41. South Dakota CRP polygons for 1995 overlaid on water-level change, 1980-1995.

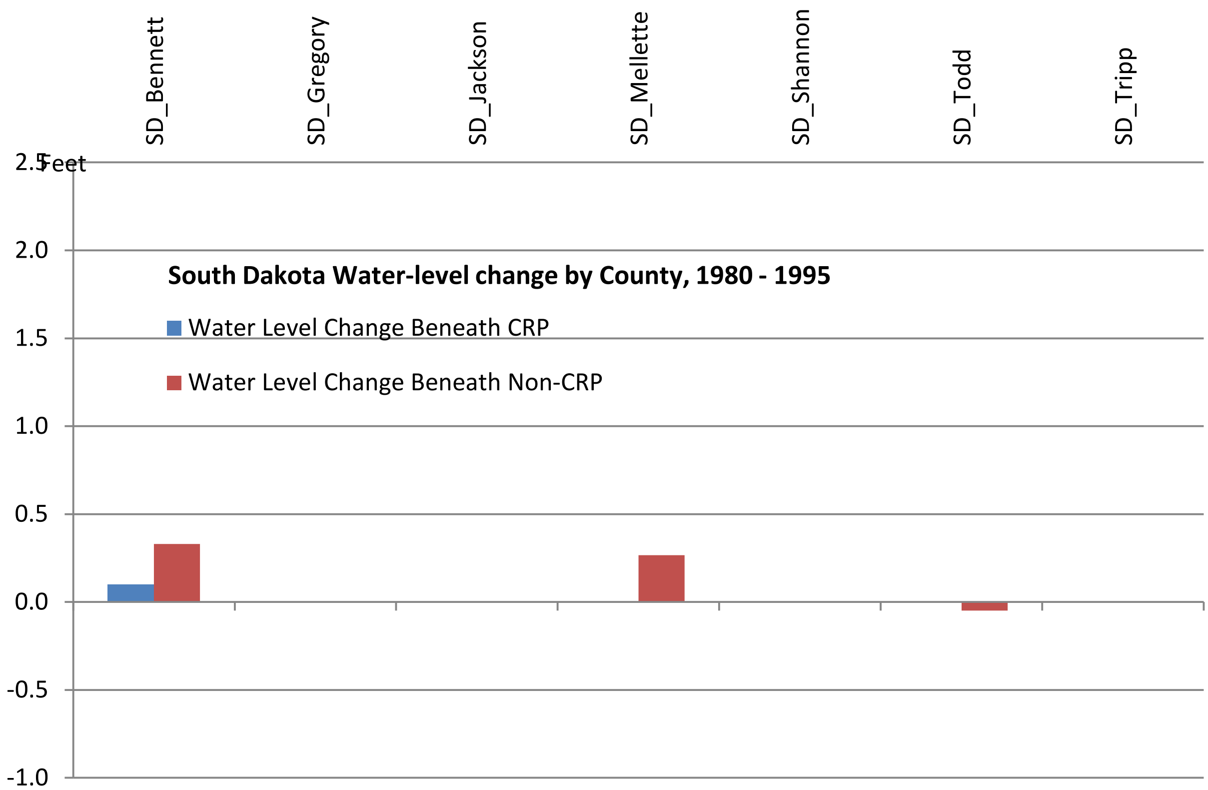

Figure 42. Comparison of water-level changes beneath CRP and non-CRP land, 1980-1995.

1980-1995 Mean Water-level Change						
State_County	**County water-level change (ft)**	**CRP water-level change (ft)**	**Non-CRP water-level change (ft)**	**Total County CRP Acres over the Aquifer**	**Total County Acres over the Aquifer**	**Percent of County over the Aquifer in CRP**
SD_Bennett	0.33	0.10	0.33	2,301	761,921	0.3
SD_Gregory	0.00	0.00	0.00	51	74,879	0.1
SD_Jackson	0.00	0.00	0.00	785	403,591	0.2
SD_Mellette	0.27	0.00	0.27	10	72,251	0.0
SD_Shannon	0.00	0.00	0.00	195	647,202	0.0
SD_Todd	-0.05	0.00	-0.05	551	815,267	0.1
SD_Tripp	0.00	0.00	0.00	207	325,210	0.1

Table 22. South Dakota water-level change beneath CRP and non-CRP land by county, 1980-1995.

Wyoming

CRP Effects on Water-level Change by County

Summary Results: Wyoming

In Wyoming, the High Plains Aquifer is located in the southeast corner of the state – with an area covering approximately 5.2 million acres (8,076 square miles) in five counties. The aquifer covers about 90 percent of Goshen and Laramie counties, 85 percent of Platte County, 43 percent of Niobrara County and pinches out in Converse County covering only 15 percent of the county. Most of the change in aquifer levels for these counties occurred in the same areas for each time period. All five counties experienced low mean annual changes in water level from 0 to 0.3 feet per year. In this part of the state, wheat was the dominant crop.

Goshen County had the greatest amount of CRP of any county about 5% or 67,200 acres (105 square miles) for the two most recent time intervals and about 86 square miles for the two older time intervals), however it exhibited a small amount of change with less than 0.3 feet decline county-wide for the 15-year period. What little change occurred were small declines beneath non-CRP for all time intervals. Areas beneath CRP showing no change for 1980-1995, 1995-2000 and 2005-2009. For the 2000-2005 interval, there was a small rise in water level of 0.1 foot beneath CRP compared to less than 0.1 foot decline beneath non-CRP.

Laramie and Platte counties had about 59,500 and 41,600 acres (93 and 65 square miles), respectively, in CRP (or less than 4% of the aquifer covered by CRP lands) for the two most recent time intervals. For the 1980-1995, 2000-2005 and 2005-2009 intervals, Laramie County showed significantly higher declines beneath CRP compared to non-CRP, except for 1995-2000 in which both areas showed rises. Platte County, on the other hand, showed higher declines beneath non-CRP for intervals 1980-1995, 2000-2005 and 2005-2009, while interval 1995-2000 showed about the same amount of rise.

Niobrara County had less than 1.5% or about 9,600 acres (15 square miles) of the county in CRP for the first two time intervals and less than 0.5% or about 5 square miles in CRP for the two older intervals. Small differences in changes between CRP and non-CRP lands were noted for intervals 1995-2000, 2000-2005 and 2005-2009 with slightly more declines beneath CRP for 1980-1995. Converse County with less than 1% of its area or about 3,840 acres (6 square miles) in CRP showed no change in aquifer level beneath CRP and non-CRP lands for all four time intervals.

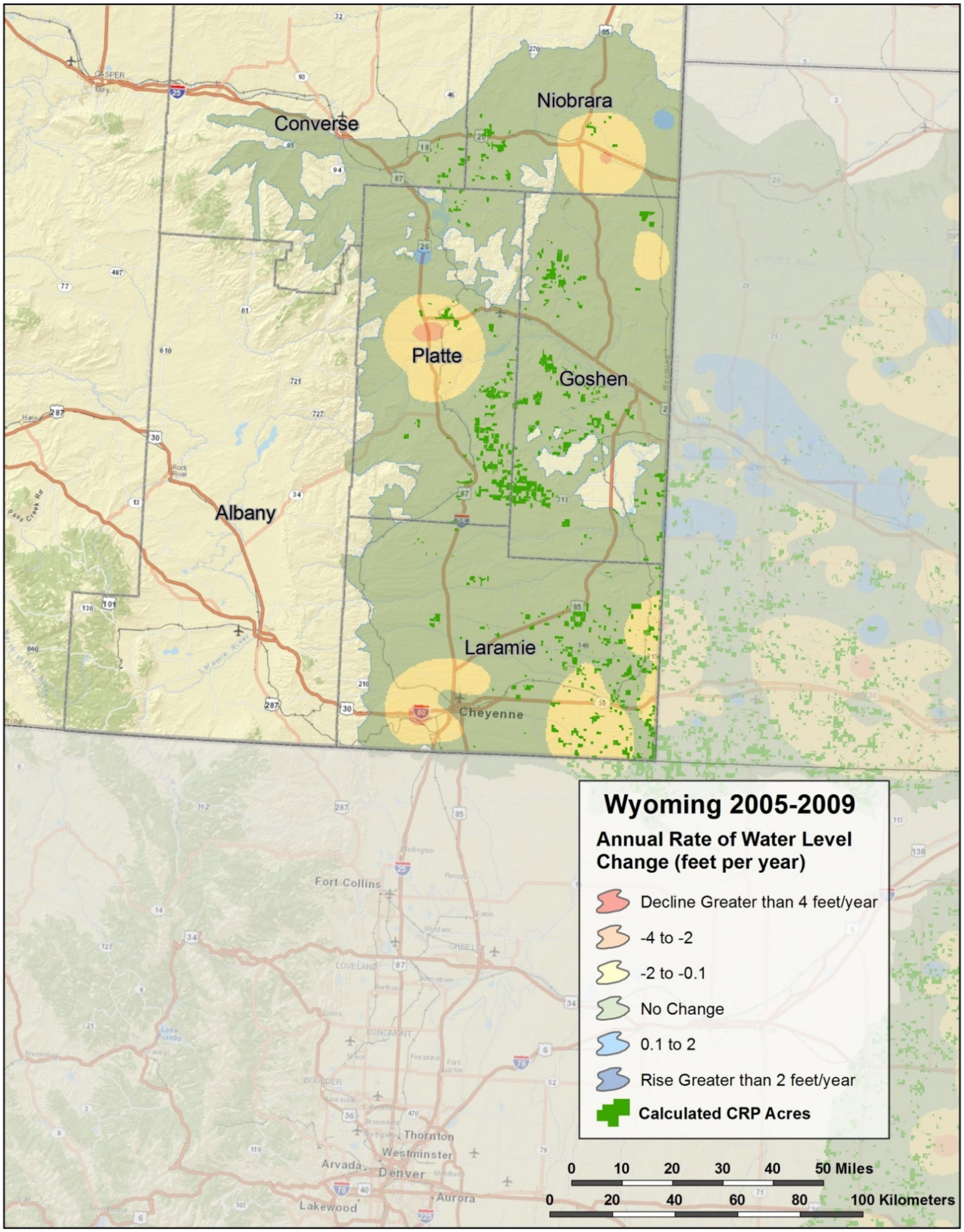

Figure 43. Wyoming CRP polygons for 2009 overlaid on water-level change, 2005-2009.

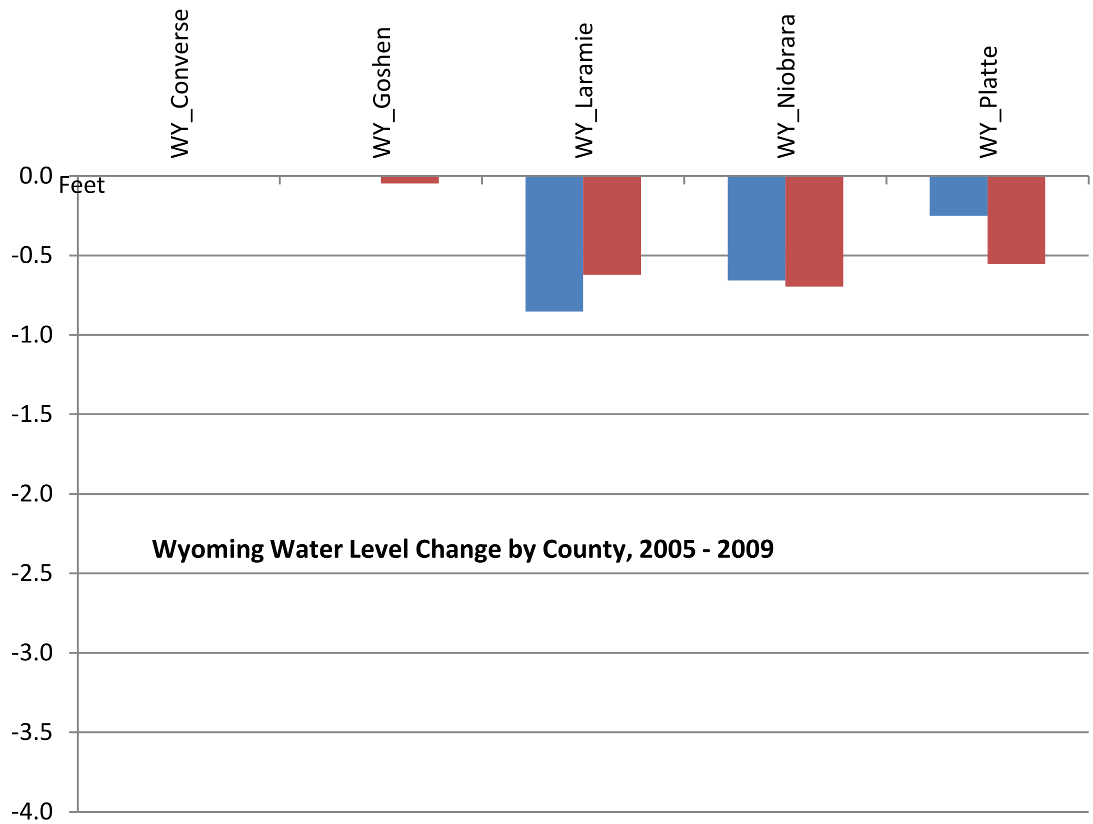

Figure 44. Comparison of water-level changes beneath CRP and non-CRP land, 2005-2009.

2005-2009 Mean Water-level Change						
State_County	County water-level change (ft)	CRP water-level change (ft)	Non-CRP water-level change (ft)	Total County CRP Acres over the Aquifer	Total County Acres over the Aquifer	Percent of County over the Aquifer in CRP
WY_Converse	0.00	0.00	0.00	1,993	420,371	0.5
WY_Goshen	-0.05	0.00	-0.05	55,176	1,282,687	4.3
WY_Niobrara	0.00	0.00	0.00	3,241	725,129	0.4
WY_Platte	0.21	0.19	0.21	15,340	1,151,469	1.3
WY_Goshen	-0.05	0.00	-0.05	55,176	1,282,687	4.3

Table 23. Wyoming water-level change beneath CRP and non-CRP land by county, 2005-2009.

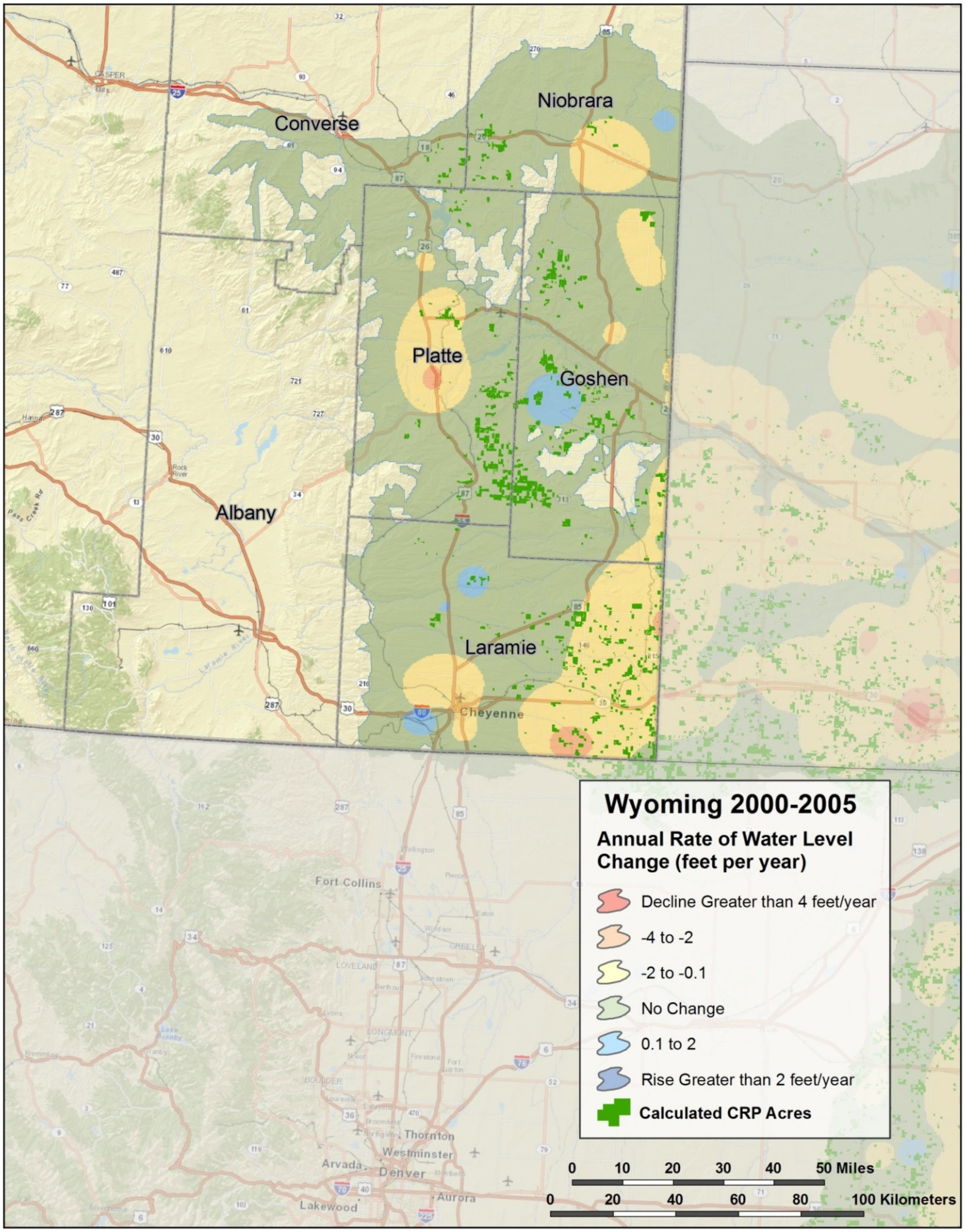

Figure 45. Wyoming CRP polygons for 2005 overlaid on water-level change, 2000-2005.

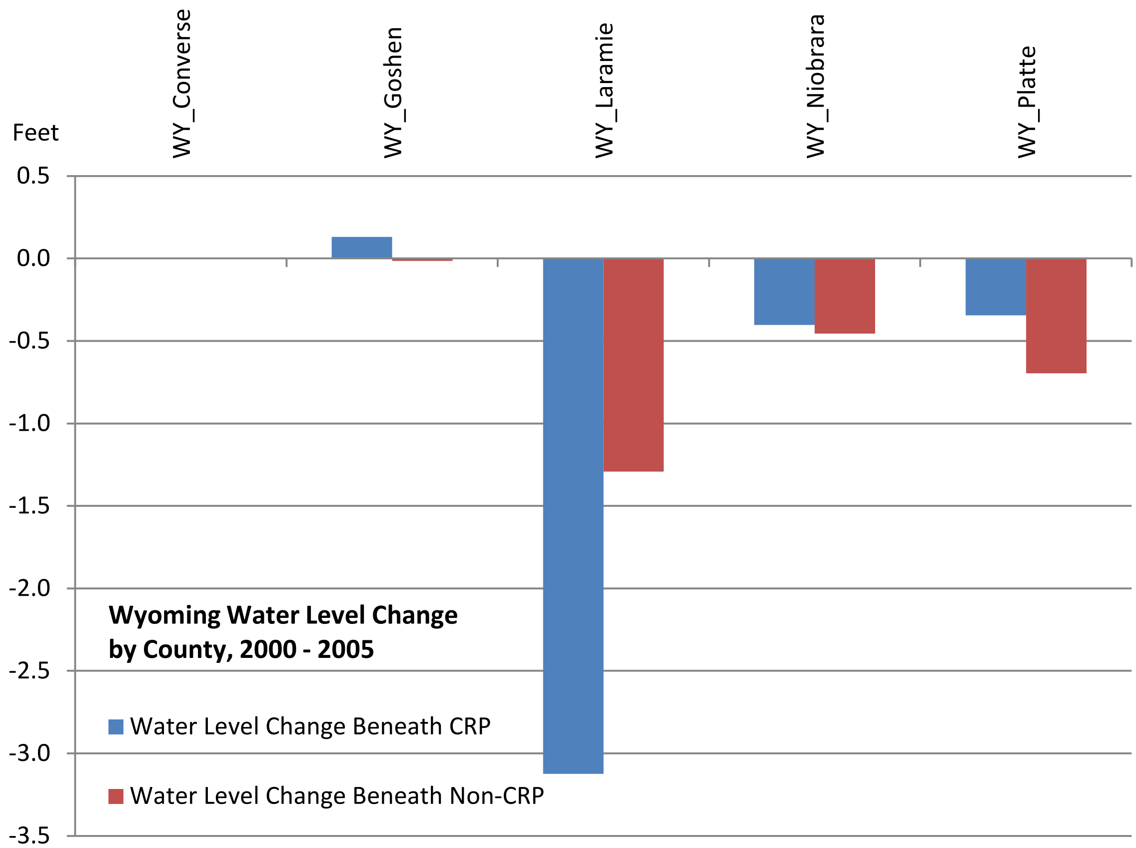

Figure 46. Comparison of water-level changes beneath CRP and non-CRP land, 2000-2005.

2000-2005 Mean Water-level Change						
State_County	**County water-level change (ft)**	**CRP water-level change (ft)**	**Non-CRP water-level change (ft)**	**Total County CRP Acres over the Aquifer**	**Total County Acres over the Aquifer**	**Percent of County over the Aquifer in CRP**
WY_Converse	0.00	0.00	0.00	3,770	420,371	0.9
WY_Goshen	-0.01	0.13	-0.02	67,488	1,282,687	5.3
WY_Laramie	-1.36	-3.12	-1.29	59,791	1,589,321	3.8
WY_Niobrara	-0.46	-0.40	-0.46	9,935	725,129	1.4
WY_Platte	-0.68	-0.34	-0.70	41,396	1,151,469	3.6

Table 24. Wyoming water-level change beneath CRP and non-CRP land by county, 2000-2005.

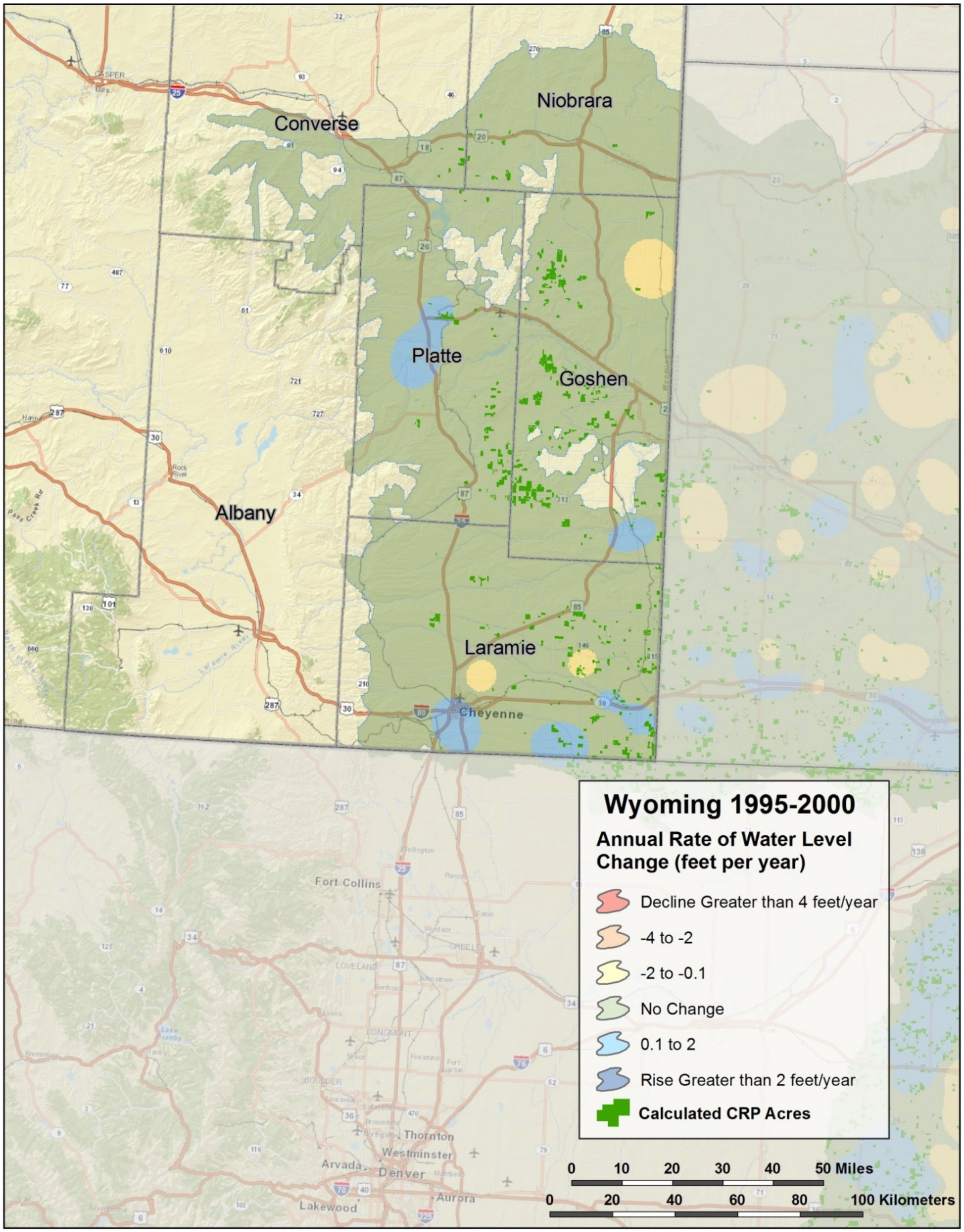

Figure 47. Wyoming CRP polygons for 2000 overlaid on water-level change, 1995-2000.

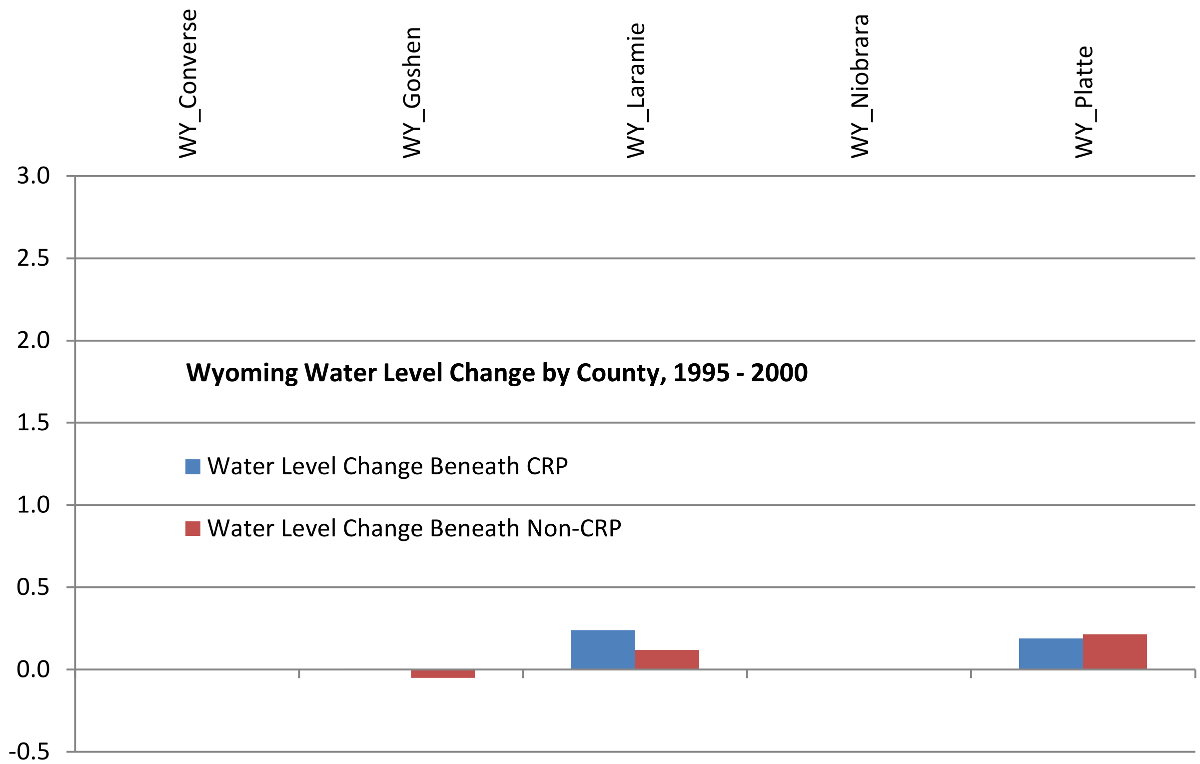

Figure 48. Comparison of water-level changes beneath CRP and non-CRP land, 1995-2000.

1995-2000 Mean Water-level Change						
State_County	County water-level change (ft)	CRP water-level change (ft)	Non-CRP water-level change (ft)	Total County CRP Acres over the Aquifer	Total County Acres over the Aquifer	Percent of County over the Aquifer in CRP
WY_Converse	0.00	0.00	0.00	1,993	420,371	0.5
WY_Goshen	-0.05	0.00	-0.05	55,176	1,282,687	4.3
WY_Laramie	0.12	0.24	0.12	34,220	1,589,321	2.2
WY_Niobrara	0.00	0.00	0.00	3,241	725,129	0.4
WY_Platte	0.21	0.19	0.21	15,340	1,151,469	1.3

Table 25. Wyoming water-level change beneath CRP and non-CRP land by county, 1995-2000.

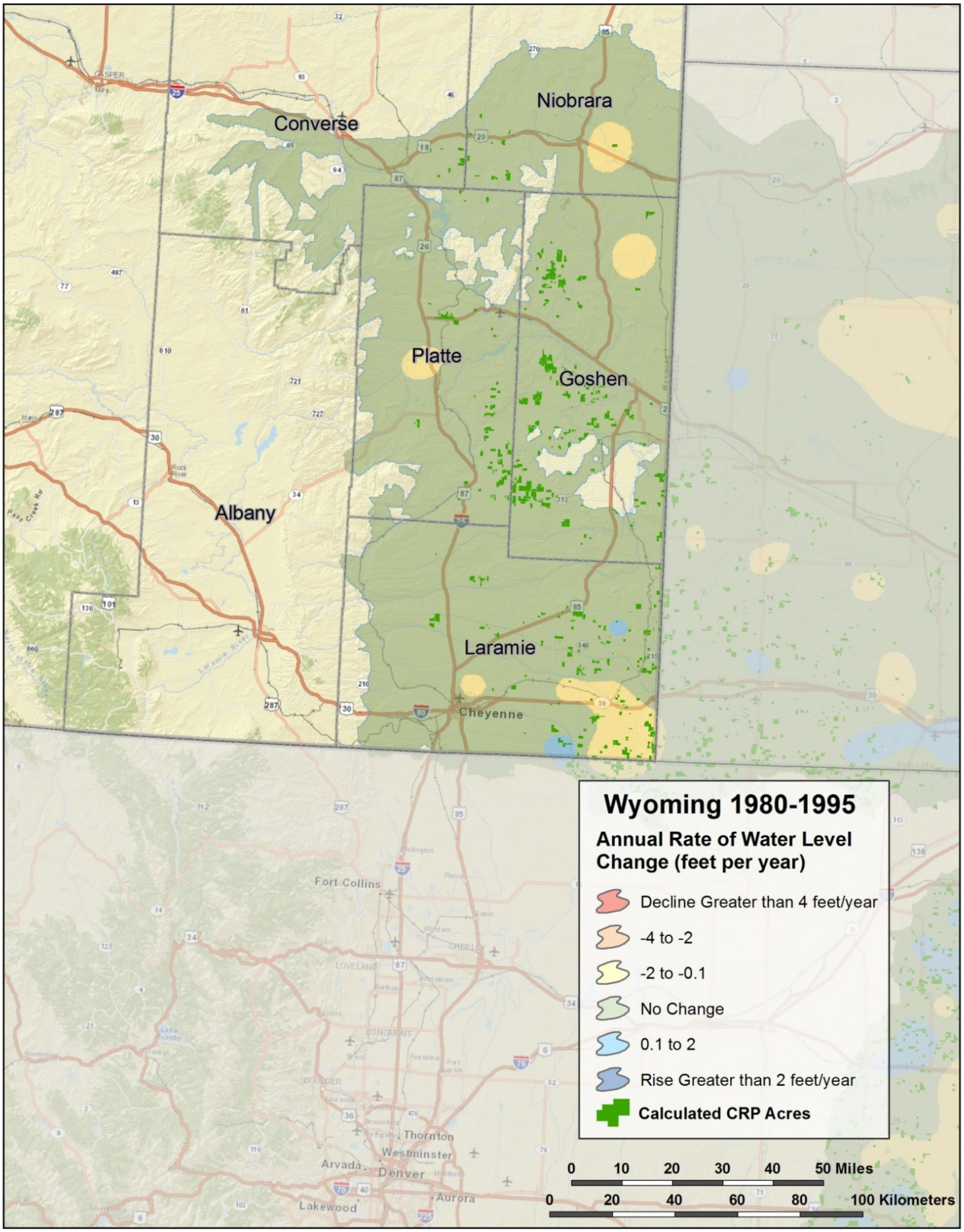

Figure 49. Wyoming CRP polygons for 1995 overlaid on water-level change, 1980-1995.

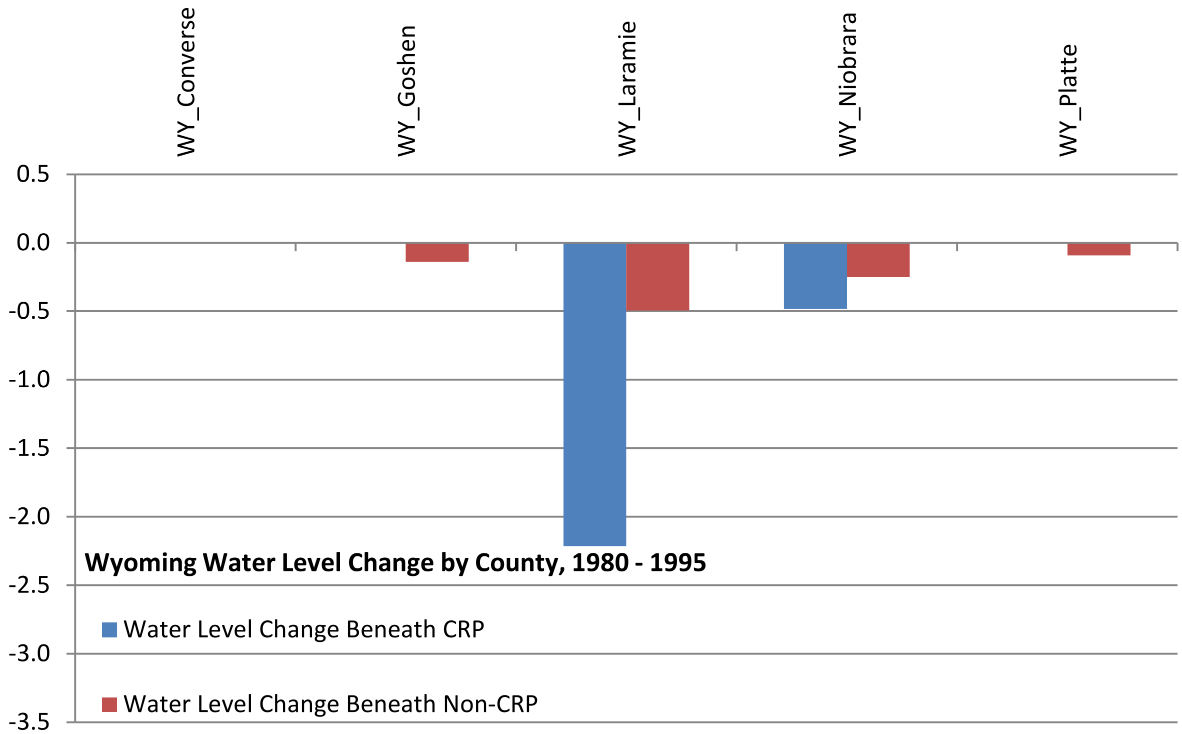

Figure 50. Comparison of water-level changes beneath CRP and non-CRP land, 1980-1995.

1980-1995 Mean Water-level Change						
State_County	**County water-level change (ft)**	**CRP water-level change (ft)**	**Non-CRP water-level change (ft)**	**Total County CRP Acres over the Aquifer**	**Total County Acres over the Aquifer**	**Percent of County over the Aquifer in CRP**
WY_Converse	0.00	0.00	0.00	1,992	420,371	0.5
WY_Goshen	-0.13	0.00	-0.14	55,056	1,282,687	4.3
WY_Laramie	-0.53	-2.21	-0.49	31,268	1,589,321	2.0
WY_Niobrara	-0.25	-0.48	-0.25	3,229	725,129	0.4
WY_Platte	-0.09	0.00	-0.09	14,940	1,151,469	1.3

Table 26. Wyoming water-level change beneath CRP and non-CRP land by county, 1980-1995.

Discussion

Analysis of Water-Level Change by State and Region

Table 27 shows the water-level change beneath CRP land and non-CRP land calculated as the mean for each state. Non-CRP land also contains native grassland that has never been irrigated. Therefore the results of CRP benefits might be considered conservative. When the water-level change is calculated on a state-wide basis, Texas and New Mexico stand out showing negative water-level changes beneath both CRP and non-CRP land across all four time intervals. While this finding indicates that the overall declines in these two states exceed any local rises in the water tables, it is important to note that the declines beneath CRP land were consistently less than the declines beneath non-CRP land across all four time intervals. Thus, the state-wide data for Texas and New Mexico suggest that CRP land provides a measurable benefit.

In Nebraska, the water-level changes were positive beneath CRP and non-CRP land in the two earlier time intervals. In each case, however, the rises beneath CRP land were less than the rises beneath non-CRP land. In the 2000-2005 time interval, the water-level change was negative beneath CRP and non-CRP land with the declines beneath CRP land exceeding those of non-CRP land. Similarly, in the 2005-2009 interval, there was a negative water-level change beneath CRP land and a positive water-level change beneath non-CRP land. For each time interval, the Nebraska state-wide data do not show any measurable benefit. Only 0.6 to 1.7 percent of the area overlying the Ogallala was in CRP during the four analysis periods. This is not a sufficiently contiguous nor large enough area to justify strong state-wide or regional conclusions about the impact of CRP on groundwater levels.

In Wyoming the results were mixed. In the 2005-2009 interval the declines beneath CRP land were less than the declines beneath non-CRP land, but the opposite was true for the 2000-2005 time interval. During the 1995-2000 interval, the water-level changes were positive beneath CRP land and non-CRP land, and the rises were greater under CRP. In the 1980-1995 interval, the water-level changes were negative and the declines were greater under CRP.

Lastly, in South Dakota, results were also mixed. In the two most recent time intervals there were negative water-level changes under CRP land and non-CRP land. In the two early time intervals the water-level changes were positive under both CRP land and non-CRP land, but only the 1995-2000 time intervals showed a positive benefit. Only 0.1 to 0.4 percent of the area overlying the Ogallala was in CRP during the four analysis periods which is not sufficiently contiguous nor large to provide justify strong state-wide or regional conclusions about the impact of CRP on groundwater levels.

WLC Time Interval	% CRP	% Non-CRP	Mean WLC Beneath CRP Land (feet)	Mean WLC Beneath Non-CRP Land (feet)	CRP Benefit % (Non-CRP - CRP)/ Non-CRP
NEBRASKA					
2005-2009	1.7	98.3	-0.174	0.464	No Benefit
2000-2005	1.6	98.4	-3.444	-2.971	No Benefit
1995-2000	1.0	99.0	0.149	0.358	No Benefit
1980-1995	0.6	99.4	0.108	1.167	No Benefit
NEW MEXICO					
2005-2009	6.7	93.3	-0.194	-0.682	Benefit (71.60%)
2000-2005	6.7	93.3	-0.927	-1.442	Benefit (35.68%)
1995-2000	5.2	94.8	-0.598	-1.395	Benefit (57.14%)
1980-1995	3.1	96.9	-0.369	-2.193	Benefit (83.18%)
SOUTH DAKOTA					
2005-2009	0.4	99.6	-0.507	-0.267	No Benefit
2000-2005	0.4	99.6	-0.802	-0.669	No Benefit
1995-2000	0.3	99.7	1.938	0.837	Benefit (131.54%)
1980-1995	0.1	99.9	0.055	0.075	No Benefit
TEXAS					
2005-2009	10.6	89.4	-1.933	-2.692	Benefit (28.20%)
2000-2005	10.5	89.5	-2.241	-2.814	Benefit (20.35%)
1995-2000	6.7	93.3	-4.092	-4.788	Benefit (14.54%)
1980-1995	5.1	94.9	-0.792	-4.542	Benefit (82.56%)
WYOMING					
2005-2009	3.5	96.5	-0.372	-0.426	Benefit (12.58%)
2000-2005	3.5	96.5	-1.076	-0.620	No Benefit
1995-2000	2.1	97.9	0.103	0.073	Benefit (41.66%)
1980-1995	2.1	97.9	-0.665	-0.242	No Benefit

Table 27. Comparison of mean water-level change (WLC) beneath calculated CRP and non-CRP land in Nebraska, New Mexico, South Dakota, Texas, Wyoming and the study region as a whole.

Analysis of Water-Level Change by State and Region for Aquifer Saturated Thickness Over 30 Feet

One issue with drawing broad conclusions from the data in Table 27 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 enhanced recharge, but the local saturated thickness must be significantly larger than 30 feet to support irrigation withdrawals. In addition, in many of these locations, the local saturated thickness is directly affected by local highs in the elevation of the base of the aquifer that encourage the groundwater to flow laterally toward locations with lower base elevations (Center for Geospatial Technology, 2014).

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 51 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 are near the fringe of the aquifer or at internal locations with locally high aquifer base elevation relative to the land surface and are not suitable for large-volume irrigation, although some CRP land is located over these areas of the aquifer. In particular, New Mexico, Texas and Wyoming have a noticeable number of CRP contracts in areas where the aquifer is relatively thin. It should be noted that the CRP originally intended to take land out of cultivation to reduce erosion losses, not to reduce irrigation water use. These areas of locally thin saturated thickness were often historically dryland farms, and the lack of potential irrigation water could have encouraged the landowners to enroll these properties in CRP.

Table 28 shows the water-level changes 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. For these areas, the water level declines and water-level rises were almost all greater beneath CRP and non-CRP land than the values in Table 27. Only in Nebraska did we find that the declines beneath CRP land were slightly less during the 2005-2009 interval, and the rises were slightly less during the 1980-1995 interval.

If we now consider only these areas where the aquifer is greater than 30 feet and there is the potential for irrigated agriculture, the end results of the analysis varied by state (Table 28). For Nebraska, the data suggest no benefit provided by CRP land, but again only 1.6 percent or less of the aquifer area had been converted into CRP. In South Dakota there was no observed benefit in three of the time intervals with 0.4 percent or less of the aquifer area converted to CRP, and in Wyoming there was no benefit in two of the time intervals. In contrast, the data for Texas and New Mexico showed strong benefits provided by CRP land across all four time intervals, and the benefit increased in the three most recent time intervals compared to the data in Table 27. In other words, when the analysis considers only those areas with a potential for irrigated agriculture, the benefits of CRP land tend to be larger in these two states.

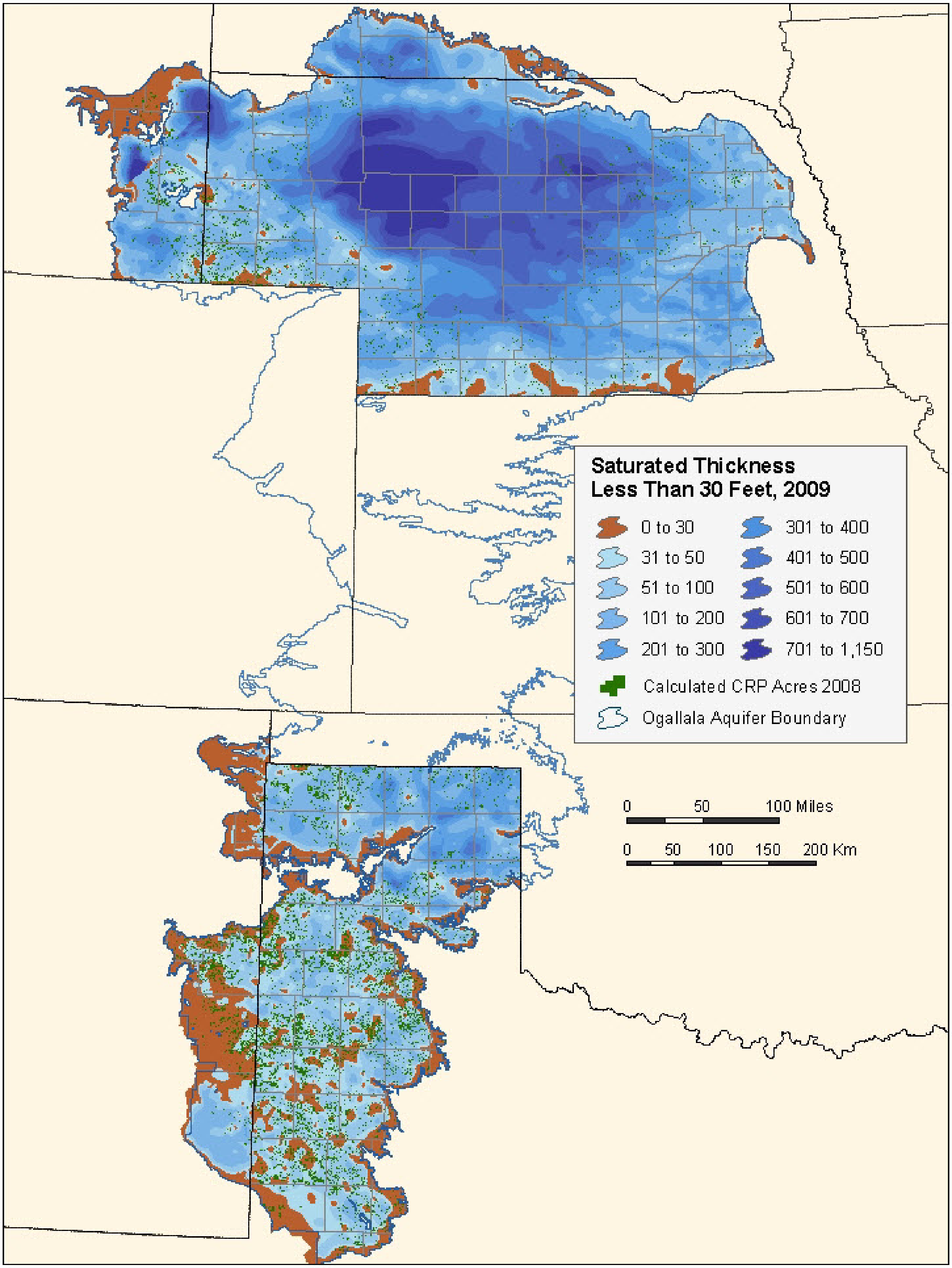

Figure 51. Saturated thickness of the aquifer in 2009 highlighting those areas where the saturated thickness is less than 30 feet.

WLC Time Interval	% CRP	% Non-CRP	Mean WLC Beneath CRP Land (feet)	Mean WLC Beneath Non-CRP Land (feet)	CRP Benefit % (Non-CRP - CRP)/ Non-CRP
NEBRASKA					
2005-2009	1.6	98.4	-0.123	0.485	No Benefit
2000-2005	1.5	98.5	-3.573	-3.055	No Benefit
1995-2000	0.9	99.1	0.158	0.369	No Benefit
1980-1995	0.6	99.4	0.093	1.195	No Benefit
NEW MEXICO					
2005-2009	7.0	93.0	-0.419	-1.489	Benefit (71.83%)
2000-2005	7.0	93.0	-1.342	-2.325	Benefit (42.28%)
1995-2000	4.8	95.2	-0.771	-2.653	Benefit (70.94%)
1980-1995	2.9	97.1	-0.955	-4.511	Benefit (78.84%)
SOUTH DAKOTA					
2005-2009	0.4	99.6	-0.638	-0.336	No Benefit
2000-2005	0.4	99.6	-0.969	-0.811	No Benefit
1995-2000	0.4	99.6	2.273	1.051	Benefit (116.40%)
1980-1995	0.2	99.8	0.061	0.094	No Benefit
TEXAS					
2005-2009	10.9	89.1	-2.043	-3.145	Benefit (35.04%)
2000-2005	10.7	89.3	-2.423	-3.306	Benefit (26.70%)
1995-2000	6.8	93.2	-4.594	-5.627	Benefit (18.365)
1980-1995	5.2	94.8	-1.074	-5.572	Benefit (80.72%)
WYOMING					
2005-2009	4.4	95.6	-0.394	-0.584	Benefit (32.52%)
2000-2005	4.4	95.6	-1.116	-0.837	No Benefit
1995-2000	2.7	97.3	0.113	0.099	Benefit (13.265)
1980-1995	2.6	97.4	-0.729	-0.321	No Benefit

Table 28. Comparison of mean water-level change (WLC) beneath calculated 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 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 27 and 28 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, most producers will 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-volume irrigated agriculture. In these counties, the water table will tend to be more stable – with either small declines or small rises. For purposes of this project, critical counties are defined as having 1 foot per year or greater decline in water level.

Figures 52 and 53 show the water-level changes for the entire study area, highlighting those counties with the greatest water-level declines. Comparing the two maps the overall patterns are similar in Texas and New Mexico, but there is a very obvious difference in Nebraska. During the period from 2005 to 2009 (Figure 52), the map shows noteworthy rises in the water table in the eastern half of Nebraska. During the period from 2000 to 2005 (Figure 53), the water levels 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 received precipitation during the 2005-2009 time interval that was well above normal (Appendix IV).

In the most recent time interval (Figure 52), the greatest water-level declines were focused in 12 critical counties. For the 2005-2009 time interval, 11 of the critical counties were located in Texas and one was located in Nebraska. In Texas the greatest water-level declines occurred in Castro, Parmer, Lamb, Hale, Dallam, Gaines, Sherman, Moore, Richardson, Hartley and Hansford counties. In Nebraska, only Perkins County averaged a water-level decline greater than 1 foot per year. Relative to the Texas counties mentioned, Perkins County has recently undergone a large increase in irrigation by adding center pivots (since the early 1990s).

In the 2000-2005 time interval, 29 critical counties were identified both Texas and Nebraska. In Texas these were the same 11 counties identified in the 2005-2009 interval, plus Terry County. In Nebraska the remaining 17 counties included York, Clay, Platte, Fillmore, Seward, Chase, Merrick, Polk, Perkins, Kearney, Dundy, Hamilton, Buffalo, Box Butte, Adams, Hall and Butler. These counties mostly contain Rainwater Basin wetlands and are the largest corn producers. Very little CRP occurs in the Rainwater Basin compared to areas like Perkins county.

Comparing Figures 52 and 53, in Texas and New Mexico there also appeared to be slightly more declines in the earlier 2000-2005 time period, but this is largely the result of the different years of record. The 2000-2005 time interval covers five years of record, whereas the 2005-2009 time interval covers only four years. Thus, the total water-level decline for the 2000-2005 interval is somewhat greater.

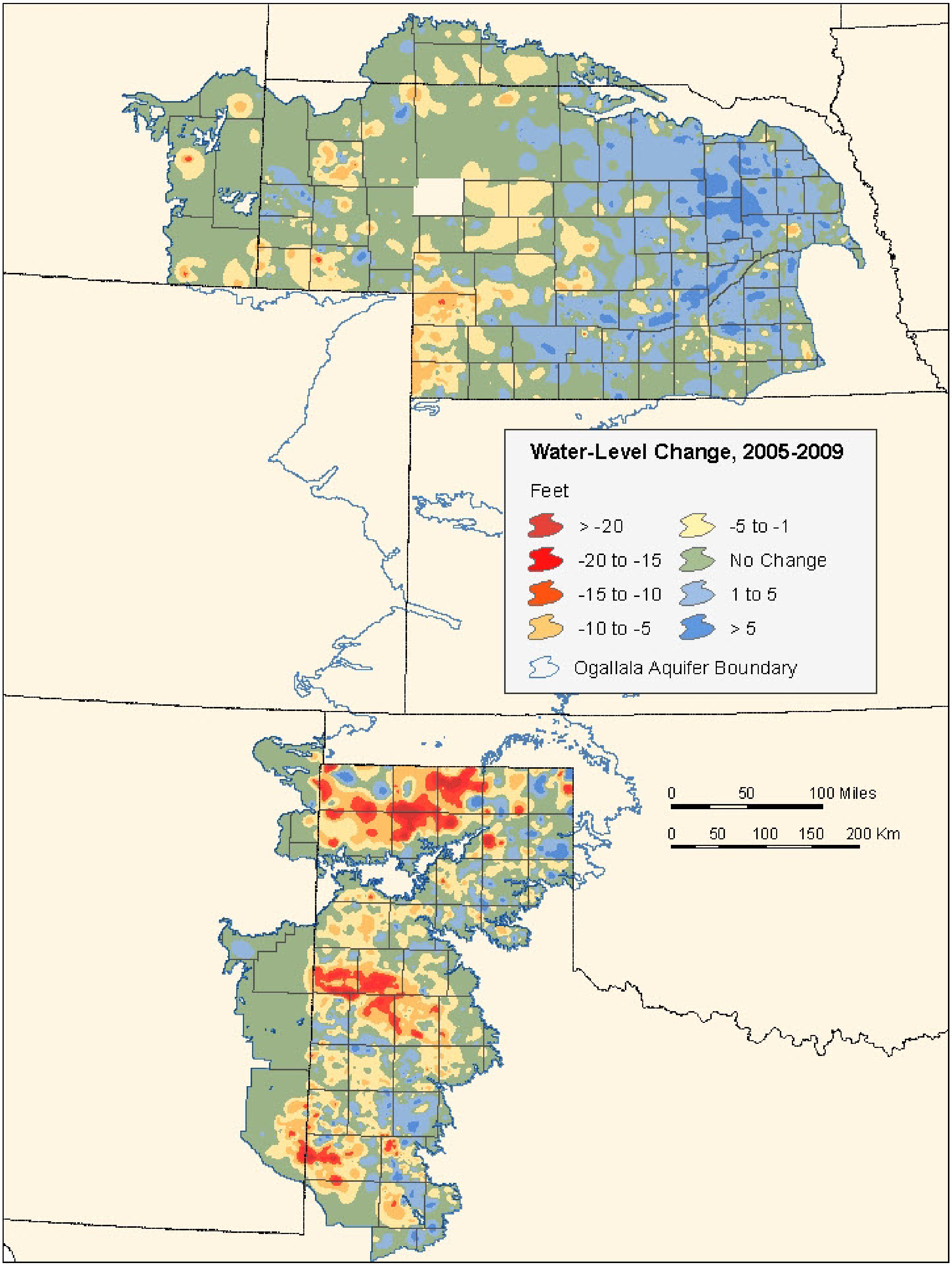

Figure 52. Water-level change, 2005-2009.

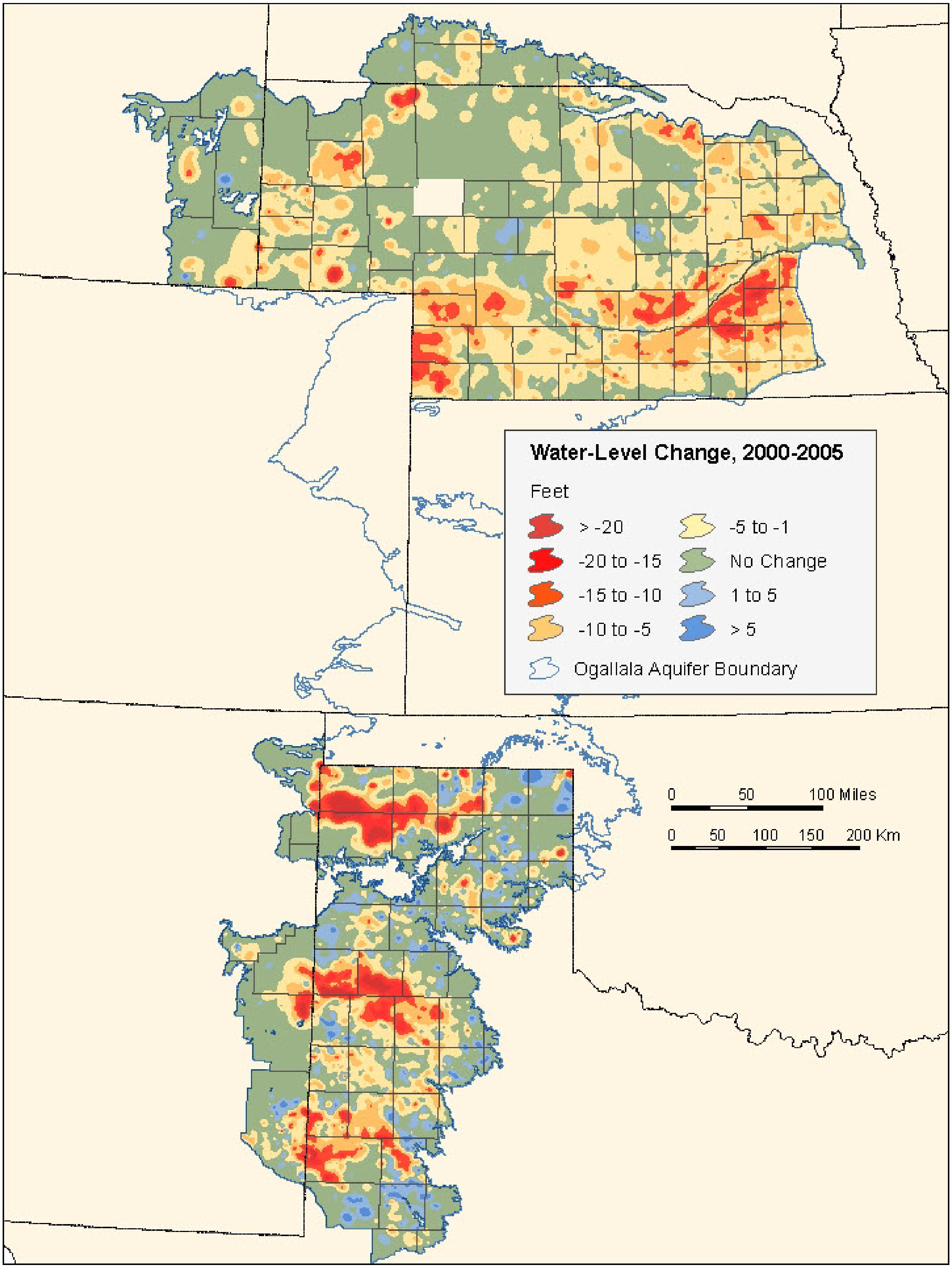

Figure 53. Water-level change, 2000-2005.

To assess the effects of CRP land on the aquifer in these 12 and 29 critical counties, the differences in the water-level changes beneath CRP land and non-CRP land were used to calculate the net benefits 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.

Figures 54 to 56 shows the water-level changes during the 2005-2009 time interval, the net benefit of CRP land, and the percent of the county area that lies over the aquifer that was enrolled in CRP in 2008. In eight of the 12 Texas counties, the water-level declines beneath CRP land were less than the water-level declines beneath non-CRP land. Consequently, these differences result in positive net benefits for the eight counties. Of these, the greatest benefits were calculated for Castro, Parmer, lamb, Hale, Dallam, Gaines and Sherman County in Texas and Perkins County in Nebraska. While there were also large declines in Moore, Richardson, Hartley and Hansford counties, the water-level declines beneath CRP land in these Texas counties were greater than the declines beneath non-CRP land. This possibly is due to these counties having more native grassland which would make it more difficult to identify differences in decline under CRP versus non-CRP.

In a similar manner, Figures 57 to 59 show the data for the 2000-2005 time interval. During this period the declines beneath CRP land were less than the declines beneath non-CRP land in 23 of the 29 counties. Of the 12 Texas critical counties, Castro, Parmer, Lamb and Dallam counties were among the top counties in terms of greatest positive benefits. Of the 17 Nebraska critical counties, there were less declines beneath CRP land in 13 counties. In this case, the greatest benefits were recorded in York and Clay counties.

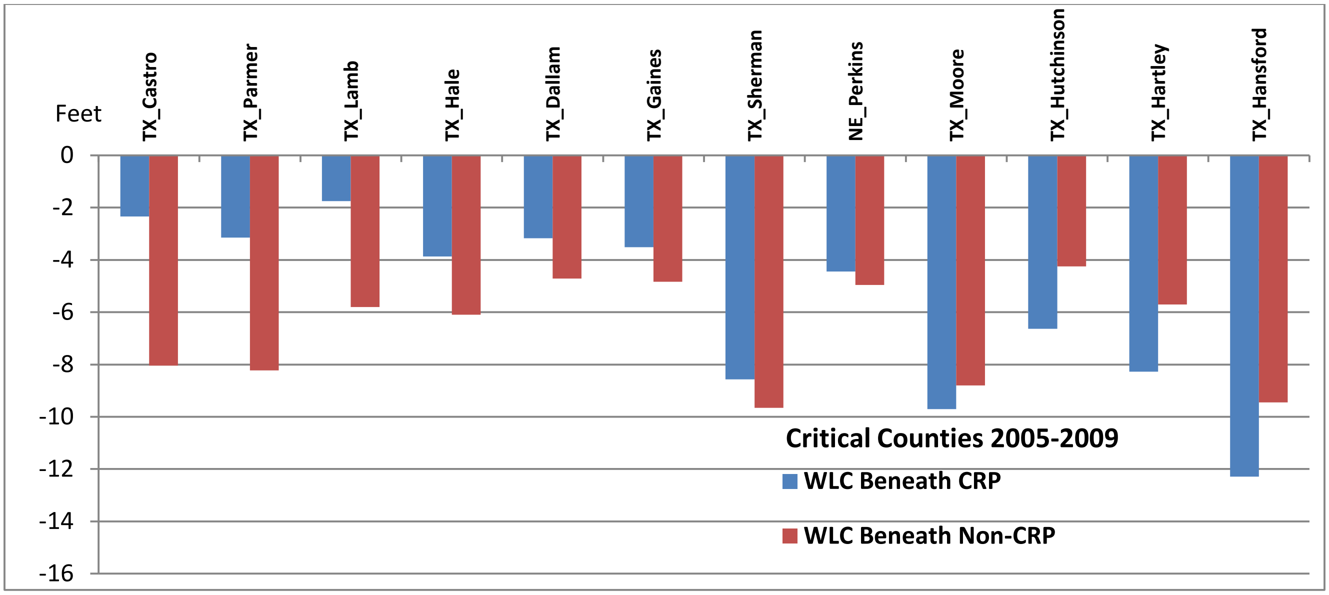

Figure 54. Comparison of water-level change for critical counties, 2005-2009.

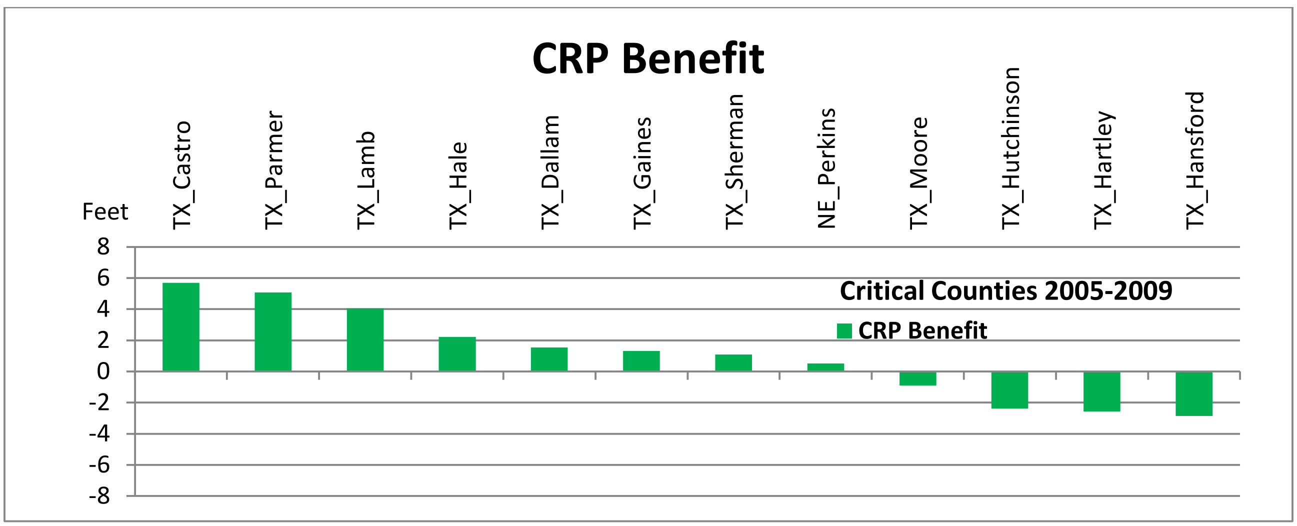

Figure 55. CRP benefit in feet in critical counties, 2005-2009.

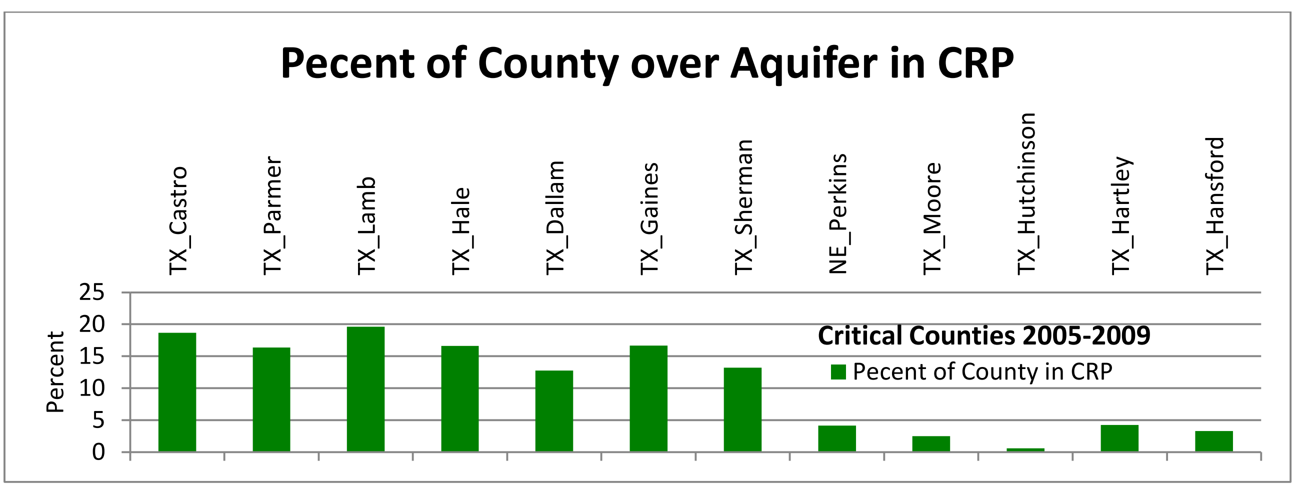

Figure 56. Percent of the county over the aquifer in CRP, 2005-2009.

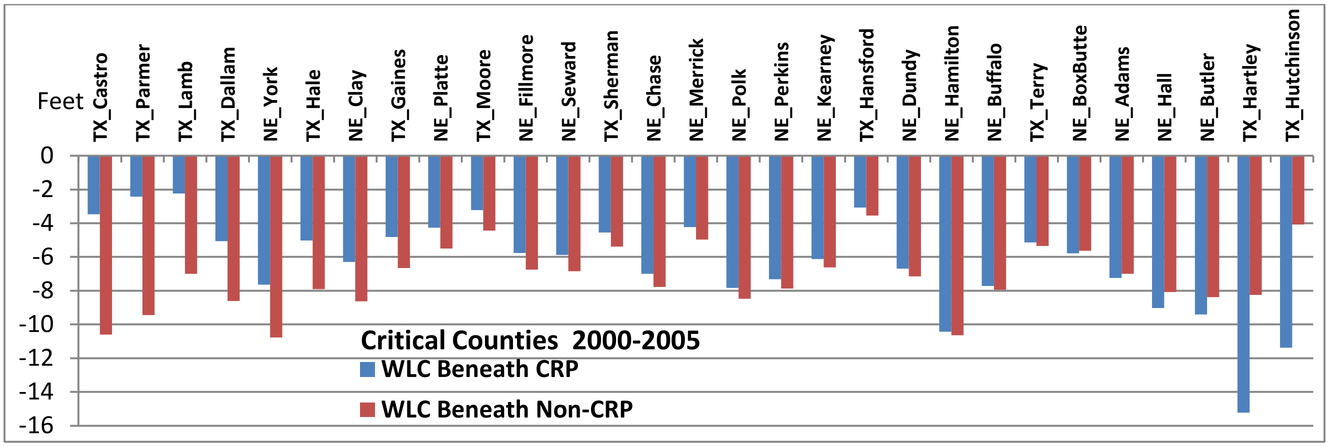

Figure 57. Comparison of water-level changes for critical counties, 2000-2005.

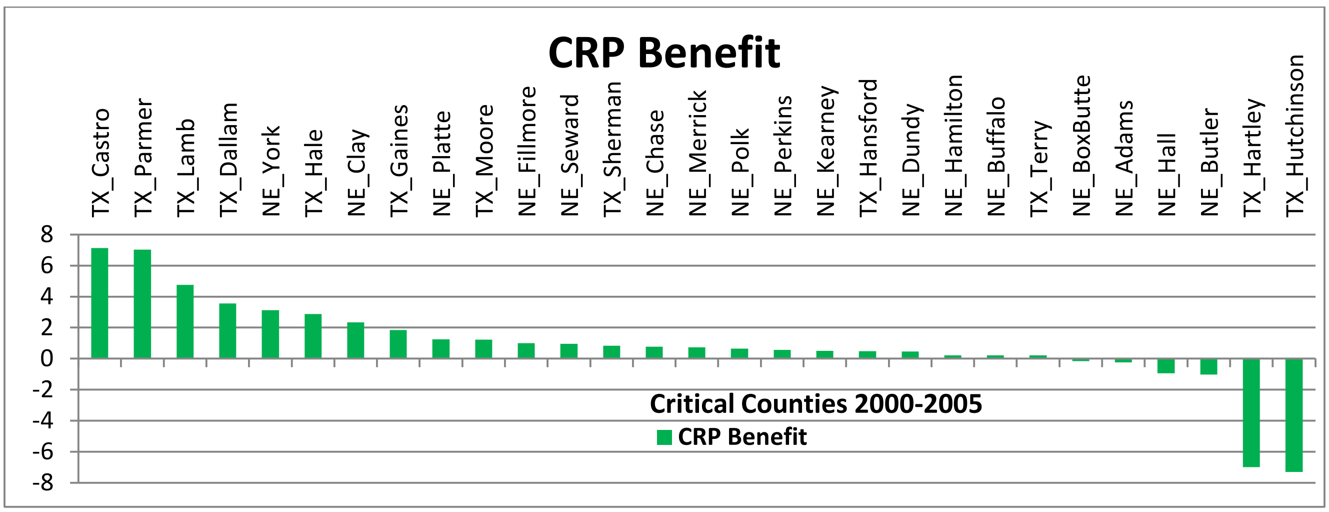

Figure 58. CRP benefit in critical counties for critical counties, 2000-2005.

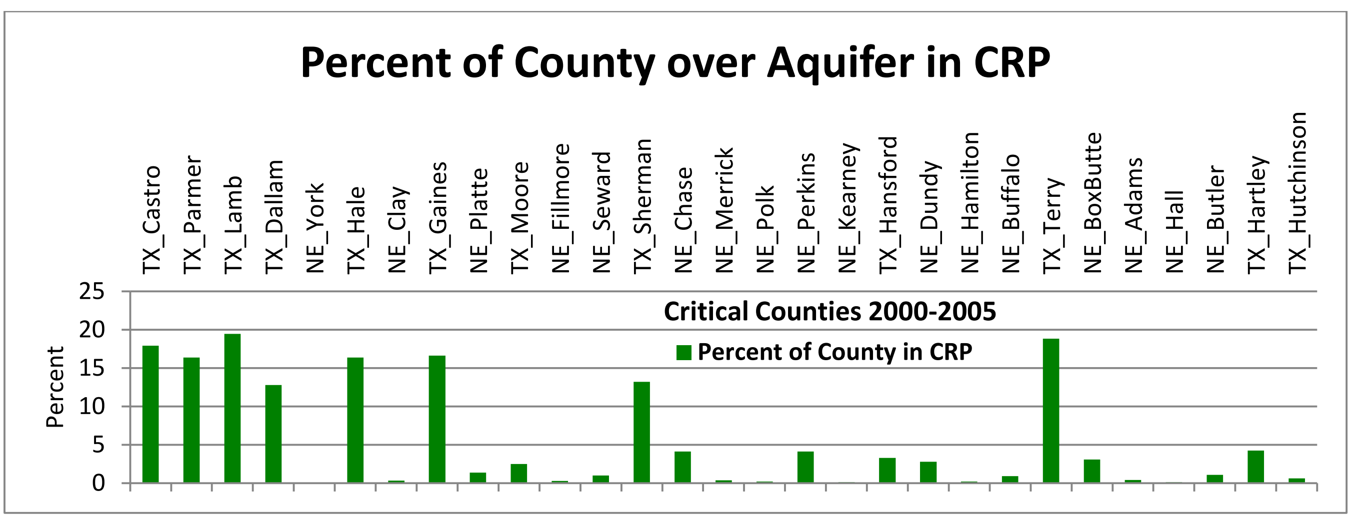

Figure 59. Percent of the county over the aquifer in CRP, 2000-2005.

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 declines and those areas where the benefits were derived by greater rises in the water table. Figures 60 through 63 show the counties in the study area classified by the type of benefit. The counties in dark green are those counties where the benefits were derived from less decline beneath CRP land compared to non-CRP land. The counties in light green are those counties where the benefits were derived from greater rises in the water table beneath CRP land. The counties mapped in the two shades of red are those counties where there were no net benefits. The darker red color corresponds to counties where the declines beneath CRP were greater than the declines beneath non-CRP land. The lighter red color indicates that the water-level rises were greater beneath non-CRP land.

For Nebraska, Wyoming and South Dakota, the results were very mixed. As stated previously, the CRP areas in Nebraska and South Dakota involved much less of the states' aquifer area than the CRP areas in Texas and New Mexico. For example, in the Rainwater Basin of Nebraska there is so little CRP that it would not be possible to estimate benefit. Comparing the maps in Figures 60 and 61, there is no obvious spatial pattern apparent in the county data. As noted earlier, PRISM climate data shows that there was much more precipitation in eastern Nebraska during the period from 2005-2009 (Appendix IV). Hence many counties in the eastern part of Nebraska experienced an overall rise in the water level during this time interval due to reduced pumping and perhaps enhanced recharge, with some counties showing greater rises beneath CRP land and some counties showing greater rises beneath non-CRP land. At the same time, in the western part of the state, most counties experienced an overall decline in water level. In this case, some counties experienced more declines beneath CRP land, and some counties experienced more declines beneath non-CRP land. These mixed results might be due to native grassland being converted to irrigated corn during this time period (e.g. Perkins County).

For the 2000-2005 time interval, the climate was much drier, and there was no pronounced spatial pattern in precipitation across the state (Appendix IV). In this case, there were very few counties in the study area that experienced overall rises in the water table. With only a few exceptions, almost all of the counties Nebraska, Wyoming and South Dakota experienced overall declines in the water level.

Compared to the northern part of the study region, the results from Texas and New Mexico were quite different. For the 2000-2005 and 2005-2009 time intervals, the PRISM climate data showed no obvious trends in precipitation, and the maps in Figure 62 and 63 are identical across the two time intervals. In this case, the majority of counties on the Llano Estacado and along the Texas/Oklahoma border experienced less decline beneath CRP land during both time intervals.

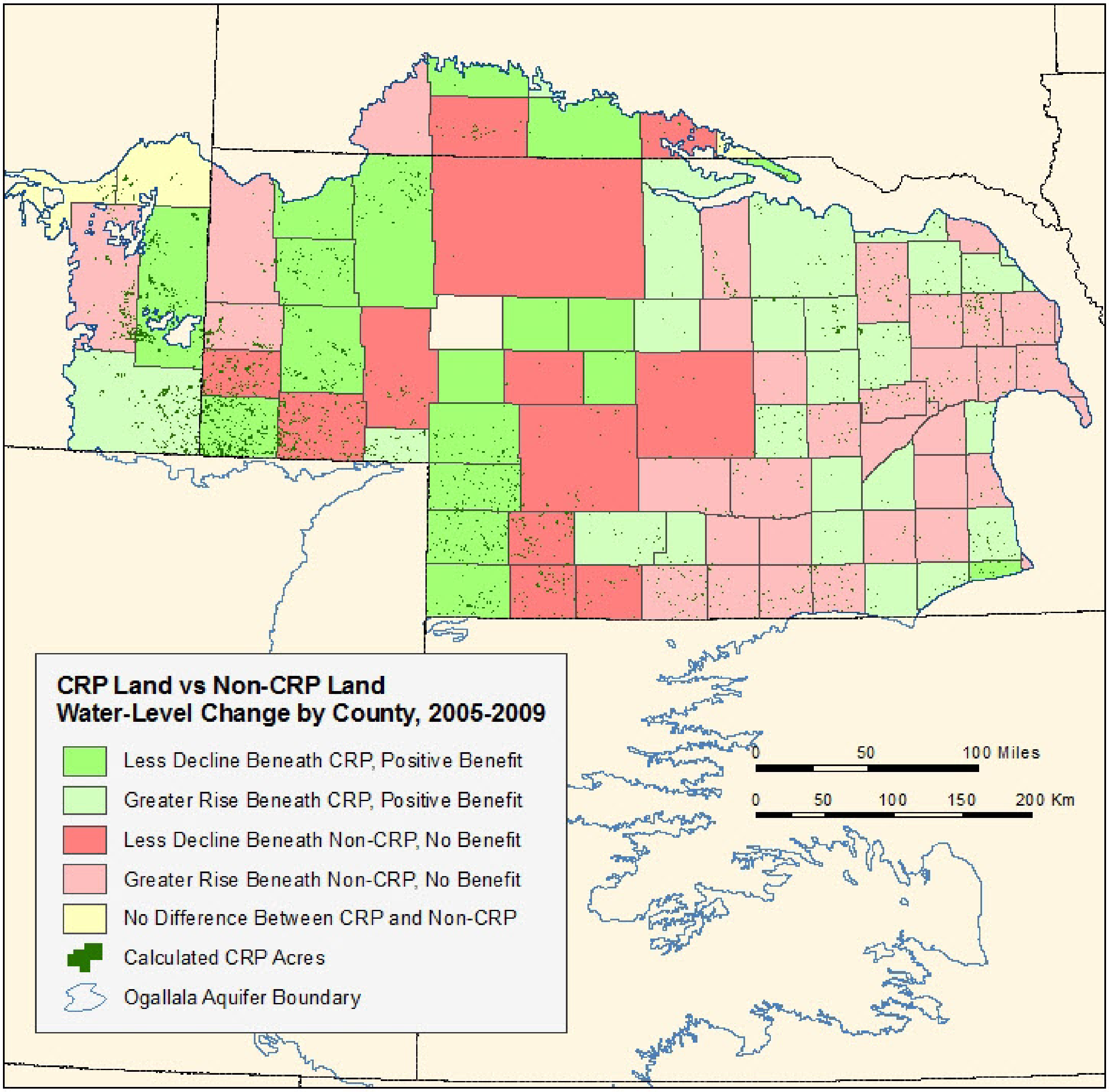

Figure 60. Counties in NE, SD and WY classified by type of water-level change, 2005-2009.

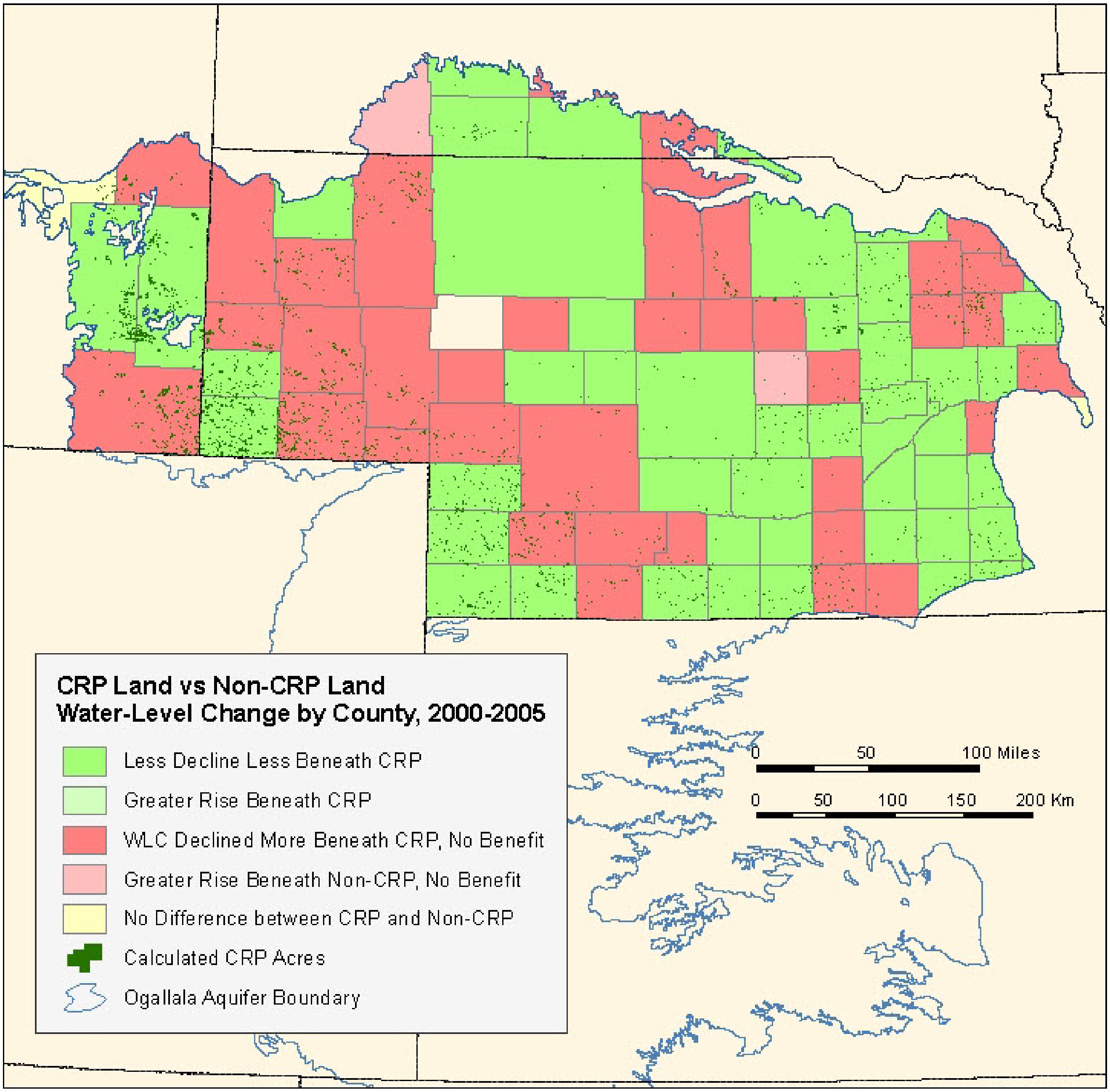

Figure 61. Counties in NE, SD and WY classified by type of water-level change, 2000-2005.

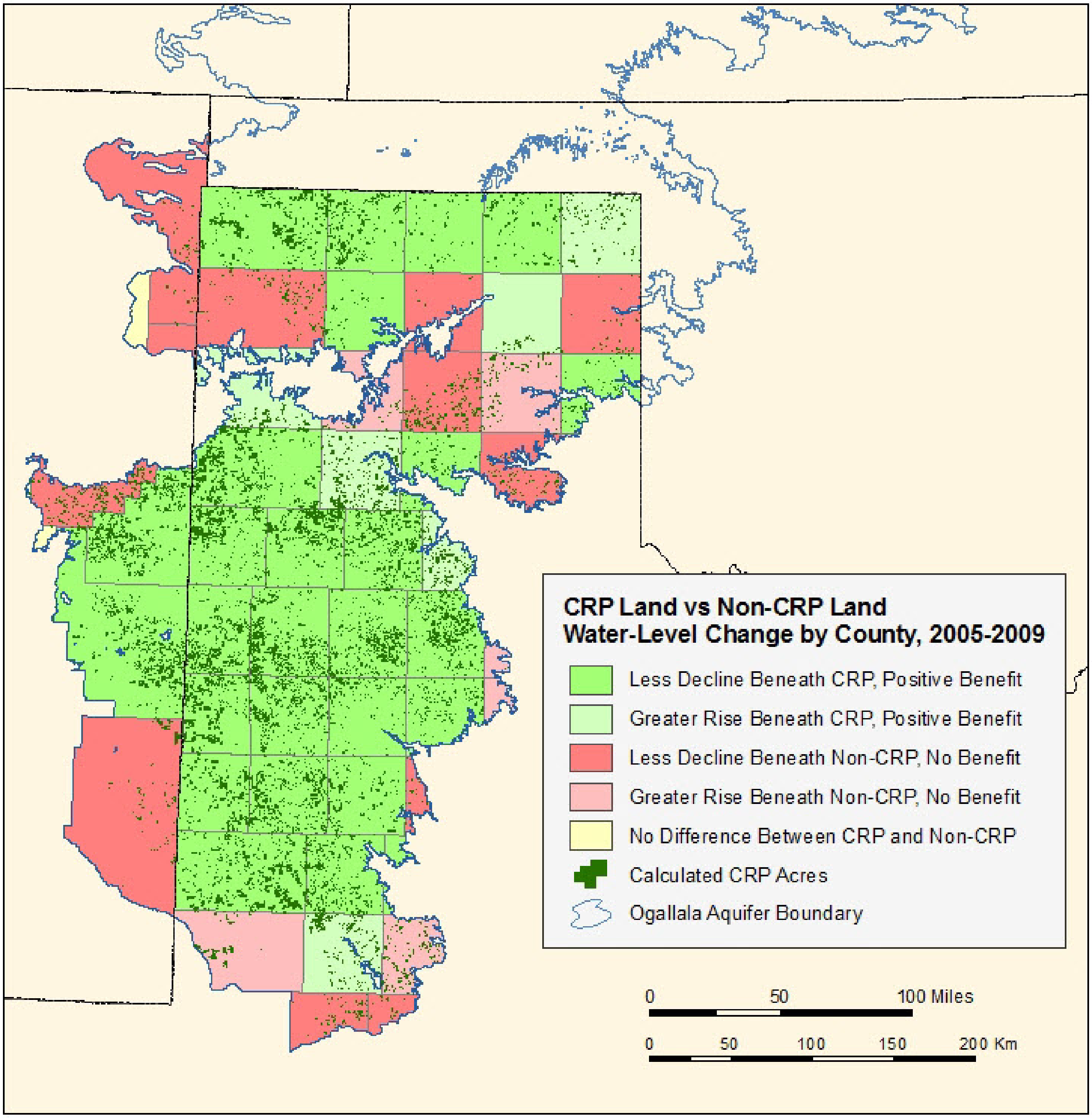

Figure 62. Counties in NM and TX classified by type of water-level change, 2005-2009.

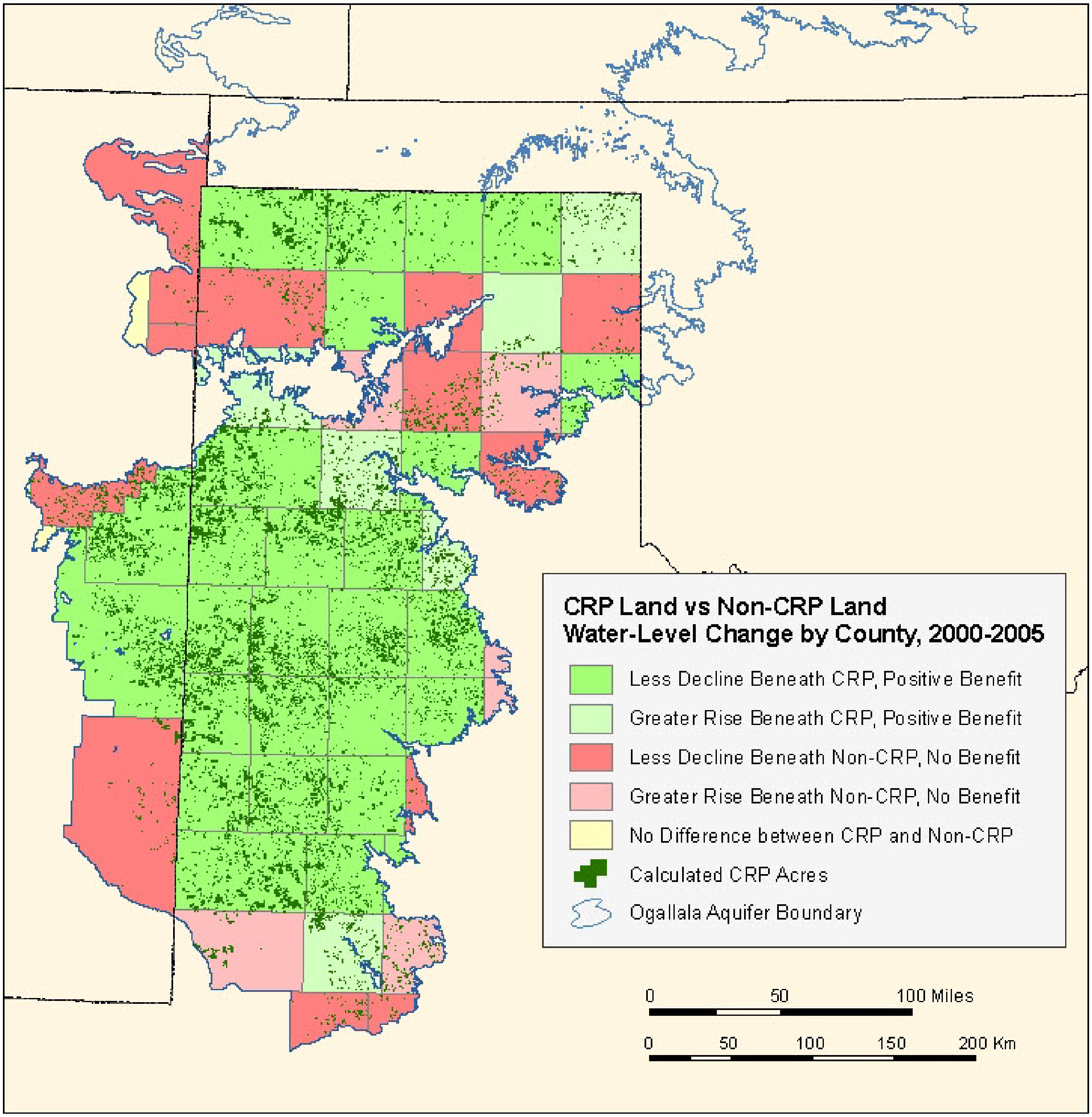

Figure 63. Counties in NM and TX classified by type of water-level change, 2000-2005.

Conclusion

The purpose of this study was to conduct a county-level analysis to assess the effects of the Conservation Reserve Program (CRP) on the Ogallala (High Plains) Aquifer in Nebraska, Wyoming, South Dakota, Texas and New Mexico. 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, and 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 accrued when the declines beneath CRP land was less than the declines beneath non-CRP land or when the water-level rises beneath CRP land were greater than the rises beneath non-CRP land.

The most promising results were obtained for Texas and New Mexico, which had 10.6 and 6.7 percent of the aquifer area enrolled in CRP by the last analysis period. The average drawdown beneath CRP land was less than the drawdown beneath non-CRP land in all four time intervals. Moreover, these regional results were strengthened when the analysis was performed only on those areas where the saturated thickness of the aquifer is more than 30 feet. In Nebraska, there was no benefit across all four time intervals, but only 1.7 percent of the aquifer area was in CRP by the last analysis period. Similarly, in South Dakota, there was no benefit in the two most recent time intervals, but only 0.4 percent of the aquifer area was in CRP. In Wyoming, with 3.5 percent of the aquifer area in CRP, the analysis showed a benefit in the 2005-2009 time interval and no benefit in the 2000-2005 time interval. It would be very difficult to discern benefits over such small CRP areas.

To better assess the effect of CRP land on the aquifer, the results of the analysis were also reported for each of the counties that overlie the aquifer in Texas, New Mexico, and Nebraska. These county-level data, however, were often difficult to interpret for several reasons.

1) First, many of the counties considered in this task had very little land enrolled in CRP. In these counties it was difficult to draw any conclusions simply because the data are sparse.

2) Secondly, in some counties, the percent difference between water-level changes observed in CRP and non-CRP area might be very large, but the actual rises or declines in the water-level were very small. In these counties it was difficult to assess the effect of CRP because any interpretation of the percent difference was suspect.

3) Thirdly, the analysis of the county-level data was complicated by the fact that the time intervals under study varied in length making comparisons difficult.

4) Fourthly, the limitations of the original CRP database made 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 underestimated the land enrolled in CRP,

especially during the 1980-1995 and 1995-2000 time intervals, it should lead to a conservative estimate of the observed differences in water-level change. Nevertheless, the underestimate of CRP land also made it difficult to interpret results. For example, in counties showing a positive net benefit, it is assumed that the result represents a minimum or conservative 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) Finally, 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 produces a conservative estimate of the difference in water-level change beneath CRP and non-CRP land, but it also added some uncertainty to the interpretation of results. Additionally non-CRP land contains native grassland where little irrigation occurs which adds to the conservative nature of the 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. During the most recent time interval (2005-2009), when the analysis focused on the 12 counties with the greatest declines, eight counties showed a net benefit – and these were all counties with a large percent of CRP land over the aquifer. In the 2000-2005 time interval, the analysis focused on the 29 counties with the greatest declines. In this case, the drawdown beneath CRP land was less than the drawdown beneath non-CRP land in 23 counties. Based on these results, the analysis shows that the benefits of CRP were greatest in those critical areas with the greatest water-level declines. Targeting land in these areas for increased CRP enrollment or re-enrollment is likely to be beneficial to the aquifer.

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Appendix I

Conservation reserve practice codes and contract lengths present in 2011 CRP Data and FSA CP Code Table

ID	Code	Description	Max Length	Min Length
1	CP1	Establishment of Permanent Introduced Grasses and Legumes	15	10
2	CP2	Establishment of Permanent Native Grasses	10	10
3	CP3	Tree Planting	10	10
4	CP3A	Hardwood Tree Planting	15	10
5	CP4	Description not available	10	10
6	CP4A	Description not available	15	10
7	CP4B	Permanent Wildlife Habitat (Corridors), Non-easement	15	10
8	CP4C	Description not available	10	10
9	CP4D	Permanent Wildlife Habitat Non-easement	10	10
10	CP5	Description not available	10	10
11	CP5A	Field Windbreak Establishment, Non-easement	15	10
12	CP7	Description not available	15	10
13	CP8	Description not available	15	15
14	CP8A	Grass Waterways, Non-easement	10	10
15	CP9	Shallow Water Areas for Wildlife	10	10
16	CP10	Vegetative Cover - Grass - Already Established	20	10
17	CP11	Vegetative Cover - Trees - Already Established	20	10
18	CP12	Wildlife Food Plot	15	10
19	CP15A	Establishment of Permanent Vegetative Cover (Contour Grass Strips), Non-easement	10	10
20	CP15B	Establishment of Permanent Vegetative Cover (Contour Grass Strips), on Terraces	10	10
21	CP16A	Shelterbelt Establishment, Non-easement	15	10
22	CP17A	Living Snow Fences, Non-easement	15	10
23	CP18B	Establishment of Permanent Vegetation to Reduce Salinity, Non-easement	10	10
24	CP18C	Establishment of Permanent Salt Tolerant Vegetative Cover, Non-easement	10	10
25	CP21	Filter Strips	15	10
26	CP22	Riparian Buffer	15	10
27	CP23	Wetland Restoration	15	10
28	CP23A	Wetland Restoration, Non-Floodplain	15	10
29	CP24	Cross Wind Trap Strips	10	10
30	CP25	Rare and Declining Habitat	10	10
31	CP27	Farmable Wetlands	15	10
32	CP28	Farmable Wetland Buffer	15	10
33	CP29	Marginal Pastureland Wildlife Habitat Buffer	15	10
34	CP30	Marginal Pastureland Wetland Buffer	15	10
35	CP31	Bottomland Timber Establishment on Wetlands	15	10
36	CP32	Expired CRP Hardwood Tree Planting on Marginal Pastureland	10	10
38	CP33	Habitat Buffers for Upland Birds	10	10
39	CP35E	Emergency Forestry - Softwood - New	10	10
40	CP37	Duck Nesting Habitat	15	10
41	CP38A	SAFE - Buffers	10	10
42	CP38D	SAFE - Longleaf Pine	10	10
43	CP38E	SAFE - Grass	10	10
44	CP40	FWP Aquaculture Wetland Restoration	15	10
45	CP42	Pollinator Habitat	10	10

Appendix II

Conservation reserve practice codes not present in 2011 CRP Data

ID	Code	Description	Max Length	Min Length
1	CP35A	Emergency Forestry - Longleaf Pine - New	10	10
2	CP35B	Emergency Forestry - Longleaf Pine - Existing	10	10
3	CP35C	Emergency Forestry - Bottomland Hardwood - New	10	10
4	CP35D	Emergency Forestry - Bottomland Hardwood - Existing	10	10
5	CP35F	Emergency Forestry - Softwood - Existing	10	10
6	CP35G	Emergency Forestry - Upland Hardwood - New	10	10
7	CP35H	Emergency Forestry - Upland Hardwood - Existing	10	10
8	CP35I	Emergency Forestry - Mixed Trees - Existing	10	10
9	CP36	Longleaf Pine - Establishment	15	10
10	CP38B	SAFE - Wetlands	10	10
11	CP38C	SAFE - Trees	10	10

Appendix III

Additional Conservation Practice Codes present in 2011 CRP Data

Eleven CP codes were discovered in the CRP database that were not previously identified in the FSA CRP table referenced in Appendix I. The contracts associated with these codes were incorporated in the analysis for this study.

ID	Code	Description	Max Length	Min Length
1	CP13	Emergency Forestry - Longleaf Pine - New	10	10
2	CP13A	Emergency Forestry - Longleaf Pine - Existing	10	10
3	CP13B	Emergency Forestry - Bottomland Hardwood - New	10	10
4	CP15	Emergency Forestry - Bottomland Hardwood - Existing	10	10
5	CP16	Emergency Forestry - Softwood - Existing	10	10
6	CP18	Emergency Forestry - Upland Hardwood - New	10	10
7	CP18A	Emergency Forestry - Upland Hardwood - Existing	10	10
8	CP19	Emergency Forestry - Mixed Trees - Existing	10	10
9	CP20	Longleaf Pine - Establishment	15	10

Appendix IV

Comparison of Precipitation Departure from Normal for 2000-2005 and 2005-2009 Time Intervals

Average annual precipitation data (PRISM) were analyzed for each year in the 2000-2005 and 2005-2009 time intervals and compared to the 30-year normal precipitation values for 1981-2010 time period. The results were mapped to show spatial patterns of precipitation for each time interval. Clearly the 2000-2005 interval was much dryer than normal while the 2005-2009 interval was much wetter in the eastern part of the Nebraska.

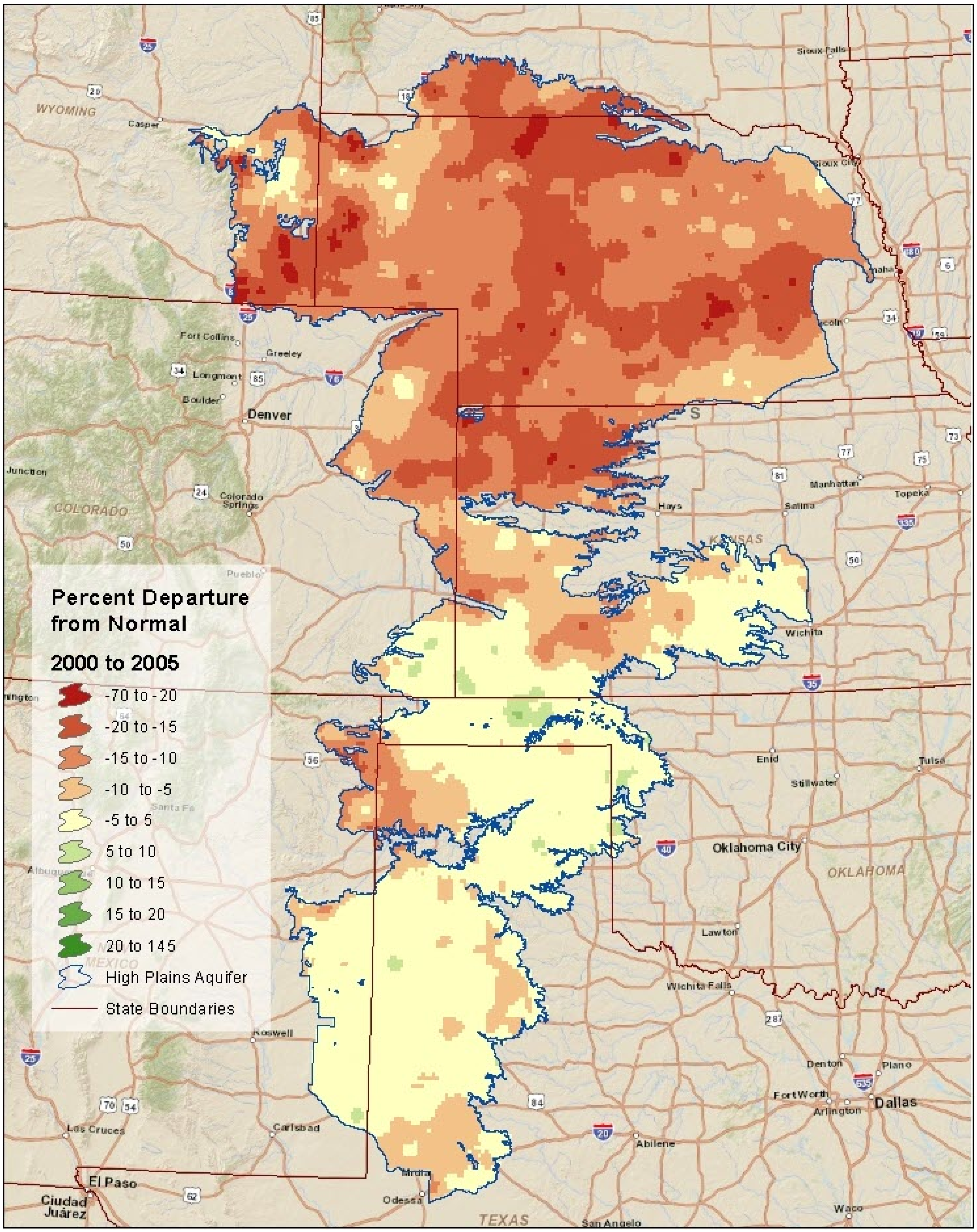

Figure IV-I. Precipitation percent departure from normal for 2000-2005 interval.

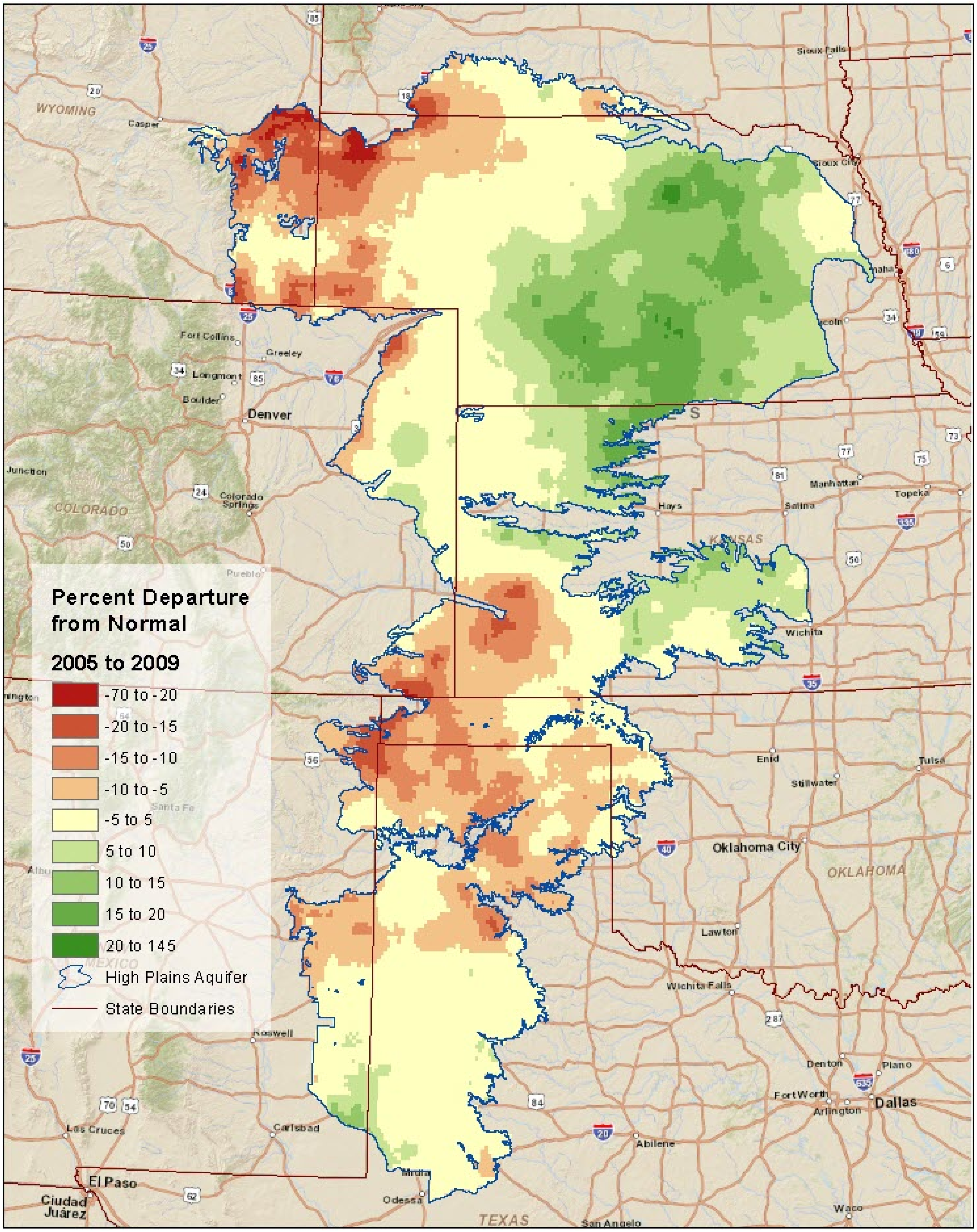

Figure IV-2. Precipitation percent departure from normal for 2005-2009 interval.