Changes in Water Levels in Texas, 1995 to 2005

Radu Boghici, P.G.

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by
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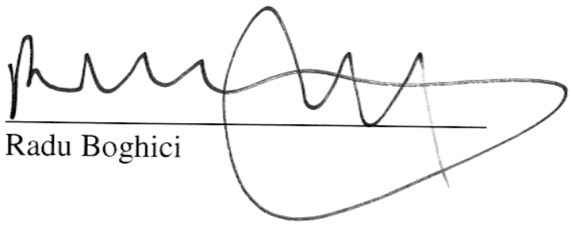
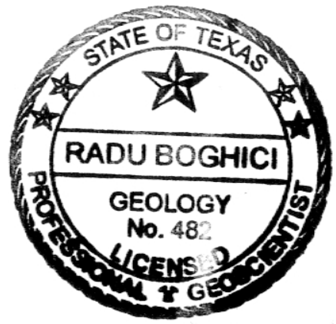


Radu Boghici



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1.0 Executive Summary

Groundwater is a critical water resource for Texas, providing 59 percent of all the water used in Texas in 2003. Measuring and monitoring water levels in the state's aquifers are important for understanding how pumping and climate affect the aquifers of the state, information that is essential for understanding and managing groundwater resources, developing groundwater availability models, and planning to meet future demands for water.

The Texas Water Development Board (TWDB) and our cooperators—primarily groundwater conservation districts—maintain a statewide water level monitoring network consisting of more than 6,500 wells. Once a year, field technicians measure the depth to water in most of these wells. For this study, we used water level measurements from over 4,300 observation wells that had water level measurements in 1995-1996 and 2005-2006. We compared the readings taken in late 1995 or early 1996 with those taken in late 2005 or early 2006 to assess the changes in groundwater levels during the decade. We show the results below (Table 1-1).

Table 1-1. Median changes in water levels in Texas aquifers, 1995 to 2005.

Aquifer	Median change (feet)	Aquifer	Median change (feet)
Major aquifers Carrizo-Wilcox	-3.8	**Minor aquifers** Blaine	-9.7
Edwards (Balcones Fault Zone)	-0.5	Blossom	-7.9
Edwards-Trinity (Plateau)	0.5	Brazos River Alluvium	1.3
Gulf Coast	0.9	Bone Spring-Victorio Peak	-12.2
Hueco-Mesilla Bolsons	-7.0	*Capitan Reef	-12.0
Ogallala	-4.3	Dockum	-0.9
Pecos Valley	1.2	Edwards-Trinity (High Plains)	2.1
Seymour	-6.7	Ellenburger-San Saba	2.1
Trinity	-4.3	Hickory	0.4
		Igneous	0.8
		Lipan	-0.1
		Marble Falls	6.6
		Nacatoch	-1.1
		Rita Blanca	-5.2
		*Rustler	19.5
		Queen City	-2.6
		Sparta	-2.2
		West Texas Bolsons	-4.1
		Woodbine	-4.4
		Yegua-Jackson	-0.1
		Other	-0.3

*Results for the Capitan Reef and Rustler aquifers are based on readings from one well each. We deem these readings to be unrepresentative of the entire aquifers.

From 1995 to 2005, most of the statewide changes in water levels were from 2 feet to 25 feet, which we hereby define as moderate changes. The median water level change statewide was a decline of 2.4 feet. The majority of the wells (1,812, or 42 percent of those with available data) showed water level declines of 2 feet to 25 feet, and 889 wells (20 percent) recorded rises of 2 to 25 feet. Of the 4,347 wells measured statewide, 1,020 wells or 23 percent showed water level rises or water level declines of 2 feet or less. The median aquifer-wide water level change was a decline of 4.3 feet in the Ogallala Aquifer, a rise of 0.9 feet in the Gulf Coast Aquifer, a decline of 3.8 feet in the Carrizo-Wilcox Aquifer, a rise of 1.2 feet in the Pecos Valley Aquifer, a decline of 0.5 feet in the Edwards (Balcones Fault Zone) Aquifer, a decline of 4.3 feet in the Trinity Aquifer, a rise of 0.5 feet in the Edwards-Trinity (Plateau) Aquifer, a decline of 6.7 feet in the Seymour Aquifer, and a decline of 7 feet in the Hueco-Mesilla Bolsons Aquifer. The median change in water level in the minor aquifers was a decline of 0.7 feet, with the largest median decline in the Bone Spring-Victorio Peak Aquifer (a decline of 12.2 feet), and the largest median rise in the Marble Falls Aquifer (a rise of 6.6 feet).

2.0 Introduction

Many Texans rely on groundwater for drinking water and for industrial and agricultural uses. Of the 15.6 million acre-feet of water used in the state in 2003, groundwater contributed 9.2 million acre-feet, or about 59 percent, with surface water supplying the rest (TWDB, 2007).

The TWDB recognizes nine major aquifers—aquifers that produce large amounts of water over large areas—and 21 minor aquifers—aquifers that produce minor amounts of water over large areas or large amounts of water over small areas (Figure 2-1). Because of the importance of groundwater supplies to Texas, TWDB monitors water levels in these aquifers to detect changes and identify areas of concern. Water level information is important for understanding and managing groundwater resources, developing groundwater availability models, and planning to meet future demands for water. We rely on a network of observation wells from which we measure water levels or compile water level information measured by groundwater conservation districts and others. Because groundwater pumping is lower—and thus aquifer levels are relatively stable—in late fall and winter, we measure water levels during those seasons.

To assess water level changes between 1995 and 2005, we used measurements from 4,347 wells and compared readings at each well between the 1995–1996 and the 2005–2006 water level monitoring seasons. The density of well coverage is a function of groundwater pumpage. Areas of aquifers that have increased production also contain a greater number of monitoring wells.

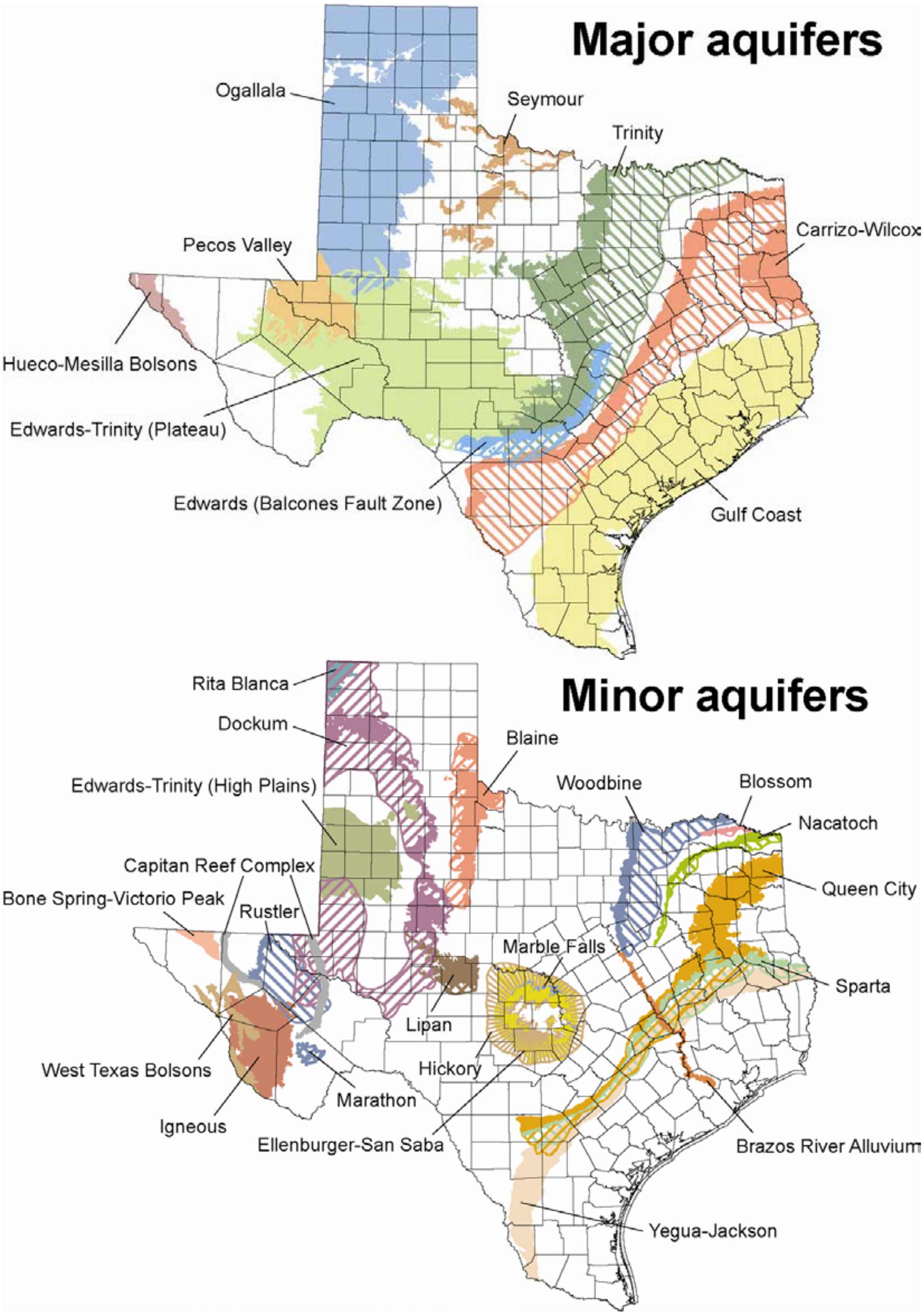


Figure 2-1. Major and minor aquifers of Texas.

The initial data set for this study consisted of water level measurements from more than 6,000 observation wells. Because our goal was to examine aquifer levels under stable conditions, we eliminated numerous measurements from wells that were being pumped when the levels were recorded. We also eliminated many readings in which at least one of the measurements showed the effects of pumping from neighboring wells. This is a common occurrence in large public water supply well fields, such as the ones in the greater Houston area. We also generated well hydrographs—plots of water levels over time—to help assess the changes in water levels. If we saw considerable departures from the general water level trend, we did not use the data in our analysis.

If a reader is interested in water levels in a particular area of the state, we suggest visiting our website at http://www.twdb.texas.gov.

Water well data are available on an interactive map at http://wiid.twdb.texas.gov.

Measurements in select wells that are measured daily are at http://www.twdb.texas.gov/groundwater/data/waterlevel.asp.

These and other groundwater data can be downloaded at http://www.twdb.texas.gov/groundwater/data/gwdbrpt.asp.

This report examines the median water level changes in the state's major and minor aquifers. It also describes where the largest declines and increases were within an aquifer and presents regional trends. Throughout the report, histograms illustrate state- and aquifer-wide water level changes, and hydrographs depict water level changes through time at selected sites thought to be representative of the general water level trends in the aquifer.

3.0 Texas Climate Considerations, 1995 to 2005

Water levels in wells change in response to aquifer recharge (water from precipitation that replenishes the aquifer, inputs from other aquifers and surface water bodies) and discharge (pumping, natural discharge such as springflow, flow to streams, and cross-formational flow). Since aquifer recharge is derived from precipitation, and because pumping rates are influenced by temperature and precipitation, it is important to examine Texas weather patterns from 1995 to 2005 to determine what influence the weather and short-term climate fluctuations may have had on well water levels. This is particularly important in karst aquifers, such as the Edwards (Balcones Fault Zone) Aquifer, where short-term climate fluctuations are the primary control on water levels. In the case of sandy aquifers, such as the Ogallala, Gulf Coast, Carrizo-Wilcox, Hueco-Mesilla Bolsons, and Trinity north of the Colorado River, these fluctuations themselves have less of an effect on water levels than pumping rates.

One way to analyze long-term weather trends is to examine the Palmer Drought Severity Index (Palmer, 1965). This index quantifies the duration and intensity of long-term, drought-inducing weather patterns. It is a water balance index that incorporates precipitation, evapotranspiration, and runoff in a formula to determine soil dryness, which makes the index a suitable indicator of the effects of rainfall on groundwater supplies. The Palmer Drought Severity Index assigns a numerical value to indicate a region's climate conditions. Zero signifies normal conditions, negative values indicate drier-than-normal, and positive values suggest wetter-than-normal conditions. The GreenLeaf Project (a partnership between the U.S. Department of Agriculture (USDA) Risk Management Agency, the National Drought Mitigation Center, and the University of Nebraska—Lincoln) maintains a nationwide database of this information including up-to-date readings from 329 stations in Texas.

Texas is divided into 10 climatic divisions by the National Weather Service. These are geographically referred to as the Trans Pecos, High Plains, Low Rolling Plains, Edwards Plateau, North Central, South Central, Southern, East, Upper Coast, and Lower Valley divisions (Figure 3-1). Using data provided by the GreenLeaf Project, we examined climate conditions in these regions in two ways: (1) over the duration of the decade and (2) in 1995 and 2005 only. When we computed the Palmer Drought Severity Index values for each station, we found that most of the state experienced drier-than-normal conditions at least 50 percent of the time and was wetter than normal less than half the time. These regions include just about all of the Trans Pecos and Edwards Plateau divisions, parts of the Low Rolling Plains, the southern and northwestern High Plains, and most of North Central, South Central, and Southern divisions (Figure 3-2). These areas correspond with the aquifers of Far West Texas, almost all of the Edwards-Trinity (Plateau) and Seymour aquifers, the northern segment of the Carrizo-Wilcox Aquifer, and the southern Gulf Coast Aquifer.

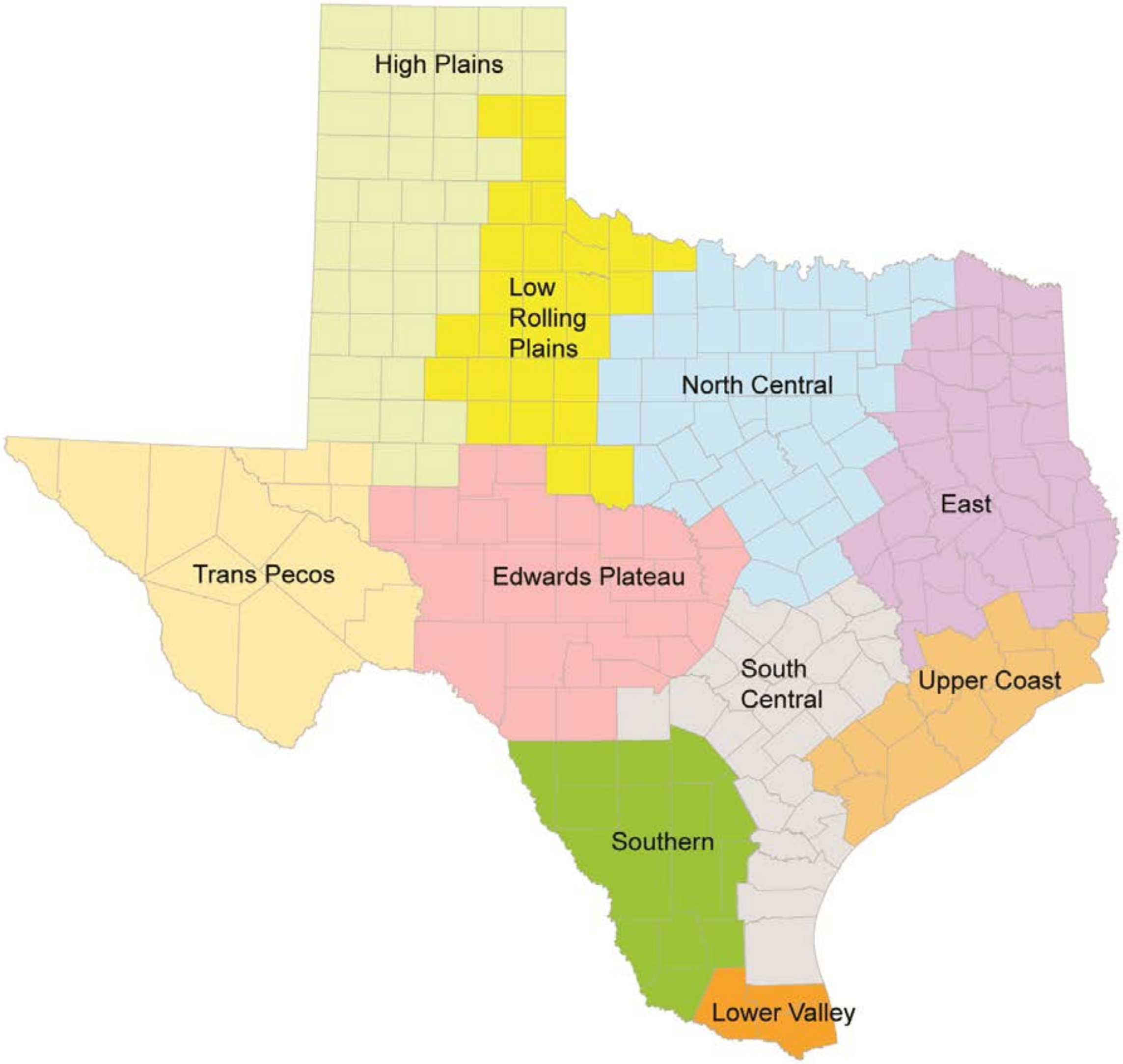


Figure 3-1. Texas climatic divisions.

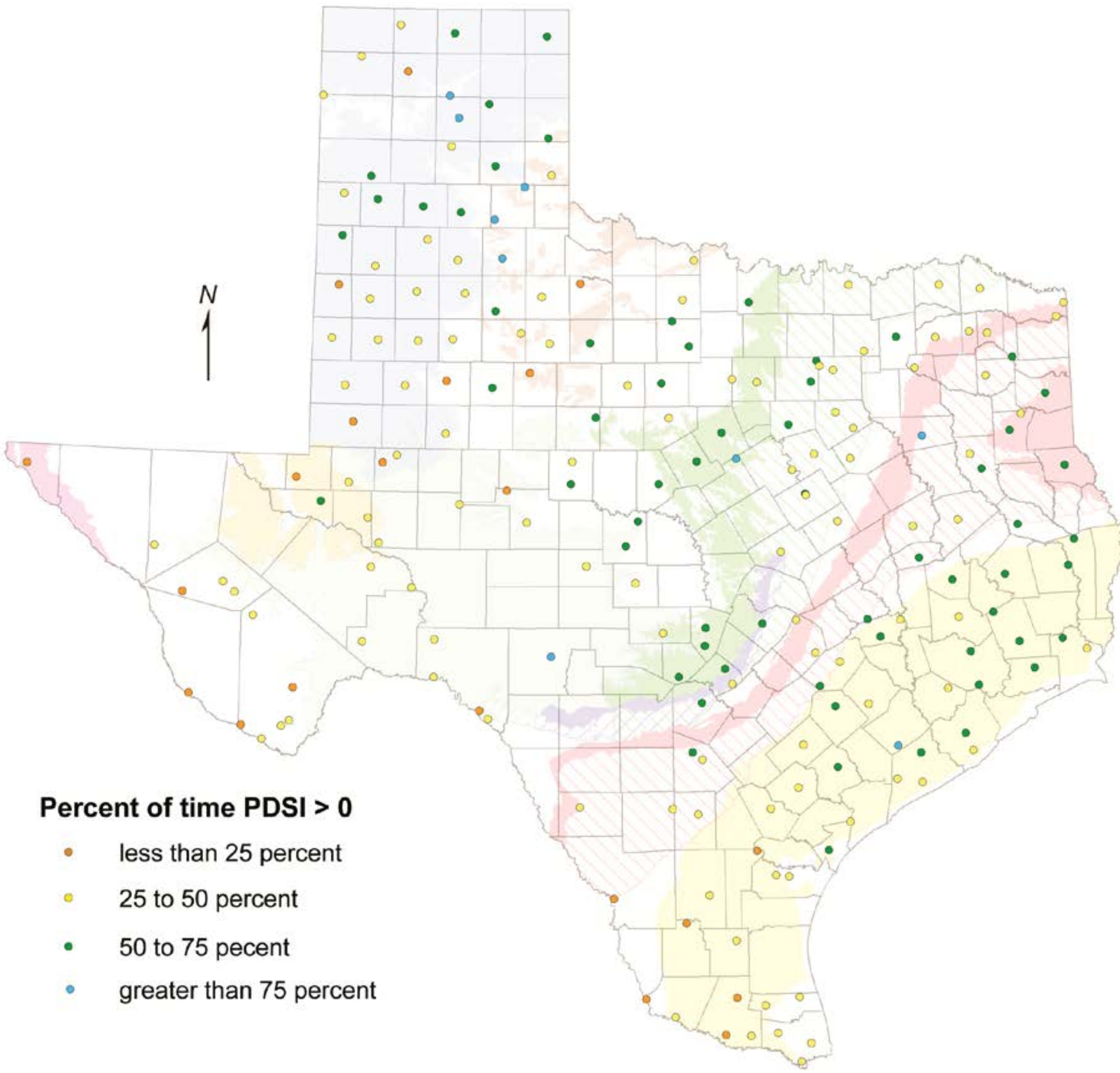


Figure 3-2. Percent of time with near-normal to wetter-than-normal weather at climate monitoring stations, 1995 to 2005 (Green Leaf Project, http://greenleaf.unl.edu/). PDSI=Palmer Drought Severity Index.

Parts of the High Plains and Low Rolling Plains divisions (central and northeastern Ogallala Aquifer), most of the North Central and South Central divisions (Trinity Aquifer), and the Upper Coast climatic division (northern Gulf Coast Aquifer) were predominantly wetter than normal, with some locations yielding positive Palmer Drought Severity Index readings over 50 percent of the time.

Water levels in some unconfined aquifers and those that are highly permeable, such as the Edwards (Balcones Fault Zone) Aquifer, can be very responsive to recharge caused by short-term, unusually wet conditions. Water level changes in such aquifers can be misleading if such weather events occurred either at the beginning (1995) or at the end (2005) of the study period. To investigate this issue, we compared the Palmer Drought Severity Index values at stations across Texas for the years 1995 and 2005 only (Figure 3-3).

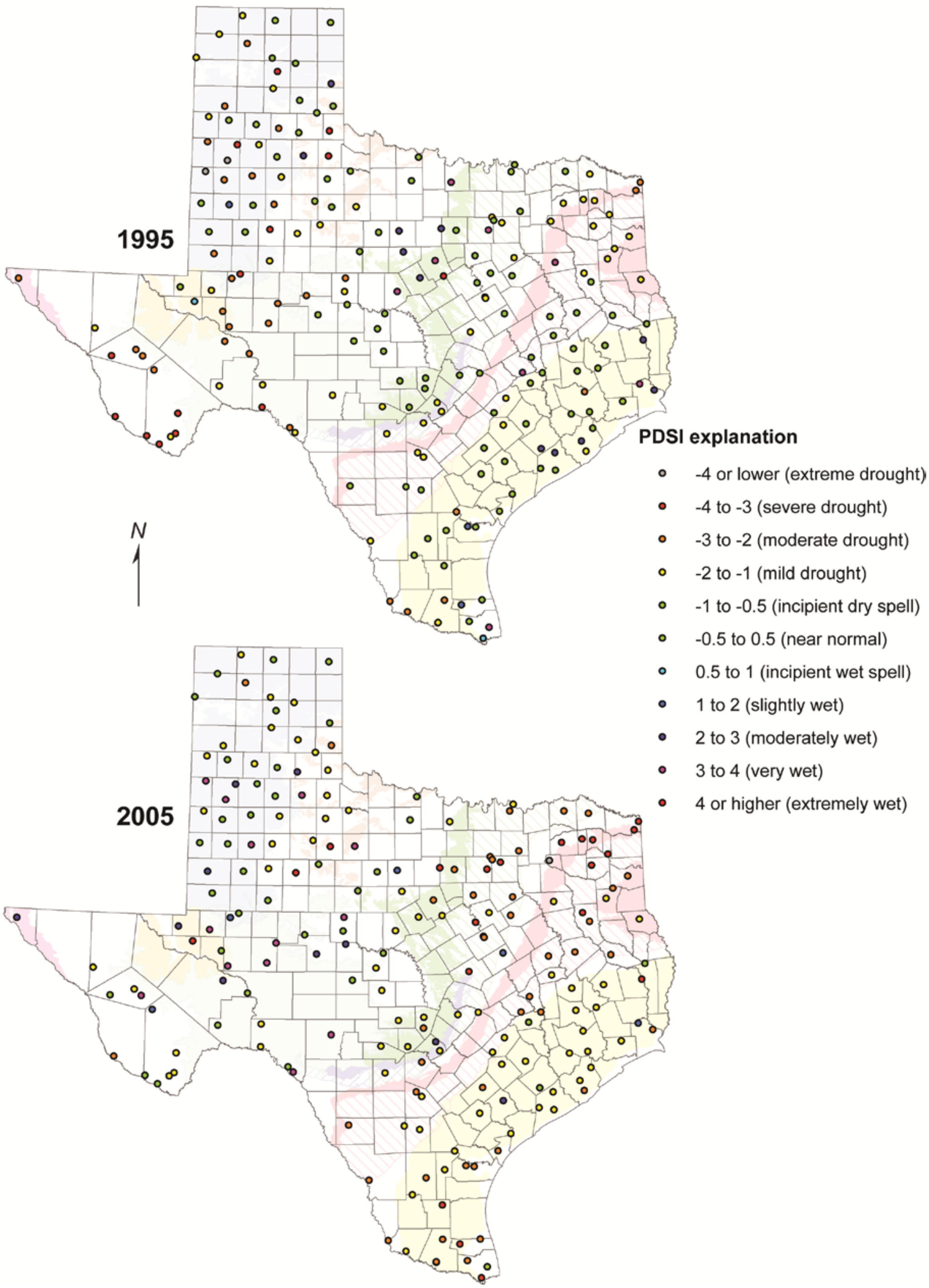


Figure 3-3. Climate comparison at climate monitoring stations for the years 1995 and 2005. PDSI=Palmer Drought Severity Index.

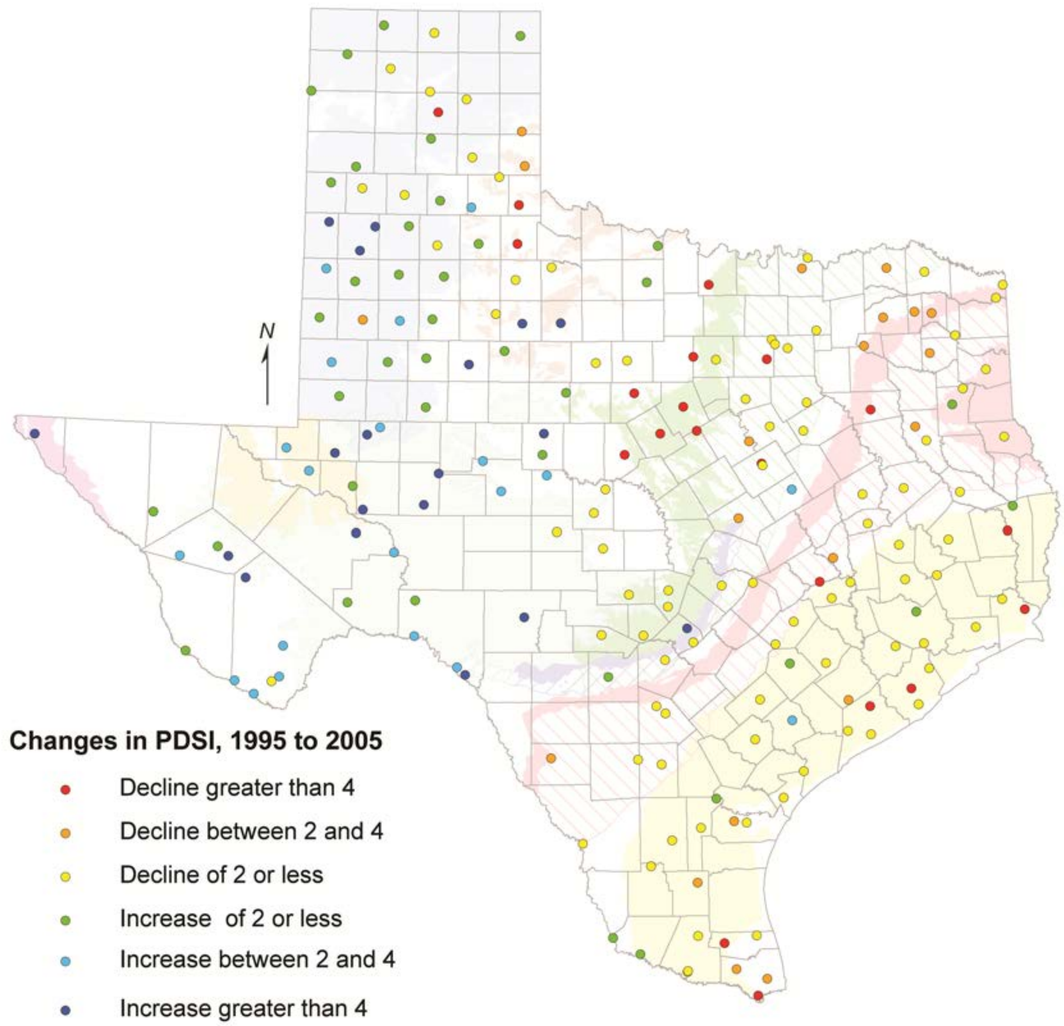


Figure 3-4. Changes in Palmer Drought Severity Index (PDSI) between 1995 and 2005 at climate monitoring stations.

Declines indicate drier conditions in 2005 than in 1995, while increases indicate wetter conditions in 2005 than in 1995.

To aid with the visualization of these data, we computed the changes in the Palmer Drought Severity Index between 1995 and 2005 and plotted the results on a map (Figure 3-4).

The Texas climate was predominantly drier in 2005 in many areas in eastern Texas, and over portions of High Plains and Low Rolling Plains climatic divisions, corresponding to the Gulf Coast, Carrizo-Wilcox, Trinity, Edwards, and Seymour aquifers, and the northeastern Ogallala Aquifer. The Trans Pecos (Hueco-Mesilla Bolsons, Pecos Valley, and Edwards-Trinity [Plateau] aquifers), southern High Plains (Ogallala Aquifer), and central Edwards Plateau (Edwards-Trinity [Plateau] Aquifer) divisions were significantly wetter in 2005 than 1995.

4.0 Statewide Groundwater Conditions

Water level changes in wells are driven by the interplay between groundwater recharge to and discharge from aquifers. In general, water levels in wells decline due to increased groundwater withdrawal and/or reduced aquifer recharge. Conversely, decreased groundwater withdrawal, a decrease in groundwater discharge, and/or increased aquifer recharge cause rises in groundwater levels. In most aquifers, the discharge component having the greatest impact on aquifer levels is the pumpage of water wells. Groundwater withdrawals tend to have a larger effect on water levels in aquifers with deep water tables and in confined aquifers where recharge is not readily available. For example, the central segment of the Gulf Coast Aquifer has experienced overall water level rises between 1995 and 2005, possibly because of reductions in groundwater pumpage in the Houston-Galveston area and in Wharton and Jackson counties (Michel, 2006). Aquifer recharge tends to have a greater impact on groundwater levels in aquifers with shallow water tables and in very transmissive aquifers where karst and conduit flow predominate. Although several aquifers showed overall recovery from 1995 to 2005, water levels in the majority of wells across Texas declined slightly (Figure 4-1). The median water level change statewide was a decline of 2.4 feet. Water levels in 1,020 wells have been almost stationary, with changes less than 2 feet. Of the 4,347 wells measured, 1,812 (or 42 percent) showed moderate water level declines from 2 feet up to 25 feet, and 889 (20 percent) recorded moderate rises from 2 feet to 25 feet. The data distribution is nearly normal, with the histogram centered to the left of zero because of the overall decline in water levels. These moderate water level changes were predominant in all aquifers (Figure 4-2).

Several wells recorded more significant changes. The state's largest water level decline was 242 feet in Well 65-16-114 in the Gulf Coast Aquifer, an industrial well in Harris County. The largest recovery (312.8 feet) was recorded in Well 40-45-701, a well completed in the Trinity Aquifer in Bell County. Some wells with declining levels were close to areas of water level recovery, possibly indicating the impact of varying local pumping patterns and aquifer characteristics. The coexistence of wells with large declines (50 feet or more) and wells with significant rises (50 feet or more) near each other seems to be typical of some public water supply wells. This might be an artifact caused by collecting measurements while the water level was influenced by pumping in the well or nearby wells.

Because nearly half (2,086) of the 4,347 statewide data points for this study come from the Ogallala Aquifer, this aquifer has the largest impact on the overall statewide picture in this report. It is possible that the study results would have been different if more data from other aquifers were available.

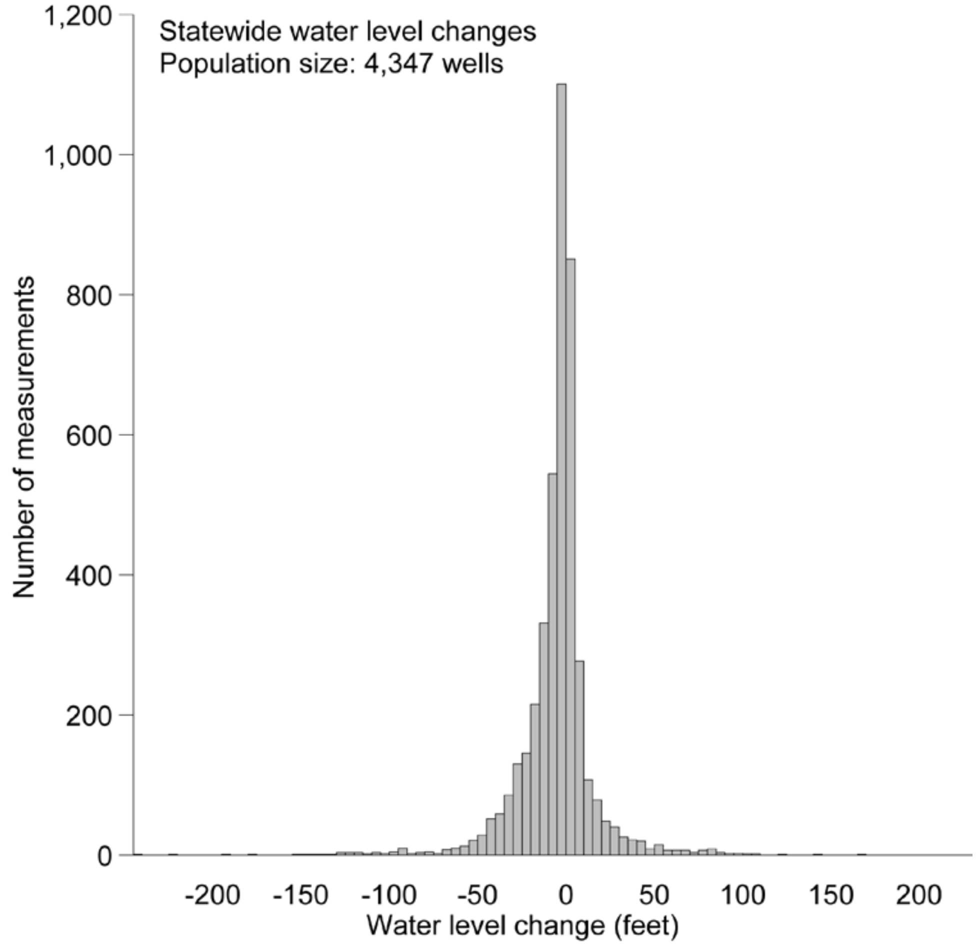


Figure 4-1. Changes in well water levels across Texas.

Table 4-1. Summary of water level changes by aquifer.

		NUMBER OF WATER LEVEL MEASUREMENTS			
Aquifer	**Median change (feet)**	**Total**	**Moderate recovery (2 to 25 feet)**	**Minimal change (± 2 feet)**	**Moderate decline (-2 to -25 feet)**
Major aquifers					
Carrizo-Wilcox	-3.8	299	42	76	143
Edwards (Balcones Fault Zone)	-0.5	110	24	27	40
Edwards-Trinity (Plateau)	0.5	140	47	42	47
Gulf Coast	0.9	776	223	144	192
Hueco-Mesilla Bolsons	-7.0	54	11	9	27
Ogallala	-4.3	2086	350	462	1019
Pecos Valley	1.2	64	23	18	18
Seymour	-6.7	47	3	10	34
Trinity	-4.3	212	31	53	77
Minor aquifers					
Blaine	-9.7	17	3	-	14
Blossom	-7.9	3	-	1	1
Brazos River Alluvium	1.3	20	7	10	3
Bone Spring-Victorio Peak	-12.2	14	-	-	14
*Capitan Reef	-12.0	1	-	-	1
Dockum	-0.9	51	17	12	19
Edwards-Trinity (High Plains)	2.1	10	5	2	2
Ellenburger-San Saba	2.1	39	19	6	8
Hickory	0.4	21	6	12	2
Igneous	0.8	19	5	5	6
Lipan	-0.1	26	8	9	8
Marble Falls	6.6	5	3	2	-
Nacatoch	-1.1	18	6	4	8
Rita Blanca	-5.2	9	1	1	5
*Rustler	19.5	1	1	-	-
Queen City	-2.6	66	8	21	36
Sparta	-2.2	27	3	9	14
West Texas Bolsons	-4.1	26	7	5	12
Woodbine	-4.4	28	3	5	13
Yegua-Jackson	-0.1	30	4	13	10
Other	-0.3	128	23	65	38

* Results for the Capitan Reef and Rustler aquifers are based on readings from one well each. We deem these readings to be unrepresentative of the entire aquifers.
Note: Water level measurements denoting minimal and moderate changes do not always add up to the total number of measurements. This is because water level changes exceeding 25 feet were not counted.

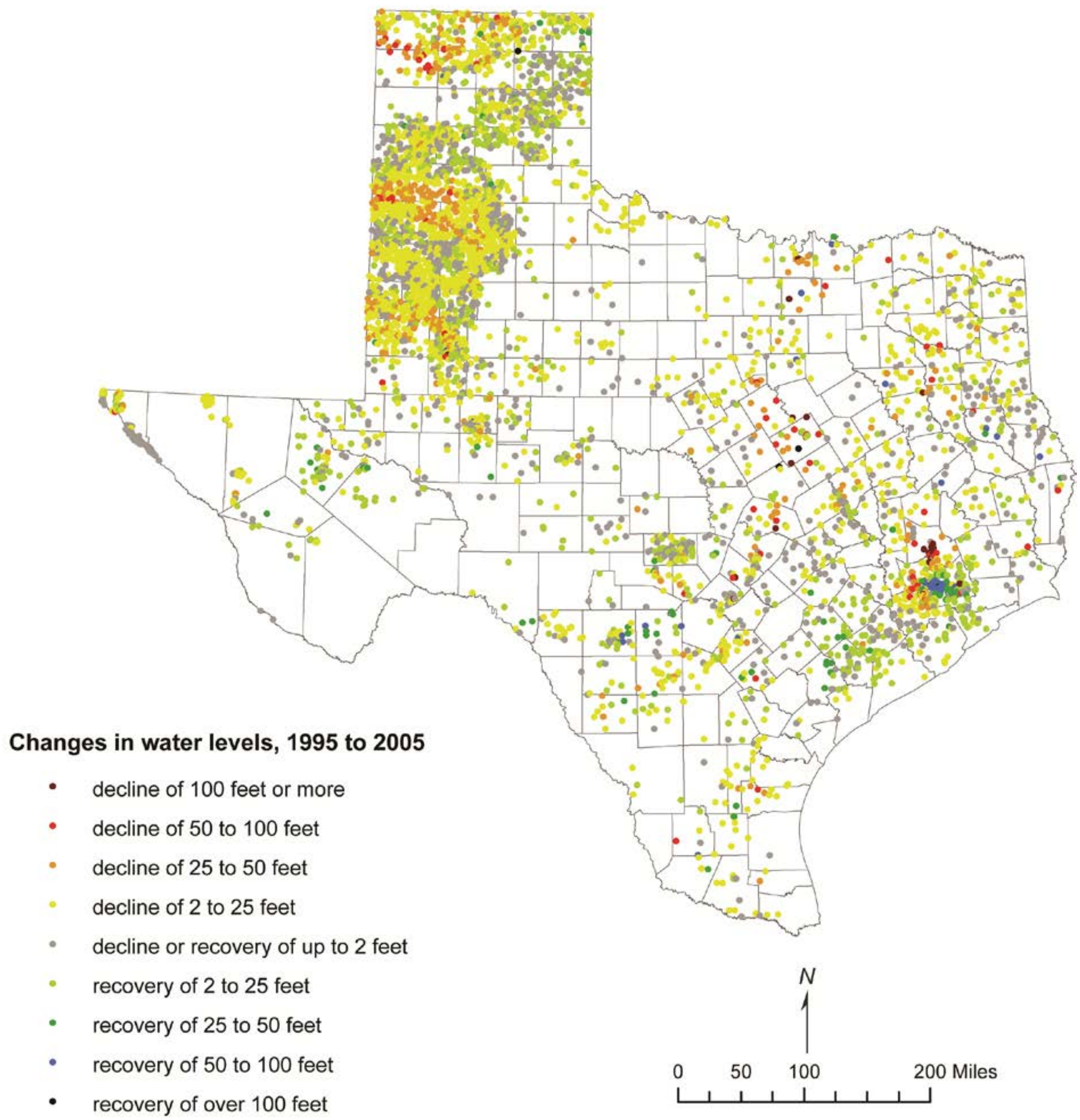


Figure 4-2. Statewide distribution of wells and observed changes in water levels, 1995 to 2005.

5.0 Major Aquifers

This section discusses changes in water levels in the nine major aquifers. We have arranged the aquifers from those with the most data available to those with the least; thus, the Ogallala Aquifer is presented first.

5.1 Ogallala Aquifer

Between 1995 and 2005, most of the wells in the Ogallala Aquifer experienced moderate water level declines (Figure 5-1). The median water level change over the 10-year period in the Ogallala Aquifer was a decline of 4.3 feet. The largest recorded decline of 106.4 feet was in Well 28-25-504 in Dawson County, and the largest rise, 167.2 feet, was in Well 03-64-602 in Hansford County.

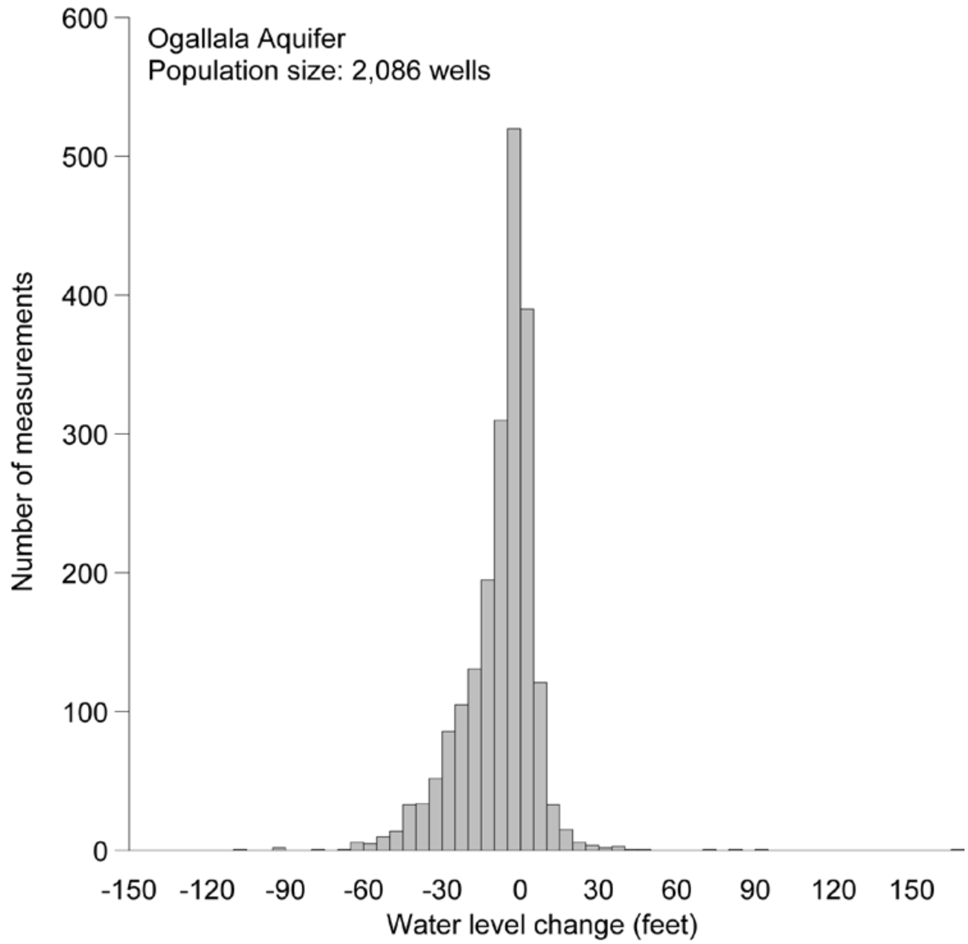


Figure 5-1. Water levels changes in the Ogallala Aquifer, 1995 to 2005.

Of the 2,086 wells analyzed in the Ogallala Aquifer, 1,369 wells, or 66 percent, recorded moderate (2 feet to 25 feet) changes in water levels. Of these, 1,019 wells, or 74 percent, showed declines. In 462 Ogallala wells, the changes in water levels were declines or rises of 2 feet or less from 1995 to 2005. Wells with water level declines are located close to wells showing water level recovery and with wells that had minimal water level change (Figure 5-2).

One area with water level declines over 25 feet stretches west to east across portions of Dallam, Hartley, Sherman, Moore, Hansford, and Hutchinson counties. Similarly, portions of Parmer, Castro, Lamb, Hale, Swisher, Yoakum, Gaines, and Dawson counties experienced declines of up to 50 feet, and even up to 100 feet in some places. In general, these areas of higher drawdown are surrounded by zones of moderate water level declines, and they sometimes transition to areas of minimal water level change and of water level recovery.

There were many wells in the Ogallala Aquifer that showed moderate water level rises between 1995 and 2005. For example, portions of the northeastern Ogallala Aquifer including Lipscomb, Roberts, Hemphill, Armstrong, and Randall counties registered mostly moderate water level rises. The Palmer Drought Severity Index shows the weather in 2005 was wetter than in 1995 in this area of the state, indicating that some of this recovery could be a result of short-term changes in weather and pumping rather than a long-term trend (see Figure 3-4).

Water levels in Carson County Well 06-36-602 in the Ogallala Aquifer have been on a gradual downward trend (Figure 5-3). Because this well was not in use, the long-term trend in water levels at this site reflects the regional effect of groundwater pumping in the surrounding area. Seasonal variations in water levels, probably due to irrigation pumping, are evident throughout the period of record. Water levels in Dawson County Well 28-18-301 fell until the mid-1970s, when economic factors led to a steep decline in regional irrigation pumping and to two decades of rebounding water levels. The resurgence of irrigated agriculture in Dawson County has resulted in a steady water level decline since 1993 (Harvey Everheart, Mesa Underground Conservation District, personal communication, 2007).

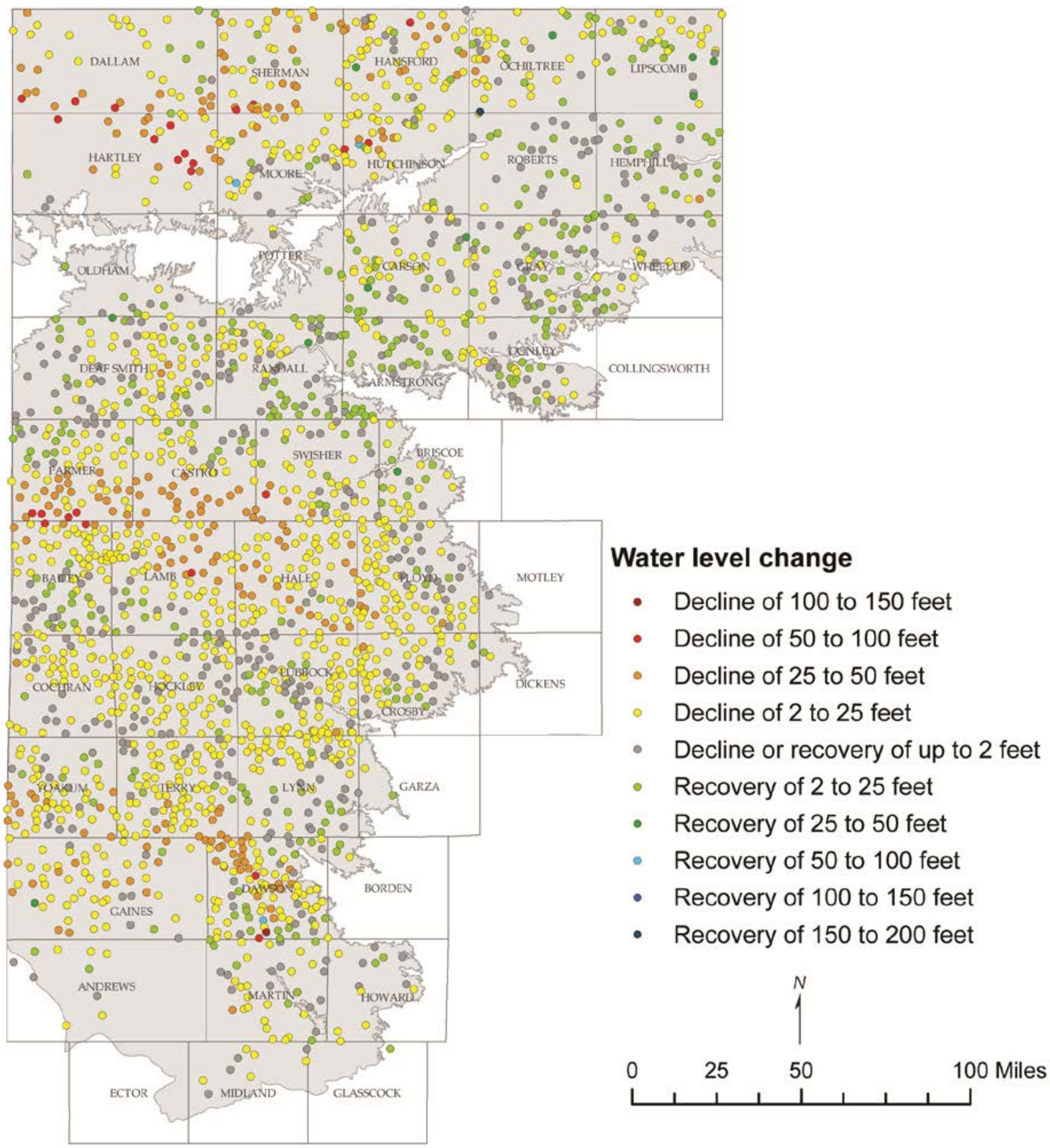


Figure 5-2. Areal distribution of wells and observed changes in water levels for the Ogallala Aquifer, 1995 to 2005.

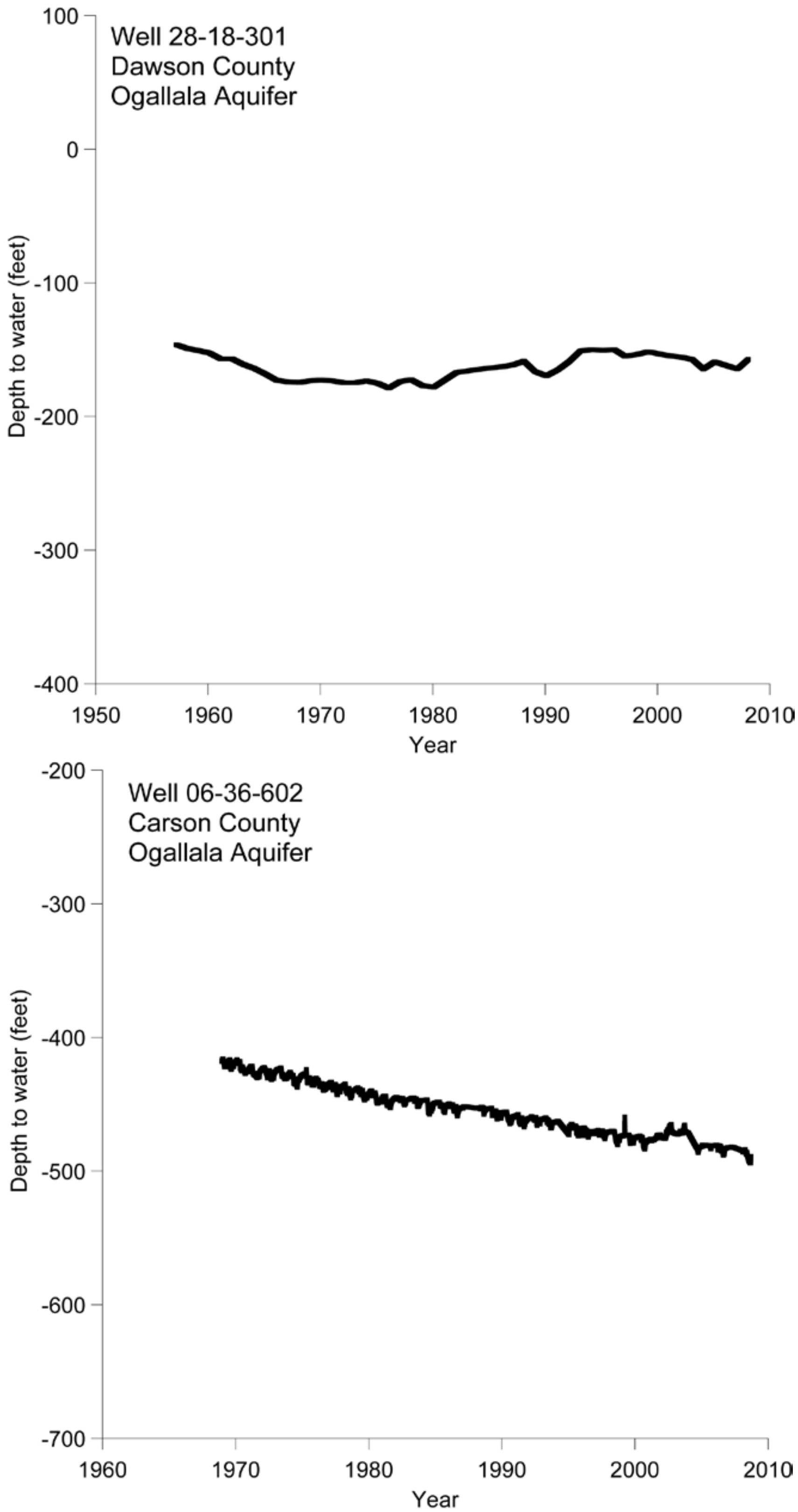


Figure 5-3. Hydrograph for two wells in the Ogallala Aquifer.

5.2 Gulf Coast Aquifer

From 1995 to 2005, the Gulf Coast Aquifer experienced an overall slight water level recovery (Figure 5-4). The median water level change was a rise of 0.9 feet. The largest water level rise, 143.8 feet, was recorded in Well 65-12-622, a public water supply well in Harris County, and the largest decline, 242.0 feet, was in Well 65-16-114, an industrial well also located in Harris County.

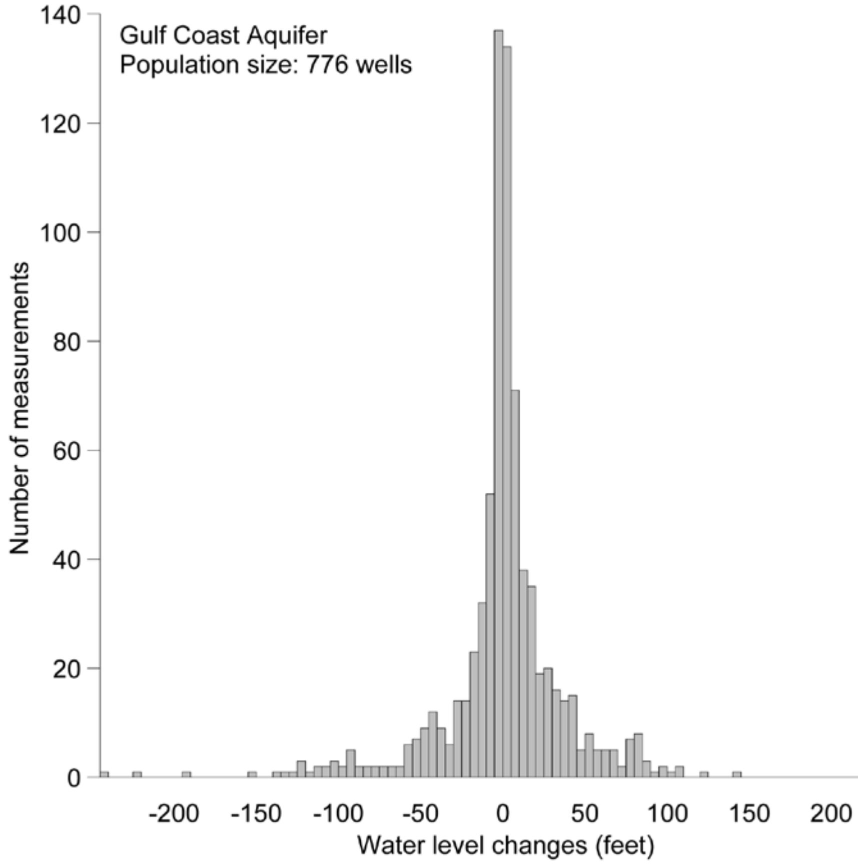


Figure 5-4. Water level changes in the Gulf Coast Aquifer, 1995 to 2005.

From 1995 to 2005, 223 wells, or 29 percent, indicated moderate water level recovery (2 to 25 feet), and a total of 192 wells, or 25 percent, showed moderate water level declines (2 to 25 feet). In 144 wells, or 19 percent, the change in water levels was minimal (up to 2 feet). The central section of the aquifer, including DeWitt, Victoria, Lavaca, Jackson, Colorado, and southern Wharton counties, recorded consistent moderate (2 to 25 feet) water level recovery (Figure 5-5). Some wells in central Harris County recorded more significant water level rebounds (25 feet or more), adding to the moderate water level recovery trend appearing in eastern Harris County and in Galveston County. These rebounds took place despite the fact that the total volume of pumped groundwater in the Harris-Galveston Subsidence District was approximately 316 million gallons per day during both 1995 and 2005 (Michel, personal communication, 2009). The 2005 pumpage in the district is an anomaly in that it followed four years (2001 to 2004) of accentuated reductions in groundwater withdrawals, as the City of Houston was switching from groundwater to surface water supplies to slow land surface subsidence in the area. During 2005, however, technical difficulties in the acquiring of surface water forced the City of Houston to revert back to groundwater for about six months (Michel, personal communication, 2009), leading to the increased pumpage for that year. The rises in water levels from 1995 to 2005 could be explained by a lag in the response of groundwater levels to changes in pumping, by the timing of the measurements, and by changes in the locations of the City of Houston pumping centers. Across the northeastern and southwestern segments of the Gulf Coast Aquifer, water level changes were mostly moderate declines of 25 feet or less. There were, however, significant declines (up to 100 feet or more) in virtually all the wells monitored in Montgomery County and in many wells in southern Harris County. Similarly, many wells in Fort Bend County across the county line from Harris County experienced water level declines of up to 100 feet.

Hydrographs for two public water supply wells in Harris County show two different trends (Figure 5-6). In Well 65-04-310, water levels declined from 1970 through year 2000. From 2000 to 2005, water levels rose, likely due to the steep decline in pumping within the Harris-Galveston Subsidence District in the first part of the decade. In Well 65-14-203, water levels have been generally rising since the early 1980s, as surface water has replaced groundwater as the area's predominant water supply.

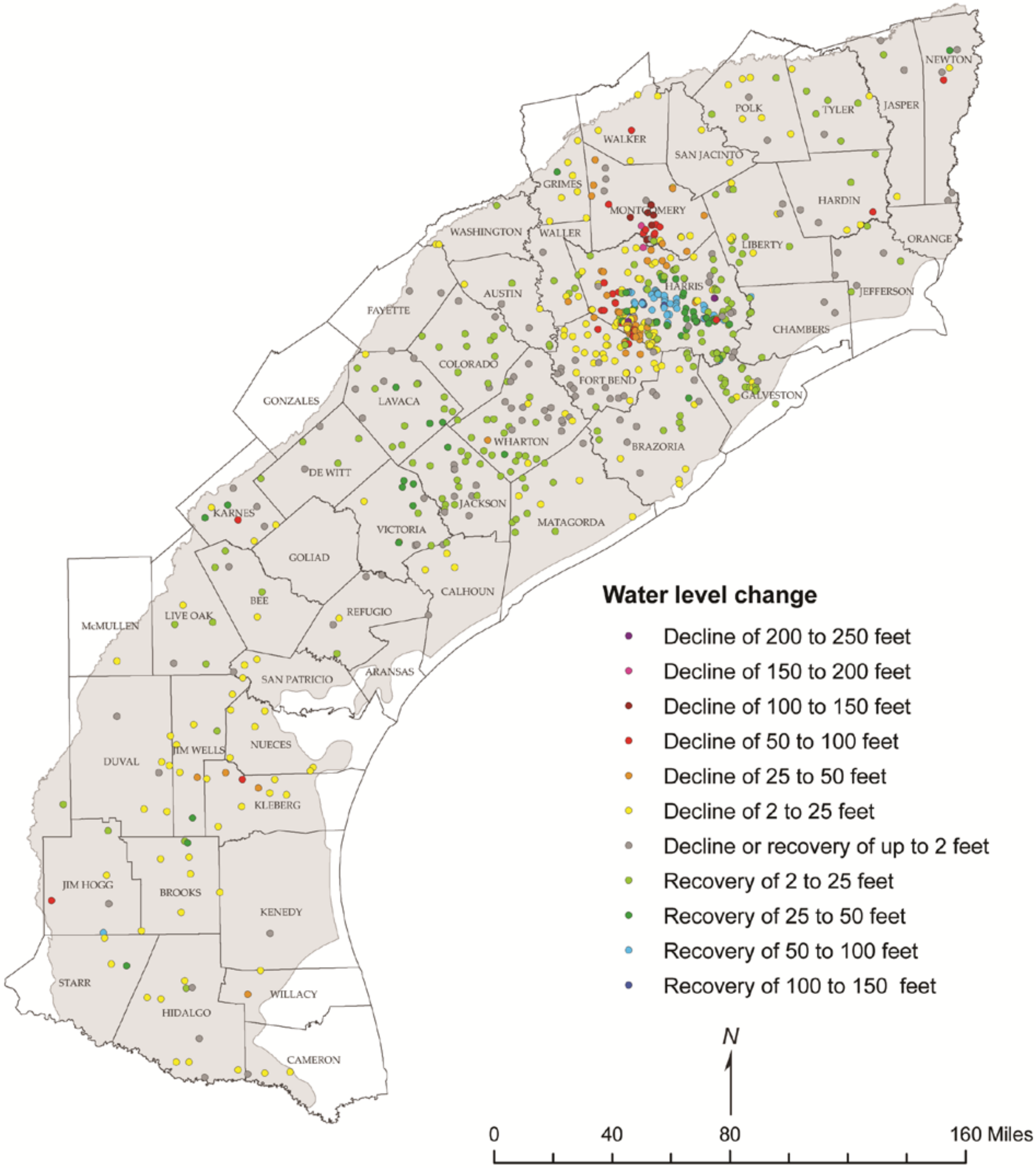


Figure 5-5. Areal distribution of wells and observed changes in water levels for the Gulf Coast Aquifer, 1995 to 2005.

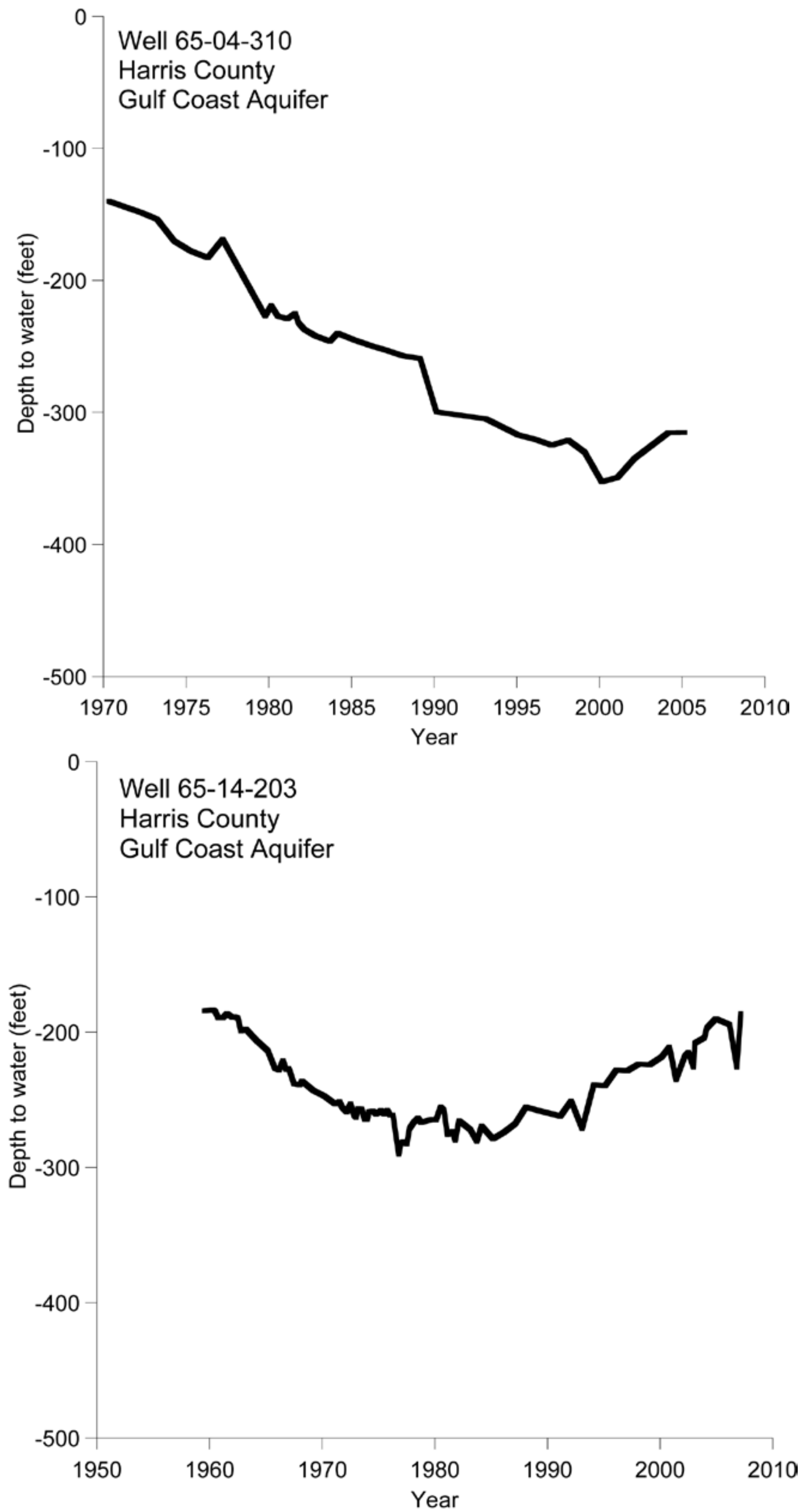


Figure 5-6. Hydrographs for two wells in the Gulf Coast Aquifer.

5.3 Carrizo-Wilcox Aquifer

From 1995 to 2005, water levels in the Carrizo-Wilcox Aquifer declined slightly (Figure 5-7). The median water level change was a decline of 3.8 feet. Well 34-60-602 in Anderson County showed the largest water level drop (107.8 feet), whereas Well 37-27-201 in Nacogdoches County recorded the largest rebound (71.1 feet). Most water level changes were moderate; of the 299 measurements, 143, or 48 percent, showed a decline from 2 to 25 feet, and 42 readings, or 14 percent, showed a rebound of 2 to 25 feet. In 76 wells, or 25 percent of total, the changes in water levels were minimal (± 2 feet).

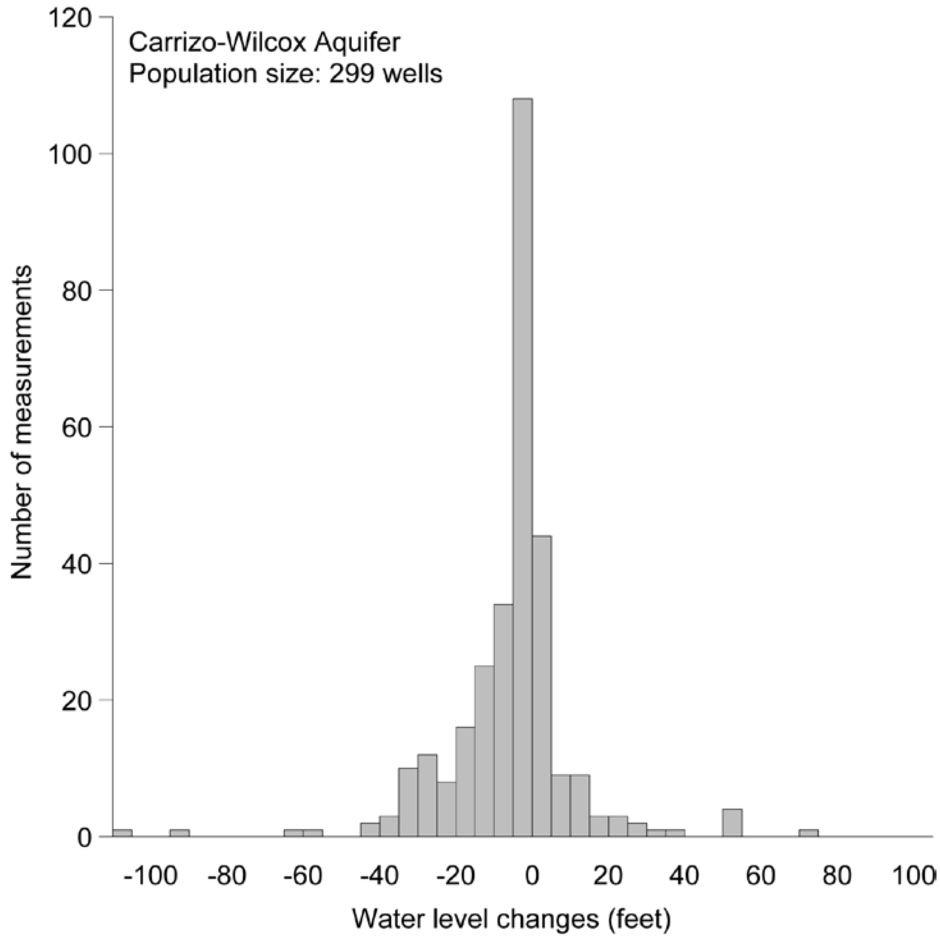


Figure 5-7. Water level changes in the Carrizo-Wilcox Aquifer, 1995 to 2005.

The aquifer-wide changes in water levels in the Carrizo-Wilcox Aquifer were mixed: wells with declining water levels were located close to wells with rebounding water levels (Figure 5-8). Parts of the Winter Garden area in the southwest sustained overall water level declines although some moderate rebounds were noticeable in Zavala and LaSalle counties. In parts of Panola, Rusk, Nacogdoches, and Cherokee counties, water levels rose moderately or showed little change. However, in the section of the Carrizo-Wilcox Aquifer north of the Brazos River, water levels in most of the wells declined moderately (2 to 25 feet). Several wells in Robertson, Smith, Henderson, and Anderson counties exhibited more substantial declines (25 feet to more than 100 feet).

Hydrographs of two wells with distinct water level change trends are shown in Figure 5-9. Well 78-18-206 (in the Winter Garden District) is a windmill used for watering cattle, while Well 37-35-702 (in the northeast) is used for public water supply. The water levels in the windmill declined from the 1920s when the well was flowing through the 1970s, mirroring the decline in well levels throughout the Winter Garden District. After the 1970s, the water levels in Well 78-18-206 stabilized and showed little variation, most likely due to reduced groundwater pumpage at the site and in the region. The water level in the public water supply well 37-35-702, however, declined steeply during the period of record due to pumping in the area.

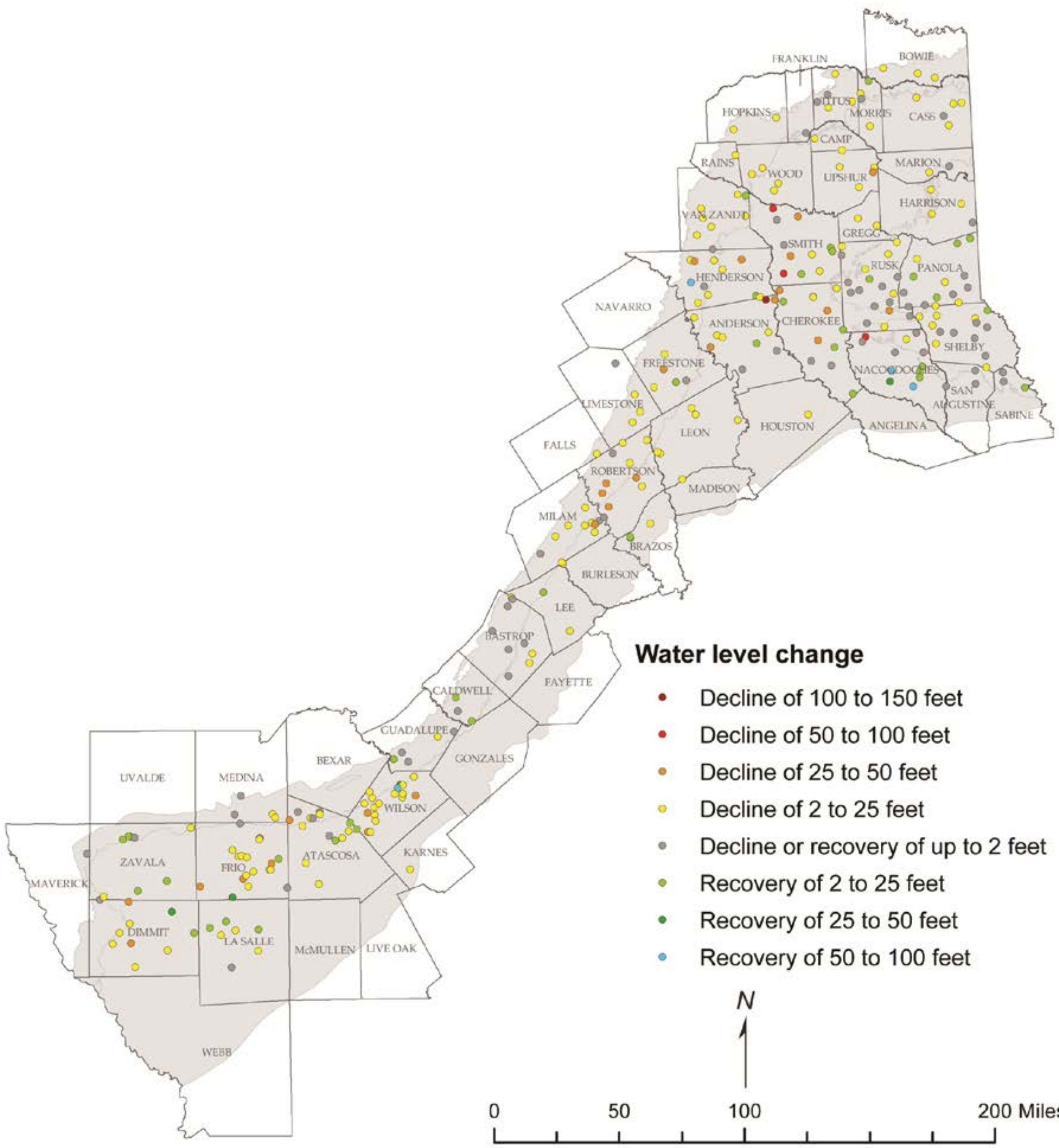


Figure 5-8. **Areal distribution of wells and observed changes in water levels for the Carrizo-Wilcox Aquifer, 1995 to 2005.**

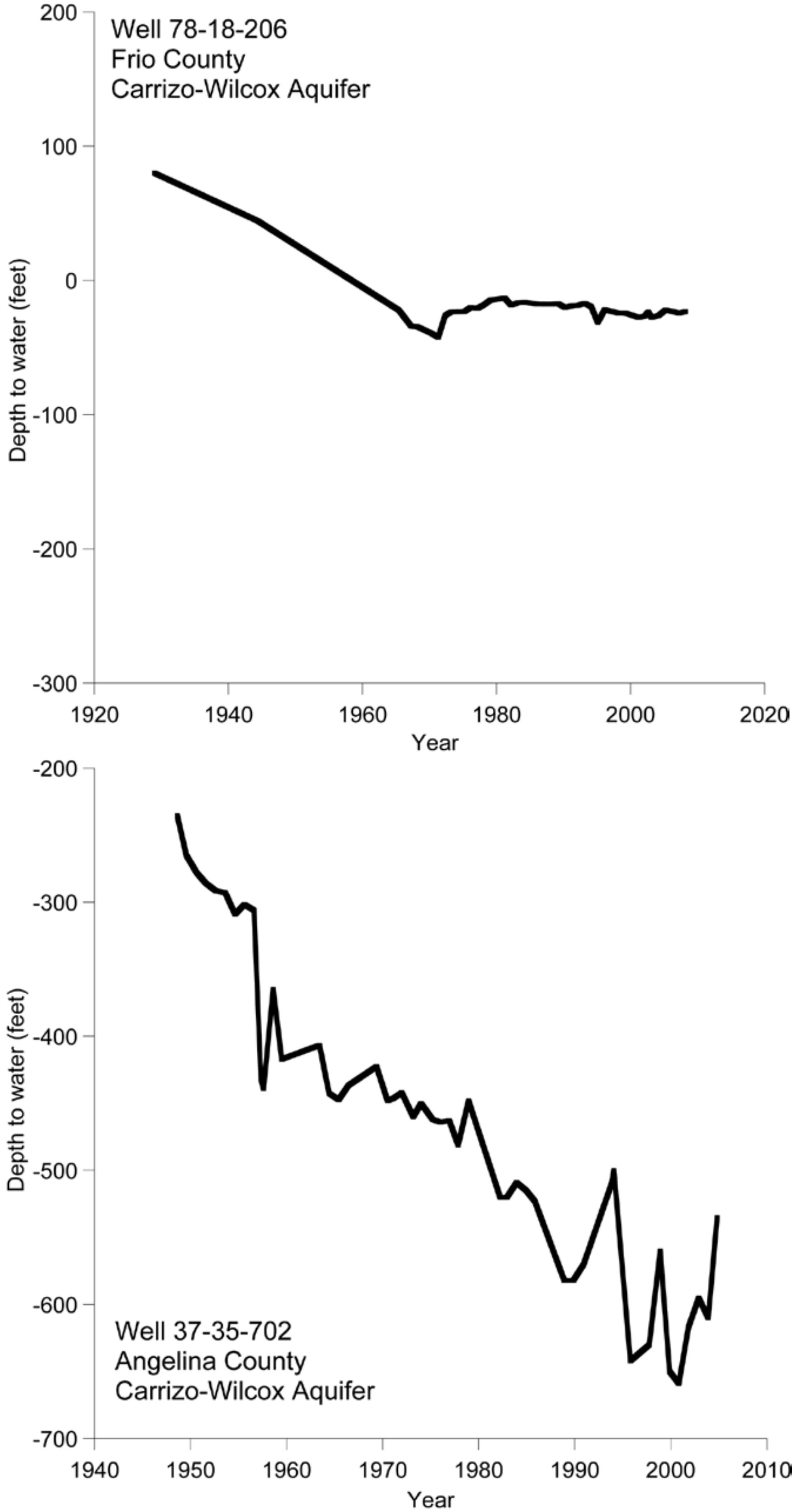


Figure 5-9. Hydrographs for two wells in the Carrizo-Wilcox Aquifer.

5.4 Edwards (Balcones Fault Zone) Aquifer

The Edwards (Balcones Fault Zone) Aquifer is contained within the carbonate rocks of the Edwards and Associated Limestones as defined by Klemt and others (1979). The Balcones Fault Zone is where this aquifer is the most prolific, supplying water to about 1.7 million people. The aquifer is subdivided into three segments: the segment north of the Colorado River, the Barton Springs segment south of the Colorado River and north of a groundwater divide near Kyle, and the San Antonio segment between the groundwater divides in Kyle and in central Kinney County. All three sections of the aquifer are karstified, more intensely so in the San Antonio and Barton Spring segments. Solution features, such as honeycombing, sinkholes, caverns, and fractures are commonplace throughout the aquifer. They allow for rapid infiltration of recharge and rapid movement of groundwater within the aquifer. There is, however, an important difference in the mechanisms of aquifer recharge between the northern segment and the other segments of the aquifer. Much of the recharge to the San Antonio and Barton Springs segments is provided by streams draining the "contributing zone" to the north and west and percolating quickly through the recharge zone. Streamflow studies have shown water losses of up to 100 percent where creekbeds cross the recharge zone of the aquifer in the Barton Springs and San Antonio segments. The northern segment, however, does not have a distinct contributing zone—recharge is more diffusely distributed and occurs mainly through sinkholes dotting the aquifer outcrop or through the less developed drainage network (Woodruff, 1985).

Because the Edwards (Balcones Fault Zone) Aquifer is a karstic aquifer—a limestone aquifer that has been partially dissolved so that it responds rapidly to rainfall and water flows through it—it is not well suited to comparing water levels between years and assessing long-term trends. Water levels in this aquifer change very quickly in response to recharge events, meaning that recharge from streamflow and rainfall percolation is the driver of water level change.
In 2005, water levels in the Edwards (Balcones Fault Zone) Aquifer were very slightly lower than in 1995 (Figure 5-10). The median change was a decrease of 0.5 feet. The largest water level fluctuations occurred in Medina County (Well 69-38-601, 63.5 feet higher in 2005) and in Comal County (Well 68-24-117, 129.5 feet lower in 2005). Of the 110 wells measured, 24, or 22 percent, had water levels moderately higher (2 to 25 feet) in 2005 than in 1995. Water levels in 40 wells, or 36 percent, were moderately lower (2 to 25 feet) in 2005 compared with 1995, while water levels in 27 wells, or 25 percent, experienced minor changes (± 2 feet).

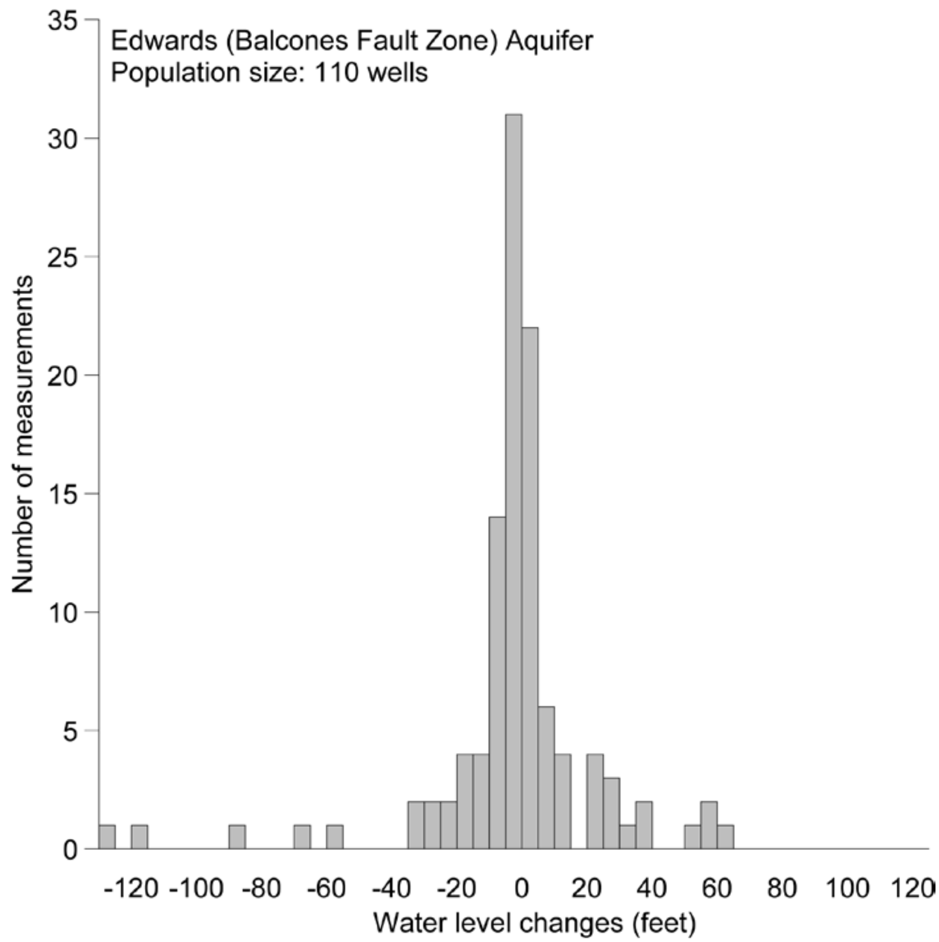


Figure 5-10. Water level changes in the Edwards (Balcones Fault Zone) Aquifer, 1995 to 2005.

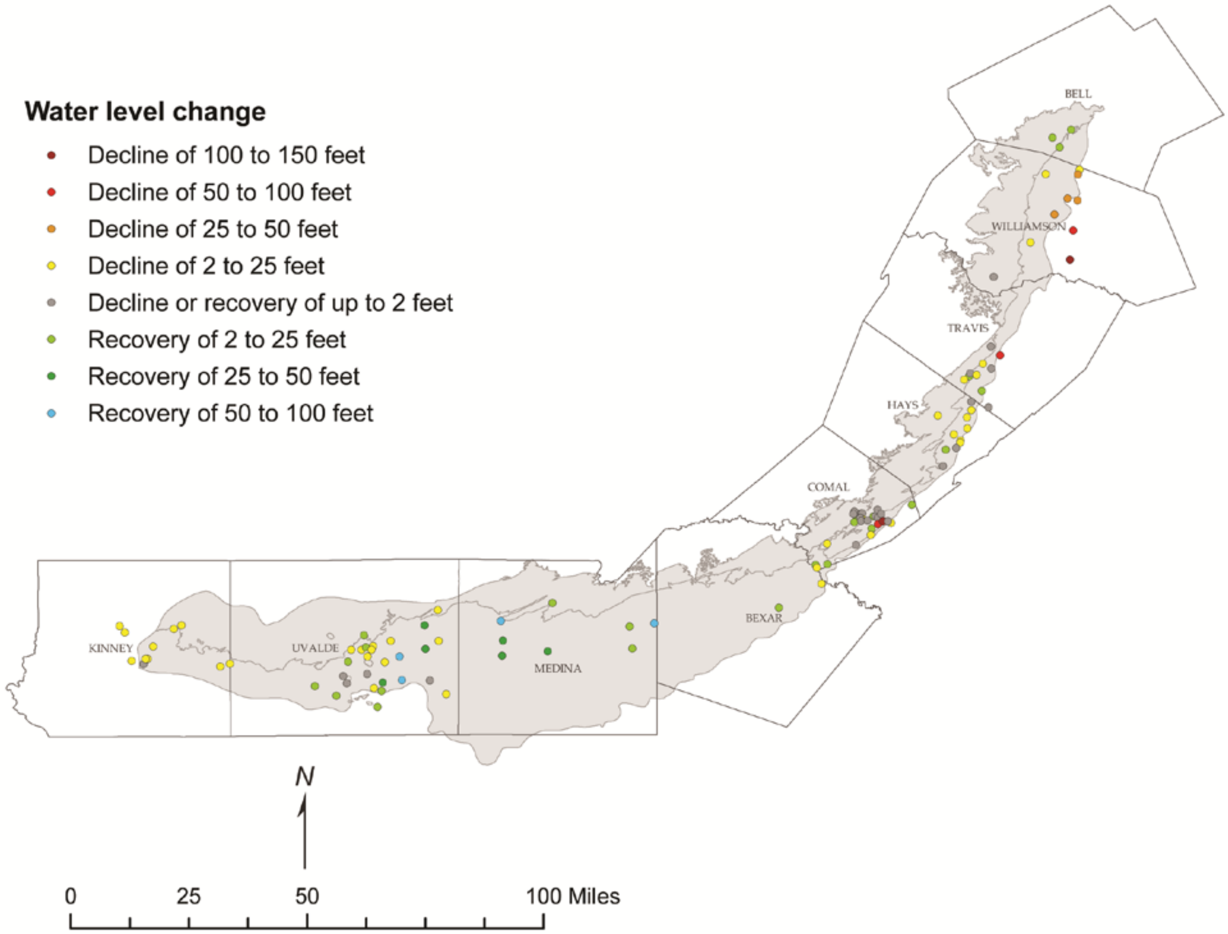


Figure 5-11. Areal distribution of wells and observed changes in water levels for the Edwards (Balcones Fault Zone) Aquifer, 1995 to 2005.

In the western segment of the aquifer in Kinney County, water levels were lower in 2005 than in 1995 in all measured wells (Figure 5-11). Wells in Medina County recorded water level rises—sometimes significant—while in Uvalde County the changes in levels were mixed. The middle segment of the Edwards (Balcones Fault Zone) Aquifer, extending from northeastern Bexar to Comal, Hays, and southern Travis counties, experienced mixed water level changes. Most wells in northern Travis and Williamson counties had water levels lower in 2005 than in 1995. In some wells, the decreases were more than 50 feet. In the northern segment of the aquifer, wells in Williamson County showed water level decreases while wells in Bell County showed moderate water level rises.

Climate data are lacking for the western half of the Edwards (Balcones Fault Zone) Aquifer (Figure 3-2). Where available, the Palmer Drought Severity Index data reveal that, with two exceptions, at stations located in the contributing zone adjacent to the Edwards (Balcones Fault Zone) Aquifer, 2005 was drier than 1995 (Figure 3-4). Many wells in Kinney, Uvalde, Comal, Hays, Travis, and Williamson counties recorded changes consistent with this trend; that is, their water levels were lower in 2005 than in 1995. Other wells, however, showed water level rises.

If one accepts that recharge is the driver of water level change in this setting, water levels higher in 2005 than in 1995 would be incompatible with drier weather. Because recharge to the San Antonio and Barton Springs segments is controlled by the infiltration of streams from the contributing zone in the aquifer outcrop, the available climate data do not fully explain the variations in water levels in this area.

The northern section of the Edwards Aquifer lacks a contributing zone. The recharge to this section of the Edwards (Balcones Fault Zone) Aquifer is derived primarily from diffuse infiltration of rainfall through the outcrop of the Edwards Limestone. Water levels in Williamson County wells were lower in 2005 than in 1995, while three wells in Bells County showed water level rises. The only climate datapoint available for the northern segment of the Edwards (Balcones Fault Zone) Aquifer shows that 2005 was drier than 1995. This is consistent with the water level declines observed in Williamson County, but it does not explain the rises in Bell County.

The Edwards Aquifer Authority uses water levels in Well 68-37-203 in the middle segment of the aquifer (known to many as the Bexar County Index Well J-17, Figure 5-12, top) as the trigger for different stages of aquifer pumping limits during times of drought. The water level variation in this well is typical of many wells in the Edwards (Balcones Fault Zone) Aquifer, which display large, short-term water level variations that are recharge-driven. Over the period of record there was little or no overall change in storage. Similarly, the hydrograph for Well 58-27-305 (Figure 5-12, bottom), in the northern segment of the aquifer, shows cyclical, climate-driven variations in water levels.

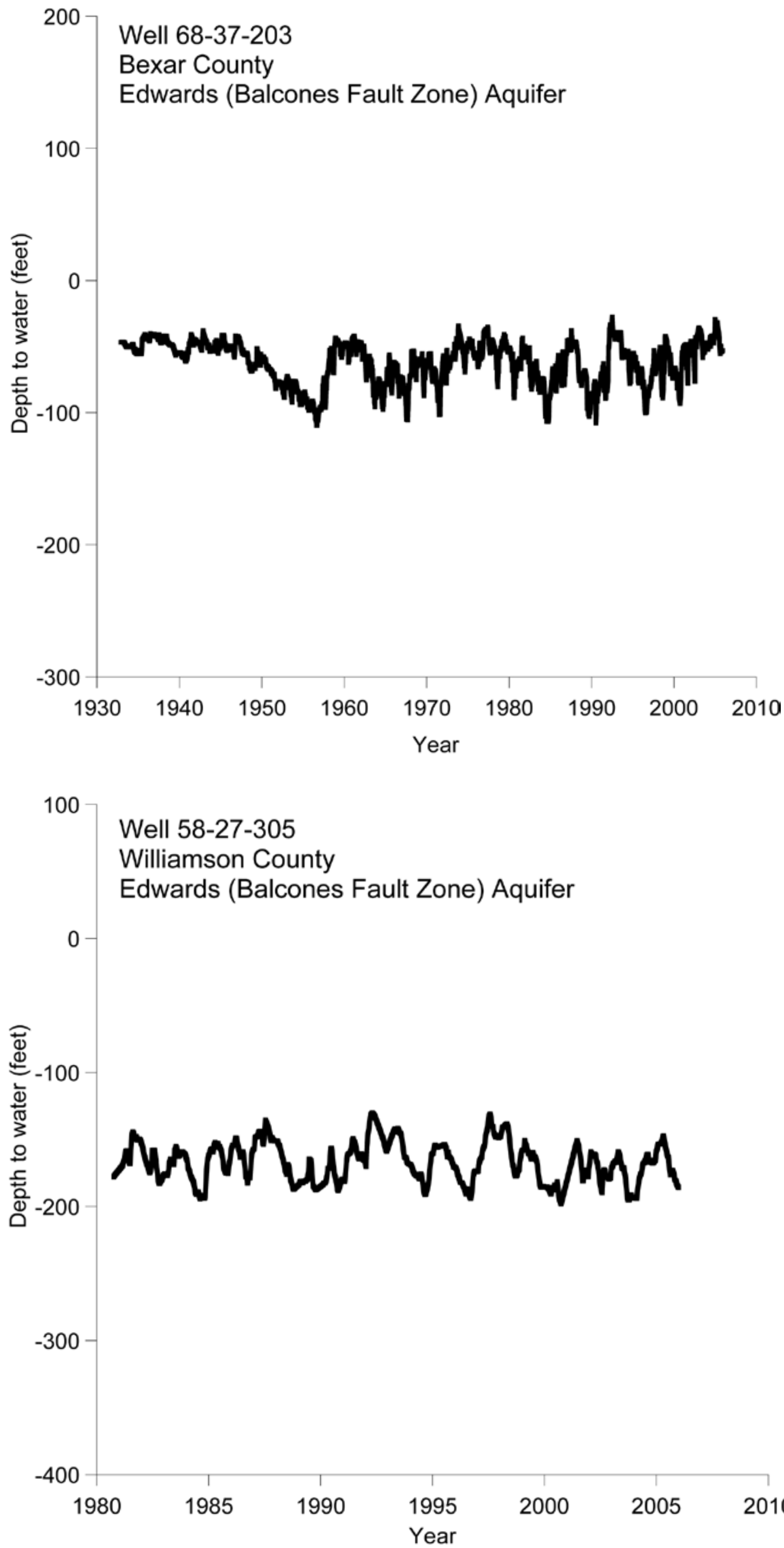


Figure 5-12. Hydrographs for two wells in the Edwards (Balcones Fault Zone) Aquifer.

5.5 Trinity Aquifer

In 2005, water levels in the Trinity Aquifer were moderately lower than in 1995 (Figure 5-13). The median change in water levels was a decline of 4.3 feet. The largest decline of 179 feet was recorded in Denton County Well 19-54-603. The largest water level rise of 312 feet was recorded in Bell County Well 40-45-701.

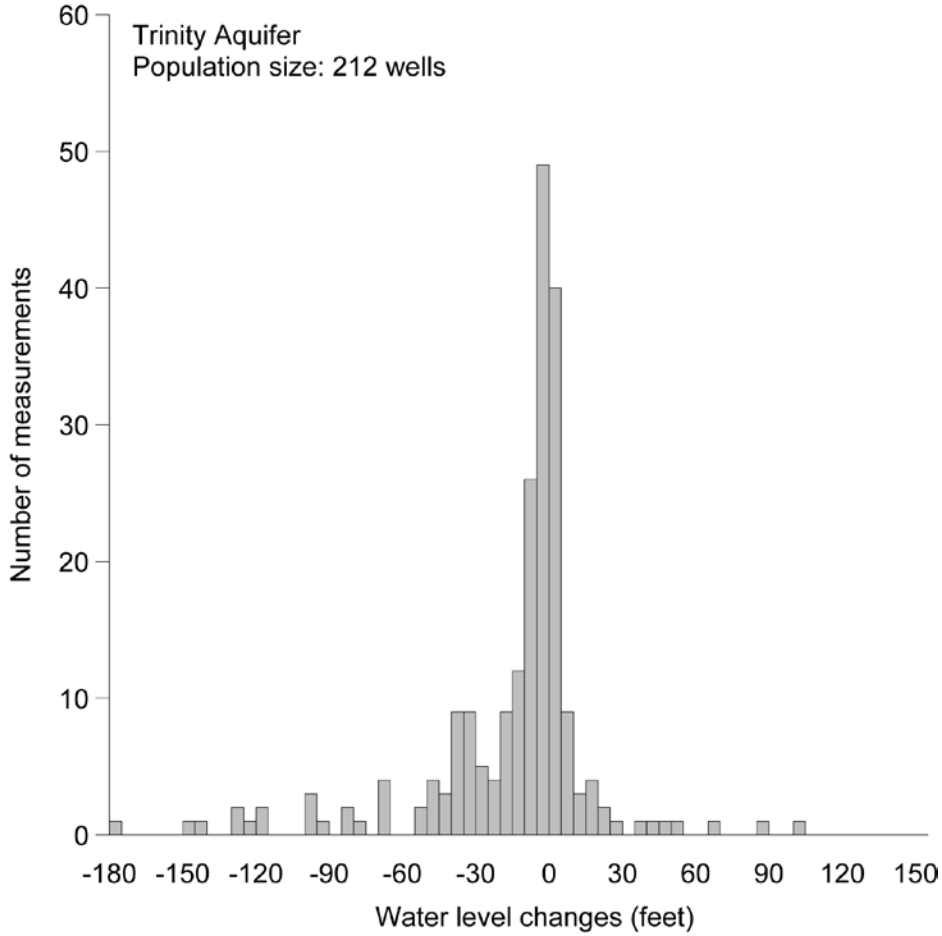


Figure 5-13. Water level changes in the Trinity Aquifer, 1995 to 2005.

On an aquifer-wide basis, moderate (2 to 25 feet) water level changes occurred in 108 wells, or 50 percent, of TWDB-measured wells. Of these, 77 wells showed water level declines and 31 wells showed water level rises. Water levels in 53 wells, or 24 percent, changed by no more than 2 feet between 1995 and 2005.

Many areas displayed consistent water level declines between 1995 and 2005 (Figure 5-14). With few exceptions, the aquifer outcrop from Montague County in the north to Kerr County in the south experienced water level declines of up to 100 feet. In Kerr, western Kendall, and northern Bexar counties, declines were larger in wells completed in the Glen Rose Formation near the aquifer's western limit and in wells completed in the Lower Trinity Aquifer near Kerrville in Kerr County. One area of notable declines is in the east-central part of the aquifer in parts of Somervell, Bosque, Hill, McLennan, and Falls counties. With the exception of five wells in McLennan County, all other wells measured in these counties recorded declines in water levels. Many of them are public water supply wells serving communities such as Hewitt, Coryell City, McGregor, and Woodway. Another area of water level decline was in the northern part of the Trinity Aquifer, extending over parts of Cooke, Denton, Tarrant, and Lamar counties. Wells supplying water to cities such as Gainesville, Glen Rose, West, Bellmead, Bosque, Coryell, Chilton, and Holland recorded some of the largest water level declines. However, areas of Tarrant, Denton, Grayson, Erath, McLennan, Kendall, Bandera, and Gillespie counties showed rising water levels. Wells owned by the cities of Denton, Valley Mills, Hewitt, Boerne, and Kerrville, and several other industrial and household wells rebounded by up to 100 feet. Although both hydrographs in Figure 5-15 record water level declines, municipal water supply Well 39-17-901 shows steeper declines than Well 69-16-201, which is used for household and livestock watering. The greater water level decline in the municipal supply well may be due to higher pumping rates.

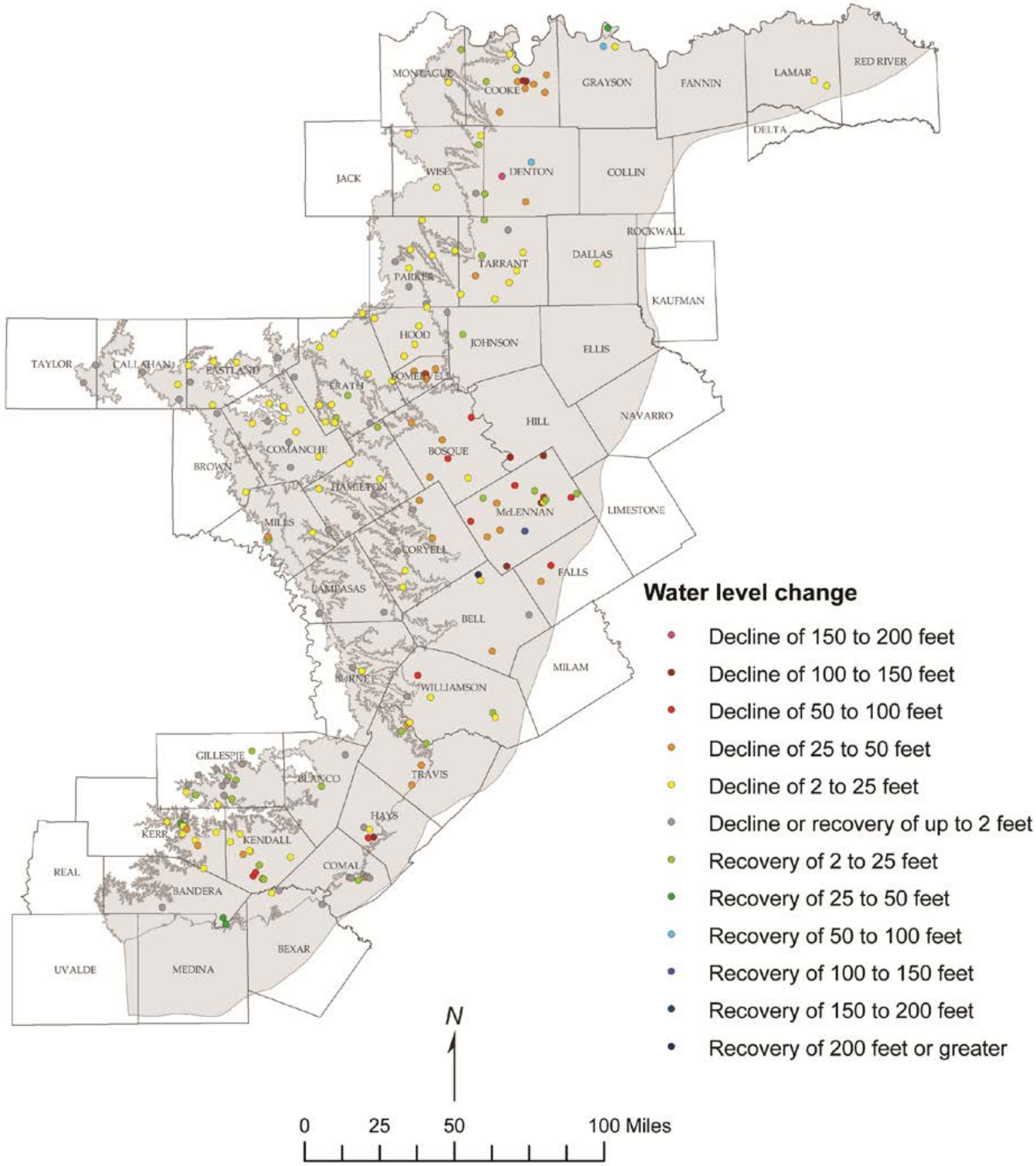
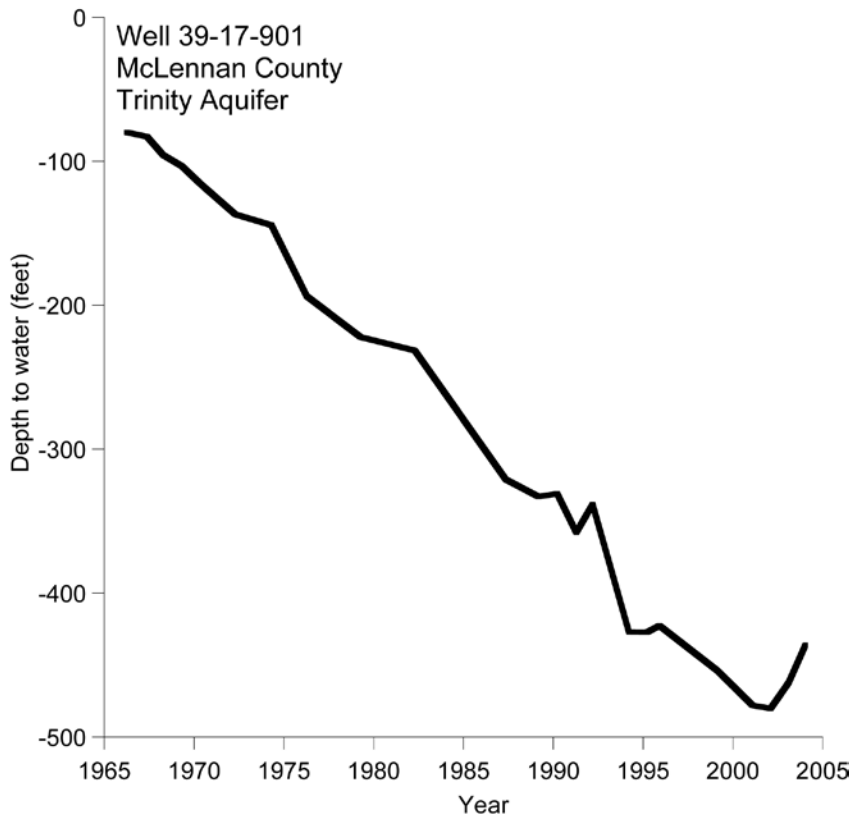


Figure 5-14. Areal distribution of wells and observed changes in water levels for the Trinity Aquifer, 1995 to 2005.



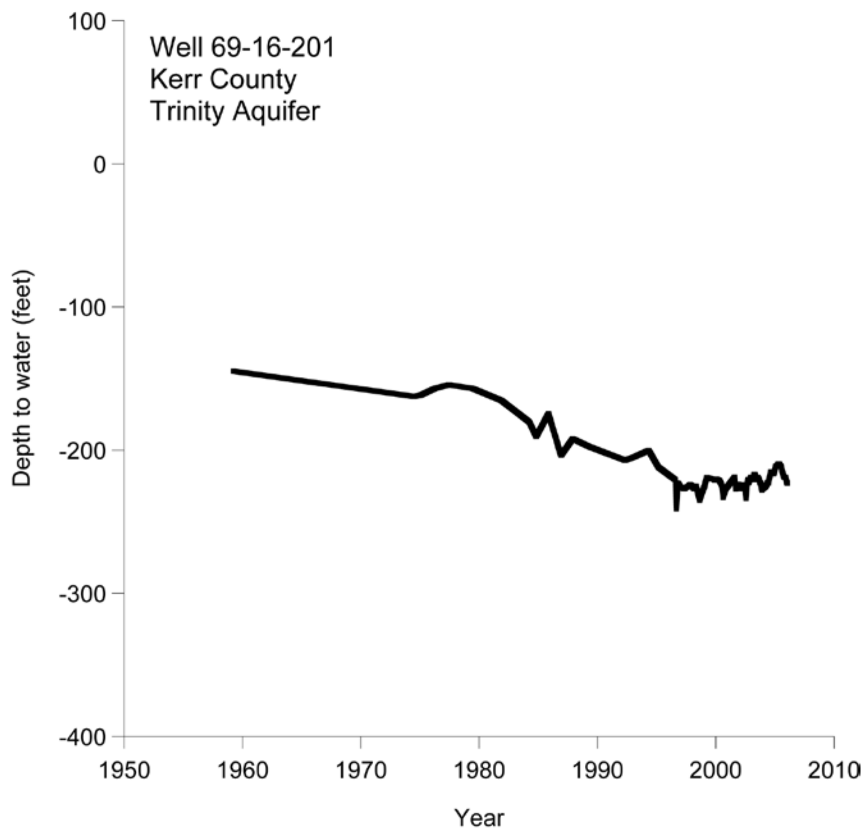


Figure 5-15. Hydrographs for two wells in the Trinity Aquifer.

5.6 Edwards-Trinity (Plateau) Aquifer

Between 1995 and 2005, the Edwards-Trinity (Plateau) Aquifer experienced a slight overall recovery in water levels (Figure 5-16). The median aquifer-wide water level change was a rise of 0.5 feet. The largest decline (34.4 feet) and the largest rise (96 feet) were both measured in Glasscock County in Well 44-11-707 and Well 44-12-705, respectively.

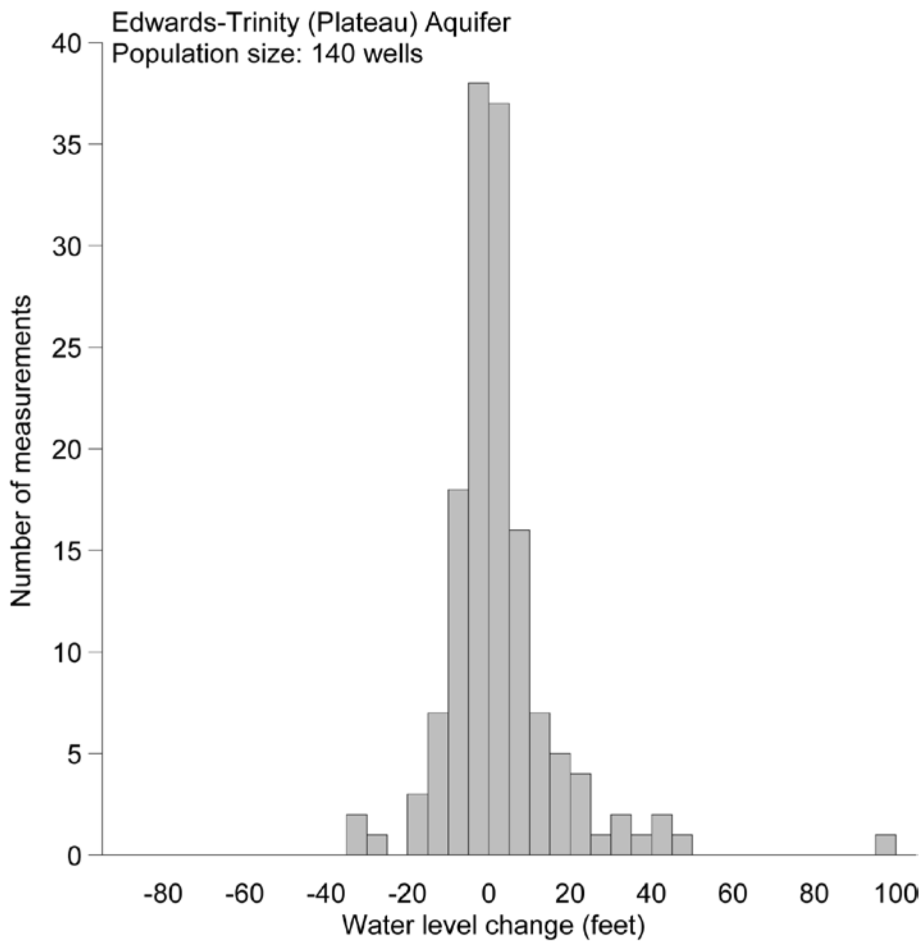


Figure 5-16. Water level changes in the Edwards-Trinity (Plateau) Aquifer, 1995 to 2005.

Changes in water levels were moderate (2 to 25 feet) in more than two-thirds of the wells for which data were available. Of the 140 wells measured, 47 wells, or 34 percent, recorded moderate declines. Forty-seven wells, or 34 percent, showed water level rises of 2 to 25 feet, while water levels in 42 wells, or 30 percent, showed minimal changes of ±2 feet.

Data coverage for parts of the Edwards-Trinity (Plateau) Aquifer is sparse, with much of the western and southern Edwards Plateau lacking any water level measurements. Overall, water levels in most of the wells measured south of the Crockett-Reagan county line changed very little or recorded rises of up to 50 feet (Figure 5-17), although in several wells in Kinney, Val Verde, Pecos, Schleicher, Kimble, and Gillespie counties, water levels dropped by 2 to 25 feet.

Water levels in wells in the north-central part of the Edwards-Trinity (Plateau) Aquifer, such as parts of Glasscock, Reagan, Ector, and Irion counties, generally declined (from less than 1 foot to up to 50 feet), with some areas showing mixed water level changes. This pattern of water level changes in wells that were mostly low capacity (for example, household and windmills) or unused could indicate areas of low aquifer transmissivity where even light pumping can significantly affect the water levels.

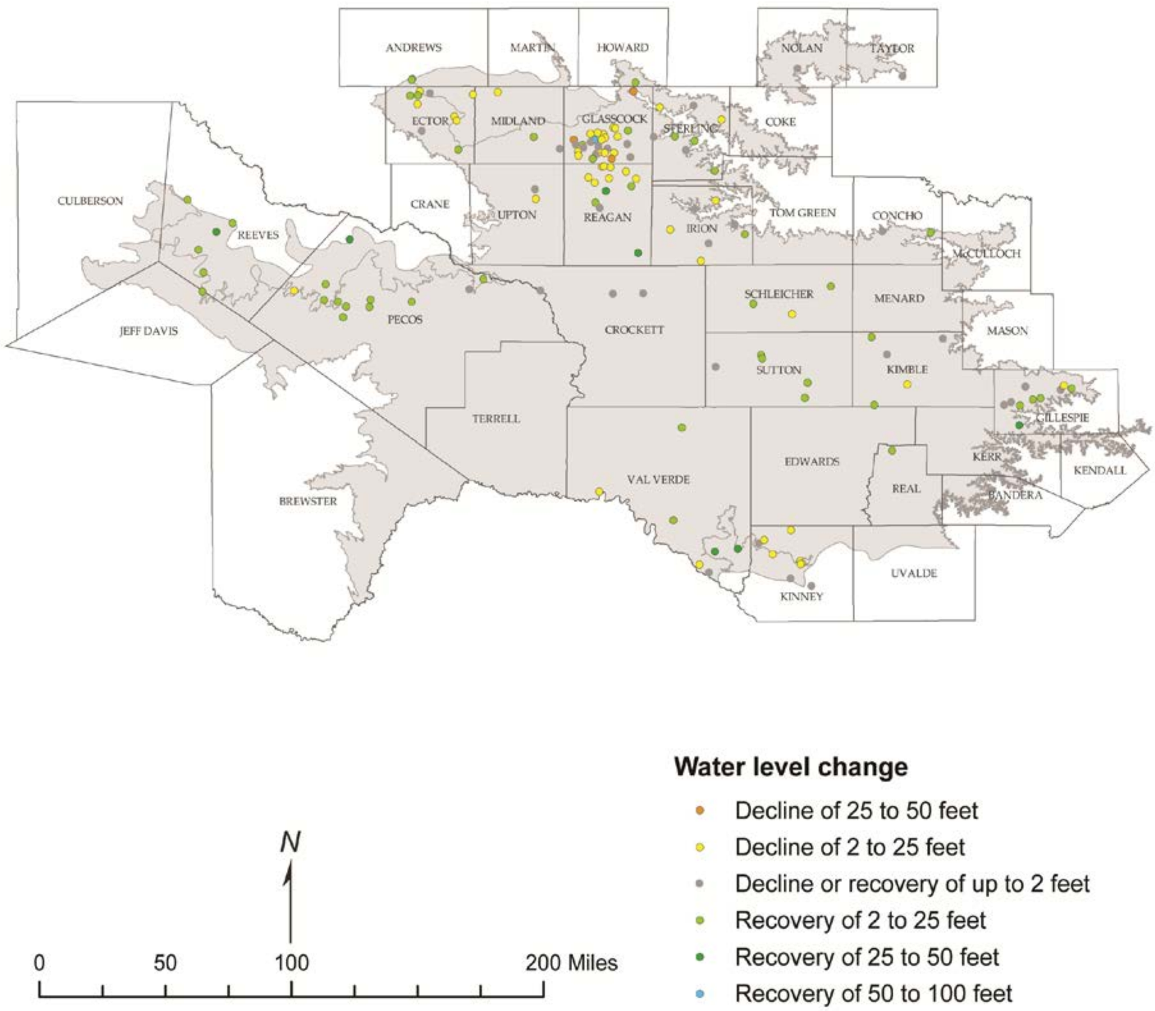


Figure 5-17. Areal distribution of wells and observed changes in water levels for the Edwards-Trinity (Plateau) Aquifer, 1995 to 2005.

We looked at two hydrographs for unused wells located in areas with different patterns of water usage (Figure 5-18). One hydrograph is for a well in Pecos County (Well 52-16-802) located near Belding where irrigation pumpage for agriculture is dominant. This hydrograph shows cyclical changes in water levels coinciding with the recurring irrigation seasons. By contrast, the other hydrograph, for a well in Val Verde County (Well 70-34-301), where water use is limited to household or cattle watering purposes, shows more subdued highs and lows. These changes are probably controlled by alternating wet and dry conditions during the period of record.

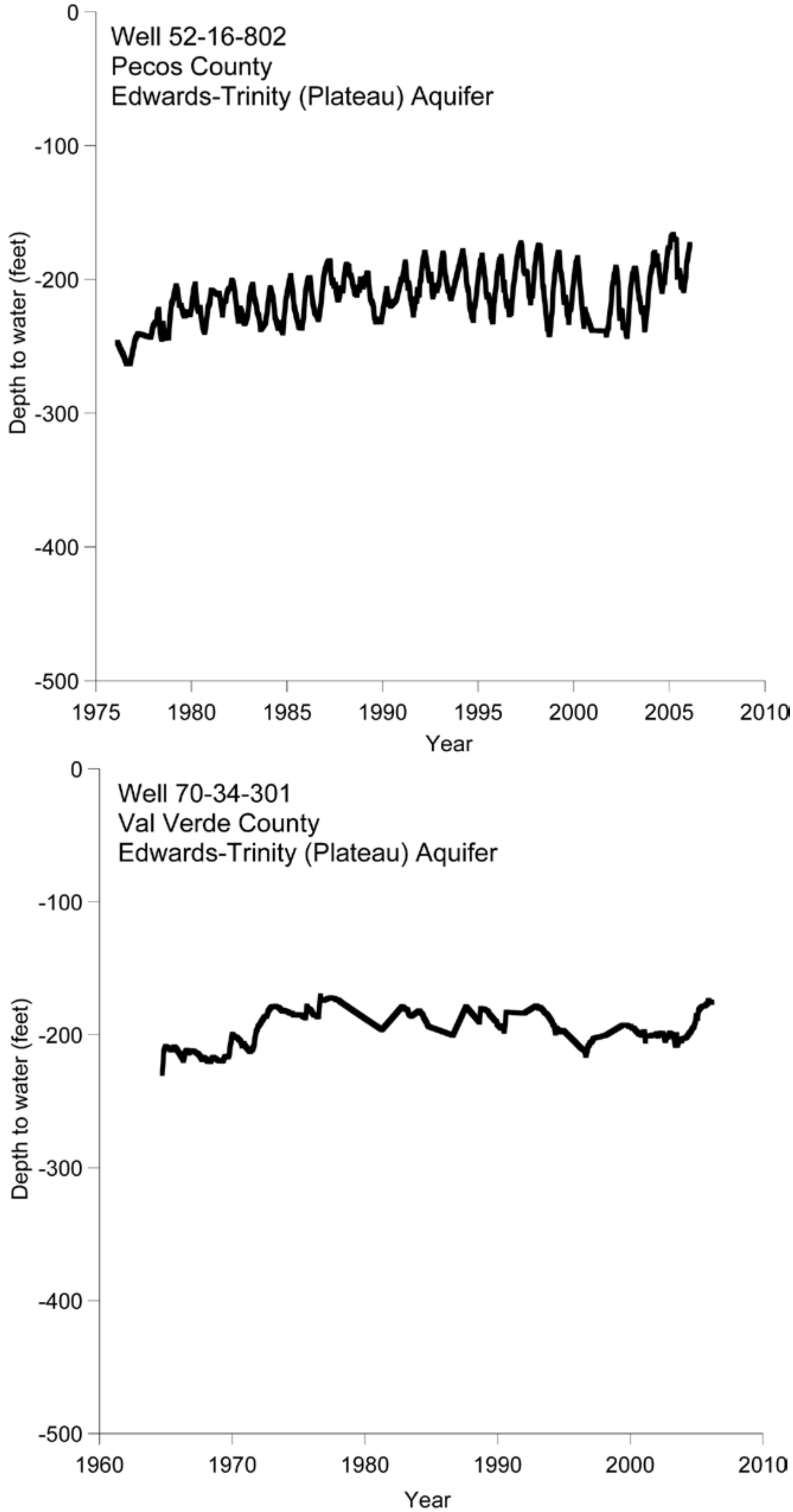


Figure 5-18. **Hydrographs for two wells in the Edwards-Trinity (Plateau) Aquifer.**

5.7 Pecos Valley Aquifer

From 1995 to 2005, water levels in the Pecos Valley Aquifer rose slightly (Figure 5-19). The median change in water levels was a rise of 1.2 feet. The largest decline was recorded in Reeves County (Well 46-36-909), while the largest water level rise took place in Pecos County (Well 46-56-201). The water level in Well 46-36-909 dropped 25.3 feet, and the water level in Well 46-56-201 rose 45.3 feet.

Of the 64 water level measurements available for this aquifer, 41 measurements, or 64 percent, showed moderate changes (2 to 25 feet). Eighteen wells, or 28 percent, recorded moderate declines, and 23 wells, or 36 percent, recorded moderate rises. Water levels in 18 wells, or 28 percent, showed a net change of no more than 2 feet in 2005 compared with 1995.

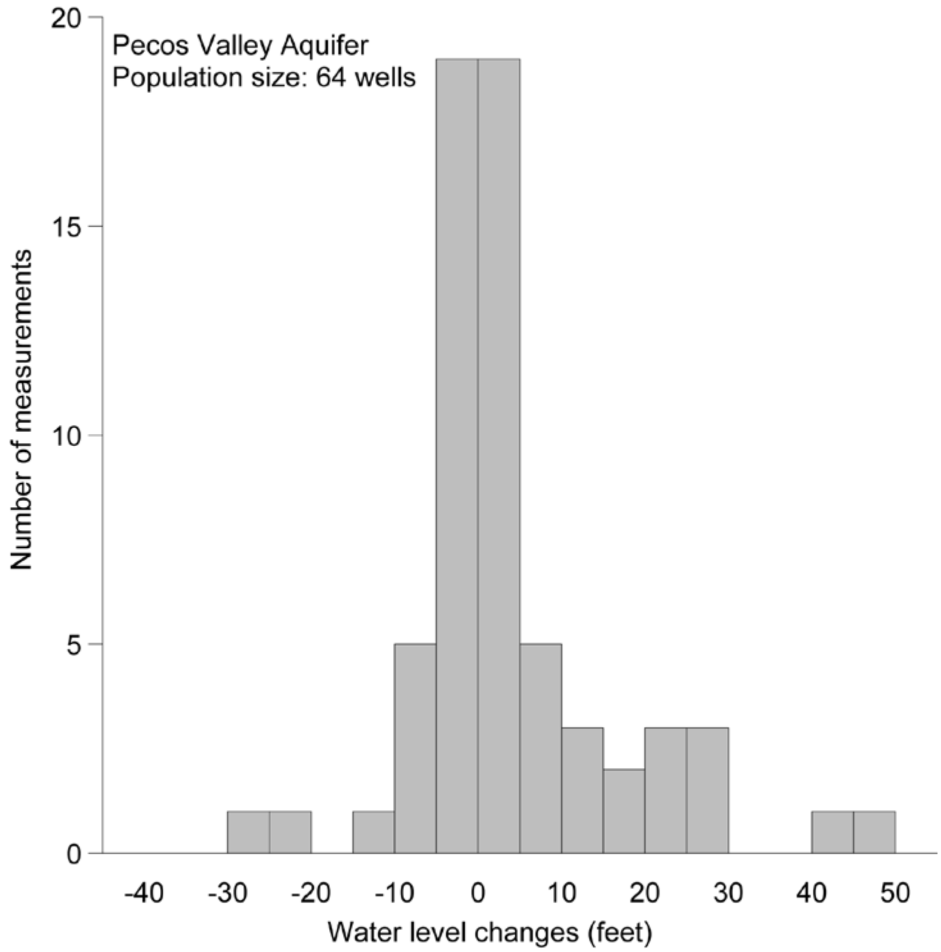


Figure 5-19. Water level changes in the Pecos Valley Aquifer, 1995 to 2005.

Water levels in Winkler, Loving, and Ward counties showed minimal to moderate water changes, with most rises taking place in Winkler County (Figure 5-20). Most of the wells in this area were used for irrigation and livestock watering purposes, with some public water supply wells—primarily those of the Pyote well field that serves the cities of Midland and Odessa.

Beginning in the 1950s, a cone of depression formed in the southwestern part of the aquifer due to irrigation pumping. From 1995 to 2005, most of the wells for which data were available in this area showed little change or water level rises of up to 50 feet, probably due to declines in irrigation pumpage. Other wells in central and northern Reeves County recorded water level declines of up to 50 feet.

Hydrographs of two wells in the study area illustrate long-term temporal water level fluctuations (Figure 5-21). Irrigation pumping appears to be the primary driver of water level changes in the Pecos Valley Aquifer. Water levels in Well 46-35-501, as well as in other wells south and east of the city of Pecos have been rising since the late 1970s, following reductions in groundwater pumping amounts. Wells with little water level variation (for example, Well 46-07-901) are characteristic of areas with little or no groundwater pumping.

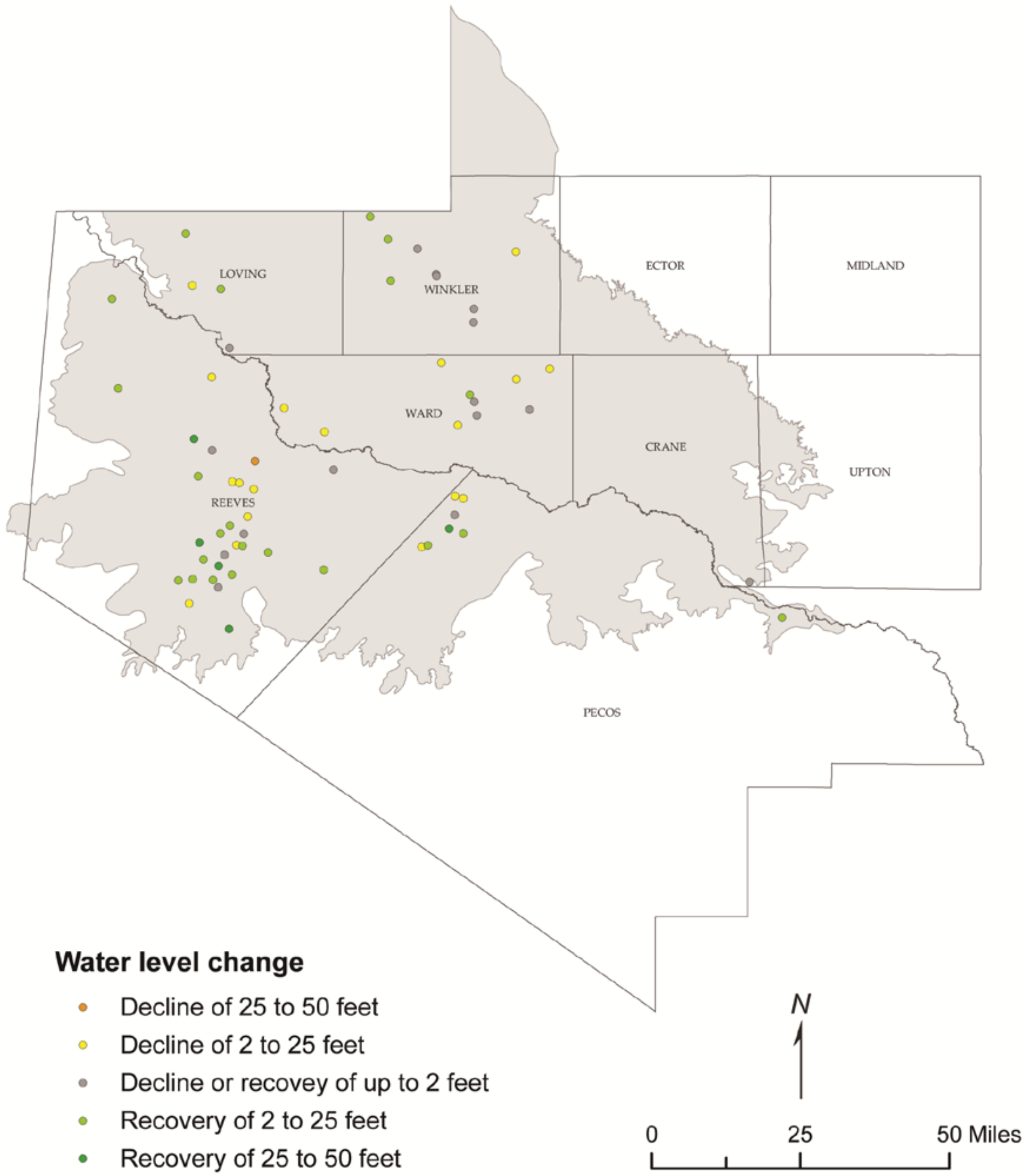


Figure 5-20. Areal distribution of wells and observed changes in water levels for the Pecos Valley Aquifer, 1995 to 2005.

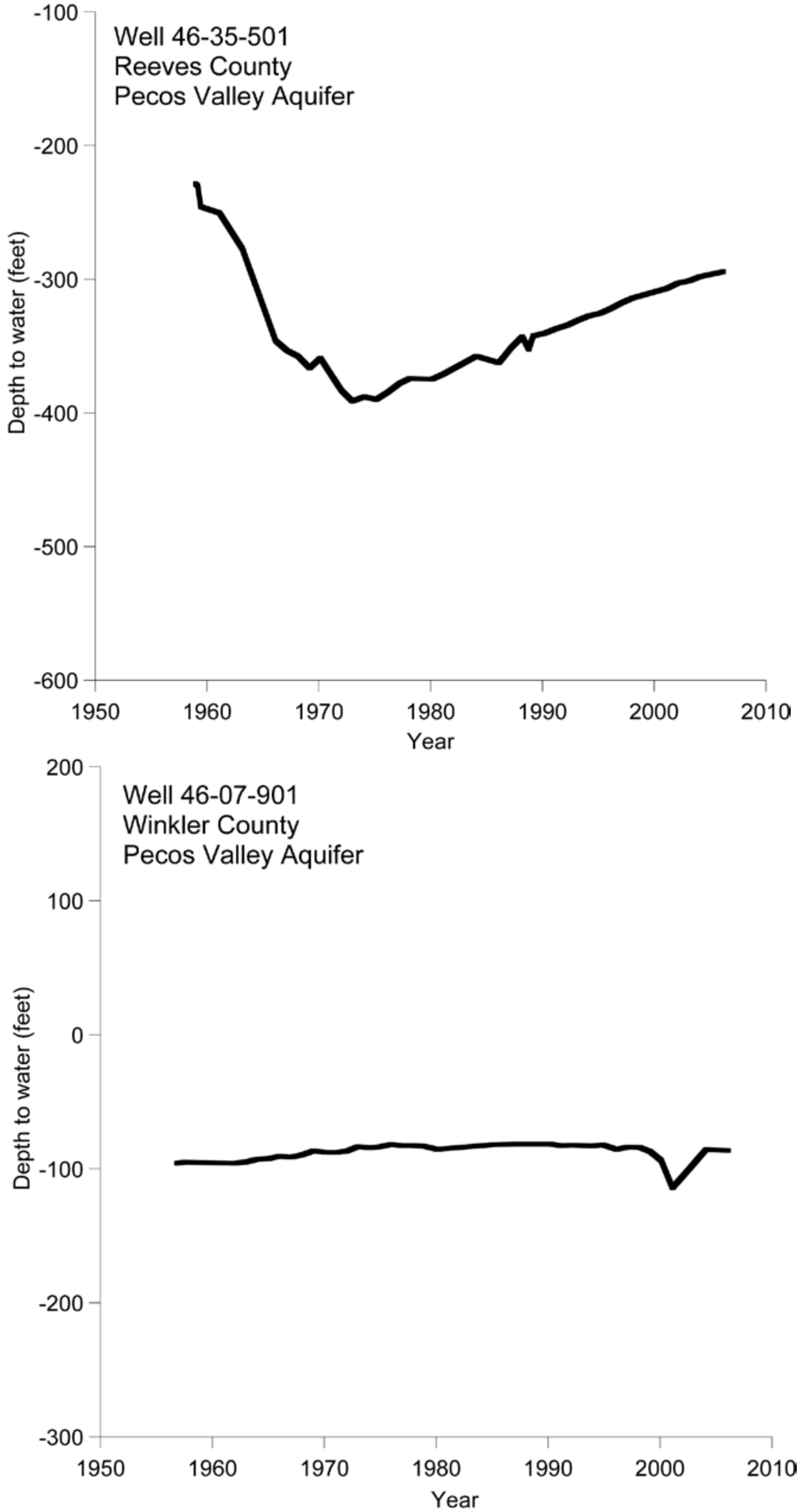


Figure 5-21. Hydrographs for two wells in the Pecos Valley Aquifer.

5.8 Hueco-Mesilla Bolsons Aquifer

Water levels in the Hueco-Mesilla Bolsons Aquifer declined moderately from 1995 to 2005 (Figure 5-22). The median change in water levels aquifer-wide was a decline of 7.0 feet. The largest decline, 50.9 feet, was recorded in the city of El Paso (Well 49-13-808). The sharpest rebound in water levels, 32 feet, occurred in the city of El Paso Well 49-13-202.

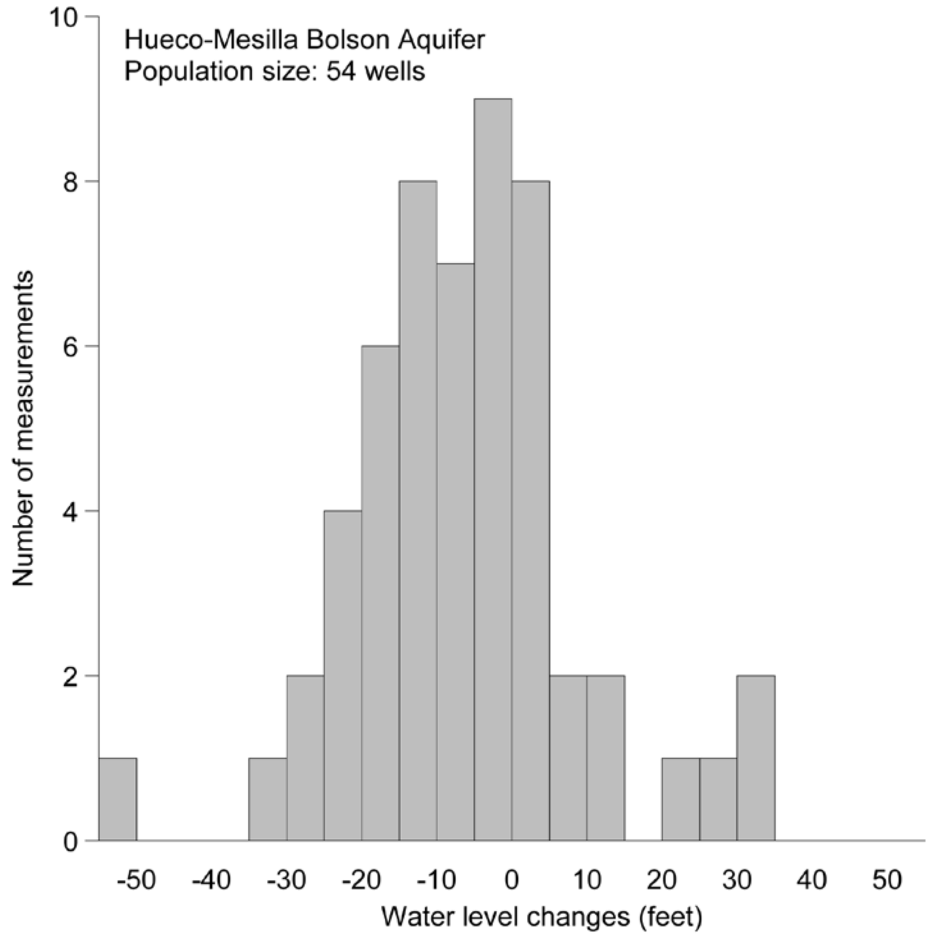


Figure 5-22. Water levels changes in the Hueco-Mesilla Bolsons Aquifer, 1995 to 2005.

Thirty-eight of the 54 measurements taken in the Hueco-Mesilla Bolsons Aquifer were indicative of moderate (2 to 25 feet) water level changes. Of these, 27 measurements, or 50 percent, were declines, and 11, or 20 percent, were rises. Water levels in nine wells changed by 2 feet or less.

El Paso Water Utilities operates 18 wells in the Mesilla Bolson, which are located in the Canutillo area and supply the west side of El Paso. From 1995 to 2005, water levels declined in most of the Canutillo wells (Figure 5-23), although groundwater pumping decreased by approximately 1,300 acre-feet during the decade (EPWU, 2007) and although conditions, as measured by the Palmer Drought Severity Index, were wetter in 2005 than in 1995 (Figure 3-4). Streamgage measurements taken by the International Boundary and Water Commission show the flow of the Rio Grande at El Paso being twice as much (or over 372,500 acre feet higher) in 1995 as the flow in 2005 (IBWC, 2009). We hypothesize that lower flows in the Rio Grande in 2005 were the cause for the observed water level declines in the Mesilla Bolson.

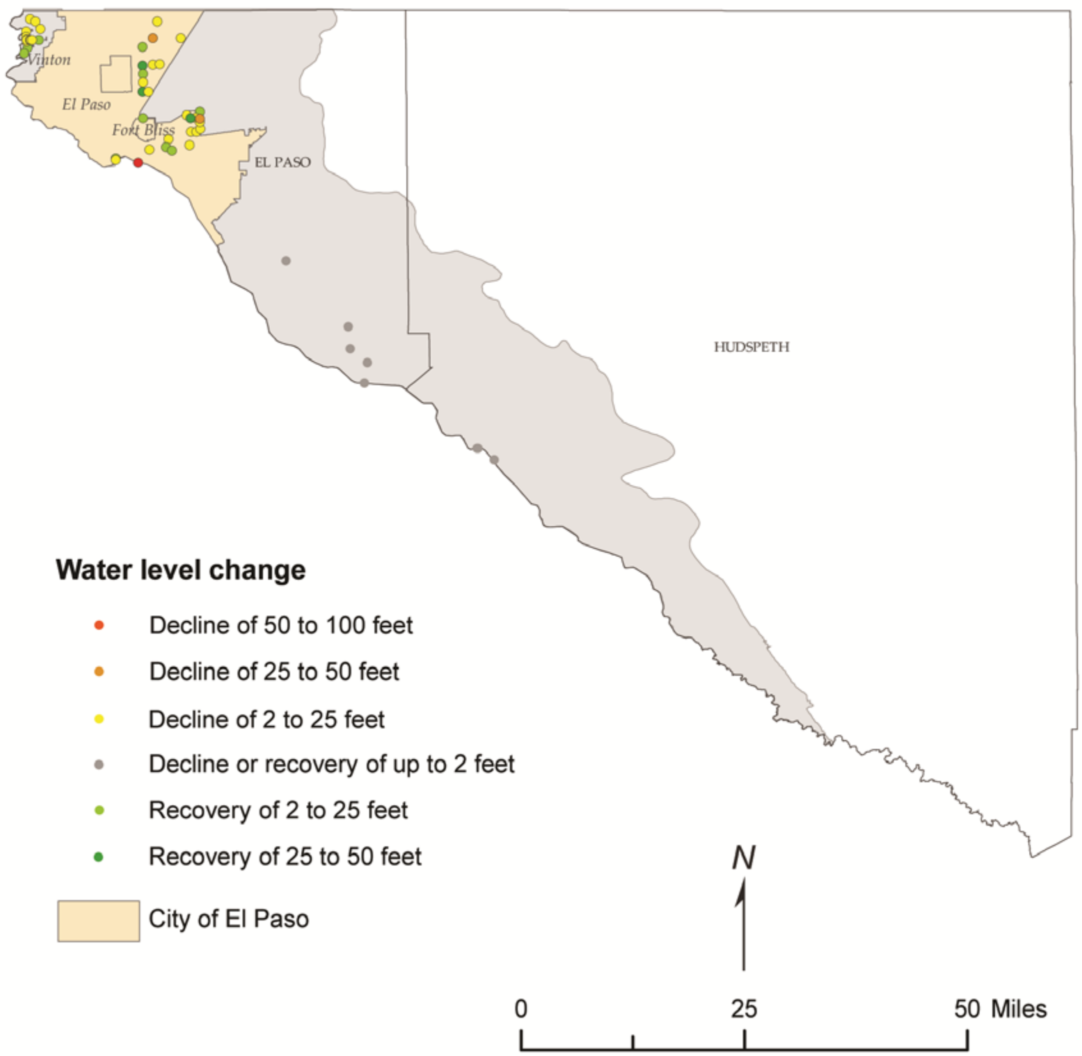


Figure 5-23. Areal distribution of wells and observed changes in water levels for the Hueco-Mesilla Bolsons Aquifer, 1995 to 2005.

On the east side of the Franklin Mountains in El Paso County, El Paso Water Utilities operates eight well fields that supply water to eastern El Paso County from the Hueco Bolson. Most of the wells experienced water level declines of 25 feet or less although several wells recorded steeper declines of 25 to 100 feet. Wells to the southeast of El Paso, in the Lower Valley field along the Rio Grande, showed minimal (±2 feet) water level changes. From 1995 to 2005, El Paso Water Utilities decreased its groundwater withdrawals in the Hueco Bolson by approximately 10,200 acre-feet (EPWU, 2007).

The hydrograph for 49-14-102 is typical of wells impacted by pumping in the Hueco Bolson in El Paso (Figure 5-24). Municipal well fields have been the focal points of water level declines, where declines of up to 150 feet have been recorded. Between 1940 and 2005, most of the water level declines near municipal well fields were from 50 to 150 feet. Water level declines are less (5 to 30 feet) near the Texas-New Mexico state line, away from the pumping centers. Well 49-04-419 is completed in the Mesilla Bolson and is part of the Canutillo well field. The hydrograph shows no substantial, long-term water level decline but does show seasonal variations reflecting pumping demands.

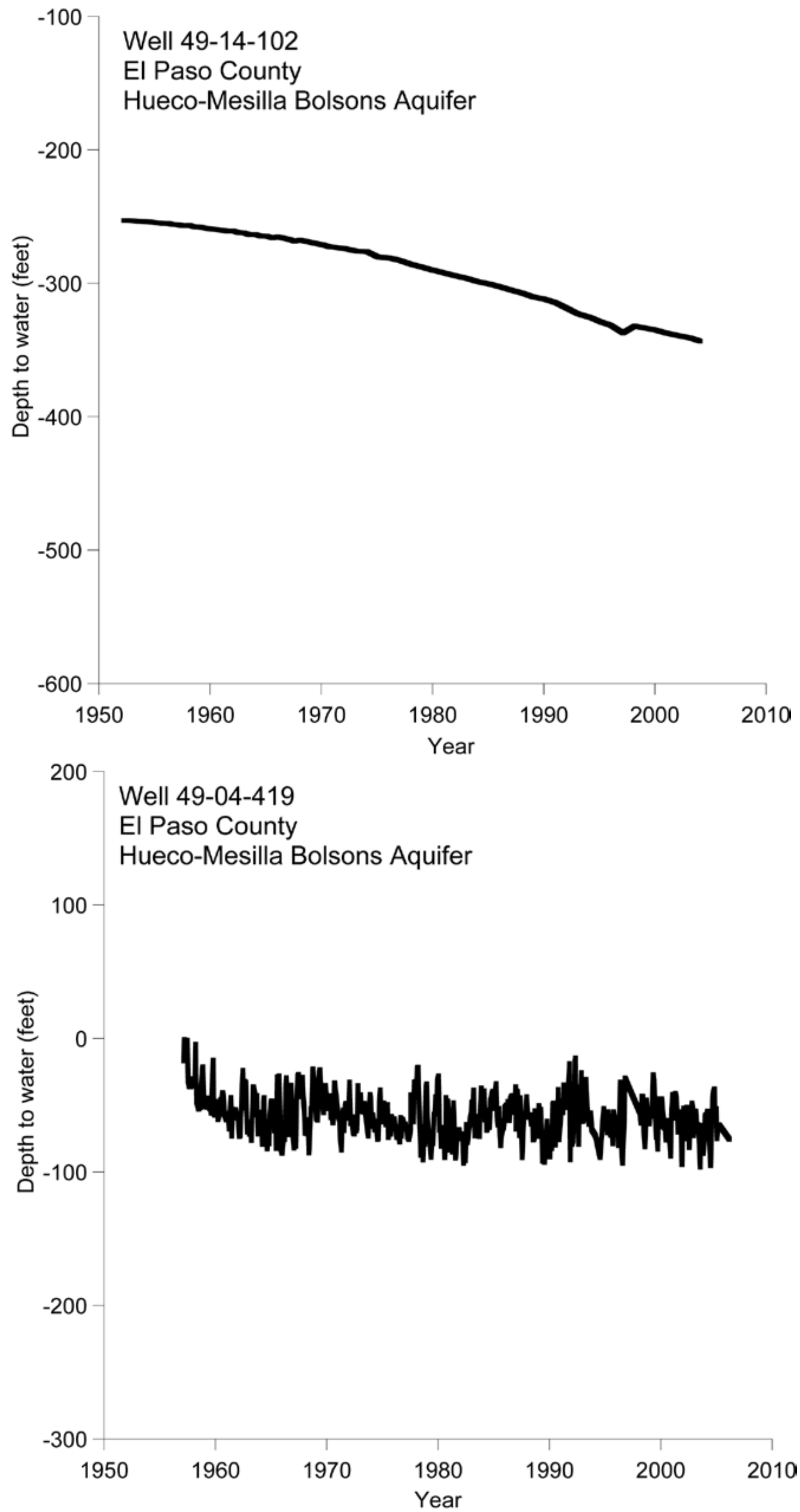


Figure 5-24. Hydrographs for two wells in the Hueco-Mesilla Bolsons Aquifer.

5.9 Seymour Aquifer

From 1995 to 2005, water levels in the Seymour Aquifer declined moderately (Figure 5-25). The median change in water levels was a decline of 6.7 feet. The largest decline was recorded in Wilbarger County where the water level in Well 13-46-106 dropped 16.6 feet. The largest water level recovery (13.6 feet) was documented in Well 12-04-609, located in Collingsworth County.

Of the 47 water level measurements available for the Seymour Aquifer, 37 showed moderate changes (2 to 25 feet); of these, 34 wells, or 72 percent of the total, recorded declines and three wells, or 6 percent, recorded rises. Ten wells, or 21 percent of the total, displayed minimal water level changes (± 2 feet) between 1995 and 2005.

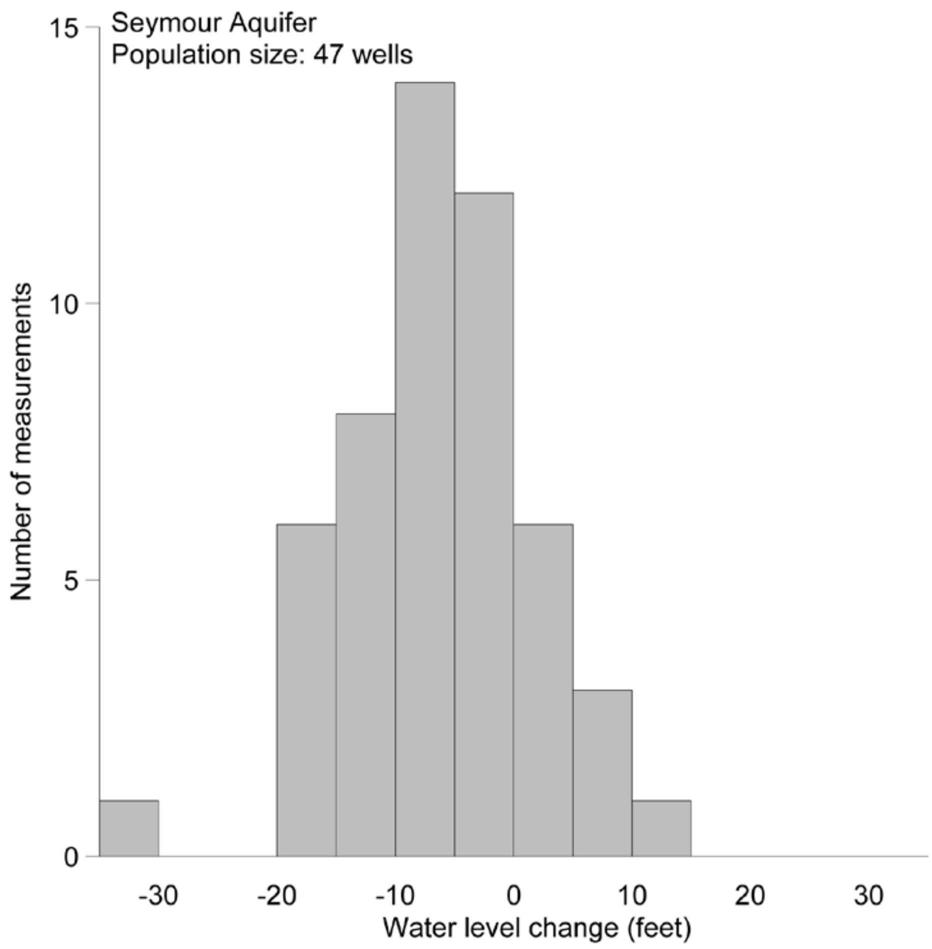


Figure 5-25. Water level changes in the Seymour Aquifer, 1995 to 2005.

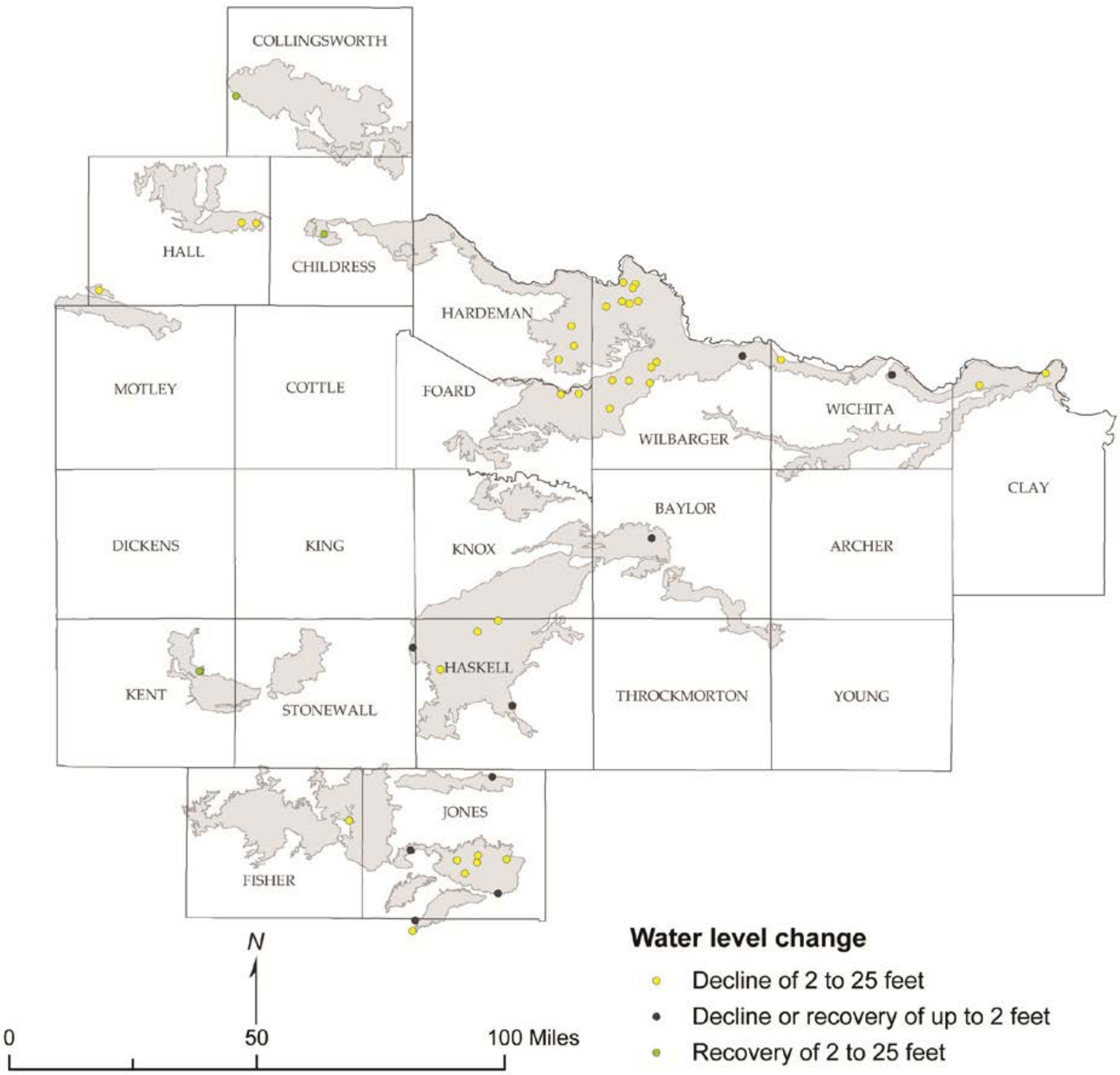
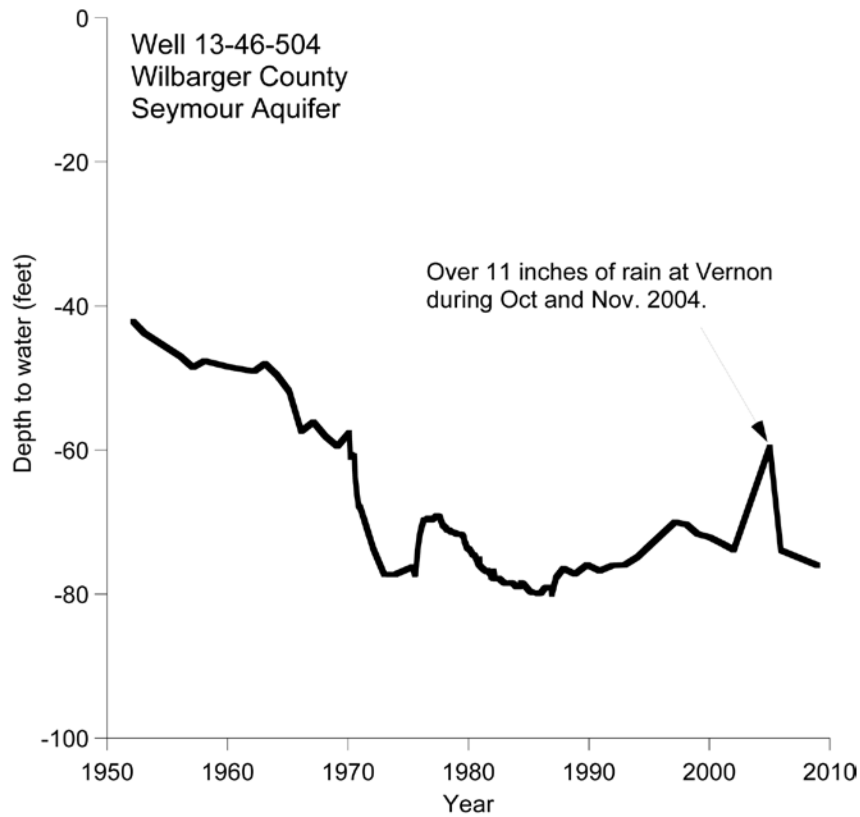


Figure 5-26. Areal distribution of wells and observed changes in water levels for the Seymour Aquifer, 1995 to 2005.

There is no discernible trend in the areal distribution of water level changes within the Seymour Aquifer. Throughout the aquifer, wells with declining water levels are scattered among recovering wells (Figure 5-26).

Time series hydrographs for two unequipped wells in Wilbarger and Jones counties show different trends in long-term water level changes (Figure 5-27). The water level in Wilbarger County Well 13-46-504 dropped precipitously from the 1950s through the early 1970s, and has been oscillating since then. The water level in Jones County Well 30-18-502 has not changed much during the period of record.



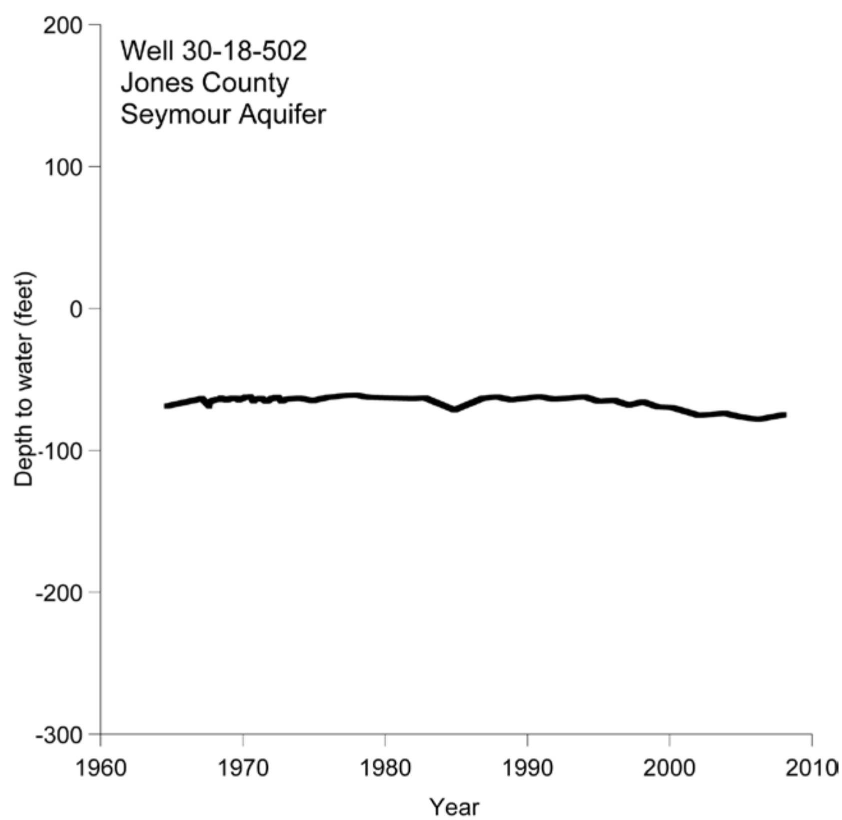


Figure 5-27. Hydrographs for two wells in the Seymour Aquifer.

6.0 Minor Aquifers

Water levels in the minor aquifers of Texas declined slightly from 1995 to 2005 (Figures 6-1 and 6-2). The median change in water levels was a decline of 0.9 feet. The largest decline, 93.1 feet, was recorded in the Woodbine Aquifer (Fannin County Well 17-25-302) as was the largest rise, 94.4 feet, (Johnson County Well 32-39-201). Of the 559 measurements in all minor aquifers, 343, or 61 percent, showed moderate (2 to 25 feet) water level changes, with 214 declines and 129 rises. Water levels in 182 wells changed only minimally (±2 feet).

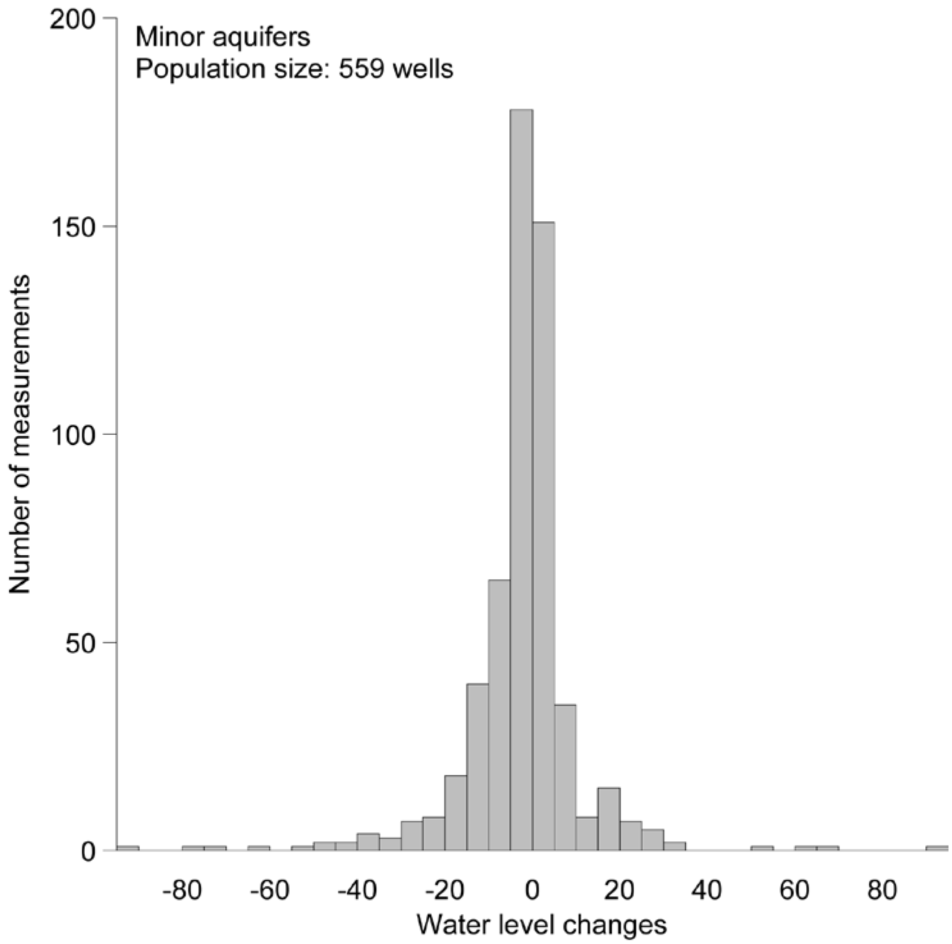


Figure 6-1. Water level changes in the minor aquifers of Texas, 1995 to 2005.

The largest median declines in water levels were recorded in the Bone Spring-Victorio Peak Aquifer (a decline of 12.2 feet), the Capitan Reef Aquifer (12 feet), the Blaine Aquifer (9.7 feet), the Blossom Aquifer (7.9 feet), and the Rita Blanca Aquifer (5.2 feet) (Table 4-1). Irrigation and municipal water supply are the main uses for most wells completed in these five aquifers. We found smaller median water level declines in the Woodbine (4.4 feet), West Texas Bolsons (4.1 feet), Queen City (2.6 feet), Sparta (2.2 feet), Nacatoch (1.1 feet), Dockum (0.9 feet), Lipan (0.1 feet), and Yegua-Jackson (0.1 feet) aquifers. Water level changes in the Capitan Reef and Blossom aquifers are based on 1 and 3 measurements, respectively.

Several aquifers showed median water level rises over the decade. They include the Rustler Aquifer (19.5 feet), Marble Falls (6.6 feet), Edwards-Trinity (High Plains) and Ellenburger-San Saba (both 2.1 feet), Brazos River Alluvium (1.3 feet), Igneous (0.8 feet), and Hickory (0.4 feet) aquifers. Note that the changes in the Marble Falls and Rustler aquifers are based on just 5 and 1 measurements, respectively.

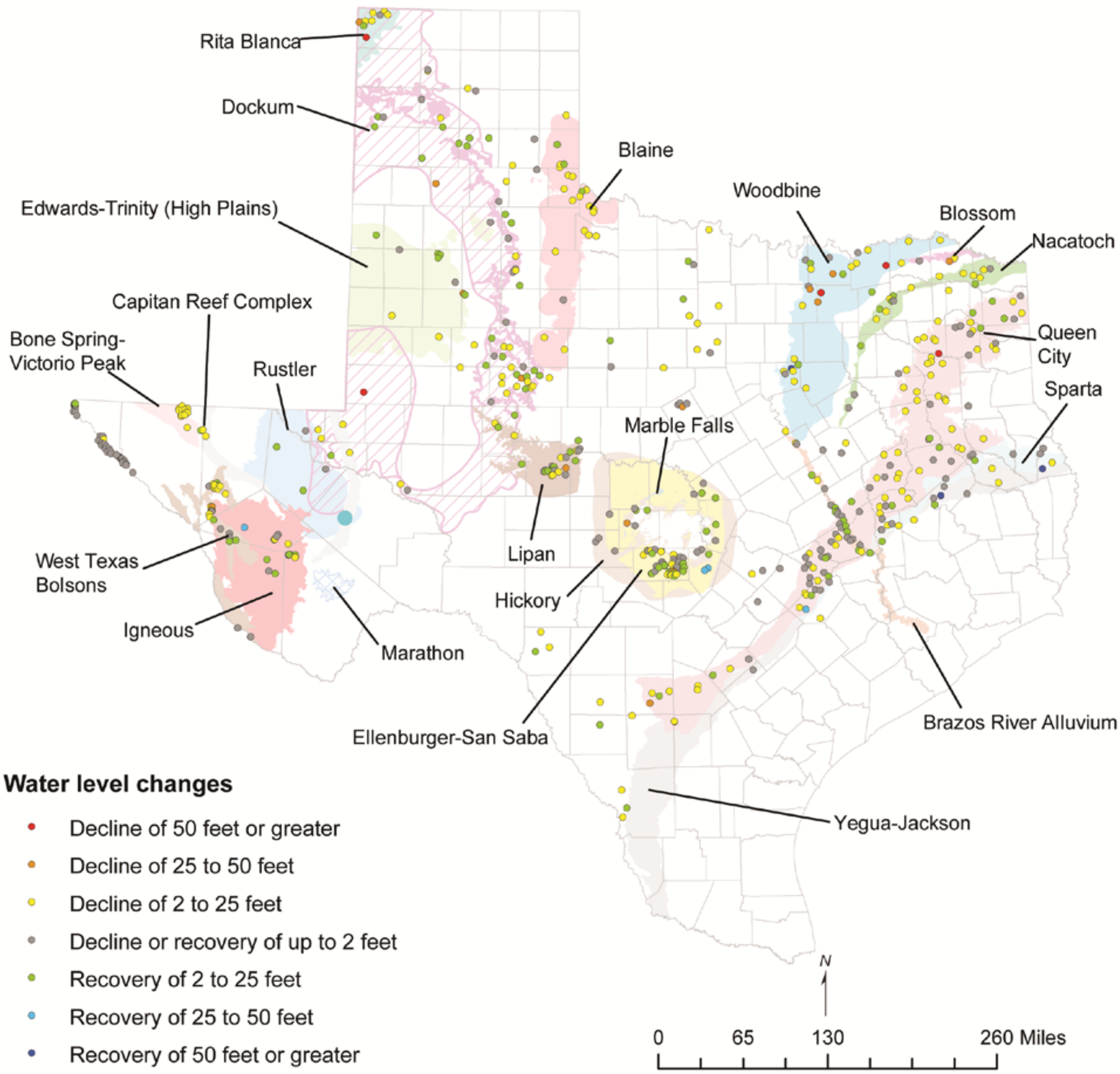


Figure 6-2. **Areal distribution of wells and observed changes in water levels for the minor aquifers of Texas, 1995 to 2005. Wells that plot outside of aquifer boundaries are completed in permeable, water-bearing formations that are not designated as a named major or minor aquifer.**

7.0 Conclusions

Water levels in the majority of wells across Texas declined from 1995 to 2005 (Table 7-1). The median water level change statewide was a decline of 2.4 feet. Most of the measured net changes in water levels from 1995 to 2005 were between 2 and 25 feet. Specifically, 1,812 wells (or 42 percent of the wells with available data) showed water level declines of 2 to 25 feet, and 889 wells (20 percent) had recorded rises of 2 to 25 feet. Water levels in 1,020 wells, or 23 percent, fluctuated by 2 feet or less.

Table 7-1. Median changes in water levels of Texas aquifers, 1995 to 2005.

Aquifer	Median change (feet)
Major aquifers	
Carrizo-Wilcox	-3.8
Edwards (Balcones Fault Zone)	-0.5
Edwards-Trinity (Plateau)	0.5
Gulf Coast	0.9
Hueco-Mesilla Bolsons	-7.0
Ogallala	-4.3
Pecos Valley	1.2
Seymour	-6.7
Trinity	-4.3
Minor aquifers	
Blaine	-9.7
Blossom	-7.9
Brazos River Alluvium	1.3
Bone Spring-Victorio Peak	-12.2
Capitan Reef	-12.0*
Dockum	-0.9
Edwards-Trinity (High Plains)	2.1
Ellenburger-San Saba	2.1
Hickory	0.4
Igneous	0.8
Lipan	-0.1
Marble Falls	6.6
Nacatoch	-1.1
Rita Blanca	-5.2
Rustler	19.5*
Queen City	-2.6
Sparta	-2.2
West Texas Bolsons	-4.1
Woodbine	-4.4
Yegua -Jackson	-0.1
Other	-0.3

* Results for the Capitan Reef and Rustler aquifers are based on readings from one well each. We deem these readings to be unrepresentative of the entire aquifers.

The median water level change over the 10-year period in the Ogallala Aquifer was a decline of 4.3 feet. Although most of the Ogallala Aquifer wells showed moderate declines, there were also many wells displaying moderate water level rises across portions of the northeastern Texas High Plains.

From 1995 to 2005, the Gulf Coast Aquifer experienced a very slight overall water level recovery. The median change in water level was a rise of 0.9 feet. Counties in the central Gulf Coast Aquifer recorded moderate water level rises, and the northern and southern regions saw mostly moderate declines.

Water levels in the Carrizo-Wilcox Aquifer, on average, declined from 1995 to 2005. The median water level change was a decline of 3.8 feet. Parts of the Winter Garden area and Northeast Texas have experienced consistent water level declines. Moderate rises in water levels occurred in counties in the aquifer outcrop.

In 2005, water levels in the Edwards (Balcones Fault Zone) Aquifer were lower than in 1995, mostly in the San Antonio and Barton Spring segments. In the northern segment, water level changes were mixed. The aquifer-wide median change was a decline of 0.5 feet.

The median change in water levels in the Trinity Aquifer was a drop of 4.3 feet between 1995 and 2005. A large part of the Trinity Aquifer outcrop, as well as several areas in north Texas, had water level declines. Some wells in the Dallas-Fort Worth area and in the Texas Hill Country showed water level rises.

From 1995 to 2005, the median change in water levels in the Edwards-Trinity (Plateau) Aquifer was a rise of 0.5 feet. Water level declines occurred across the north-central Edwards Plateau, and levels rose in areas of the eastern Edwards Plateau.

The median water level change over the 10-year period in the Pecos Valley Aquifer was a rise of 1.2 feet. Most of the measured aquifer levels were higher in 2005 than in 1995 in the northern part of the aquifer. Water level changes were mixed elsewhere.

Water levels in the Hueco-Mesilla Bolsons Aquifer declined moderately from 1995 to 2005. The median change in water levels aquifer-wide was a decline of 7.0 feet. Most of the declines occurred in the Hueco Bolson. Most wells in the Canutillo area of the Mesilla Bolson showed water level declines.

The median water level change between 1995 and 2005 for the minor aquifers of Texas was a 0.9 foot decline. Water level declines were documented in the Blaine, Blossom, Bone Spring-Victorio Peak (the largest median decline), Capitan Reef, Dockum, Lipan, Nacatoch, Rita Blanca, Queen City, Sparta, West Texas Bolsons, Woodbine, and Yegua-Jackson aquifers. The Brazos River Alluvium, Edwards-Trinity (High Plains), Ellenburger-San Saba, Hickory, Igneous, Marble Falls, and Rustler aquifers showed overall water level increases over the decade.

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