# Changes in Water Levels in Texas, 1990 – 2000

by Radu Boghici

Report 371
November 2008

Texas Water Development Board
www.twdb.state.tx.us

Texas Water Development Board
Report 371

# Changes in Water Levels in Texas, 1990 to 2000

by Radu Boghici

November 2008

STATE OF TEXAS
RADU BOGHICI
GEOLOGY
No. 48
LICENSED
PROFESSIONAL GEOSCIENTIST

The seal appearing on this document was authorized on May 7, 2009 by

Radu Boghici, P.G.

# Texas Water Development Board

Published and distributed by the
Texas Water Development Board
P.O. Box 13231, Capitol Station
Austin, Texas 78711-3231

November 2008

*This page is intentionally blank.*

## TABLE OF CONTENTS

## LIST OF FIGURES

## LIST OF TABLES

# *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, 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 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 4,200 observation wells. We compared the readings taken in late 1990 or early 1991 with those taken in late 2000 or early 2001 to assess the changes in groundwater levels during the decade. We show the results in Table 1.

From 1990 to 2000, most of the statewide changes in water levels were less than 25 feet. The majority of the wells (2,325, or 55.3 percent of those with available data) showed water level declines of up to 25 feet, and 1,243 wells (29.6 percent) recorded rises of up to 25 feet. The median aquifer-wide water level change was a decline of 5.7 feet in the Ogallala Aquifer, a rise of 1.5 feet in the Gulf Coast Aquifer, a decline of 2.9 feet in the Carrizo-Wilcox Aquifer, a rise of 6.2 feet in the Edwards (Balcones Fault Zone) Aquifer, a decline of 1.70 feet in the Trinity Aquifer, a decline of 2.65 feet in the Edwards-Trinity (Plateau) Aquifer, a decline of 3.8 feet in the Pecos Valley Aquifer, and a decline of 5.2 feet in the Hueco-Mesilla Bolsons Aquifer. The median change in water level in the minor aquifers was a decline of 1.0 foot, with the largest median changes in the Lipan Aquifer (a decline of 13.2 feet), the Woodbine Aquifer (a decline of 5.8 feet), and the Bone Spring-Victorio Peak Aquifer (a decline of 3.7 feet).

Table 1. Median changes in Texas aquifers, 1990 to 2000.

| **Aquifer** | **Median change (feet)** |
|---|---|
| Carrizo-Wilcox | -3.0 |
| Edwards (Balcones Fault Zone) | 6.2 |
| Edwards-Trinity (Plateau) | -2.7 |
| Gulf Coast | 1.5 |
| Hueco-Mesilla Bolsons | -5.2 |
| Ogallala | -5.7 |
| Pecos Valley | -3.8 |
| Seymour | -2.1 |
| Trinity | -1.7 |
| Blaine | 1.6 |
| Brazos River Alluvium | 0.4 |
| Bone Spring-Victorio Peak | -3.7 |
| Capitan Reef | -2.8 |
| Dockum | -1.1 |
| Edwards-Trinity (High Plains) | -8.5 |
| Ellenburger-San Saba | 0.5 |
| Hickory | -2.3 |
| Igneous | -1.8 |
| Lipan | -13.2 |
| Marble Falls | 1.1 |
| Nacatoch | -0.7 |
| Rita Blanca | -3.4 |
| Queen City | -1.5 |
| Sparta | -1.4 |
| West Texas Bolsons | -0.2 |
| Woodbine | -5.8 |
| Yegua-Jackson | 0.6 |

# 1 *Introduction*

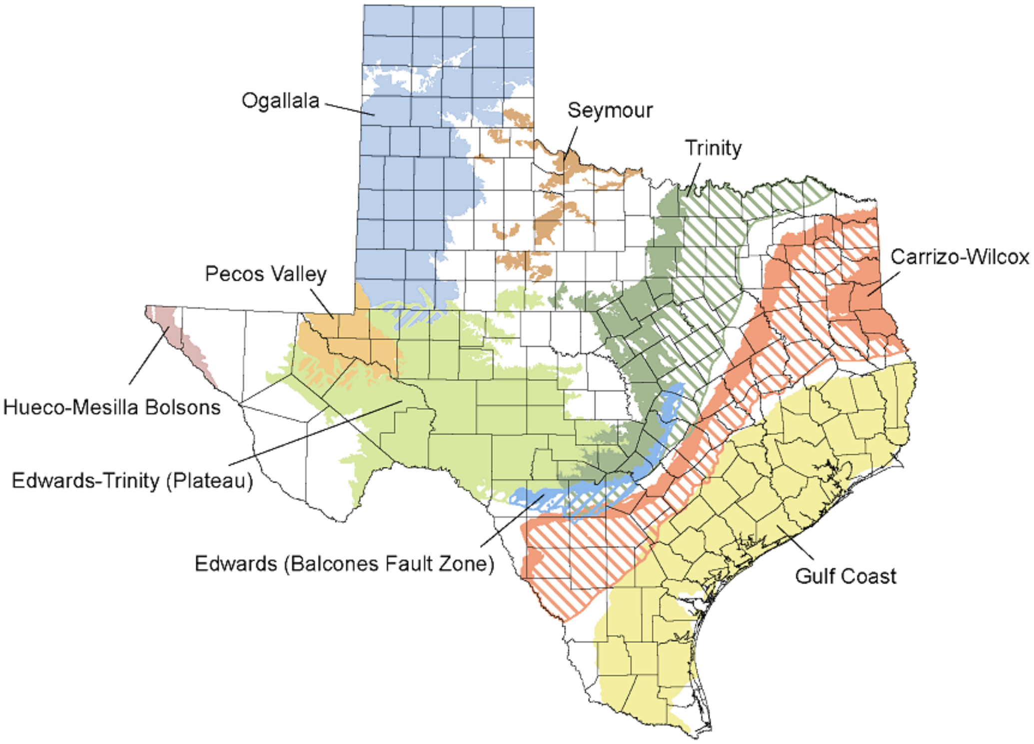
Many Texans rely on groundwater to a great extent for drinking water and for industrial and agricultural uses. Of the 15.6 million acre-feet of water used in the state in 2003, groundwater contributed 9.2 million acre-feet, or about 59 percent, with surface water supplying the rest (TWDB, 2007).

The Texas Water Development Board (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 1-1). 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 1990 and 2000, we used measurements from 4,205 wells and compared readings at each well between the 1990 to 1991 water level monitoring season and the 2000 to 2001 water level monitoring season.

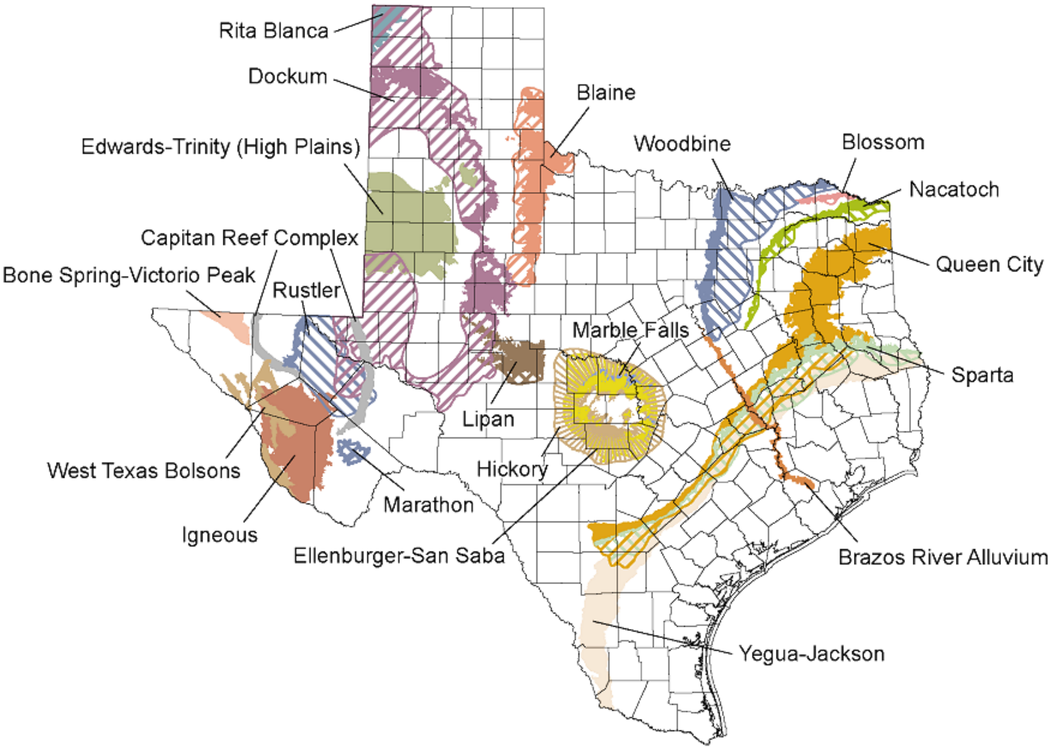
The initial data set for this study consisted of water level measurements from more than 6,000 observation wells. Because our goal was to examine aquifer levels under stable conditions, we eliminated numerous measurements from wells that were being pumped when the levels were recorded. We also eliminated 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 water well database at http://wiid.twdb.state.tx.us.

This report examines the median change 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.

## Major Aquifers



## Minor Aquifers



# 2 *Texas Climate Considerations*

Water levels in wells change in response to aquifer recharge (water from precipitation that replenishes the aquifer) and discharge (pumping, natural discharge such as springs and flow to streams, and cross-formational flow). Since aquifer recharge is derived from precipitation, it is important to examine Texas weather patterns from 1990 to 2000 to determine what influence the weather may have had on water level changes. This is particularly important in karst aquifers, such as the Edwards (Balcones Fault Zone) Aquifer, where climate is the primary driver 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, short-term climate fluctuations have less of an effect on water levels than pumping, which itself may be affected by climate.

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 conditions, and positive values suggest wetter-than-normal conditions. The National Agricultural Decision Support System maintains a nationwide database of this information, including up-to-date readings from 313 stations located across Texas (Cottingham and others, 2004).

Texas is divided into 10 climate divisions by the National Weather Service.

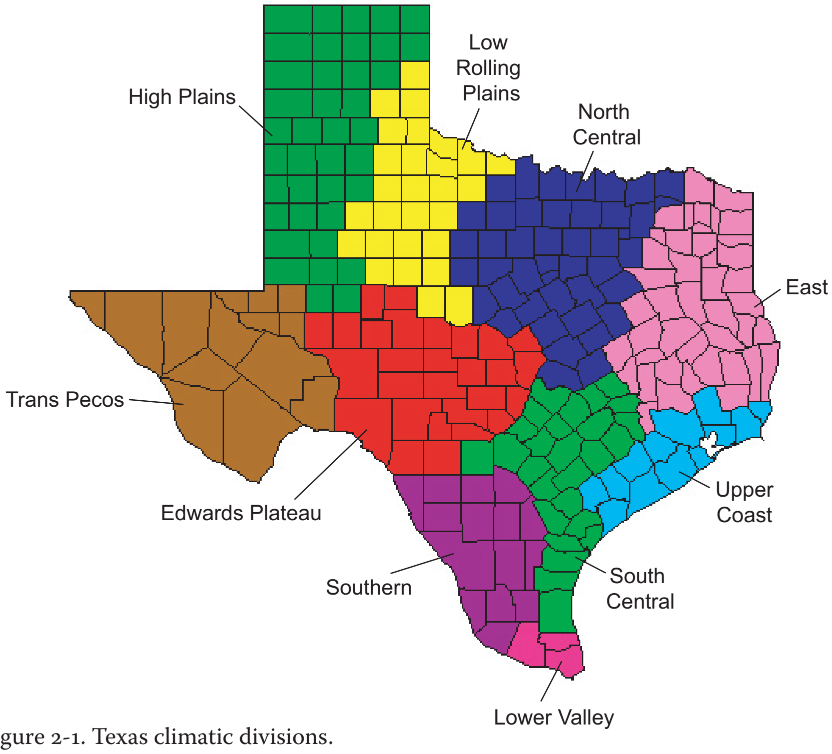


Figure 2-1. Texas climatic divisions.

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 the Lower Valley divisions (Figure 2-1). Using data from the National Agricultural Decision Support System, we examined climate conditions in these regions in two ways: (1) over the duration of the decade and (2) in 1990 and 2000 only. There is great variability in the data, but several trends emerge over the decade. When we computed the months with positive Palmer Drought Severity Index values for each station, we found that numerous regions experienced normal to wetter-than-normal conditions at least 50 percent of the time and were drier than normal less than half the time. These regions include parts of the Trans Pecos, High Plains, North Central, and East divisions (Figure 2-2). These areas correspond with portions of the Ogallala and Seymour aquifers, the northern segment of the Trinity Aquifer, the northeastern Carrizo-Wilcox Aquifer, and the central Gulf Coast Aquifer.

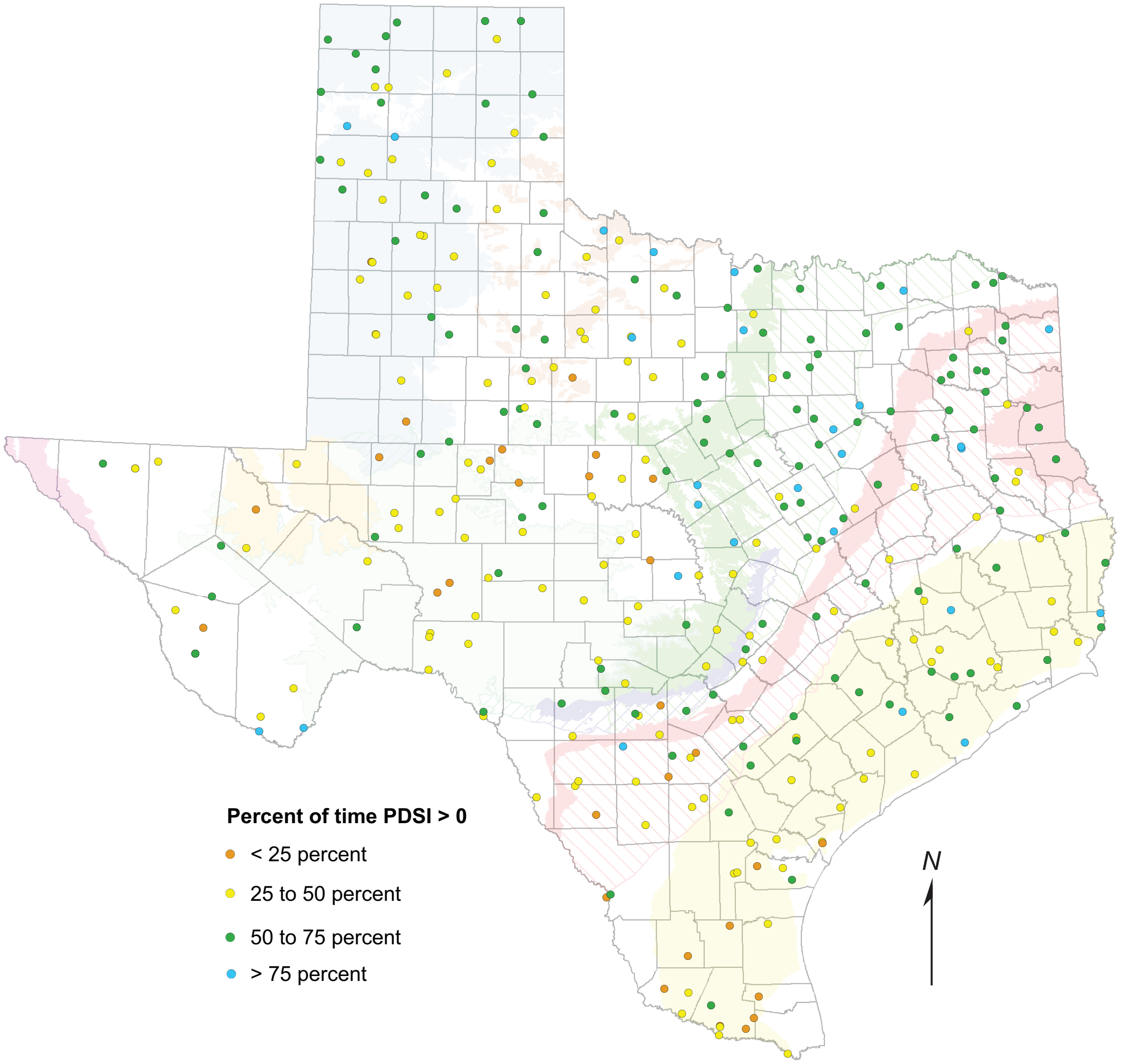


Figure 2-2. Percent of time with near-normal to wet weather, 1990 to 2000.
PDSI = Palmer Drought Severity Index

Parts of the High Plains and Low Rolling Plains divisions (parts of the Ogallala and Seymour aquifers), most of the Edwards Plateau division (Edwards-Trinity [Plateau] Aquifer), and parts of the Southern and Lower Valley climatic divisions (southern Carrizo-Wilcox and southern Gulf Coast aquifers) were predominantly drier than normal, with some locations yielding positive Palmer Drought Severity Index readings less than 25 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 (1990) or at the end (2000) of the study period. To investigate this issue, we compared the Palmer Drought Severity Index values at stations across Texas for the years 1990 and 2000 only (Figure 2-3).

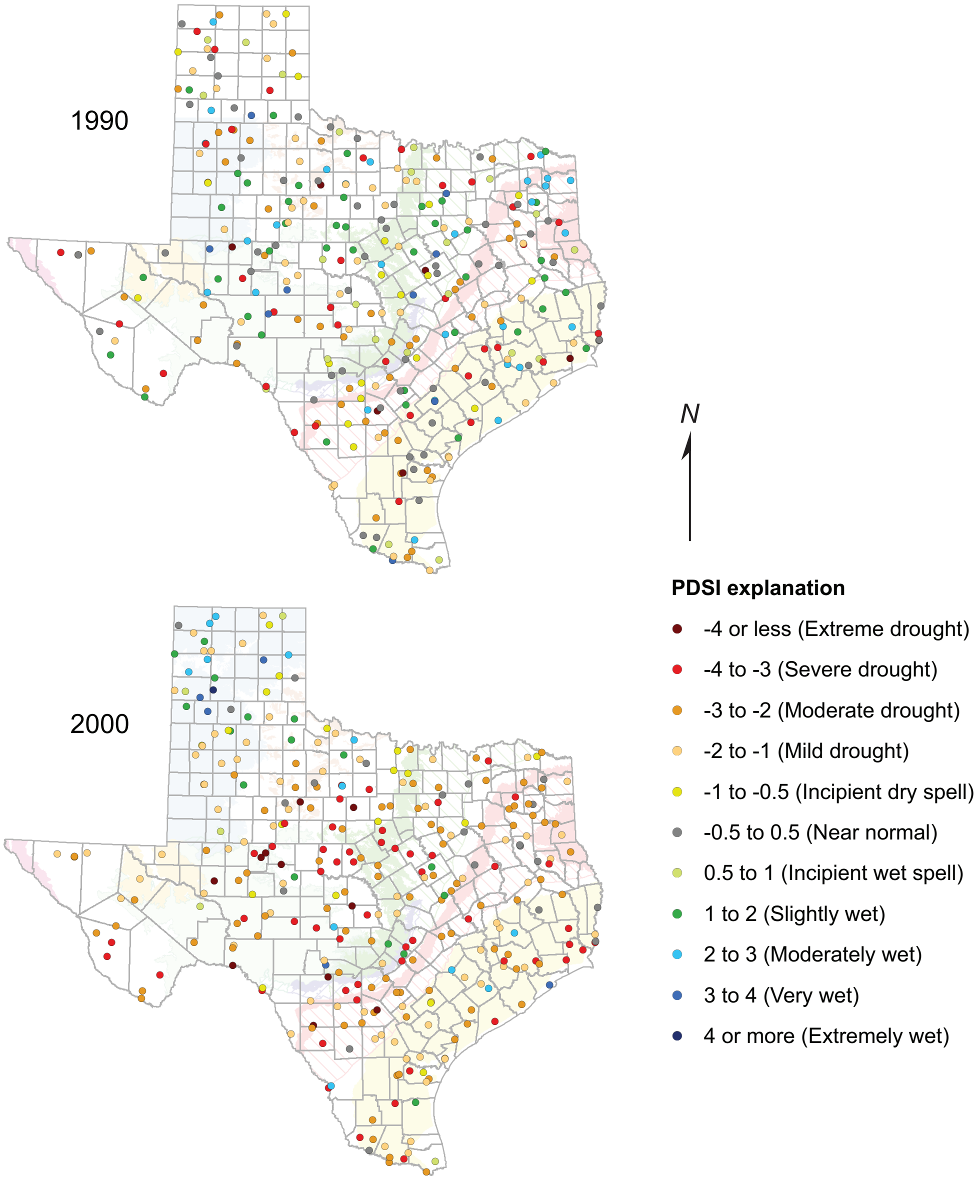


Figure 2-3. Climate comparison between the years 1990 and 2000.
PDSI = Palmer Drought Severity Index.

To aid with the visualization of these data, we computed the changes in the Palmer Drought Severity Index between 1990 and 2000 and plotted the results on a map (Figure 2-4).

The climate was drier in 2000 than in 1990 over parts of the southern High Plains division (southern Ogallala Aquifer), Edwards Plateau division, North Central division (Trinity Aquifer), areas in the South Central division (Edwards Aquifer), and East division (parts of the Carrizo-Wilcox and central Gulf Coast aquifers). The Trans Pecos (western Edwards-Trinity [Plateau] Aquifer), northern High Plains (Ogallala Aquifer), and central Edwards Plateau divisions were significantly wetter in 2000 than 1990.

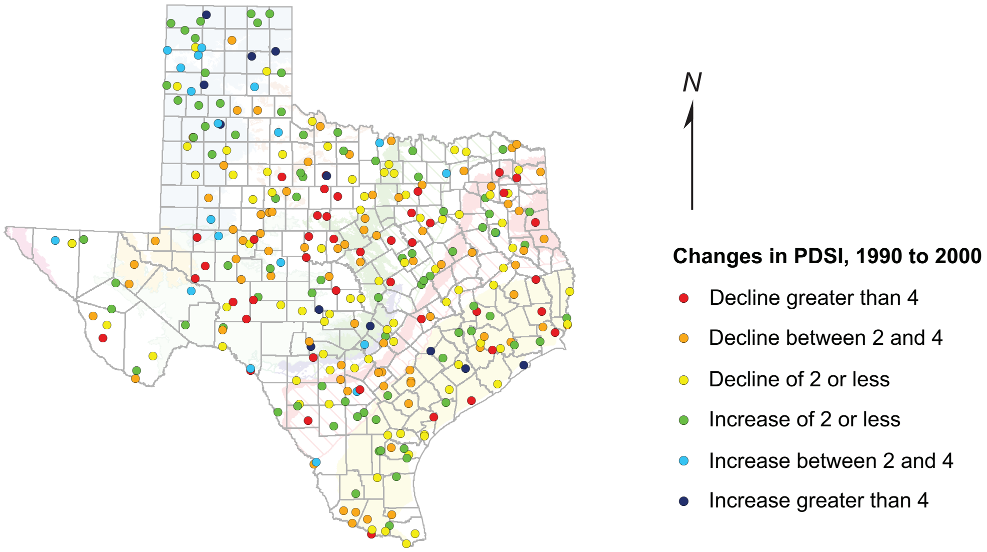


Figure 2-4. Changes in the Palmer Drought Severity Index, 1990 to 2000.
PDSI = Palmer Drought Severity Index

# 3 *Statewide Groundwater Conditions*

Water level changes in wells are driven by the interplay between groundwater recharge and discharge to and from aquifers. In general, water levels in wells decline due to increased groundwater withdrawal and/or reduced aquifer recharge. Conversely, limited groundwater discharge, 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 1990 and 2000, likely 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. An example of the latter is the Edwards (Balcones Fault Zone) Aquifer, which had areas with higher groundwater levels in 2000 than in 1990, possibly due to rainfall over the contributing zone north of the recharge area.

Although several aquifers showed overall recovery from 1990 to 2000, water levels in the majority of wells across Texas declined slightly (Figure 3-1). Most of the changes were moderate (that is, 25 feet or less), with a median water level decline of 3.0 feet (Table 3-1). Of the 4,205 wells measured, 2,325 (or 55.3 percent) showed water level declines of up to 25 feet, and 1,243 (29.6 percent) recorded rises of up 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 3-2).

Several wells recorded more significant changes. The state's largest water level decline was 135.1 feet in Well 39-17-901 in the Trinity Aquifer, a well belonging to the Prairie Hill Water Supply Corporation. The largest recovery (107 feet) was recorded in Well 40-28-902, a public water supply well also completed in the Trinity Aquifer and serving Coryell City. 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 may be an artifact of pumpage-induced water level conditions at the time the measurements were collected.

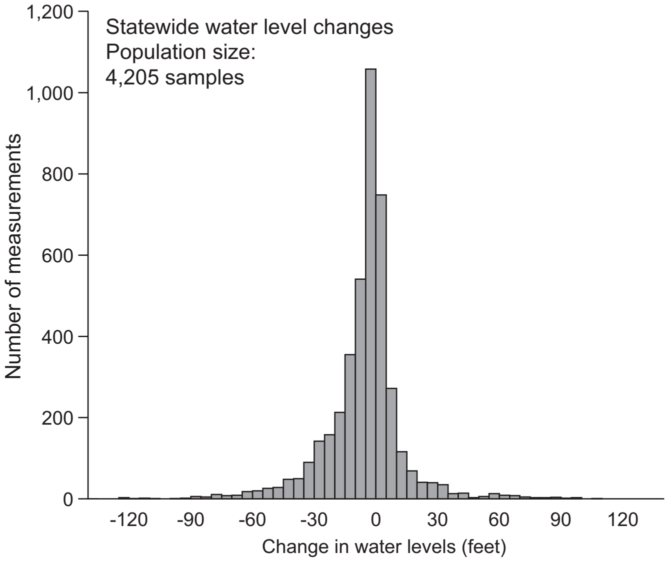


Figure 3-1. Changes in well water levels across Texas.

Because many (2,029) of the 4,205 statewide data points for this study come from the Ogallala Aquifer, that 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. The major aquifers as described by Ashworth and Hopkins (1995) furnished 3,650, or 87 percent, of all water level readings throughout the state.

Table 3-1. Summary of water level changes by aquifer.

| | | *Number of water level measurements* | | |
|---|---|---|---|---|
| **Aquifer** | **Median change (feet)** | **Total** | **Moderate recovery (≤25 feet)** | **Moderate decline (≤25 feet)** |
| ***Major aquifers*** | | | | |
| Carrizo-Wilcox | -3.0 | 280 | 75 | 175 |
| Edwards (Balcones Fault Zone) | 6.2 | 75 | 35 | 15 |
| Edwards-Trinity (Plateau) | -2.7 | 132 | 45 | 50 |
| Gulf Coast | 1.5 | 755 | 327 | 225 |
| Hueco-Mesilla Bolsons | -5.2 | 70 | 21 | 47 |
| Ogallala | -5.7 | 2,019 | 432 | 1,321 |
| Pecos Valley | -3.8 | 72 | 13 | 55 |
| Seymour | -2.1 | 37 | 28 | 9 |
| Trinity | -1.7 | 210 | 72 | 75 |
| ***Minor aquifers*** | | | | |
| Blaine | 1.6 | 25 | 9 | 16 |
| Brazos River Alluvium | 0.4 | 10 | 6 | 4 |
| Bone Spring-Victorio Peak | -3.7 | 17 | 2 | 15 |
| Capitan Reef | -2.8 | 3 | 0 | 3 |
| Dockum | -1.1 | 59 | 23 | 31 |
| Edwards-Trinity (High Plains) | -8.5 | 9 | 2 | 7 |
| Ellenburger-San Saba | 0.5 | 18 | 10 | 7 |
| Hickory | -2.3 | 47 | 15 | 31 |
| Igneous | -1.8 | 14 | 4 | 7 |
| Lipan | -13.2 | 12 | 0 | 11 |
| Marble Falls | 1.1 | 6 | 4 | 1 |
| Nacatoch | -0.7 | 19 | 7 | 10 |
| Rita Blanca | -3.4 | 14 | 3 | 7 |
| Queen City | -1.5 | 59 | 21 | 35 |
| Sparta | -1.4 | 24 | 7 | 17 |
| West Texas Bolsons | -0.2 | 20 | 10 | 10 |
| Woodbine | -5.8 | 30 | 8 | 16 |
| Yegua-Jackson | 0.6 | 21 | 10 | 9 |

*Note:* Water level measurements denoting moderate recovery and moderate decline do not always add up to the total number of measurements. This is because water level changes exceeding 25 feet were not counted.

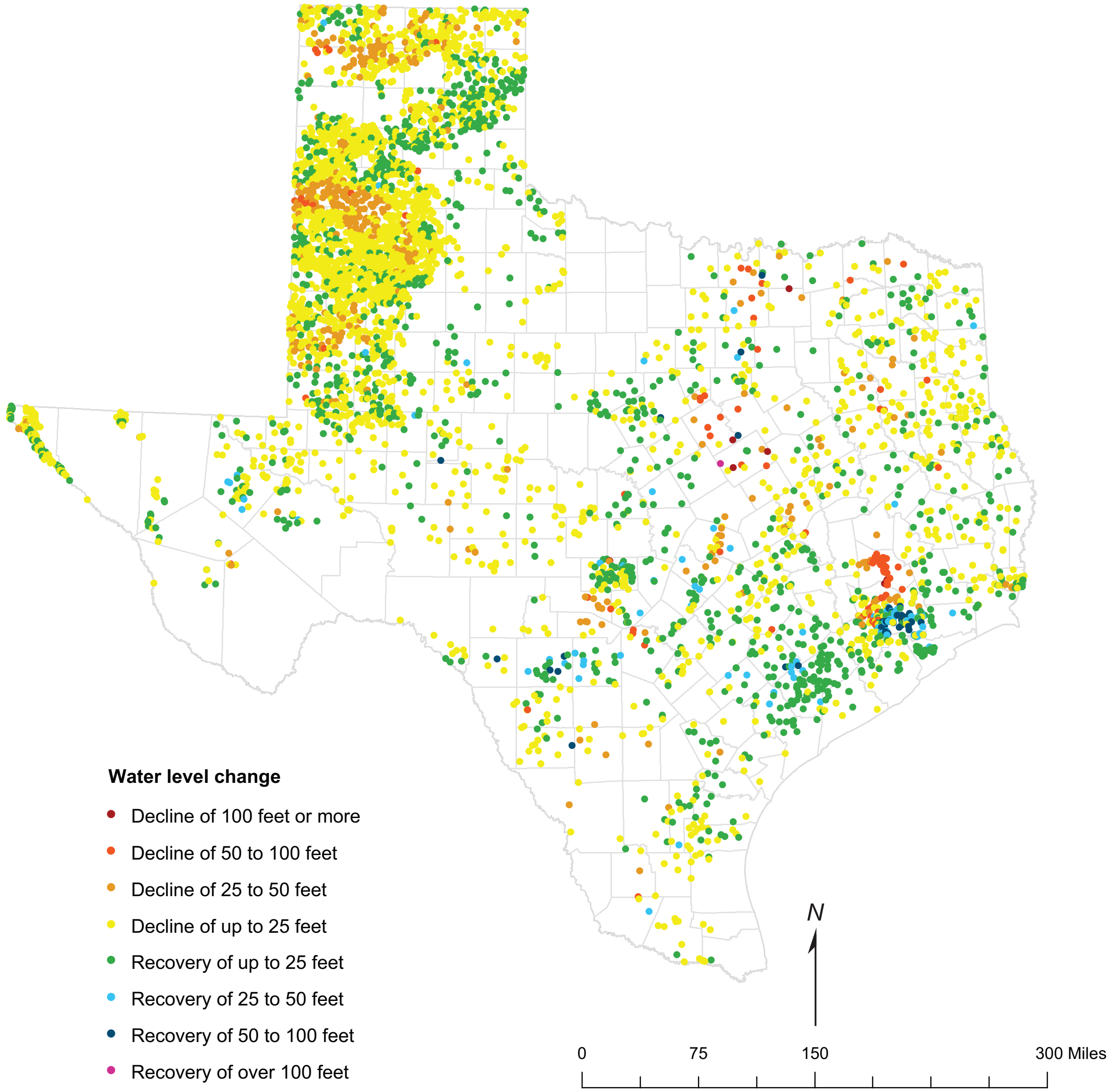


Figure 3-2. Statewide distribution of wells and observed changes in water levels, 1990 to 2000.

# 4 *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.

## 4.1

## OGALLALA AQUIFER

Between 1990 and 2000, most of the wells in the Ogallala Aquifer experienced moderate water level declines (Figure 4-1). The median water level change over the 10-year period in the Ogallala Aquifer was a decline of 5.7 feet. The largest recorded decline of 69.9 feet was in Well 02-59-602 in Hartley County, and the largest rise, 37.1 feet, was in Well 28-61-502 in Glasscock County.

Of the 2,019 wells analyzed in the Ogallala Aquifer, 1,753 wells, or 86.8 percent, recorded moderate (25 feet or less) changes in water levels. Of these, 1,321 wells, or 75.3 percent, showed declines (Figure 4-2).

Although most wells recorded moderate declines, several areas registered larger declines. For example, one area with water level declines over 25 feet stretches west to east across portions of Parmer, Castro, Lamb, Hale, and Crosby counties. Similarly, portions of Gaines, Terry, and Dawson counties experienced declines of up to 50 feet. However, counties surrounding Parmer, Castro, Lamb, Hale, and Crosby counties registered water level declines of less than 25 feet (Deaf Smith, Randall, Swisher, Briscoe, Floyd, Crosby, Lubbock, Hockley, and Cochran counties).

There were many wells in the Ogallala Aquifer that showed moderate water level rises between 1990 and 2000. For example, a southwest-northeast-trending belt in eastern Randall, Armstrong, Gray, Wheeler, Hemphill, and Roberts counties registered moderate rises. The Palmer Drought Severity Index shows the weather in 2000 was wetter than in 1990 in this area of the state (see Figure 2-3). Throughout most of the High Plains of Texas, wells with declining water levels are scattered among recovering wells (Figure 4-2).

Water levels in Carson County Well 06-36-602 in the Ogallala Aquifer have been on a gradual downward trend (Figure 4-3). 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, likely due to irrigation pumping, are evident throughout the period of record. Water levels in Dawson County Well 28-18-301 fell through the mid-1970s. For the next two decades, however, economic factors led to a steep decline in regional irrigation pumping and 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).

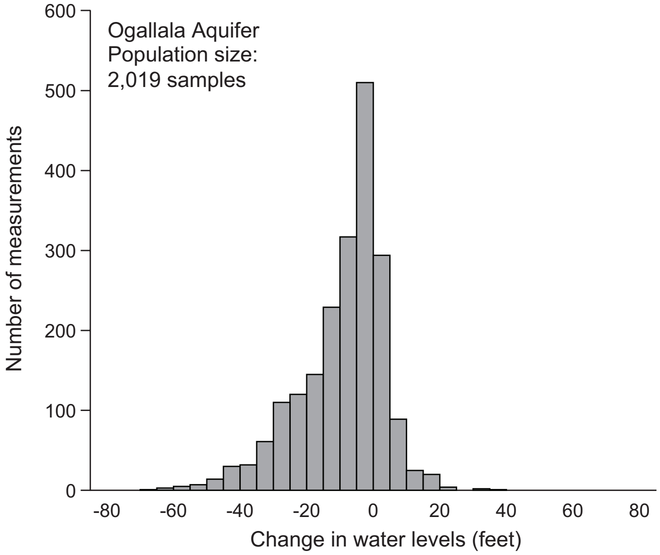


Figure 4-1. Water level changes in the Ogallala Aquifer, 1990 to 2000.

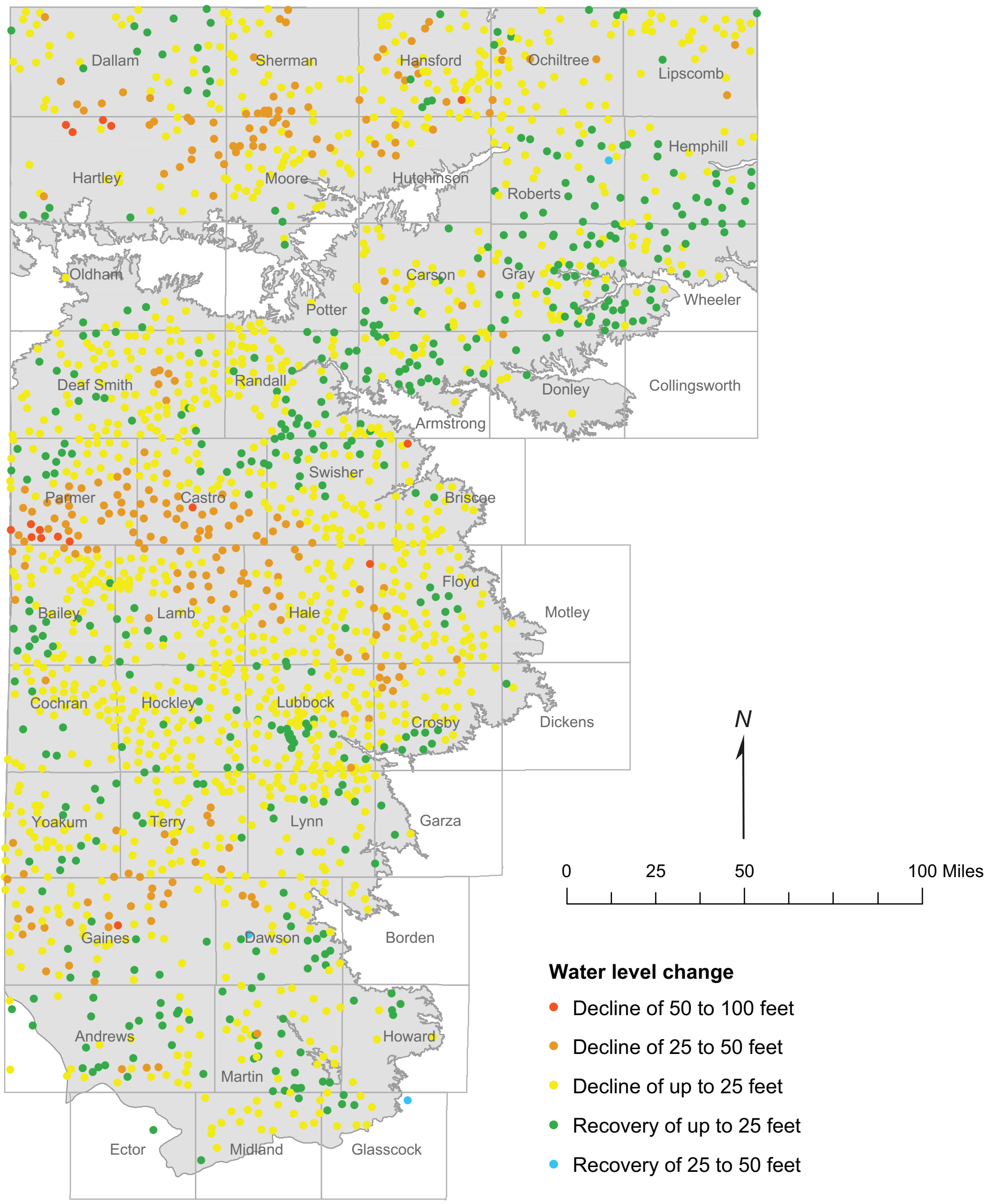


Figure 4-2. Areal distribution of wells and observed changes in water levels in the Ogallala Aquifer, 1990 to 2000.

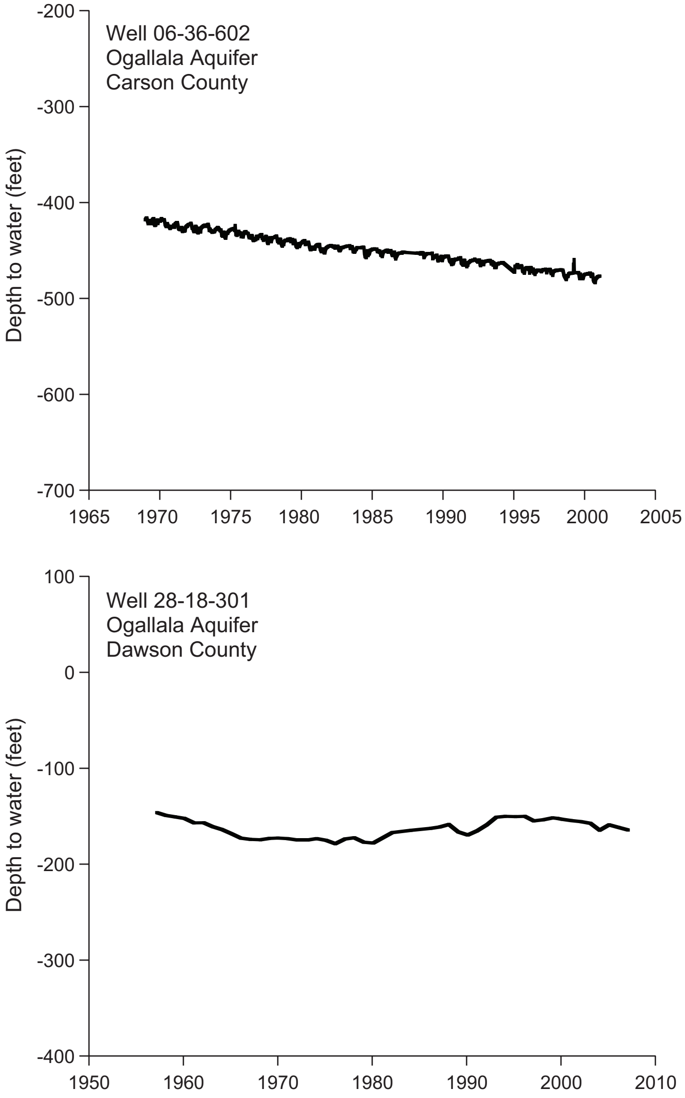


Figure 4-3. Hydrographs for two wells in the Ogallala Aquifer.

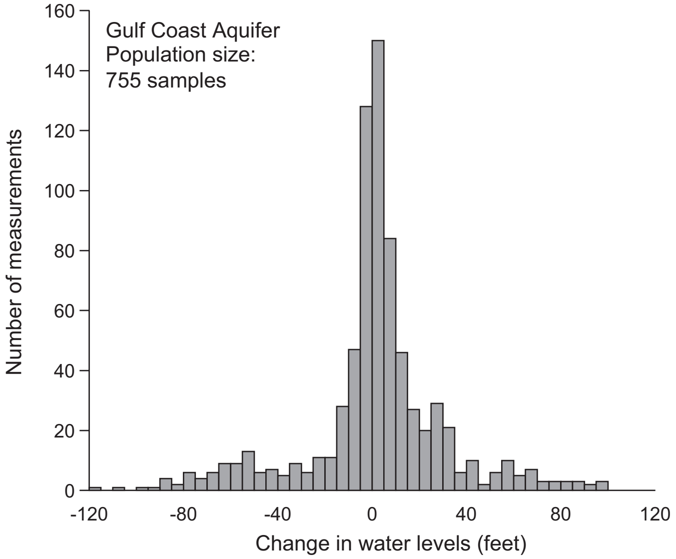


Figure 4-4. Water level changes in the Gulf Coast Aquifer, 1990 to 2000.

## 4.2
## GULF COAST AQUIFER

From 1990 to 2000, the Gulf Coast Aquifer experienced an overall slight water level recovery (Figure 4-4). The median water level change was a rise of 1.5 feet. The largest water level rise, 98.9 feet, was recorded in Well 65-28-311 owned by the City of Houston, and the largest decline, 118.3 feet, was in Well 60-53-714, a public water supply well in Montgomery County.

From 1990 to 2000, 327 wells, or 43.3 percent, indicated moderate water level recovery (25 feet or less), and a total of 225 wells, or 29.8 percent, showed moderate water level declines (25 feet or less). The central section of the aquifer, including De Witt, Victoria, Calhoun, Lavaca, Jackson, and Matagorda counties, revealed a consistent trend of moderate (up to 25 feet) water level recovery (Figure 4-5). Wells in southern Harris County and Galveston, Chambers, and Liberty counties recorded more significant water level rebounds (25 feet or more). In an effort to curtail dependency on groundwater and slow land subsidence rates, groundwater withdrawals in the Harris-Galveston Subsidence District were reduced from approximately 375 million gallons per day in 1990 to just under 350 million gallons per day in 2000 (Michel, 2006). This has resulted in rising water levels in the multicounty area.

Across the northern and southern segments of the Gulf Coast Aquifer, water level changes were mostly moderate declines of 25 feet or less. There were, however, significant declines in virtually all the wells monitored in Montgomery County and some in northern Harris County, with declines of up to 100 feet or more.

Hydrographs for two wells in Harris County show two contrasting trends (Figure 4-6). In one well, water levels declined over time; in the other well, water levels have been rising since the early 1980s. Both wells were used for public water supply in Harris County; however,

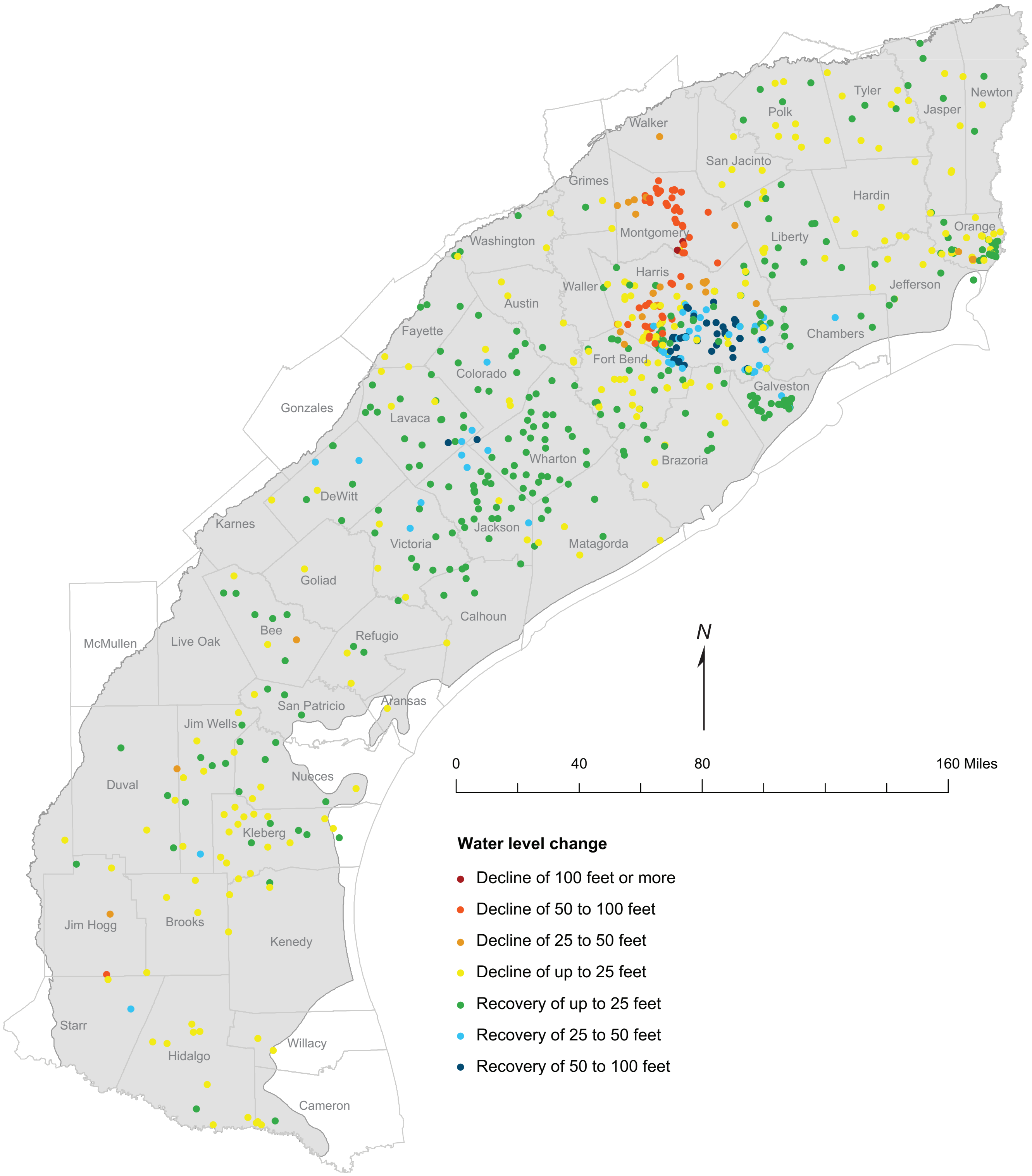


Figure 4-5. Areal distribution of wells and observed changes in water levels in the Gulf Coast Aquifer, 1990 to 2000.

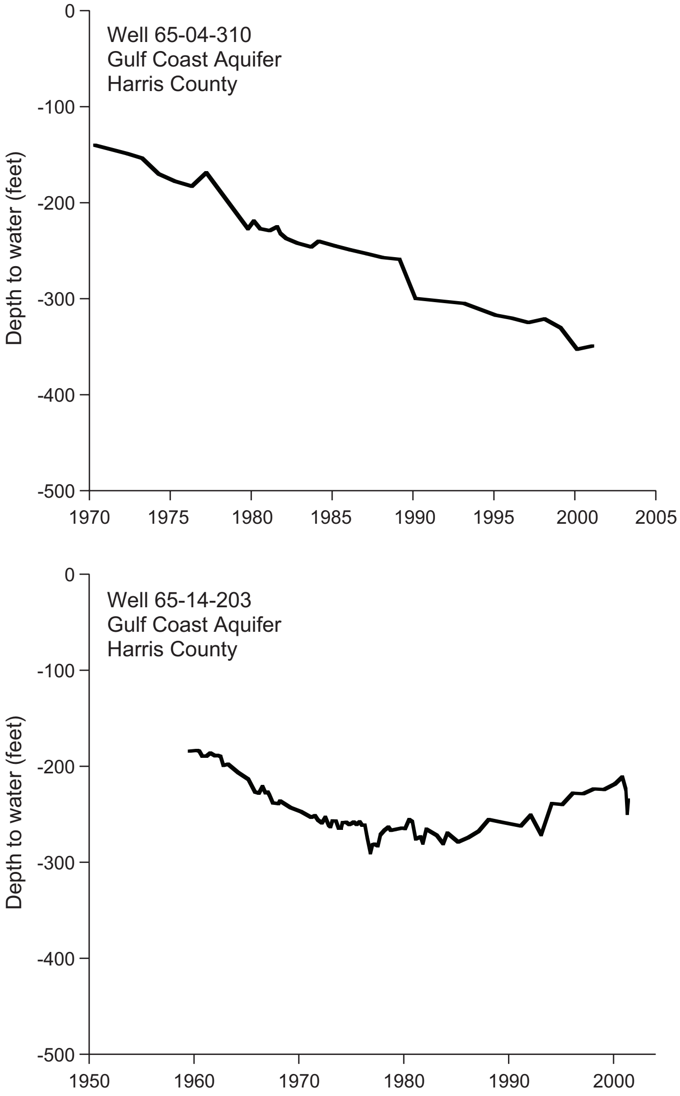


Figure 4-6. Hydrographs for two wells in the Gulf Coast Aquifer.

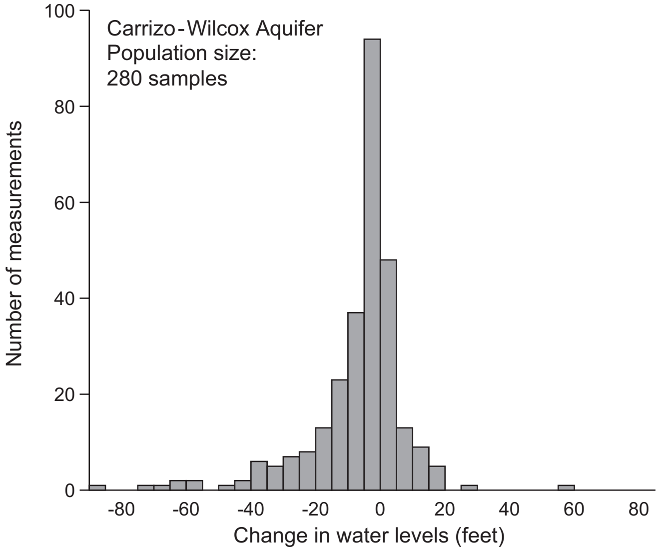


Figure 4-7. Water level changes in the Carrizo-Wilcox Aquifer, 1990 to 2000.

Well 65-14-203 (located in Houston's Scenic Woods area) has recorded water level rises. Groundwater pumping in the Houston region has been gradually declining as surface water replaces groundwater as the area's predominant water supply. The result has been a rise in local water levels in the aquifer.

## 4.3

## CARRIZO-WILCOX AQUIFER

From 1990 to 2000, water levels in the Carrizo-Wilcox Aquifer, on average, declined slightly (Figure 4-7). The median water level change was a decline of 2.9 feet. Well 34-45-803 in Smith County showed the largest water level drop of 86.7 feet, whereas Well 77-37-501 in Dimmit County recorded the largest rebound of 57.7 feet. Most water level changes were moderate: of the 280 measurements, 175, or 62.5 percent, showed a decline of less than 25 feet, and 75 readings, or 26.8 percent, showed a rebound of up to 25 feet.

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 4-8). The southwest segment of the Winter Garden area (Zavala, Medina, Dimmitt, Frio, and La Salle counties) sustained overall water level declines, although some moderate rebounds are noticeable in Zavala and Medina counties. Other areas of consistent water level decline were in parts of Rusk, Harrison, Upshur, Gregg, Smith, Wood, Hopkins, Van Zandt, Henderson, Anderson, and Cherokee counties. Moderate declines of up to 25 feet were common here, although levels in some wells declined by more than 50 feet. North of there, in parts of Bowie, Titus, Morris, Cass, Marion, Panola, Sabine, and Shelby counties, water levels in wells rose moderately. Most of the wells showing water level rises in these areas are located in the outcrop of the Carrizo Formation.

Hydrographs show distinct trends in water level changes in two wells (Figure

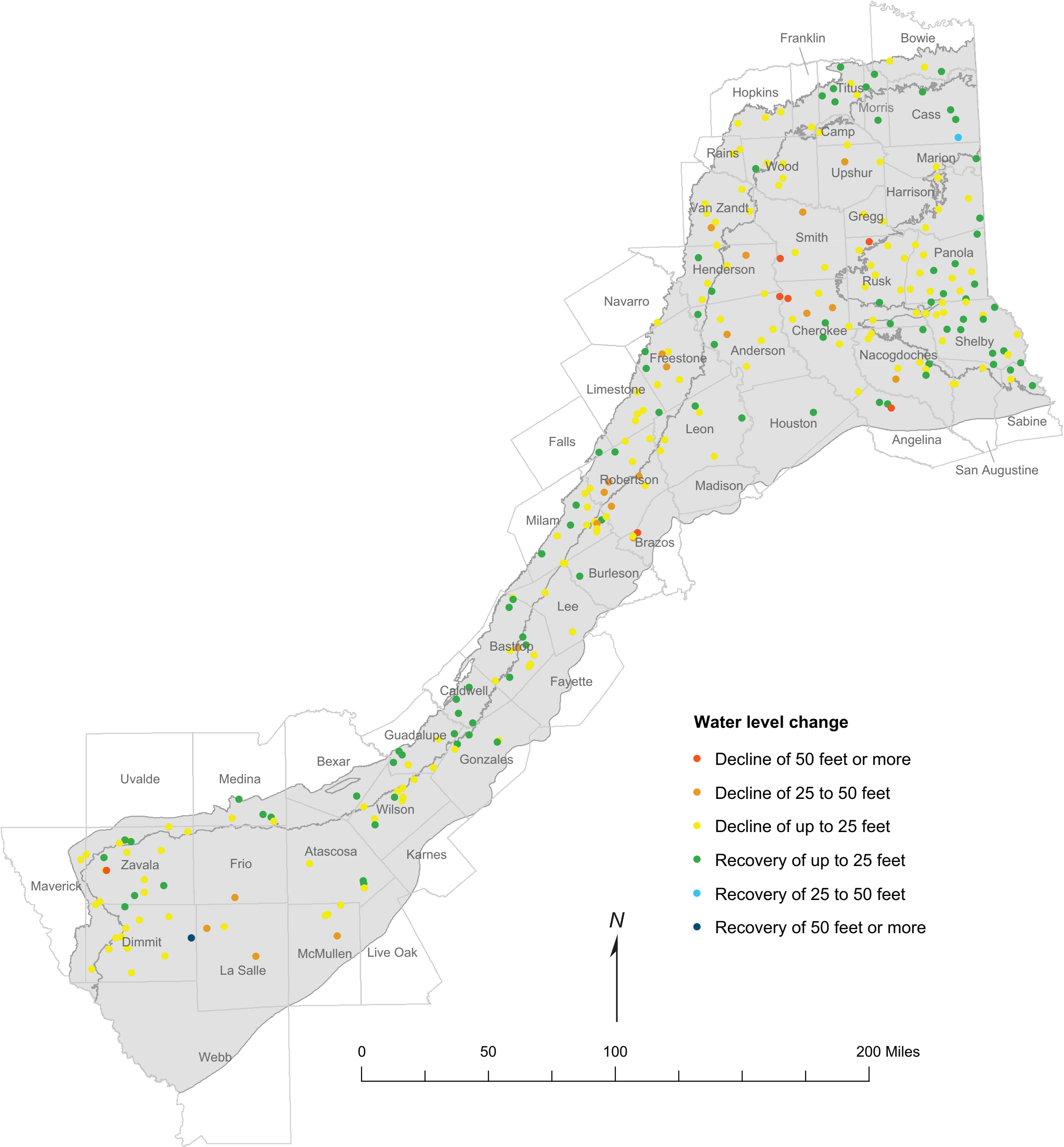


Figure 4-8. Areal distribution of wells and observed changes in water levels in the Carrizo-Wilcox Aquifer, 1990 to 2000.

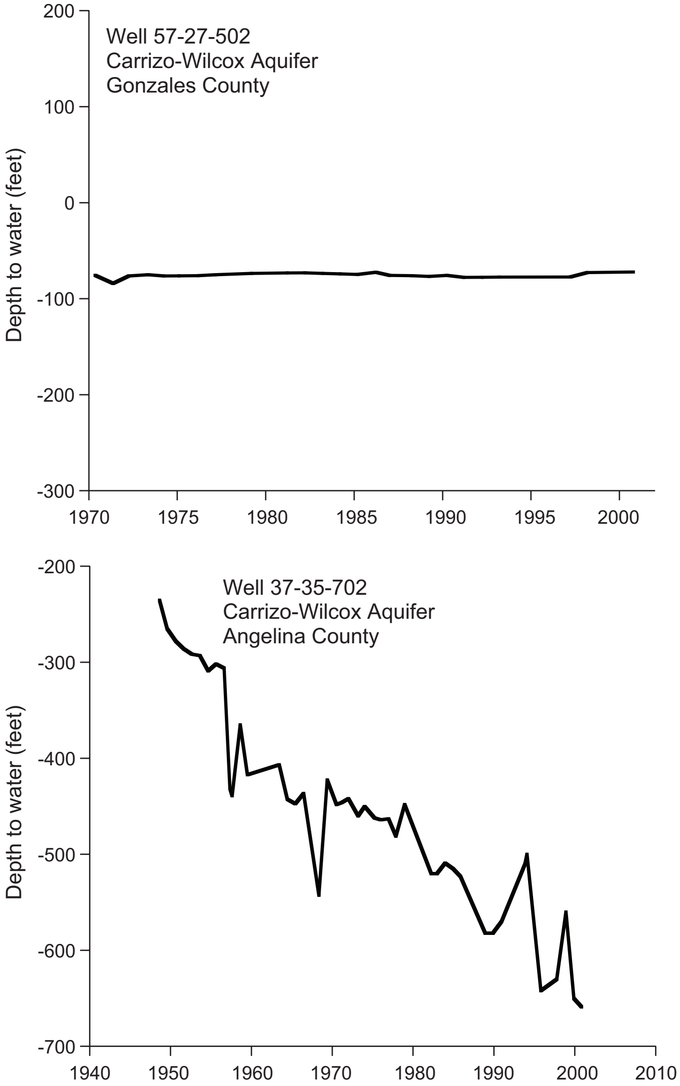


Figure 4-9. Hydrographs for two wells in the Carrizo-Wilcox Aquifer.

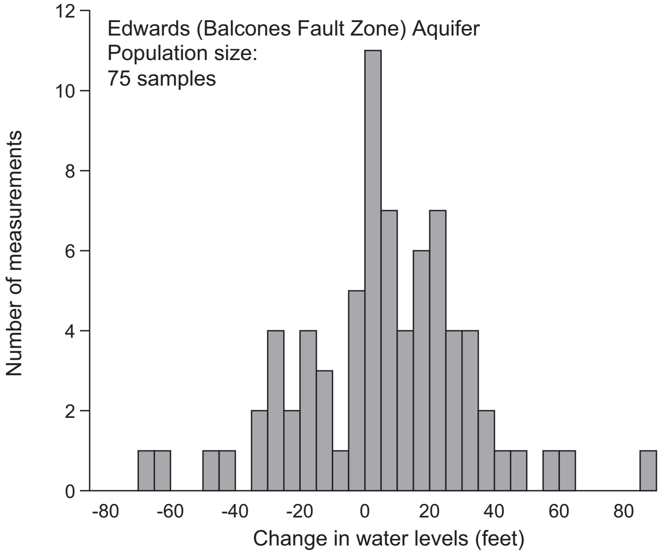


Figure 4-10. Water level changes in the Edwards (Balcones Fault Zone) Aquifer, 1990 to 2000.

4-9). Well 57-27-502 is a windmill used for watering cattle, and the other, Well 37-35-702, is a public water supply well in Angelina County. The water levels in the windmill well remained constant during the period of record, most likely due to minimal groundwater pumpage at the site and in the greater area. The water level in the public water supply well, however, declined steeply during the period of record from pumping in the area.

## 4.4

## EDWARDS (BALCONES FAULT ZONE) AQUIFER

The Edwards (Balcones Fault Zone) Aquifer is contained within the Edwards Limestone. The Balcones Fault Zone is where this aquifer is the most prolific, supplying water for 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 in Kyle and a groundwater divide in central Kinney County.

All three sections of the aquifer are karstified, more intensely so in the San Antonio and Barton Springs 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 rest of the Edwards (Balcones Fault Zone) 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

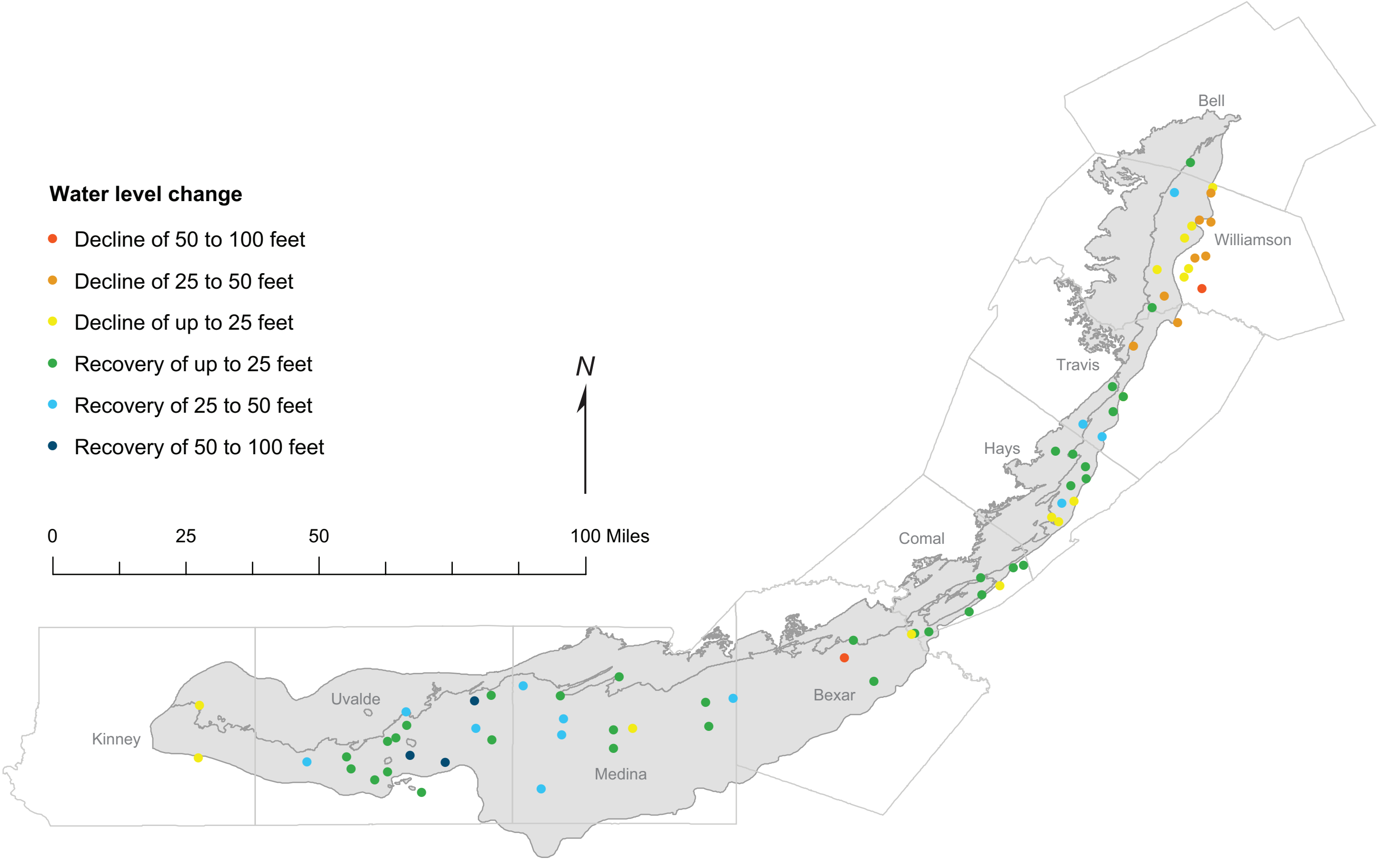


Figure 4-11. Areal distribution of wells and observed changes in water levels in the Edwards (Balcones Fault Zone) Aquifer, 1990 to 2000.

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 very quickly—it is not as well suited to comparing water levels between years and assessing 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 2000, water levels in the Edwards (Balcones Fault Zone) Aquifer were moderately higher than in 1990 (Figure 4-10). The median change was 6.2 feet. The largest water level fluctuations occurred in Medina County (Well 69-43-804, 86.8 feet higher in 2000) and in Williamson County (Well 58-28-601, 67.5 feet lower in 2000). Of the 75 wells measured, 35, or 46.6 percent, had water levels moderately higher (25 feet or less) in 2000 than in 1990. Water levels in 15 wells, or 20 percent, were moderately lower (25 feet or less) in 2000 compared with 1990.

In the western segment of the aquifer in Medina and Uvalde counties, water levels were higher in 2000 than in 1990 in all measured wells except one (Figure 4-11). 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

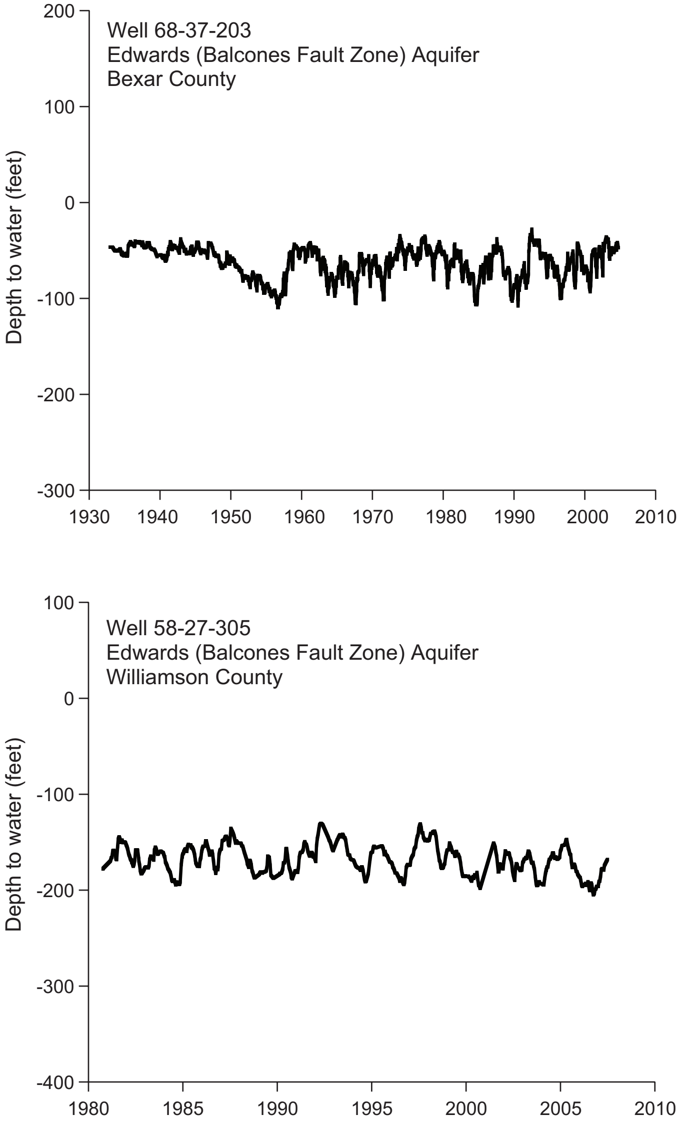


Figure 4-12. Hydrographs for two wells in the Edwards (Balcones Fault Zone) Aquifer.

counties had water levels lower in 2000 than in 1990. In some wells, the changes were significant.

The Palmer Drought Severity Index in 1990 and 2000 (Figure 2-3) reveals that at stations immediately adjacent to the Edwards (Balcones Fault Zone) Aquifer, 2000 was drier than 1990. If one accepts that recharge is the driver of water level change in this setting, water levels higher in 2000 than in 1990 would be incompatible with drier weather. However, the Palmer Drought Severity Index at locations away from the aquifer but inside the contributing zone showed that some of those locations (in Comal and Hays counties, in particular) had wetter conditions in 2000 than in 1990. Most of the stations located in the San Antonio segment of the aquifer recorded drier conditions in 2000 than in 1990, and one showed 2000 as the wetter year. 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, we hypothesize that wetter weather in parts of the contributing zone resulted in locally elevated streamflows and increased aquifer recharge, thus accounting for some of the water level rises despite the relative dryness of 2000.

By contrast, 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 most wells were lower in 2000 than in 1990 because 2000 was a drier year than 1990, and there was no other source of recharge.

The Edwards Aquifer Authority uses water levels in Well 68-37-203 (known to many as J-17, Figure 4-12, top) as the trigger for different stages of aquifer pumping limits during times of drought. The water level variation in this well is typical for 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 change in storage. Similarly, the hydrograph for Well 58-27-305 (Figure 4-12, bottom) shows cyclical, climate-driven variations in water levels.

## 4.5
## TRINITY AQUIFER

In 2000, water levels in the Trinity Aquifer were moderately lower than in 1990 (Figures 4-13 and 4-14). The median change in water levels was a decline of 1.70 feet. Both the largest decline and

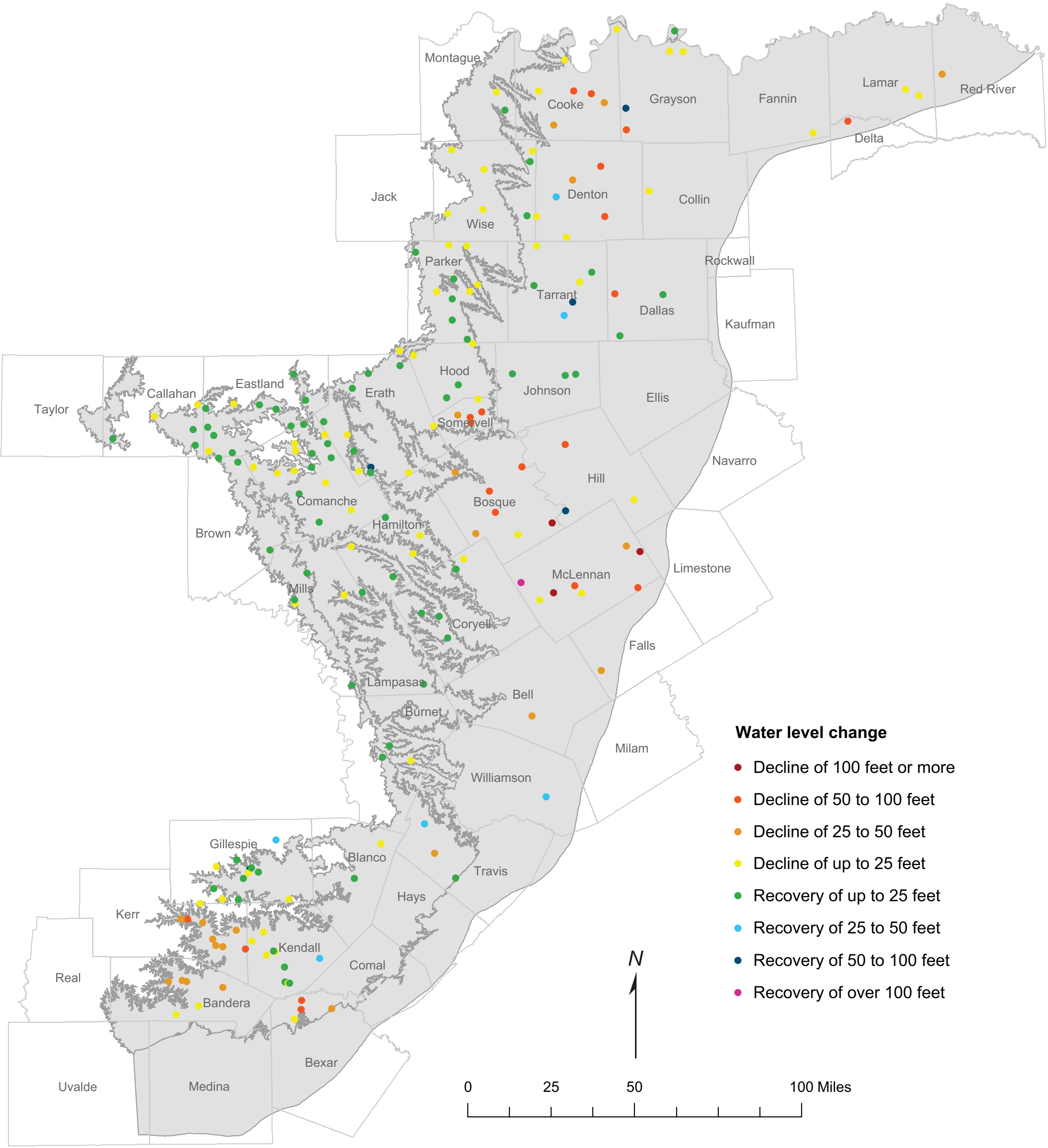


Figure 4-13. Areal distribution of wells and observed changes in water levels in the Trinity Aquifer, 1990 to 2000.

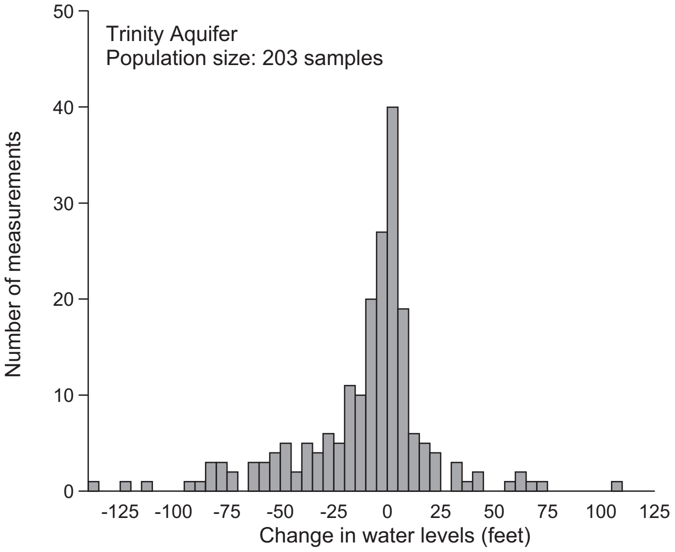


Figure 4-14. Water level changes in the Trinity Aquifer, 1990 to 2000.

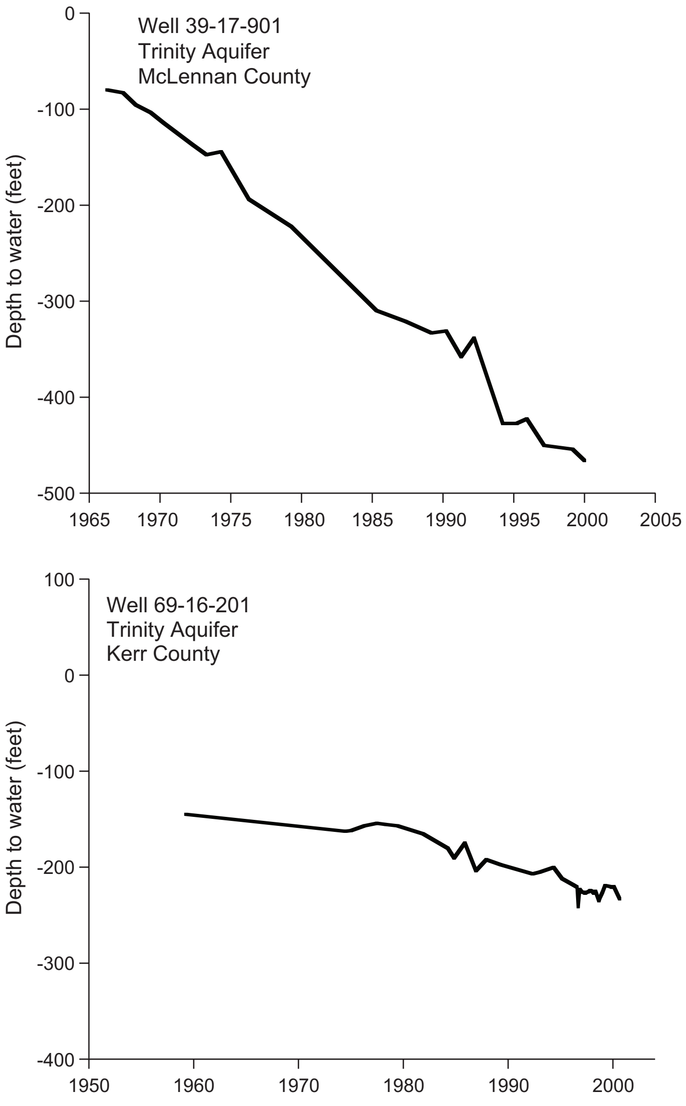


Figure 4-15. Hydrographs for two wells in the Trinity Aquifer.

the largest recovery were in McLennan County: the water level in Well 39-17-901 dropped 135.1 feet, and the water level in Well 40-28-902 rose 107 feet.

On an aquifer-wide basis, moderate (25 feet or less) water level changes occurred in 147 wells, or 70 percent, of TWDB-measured wells. Of these, 75 wells showed water level declines, and 72 wells showed water level rises.

Several areas displayed consistent water level declines or rises between 1990 and 2000. The area of Bandera, Kerr, western Kendall, and northern Bexar counties experienced water level declines of up to 100 feet. 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 was in the east-central part of the aquifer in parts of Hood, Bosque, Hill, McLennan, and Falls counties. With the exception of one well in Hill County, all other wells measured in these counties recorded declines in water levels. Many of these wells 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, Collin, Grayson, Fannin, and Lamar counties. Wells supplying water to cities such as Grand Prairie, Hurst, Gainesville, Tioga, and Detroit recorded the largest water level declines. However, the region encompassing portions of Erath, Hood, Parker, Tarrant, Johnson, and Dallas counties showed rising water levels, reversing the trend of declines identified during the 1985 to 1995 monitoring period (Hopkins, 1996). Wells owned by the cities of Euless, Forrest Hill, Bethany, and Alvarado and several other industrial and household wells rebounded by up to 100 feet.

Although both hydrographs in Figure 4-15 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 stock watering. The greater water level decline in the municipal supply well was likely due to higher pumping rates.

## 4.6
## EDWARDS-TRINITY (PLATEAU) AQUIFER

Between 1990 and 2000, the Edwards-Trinity (Plateau) Aquifer experienced an overall moderate decline in water levels (Figures 4-16 and 4-17). The median aquifer-wide water level change was a decline of 2.65 feet. The largest decline, 40.4 feet, was measured in Irion County (Well 43-57-103), and the largest rise, 73.9 feet, occurred in Sterling County (Well 44-32-402).

Changes in water levels were moderate (25 feet or less) in nearly three quarters of the wells for which data were available. Of the 132 wells sampled, 50, or 37.8 percent, recorded declines. Forty-five wells, or 34.1 percent, showed water level rises of up to 25 feet.

Water levels in an area extending south and then east from Midland County through Upton County and eastern Pecos, Crockett, Sutton, Schleicher, Tom Green, and Concho counties dropped by as much as 40 feet. However, water levels in wells in the north central part of the Edwards-Trinity (Plateau) Aquifer comprising Reagan, northern Crockett, Glasscock, and western Sterling counties generally rose (from less than 1 foot to over 70 feet). Wells in Ector, western Midland, northwest Pecos, and Val

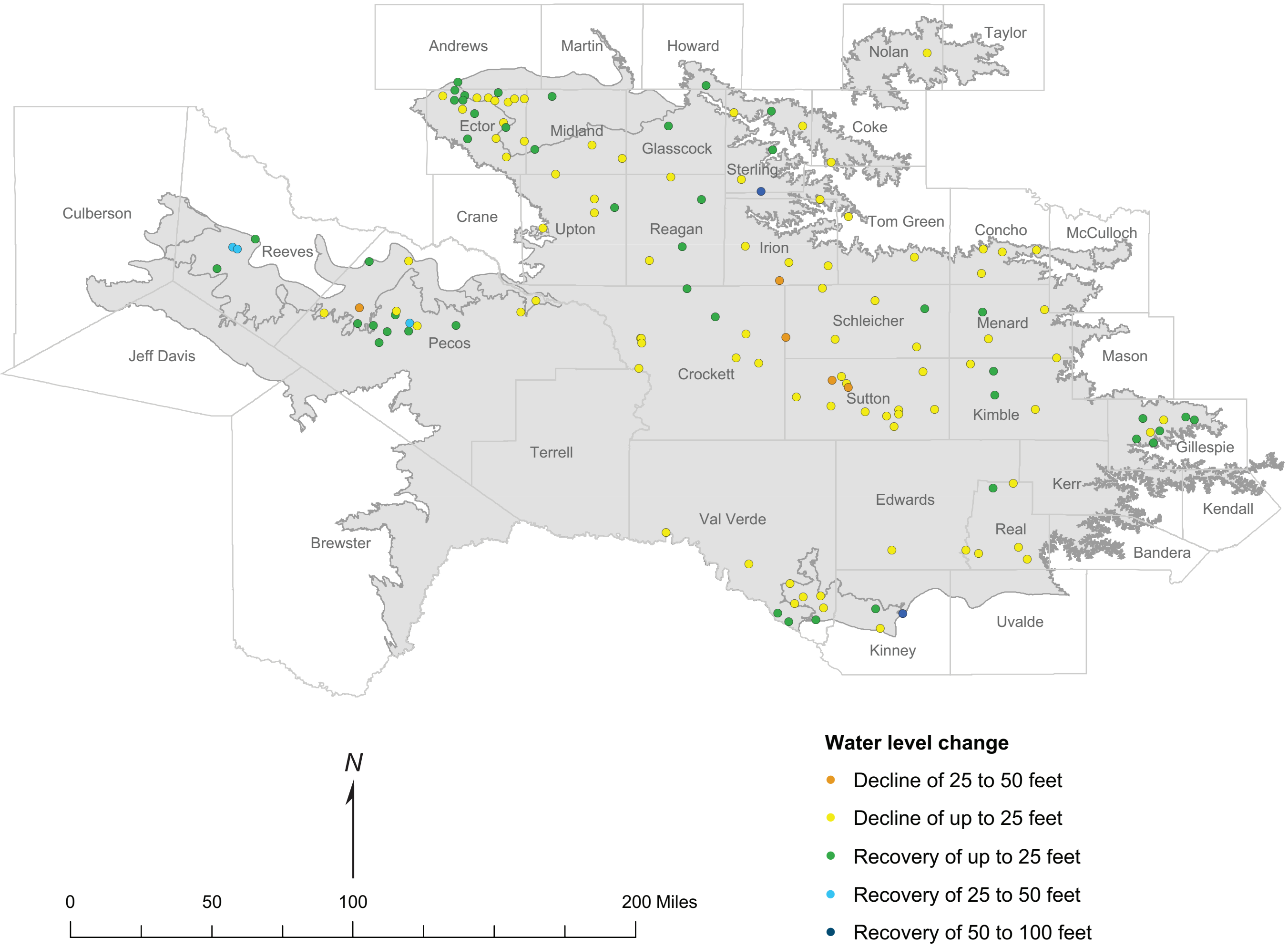


Figure 4-16. Areal distribution of wells and observed changes in water levels in the Edwards-Trinity (Plateau) Aquifer, 1990 to 2000.

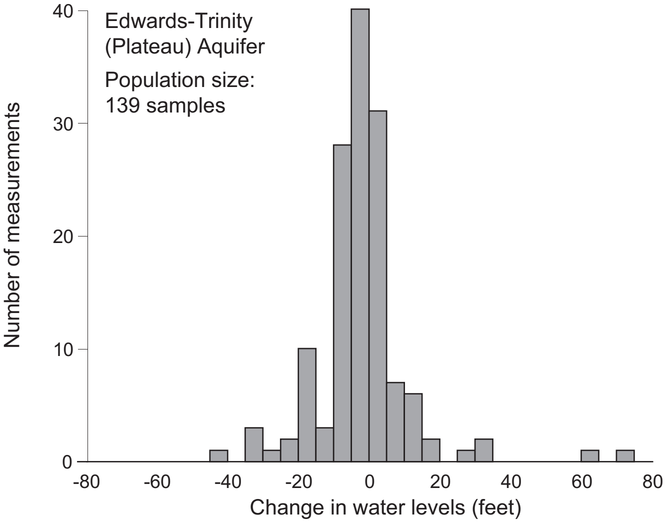


Figure 4-17. Water level changes in the Edwards-Trinity (Plateau) Aquifer, 1990 to 2000.

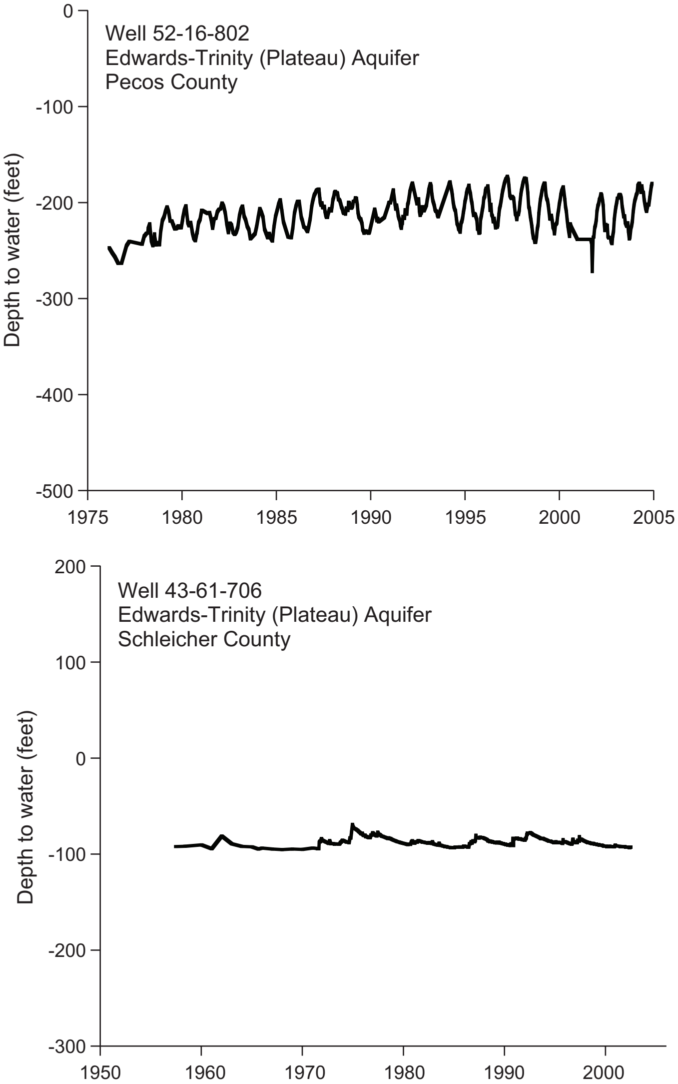


Figure 4-18. Hydrographs for two wells in the Edwards-Trinity (Plateau) Aquifer.

Verde counties showed mixed water level changes. This pattern of water level changes in wells that were mostly low capacity (for example, household and windmills) or even unequipped could indicate areas of low aquifer transmissivity where even light pumping can significantly affect the water levels. There were not many measurements for the southern part of the aquifer.

We looked at two hydrographs for unused wells located in areas with different patterns of water usage (Figure 4-18). One hydrograph is for a well in Pecos County 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 Schleicher County where water use is limited to household or cattle watering purposes shows more subdued highs and lows. Its changes are likely controlled by alternating wet and dry conditions during the years.

## 4.7

## PECOS VALLEY AQUIFER

From 1990 to 2000, water levels in the Pecos Valley Aquifer declined moderately (Figures 4-19 and 4-20). The median change in water levels was a decline of 3.8 feet. The largest decline and recovery were recorded in Reeves County. The water level in Well 46-44-803 dropped 24.5 feet, and the water level in Well 52-04-105 rose 30.9 feet.

Of the 72 water level measurements available for this aquifer, 68 measurements, or 94 percent, showed moderate changes (25 feet or less). Fifty-five wells, or 76 percent, recorded moderate declines, and 13 wells, or 18 percent, recorded rises of up to 25 feet.

Water levels in the eastern part of the aquifer in Winkler, Ward, Crane, and northern Pecos counties showed declines. Most of the wells in this area were used for irrigation and stock watering purposes, with some public water

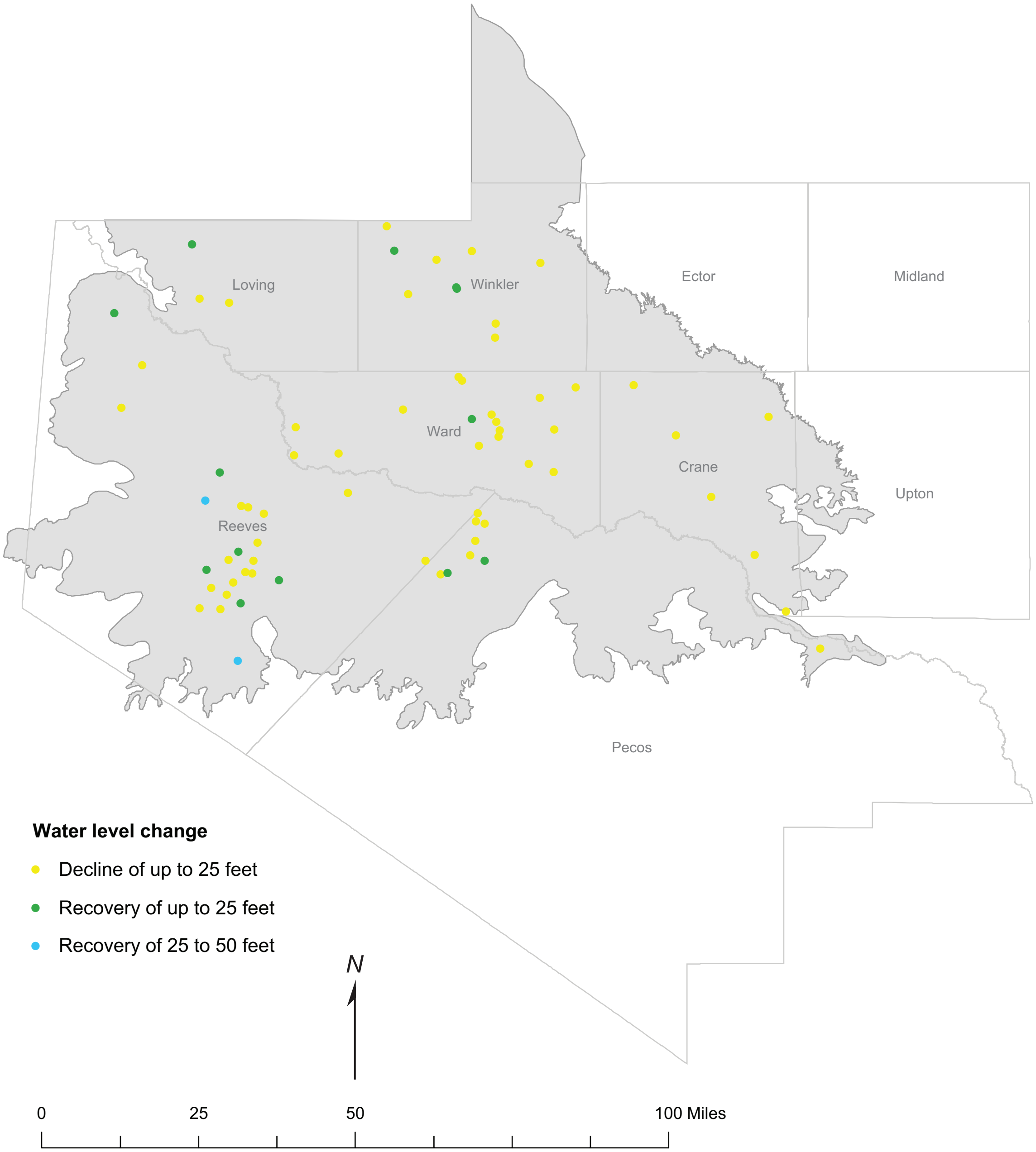


Figure 4-19. Areal distribution of wells and observed changes in water levels for the Pecos Valley Aquifer, 1990 to 2000.

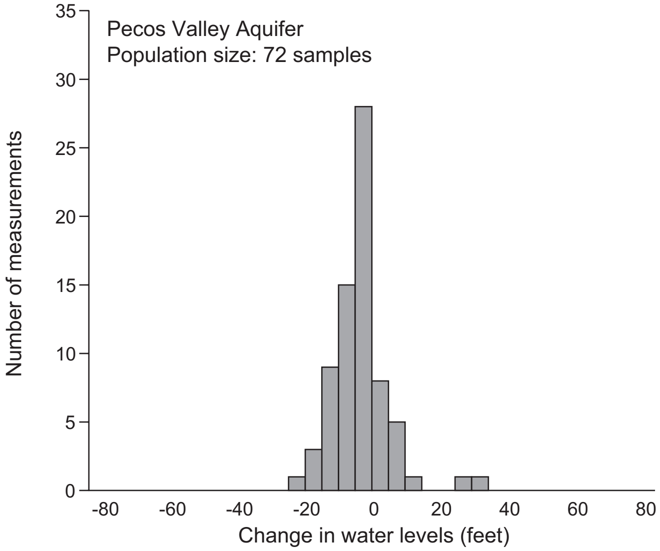


Figure 4-20. Water level changes in the Pecos Valley Aquifer, 1990 to 2000.

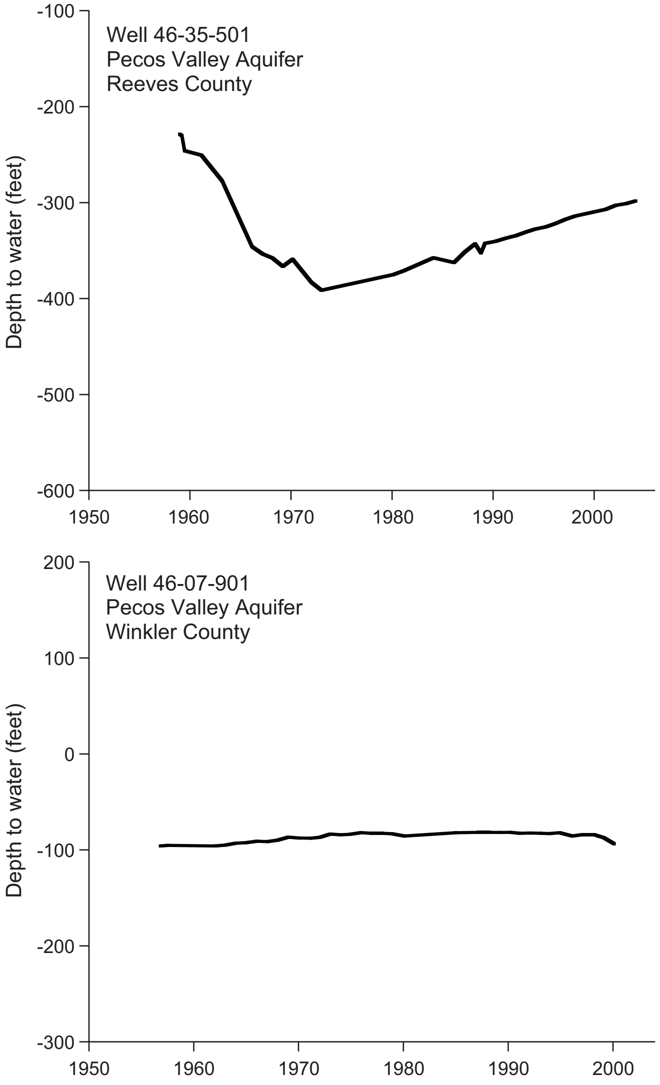


Figure 4-21. Hydrographs for two wells in the Pecos Valley Aquifer.

supply wells—prominently those of the Pyote well field that serves the cities of Midland and Odessa.

Central Reeves County sits above most of the western portion of the Pecos Valley Aquifer. Beginning in the 1950s, a cone of depression formed there due to irrigation pumping. From 1990 to 2000, most of the wells for which data were available showed a continuing trend of water level declines, likely due to localized pumpage. However, other wells in the area showed water level rises of up to 50 feet, probably because they were removed from service between 1990 and 2000.

Hydrographs of two wells in the study area illustrate long-term temporal water level fluctuations (Figure 4-21). 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 going up 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.

## 4.8
## HUECO-MESILLA BOLSONS AQUIFER

Water levels in the Hueco-Mesilla Bolsons Aquifer declined moderately from 1990 to 2000 (Figures 4-22 and 4-23). The median change in water levels aquifer-wide was a decline of 5.2 feet. The largest decline, 57.1 feet, was recorded in the city of El Paso (Well 49-13-808). The sharpest rebound in water levels, 16.5 feet, occurred in Well 49-04-138 located in the Canutillo area.

Sixty-eight of the 70 measurement pairs taken in the Hueco-Mesilla Bolsons Aquifer were indicative of moderate (25 feet or less) water level changes. Of these, 47 measurements, or 69 percent, were declines, and 21, or 31 percent, were rises. El Paso Water Utilities operates 18

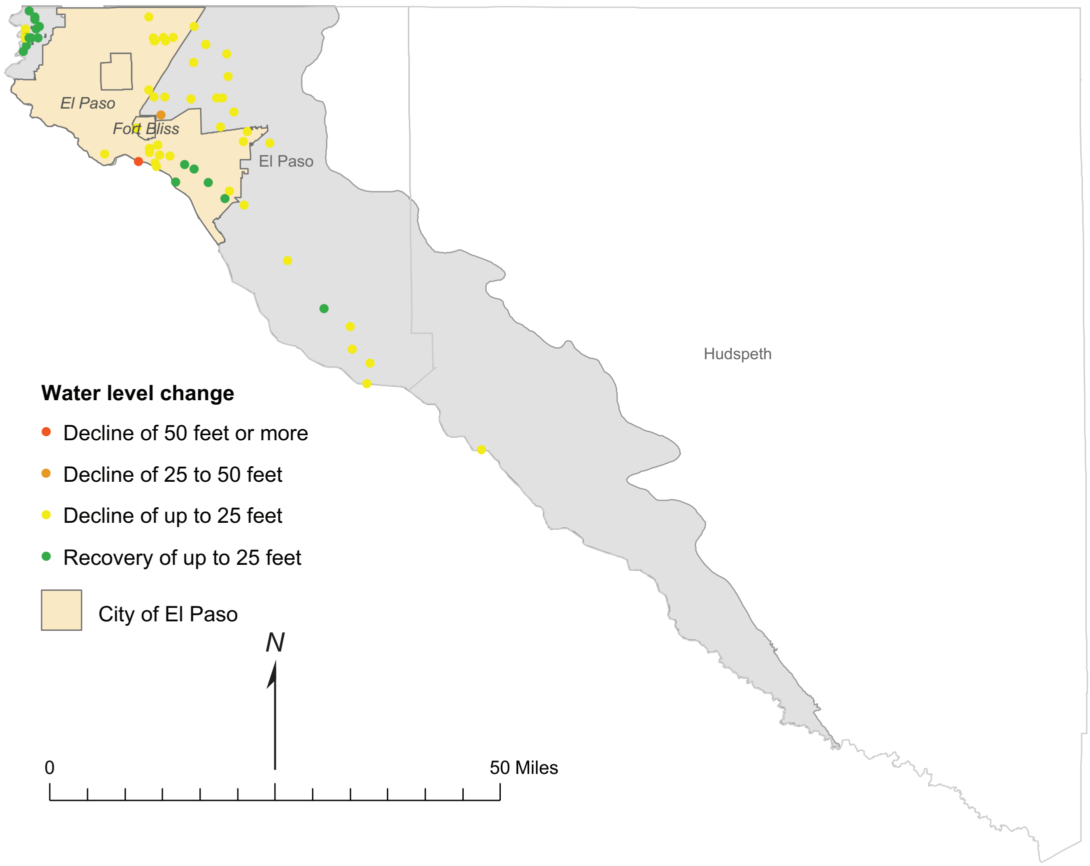


Figure 4-22. Areal distribution of wells and observed changes in water levels in the Hueco-Mesilla Bolsons Aquifer, 1990 to 2000.

wells in the Mesilla Bolson, which are located in the Canutillo area and supply the west side of El Paso. From 1990 to 2000, water levels rose in most of the Canutillo wells, although groundwater pumping increased by 7,762 acre-feet during the decade (EPWU, 2004). Streamgage measurements taken at El Paso by the International Boundary and Water Commission show the flow of the Rio Grande being over 41,000 acre feet higher in 2000 than in 1990 (IBWC, 1990, 2000).

We hypothesize that higher flows in the Rio Grande recharged the Mesilla Bolson, compensating for the increased aquifer pumping, and caused the observed water level increases.

On the east side of the Franklin Mountains, 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 two wells in the city recorded steeper drops of 40 to 50 feet. A few of the wells in the Lower Valley field along the Rio Grande showed water level rises. From 1990 to 2000, El Paso Water Utilities decreased its groundwater withdrawals in the Hueco Bolson by 17 percent (EPWU, 2004).

The hydrograph for 49-14-102 is typical of wells impacted by pumping in the Hueco Bolson (Figure 4-24). 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 1990, most of the water level declines near municipal well fields were from 50 to 150 feet. Since the late 1990s, water levels have declined at a much

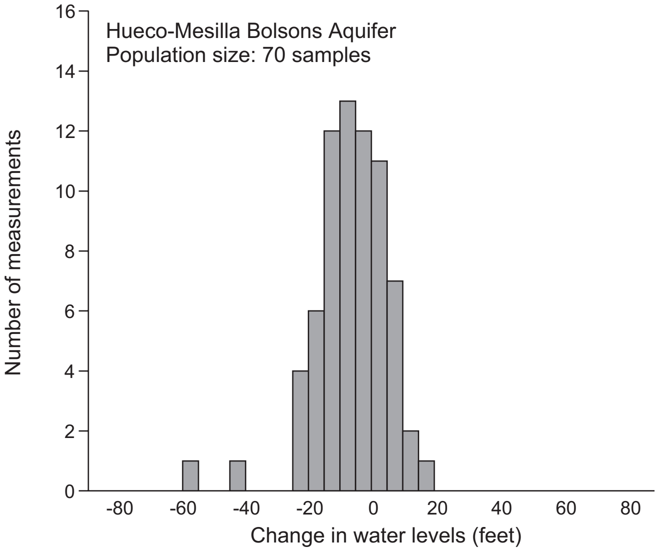


Figure 4-23. Water level changes in the Hueco-Mesilla Bolsons Aquifer, 1990 to 2000.

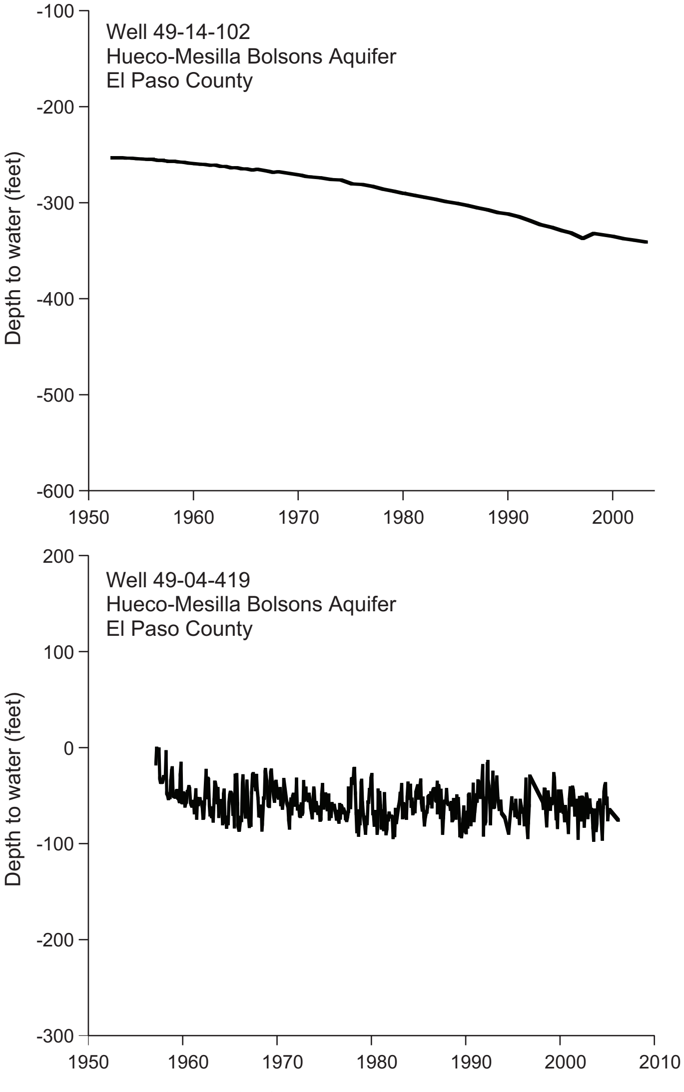


Figure 4-24. Hydrographs for two wells in the Hueco-Mesilla Bolsons Aquifer.

lower rate. 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.

## 4.9
## SEYMOUR AQUIFER

From 1990 to 2000, water levels in the Seymour Aquifer declined moderately (Figures 4-25 and 4-26). The median change in water levels was a decline of 2.1 feet. The largest decline was recorded in Jones County where the water level in Well 30-18-222 dropped 12.3 feet. The largest water level recoveries, 8.35 feet, were documented in both Well 22-52-110, located in Kent County, and in Well 12-04-609, located in Collingsworth County.

All 36 water level measurements available for the Seymour Aquifer showed moderate changes (25 feet or less). Twenty-seven wells, or 75 percent, recorded declines, and 9 wells, or 25 percent, recorded rises.

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 4-26).

Time series hydrographs for two unequipped wells in Knox and Wilbarger counties show different trends in long-term water level changes (Figure 4-27). Water levels in Wilbarger County Well 13-46-504 dropped precipitously from the 1950s through the 1970s, rebounded somewhat in the late 1970s, dropped again during the early 1980s, and have been rising slightly since then. Water levels in Knox County Well 21-20-901 have been rising ever so slightly since the late 1950s.

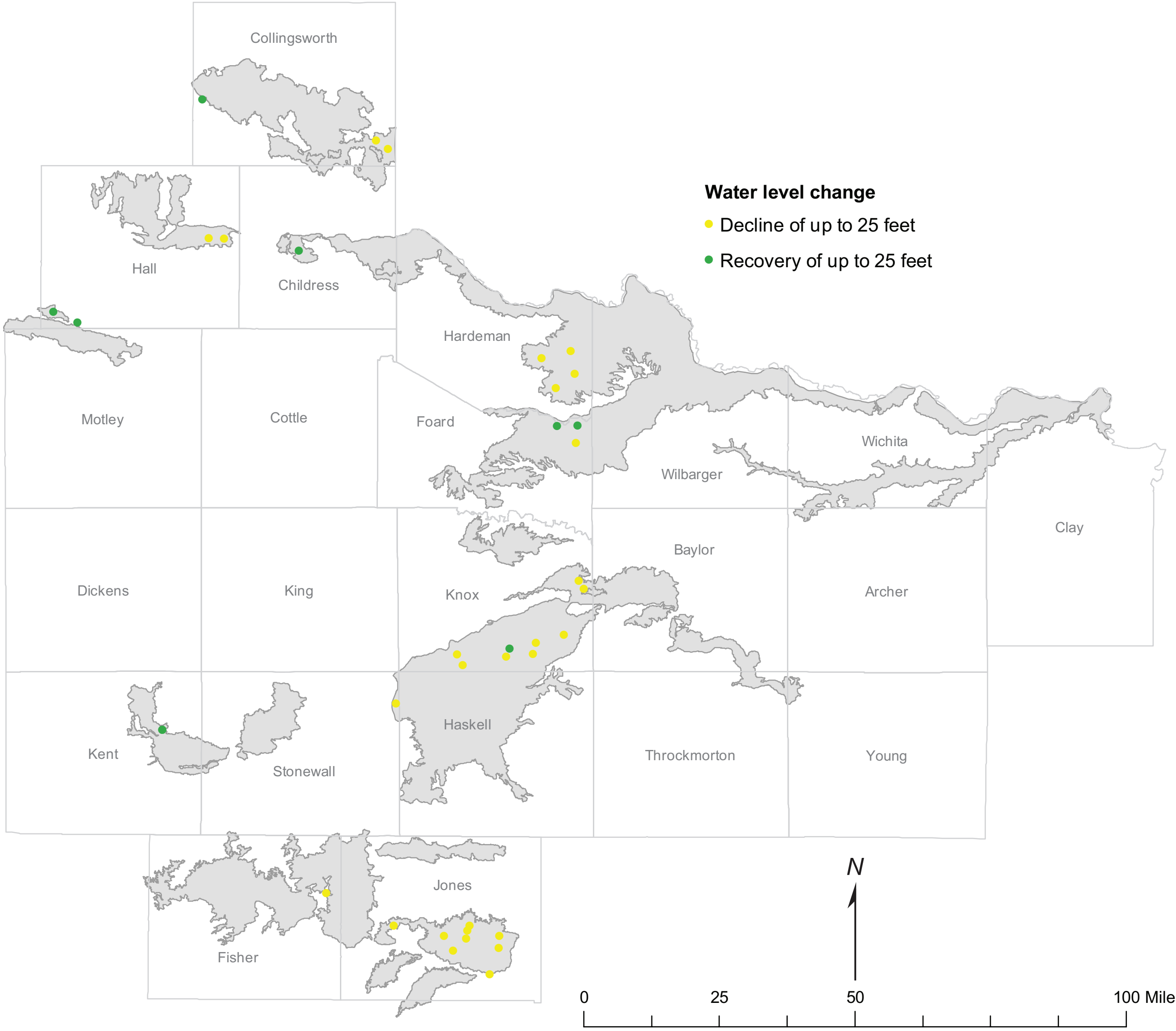


Figure 4-25. Areal distribution of wells and observed changes in water levels in the Seymour Aquifer, 1990 to 2000.

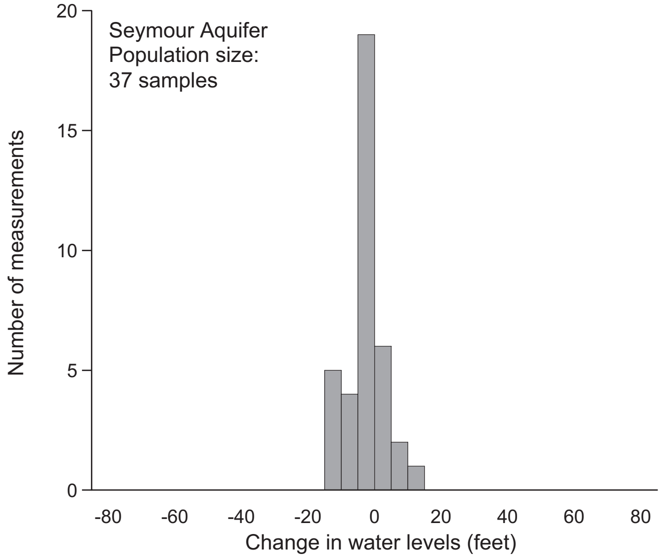


Figure 4-26. Water level changes in the Seymour Aquifer, 1990 to 2000.

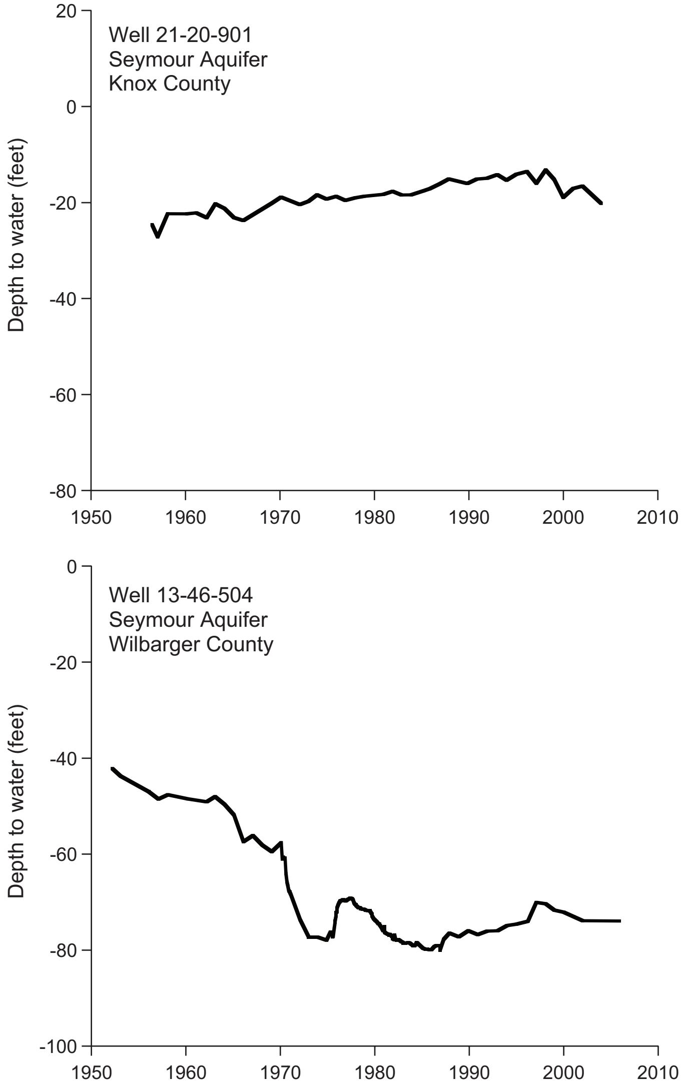


Figure 4-27. Hydrographs for two wells in the Seymour Aquifer.

# 5 *Minor Aquifers*

Water levels in the minor aquifers of Texas declined slightly from 1990 to 2000 (Figures 5-1 and 5-2). The median change in water levels was a decline of 1.0 foot. The largest decline, 78.2 feet, was recorded in the Blossom Aquifer (Well 17-32-201, which serves the city of Clarksville). The largest rise, 44.9 feet, was observed in the Ellenburger-San Saba Aquifer (Well 57-35-302). Of the 551 measurements in all minor aquifers, 518, or 94 percent, showed moderate (25 feet or less) water level changes, with 305 declines and 213 rises.

The largest median changes in water levels were recorded in the Lipan Aquifer (a decline of 13.2 feet), the Woodbine Aquifer (a decline of 5.8 feet), the Bone Spring-Victorio Peak Aquifer (a decline of 3.7 feet, although note that this is a responsive limestone aquifer), and the Rita Blanca Aquifer (a decline of 3.4 feet) (Table 3-1). Irrigation and municipal water supply are the main uses for most wells completed in these four aquifers. We found smaller median water level declines in the Hickory (2.3 feet), Igneous (1.8 feet), Queen City (1.5 feet), Sparta (1.4 feet), Dockum (1.1 feet), Nacatoch (0.7 feet), and West Texas Bolsons (0.6 feet) aquifers.

Several aquifers showed median water level rises over the decade. They include the Blaine Aquifer (1.6 feet), Yegua-Jackson Aquifer (0.6 feet), Ellenburger-San Saba Aquifer (0.5 feet), and the Brazos River Alluvium (0.4 feet).

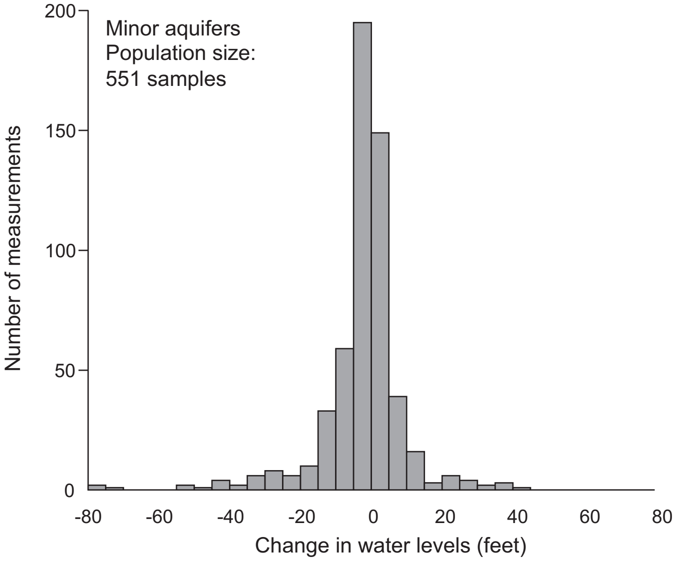


Figure 5-1. Water level changes in the minor aquifers of Texas, 1990 to 2000.

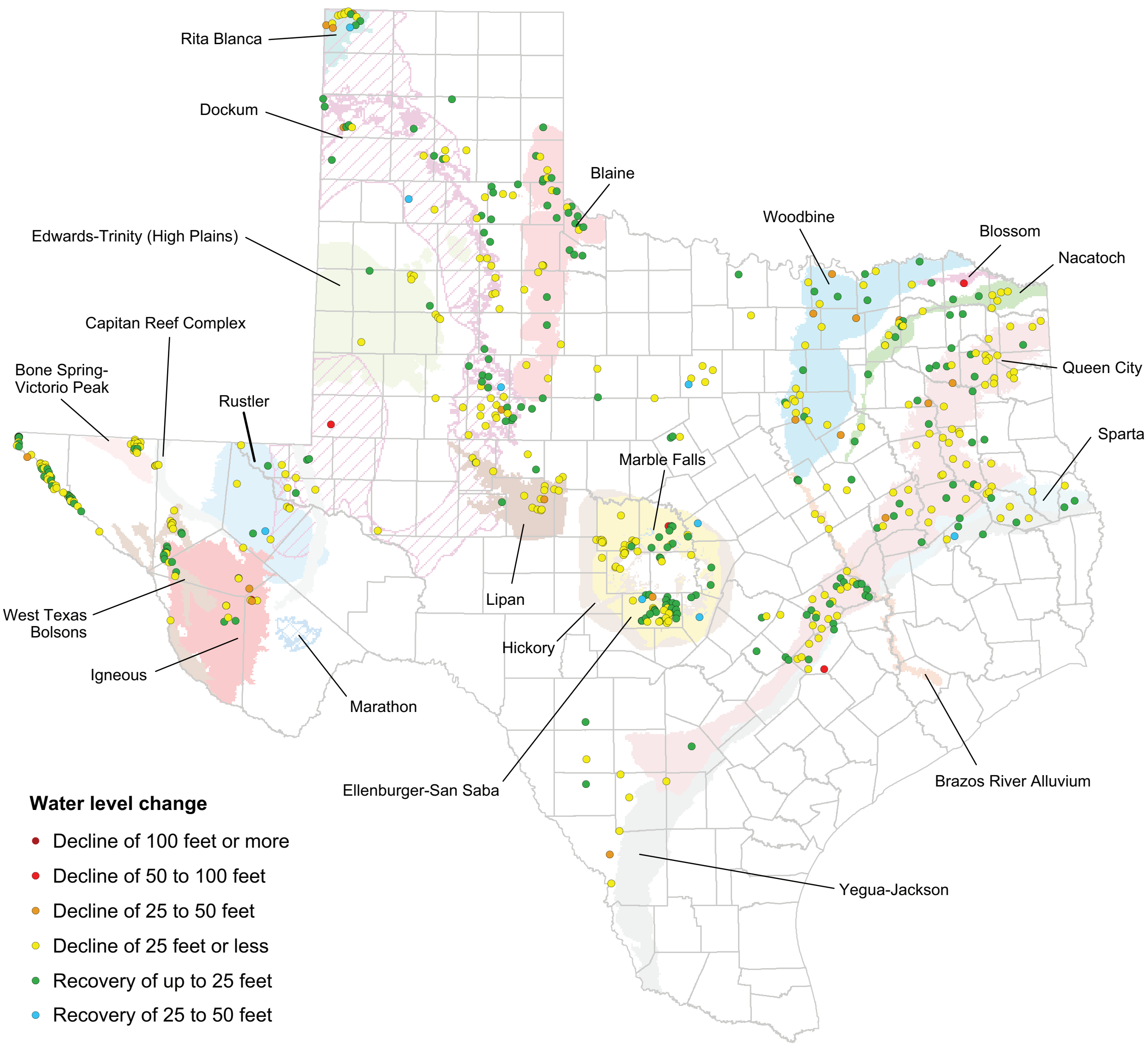


Figure 5-2. Areal distribution of wells and observed changes in water levels in the minor aquifers of Texas, 1990 to 2000. Wells that plot outside of aquifer boundaries are completed in permeable, water-bearing formations that are not designated as a named major or minor aquifer.

# 6 *Conclusions*

Water levels in the majority of wells across Texas declined from 1990 to 2000. The median water level change statewide was a decline of 3.0 feet. Most of the statewide changes in water levels were less than 25 feet. Specifically, 2,325 wells (or 55.3 percent of the wells with available data) showed water level declines of up to 25 feet, and 1,243 wells (29.6 percent) had recorded rises of up to 25 feet. Changes in water levels were as follows (Table 6-1):

Table 6-1. Median changes in Texas aquifers, 1990 to 2000.

| Aquifer | Median change (feet) |
|---|---|
| Carrizo-Wilcox | -3.0 |
| Edwards (Balcones Fault Zone) | 6.2 |
| Edwards-Trinity (Plateau) | -2.7 |
| Gulf Coast | 1.5 |
| Hueco-Mesilla Bolsons | -5.2 |
| Ogallala | -5.7 |
| Pecos Valley | -3.8 |
| Seymour | -2.1 |
| Trinity | -1.7 |
| Blaine | 1.6 |
| Brazos River Alluvium | 0.4 |
| Bone Spring-Victorio Peak | -3.7 |
| Capitan Reef | -2.8 |
| Dockum | -1.1 |
| Edwards-Trinity (High Plains) | -8.5 |
| Ellenburger-San Saba | 0.5 |
| Hickory | -2.3 |
| Igneous | -1.8 |
| Lipan | -13.2 |
| Marble Falls | 1.1 |
| Nacatoch | -0.7 |
| Rita Blanca | -3.4 |
| Queen City | -1.5 |
| Sparta | -1.4 |
| West Texas Bolsons | -0.2 |
| Woodbine | -5.8 |
| Yegua-Jackson | 0.6 |

The median water level change over the 10-year period in the Ogallala Aquifer was a decline of 5.7 feet. Although most of the Ogallala Aquifer wells showed declines of 25 feet or less, there were also many wells displaying water level rises of up to 23.8 feet across portions of the northeastern Texas High Plains.

From 1990 to 2000, the Gulf Coast Aquifer experienced an overall water level recovery. The median change in water level was a rise of 1.5 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 1990 to 2000. The median water level change was a decline of 2.9 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 2000, water levels in the Edwards (Balcones Fault Zone) Aquifer were moderately higher than in 1990, mostly in the San Antonio and Barton Spring segments. In the northern segment, water levels were lower in 2000 than in 1990. The aquifer-wide median change was a rise of 6.2 feet.

The median change in water levels in the Trinity Aquifer was a drop of 1.97 feet between 1990 and 2000. Portions of the northern and east-central parts of the Trinity Aquifer, as well as areas in the Texas Hill Country, had water level declines. Some wells in the Dallas-Fort Worth area and near the aquifer outcrop to the west showed water level rises.

From 1990 to 2000, the median change in water levels in the Edwards-Trinity (Plateau) Aquifer was a decline of 2.5 feet. Water level declines occurred across the north-central Edwards Plateau, and levels rose in the Trans Pecos and areas of the eastern Edwards Plateau.

The median water level change over the 10-year period in the Pecos Valley Aquifer was a decline of 3.8 feet. Most of the measured aquifer levels were lower in 2000 than in 1990. Water levels rose at several locations.

Water levels in the Hueco-Mesilla Bolsons Aquifer declined moderately from 1990 to 2000. The median change in water levels aquifer-wide was a decline of 5.2 feet. Most of the declines occurred in the Hueco Bolson. Many wells in the Canutillo area of the Mesilla Bolson showed water level rises.

The median water level change between 1990 and 2000 for the minor aquifers of Texas was a 1-foot decline. Water level declines were documented in the Bone Spring-Victorio Peak, Capitan Reef, Dockum, Edwards-Trinity (High Plains), Hickory, Igneous, Lipan (largest median decline), Nacatoch, Rita Blanca, Queen City, Sparta, West Texas Bolsons, and Woodbine aquifers. The Blaine, Brazos River Alluvium, Ellenburger-San Saba, Marble Falls, and Yegua-Jackson aquifers showed overall water level increases over the decade, with the Blaine posting the largest change of the group.

# 7 *Acknowledgments*

I thank Ali Chowdhury, Lance Christian, Janie Hopkins, Ian Jones, Sanjeev Kalaswad, Merry Klonower, Robert Mace, and Bill Mullican for their time and suggestions in reviewing the report and JoAnn Estrada for her design assistance.

# 8 *References*

Ashworth, J.B. and Hopkins, J.E., 1995, Aquifers of Texas: Texas Water Development Board Report 345, 69 p.

Cottingham, I.J., Goddard, S., Zhang, S., Wu, X., Lu, K., Rutledge, A., Waltman, W.J., 2004, Demonstration of the national agricultural decision support system: Digital Government Society of North America, ACM International Conference Proceeding Series, v. 262, 2 p.

Hopkins, J.E., 1996, Areas experiencing significant water level decline, 1985–1995: Texas Water Development Board Hydrologic Atlas no. 7, 2 p.

IBWC (International Boundary and Water Commission, United States and Mexico), 2000, Flow of the Rio Grande and related data: Water Bulletin 70.

IBWC (International Boundary and Water Commission, United States and Mexico), 1990, Flow of the Rio Grande and related data: Water Bulletin 60.

Michel, T.A., 2006, 100 years of groundwater use and subsidence in the Upper Texas Gulf Coast, *in* Mace, R.E., and others, eds., Aquifers of the Gulf Coast of Texas: Texas Water Development Board Report 365, 304 p.

Palmer, W.C, 1965, Meteorological drought: Washington, D.C., Department of Commerce Research Paper No. 45, 58 p.

EPWU (El Paso Water Utilities), 2004, Hueco Bolson groundwater conditions and management report, El Paso area: El Paso Water Utilities, http://www.epwu.org/water/hueco_bolson.html

Woodruff, C.M., 1985, Jollyville Plateau—Geomorphic controls on aquifer development, *in* Woodruff, C.M., and others, eds., Edwards Aquifer—Northern segment, Travis, Bell, and Williamson counties, Texas: Austin Geological Society Guidebook 8, 104 p.

TWDB (Texas Water Development Board), 2007, Water for Texas 2007: Texas Water Development Board State Water Plan, v. 2, 392 p.