EDWARDS AQUIFER AUTHORITY

# Hydrologic Data Report

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For 2013

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# SUMMARY

This report presents results of the Edwards Aquifer Authority's (EAA's) Edwards Aquifer Data Collection Program for calendar year 2013. The report also provides a summary of events that were considered significant and that may have affected the Edwards Aquifer during the year. During 2013, the EAA collected a wide variety of Edwards Aquifer related data, including

- Groundwater level data;
- Precipitation measurement data;
- Groundwater recharge data;
- Groundwater discharge and usage data; and
- Water quality data from groundwater, surface water, and springs.

## Groundwater Level Data (p. 6–13)

Water levels at the Bexar County (J-17) index well were below the historical mean for the entire year. The maximum level of 658.4 feet above msl at J-17 occurred during May, and the low of 631.4 feet above msl occurred in September.

Other wells in the region exhibited similar behavior with regard to lower than normal water levels. The Comal County observation well (DX-68-23-302) had an annual high water level slightly below the historical mean high. However, for most of the year, this well also exhibited lower than normal water levels.

## Precipitation Measurement Data (p. 14–21)

In 2013, rainfall amounts were above the mean in Bexar County and below the mean in Comal, Hays, Medina, and Uvalde counties. In general, the region received between 67 and 105 percent of normal precipitation during the year, with Hondo receiving the lowest rainfall total and the rest of the region receiving higher rainfall totals.

## Groundwater Recharge Data (p. 22–27)

Total estimated recharge to the Edwards Aquifer was below normal in 2013. Recharge for the year was estimated at 182,600 acre-feet compared with that of the period-of-record (1934–2013) median annual recharge of 556,950 acre-feet. Compared with recharge for the period of record, recharge in 2013 was below the period-of-record median value for all basins except the Blanco River Basin, which was above the median.

## Groundwater Discharge and Usage Data (p. 28–39)

In calendar year 2013, total groundwater discharge from the Edwards Aquifer through wells and springs was estimated at 588,630 acre-feet. This amount is below the median total discharge of 689,950 acre-feet for the period of record (1934–2013).

Discharge from wells in 2013 was estimated to be 355,824 acre-feet, approximately 27,224 acre-feet above the 328,600 acre-foot median for the period of record (1934–2013). The lowest annual estimated discharge from wells for the period of record was 101,900 acre-feet in 1934, and the highest was 542,400 acre-feet in 1989.

Discharge from springs in 2013 was estimated at 232,806 acre-feet, below the period of record median of 379,850 acre-feet. The lowest annual discharge from springs for the period of record (1934–2012) was 69,800 acre-feet in 1956, and the highest was 802,800 acre-feet in 1992. Spring discharge in 2013 was the twelfth-lowest discharge on record.

## Water Quality Data from Groundwater, Surface Water, and Springs (p. 40–64)

In 2013, EAA staff collected water quality samples from 73 wells (some wells were sampled multiple times), ten streams, and five spring groups. Samples for personal care and pharmaceutical products (PPCPs) were collected at four wells, four springs, and four streams. Samples collected for the year are summarized below by sample type and location.

Sample-Collection Summary, Calendar Year 2013

Bacteria Samples

- 83 samples collected at 73 wells
- 71 samples collected at five spring groups
- 19 samples collected at ten stream sites

Metals Samples

- 78 samples collected at 62 wells
- 74 samples collected at five spring groups
- 19 samples collected at ten stream sites

Nitrate-Nitrite as Nitrogen

- 91 samples collected at 72 wells
- 74 samples collected at five spring groups
- 19 samples collected at ten stream sites

Volatile Organic Compounds

- 79 samples collected at 63 wells
- 74 samples collected at five spring groups
- Four samples collected at two streams

Semivolatile Organic Compounds

- 73 samples collected at 54 wells
- 73 samples collected at five spring groups
- 19 samples collected at ten streams

Pesticide and/or Herbicide Compounds

- 50 samples collected at 49 wells
- 73 samples collected at five spring groups
- 20 samples collected at ten stream sites

Polychlorinated Bi-Phenyls

- 32 samples collected at 32 wells
- 72 samples collected at five spring groups
- 16 samples collected at nine stream sites

Pharmaceuticals and Personal Care Products

- Five samples collected at five wells
- Four samples collected at four spring groups
- Five samples at four streams

## Significant Events Affecting the Edwards Aquifer in Calendar Year 2013

(p. 65–71)

In calendar year 2013, drought conditions persisted in the Central Texas region. Except for 2010, total annual recharge had been significantly below the long-term average of 700,000 acre-feet since 2008, and total recharge for the region was estimated at 182,600 acre feet for 2013. Dry conditions and above-normal temperatures resulted in a general trend of declining water levels in Uvalde, Medina, and Bexar counties. Below-average rainfall in 2012 and 2013 reduced recharge rates and lowered both the Uvalde and San Antonio pools to levels at the end of 2013 that had not been reached since the drought of record ended in 1957. On March 28, 2013, the Uvalde pool of the aquifer reached the Stage V critical-period management trigger (840 ft msl) for the first time since its inception and remained there for the rest of 2013. The San Antonio pool finished the year with San Antonio Index Well J-17 below the Stage III critical-period management trigger of 640 feet msl.

# INTRODUCTION

The Balcones Fault Zone Edwards Aquifer in south central Texas is one of the largest and most productive karst aquifer systems in the United States. The physical extent of the aquifer covers an area approximately 180 miles long and five to 40 miles wide. The aquifer is the primary water source for much of this area, including the City of San Antonio and surrounding communities. Historically the cities of Uvalde, San Antonio, New Braunfels, and San Marcos were founded around large springs that discharged from the aquifer. As the region grew and technology improved, wells were drilled into the aquifer to supplement and later replace water provided by the springs. In addition, the Edwards Aquifer is the principal source of water for agriculture and industry in the region and provides springflow required for endangered species habitat, as well as recreational purposes and downstream uses in the Nueces, San Antonio, Guadalupe, and San Marcos river basins.

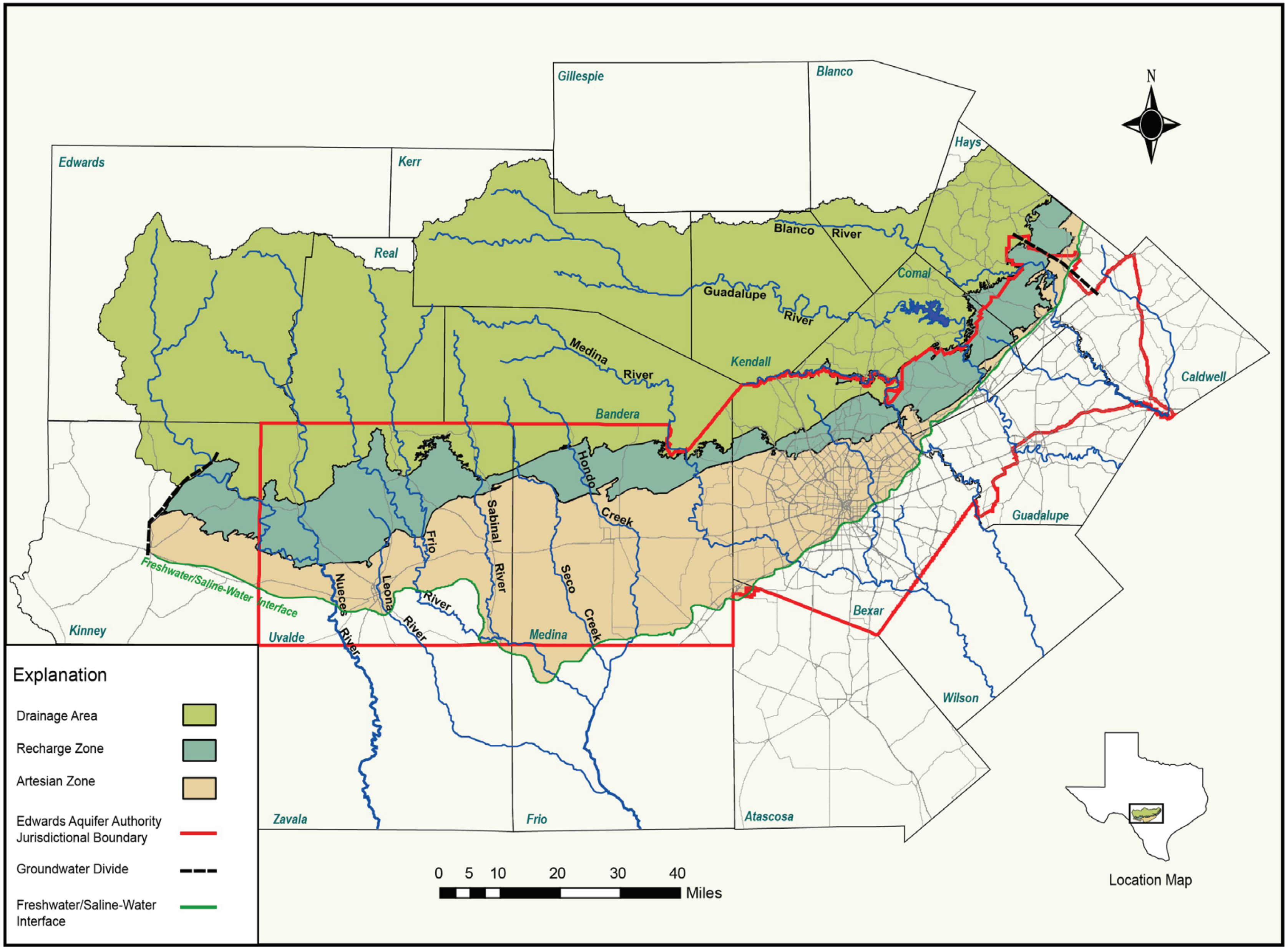
The Southern Segment of the Balcones Fault Zone Edwards Aquifer (Edwards Aquifer) in south central Texas is one of the most permeable and productive aquifers in the United States. The Edwards Aquifer extends from the groundwater divide east of Brackettville in Kinney County, east to San Antonio in Bexar County, then northeast to the groundwater divide near Kyle in Hays County—a distance of approximately 180 miles (Figure 1). The aquifer, the primary source of water for approximately two million people in the region (http://quickfacts.census.gov/qfd/), also provides most of the water for agriculture and industry. In addition, the aquifer discharges through a series of large springs that provide aquatic habitat for a number of threatened and endangered species. Springflow also provides water for downstream interests in the Guadalupe River Basin.

The EAA was created by the Texas Legislature in 1993 to succeed the Edwards Underground Water District (EUWD) as a special regional water management district for the Edwards Aquifer. The EAA jurisdictional area encompasses all or parts of Uvalde, Medina, Atascosa, Bexar, Comal, Guadalupe, Hays, and Caldwell counties (Figure 1). The EAA is governed by a 17-member board of directors, with voting members elected to represent 15 districts across the EAA region and two non-voting members appointed by other entities. The board is constructed to represent agricultural, industrial, domestic, municipal, spring, and downstream user groups. The Legislature also created the South Central Texas Water Advisory Committee (SCTWAC) to interact with the EAA when issues that could impact downstream water rights are being considered.

The Legislature mandated that the EAA take all necessary measures to effectively manage the resource to ensure domestic and municipal water supplies, to provide water supplies for agriculture and industry, to protect terrestrial and aquatic habitat, and to sustain the economic development of the region. To accomplish these goals, the EAA is vested with all of the "powers, rights, and privileges necessary to manage, conserve, preserve, and protect the aquifer, and to increase the recharge of, and prevent the waste or pollution of water in, the aquifer." (From the Edwards Aquifer Authority Act, as amended. The Act may be viewed at www.edwardsaquifer.org.)

This report presents results of the EAA's Edwards Aquifer data collection program for calendar year 2013. The EAA and cooperating agencies collected a wide variety of data regarding the Edwards Aquifer, including aquifer levels, precipitation measurements, recharge estimates, groundwater discharge and use, and water quality samples. In addition, the report contains historical aquifer recharge and discharge data for the period of record (1934–2013). Subsequent sections contain definitions and references.

## Figure 1. Balcones Fault Zone Edwards Aquifer and Other Physiographic Features in the Region



# HYDROGEOLOGY OF THE EDWARDS AQUIFER

The Edwards Aquifer is contained within the Cretaceous-age Edwards Group limestone (Edwards Limestone) and associated units. The Edwards Limestone, which is generally capped by the Del Rio Clay, overlies the upper member of the Glen Rose Limestone (upper unit of the Trinity Aquifer). The Edwards Limestone forms the top of the Edwards Plateau within the drainage area (contributing zone) of the aquifer. However, the Edwards Limestone is missing from the south and east flanks of the plateau as a result of erosion along the Balcones Escarpment. Normal faulting, associated with the Balcones Fault Zone, has downfaulted the geologic units in this area. The Texas Hill Country is formed by retreat of the Edwards Plateau by erosional processes. Generally from northwest to southeast across this region, the Edwards Limestone is exposed at higher elevations along much of the plateau. Erosional processes have removed the Edwards Limestone and exposed the older Glen Rose Limestone throughout much of the Texas Hill Country. To the south and east, the Edwards Limestone is again present and exposed at the surface by downfaulting along the Balcones Fault Zone. This surface exposure is the recharge zone of the Edwards Aquifer. Farther south and east, downfaulting has dropped the Edwards Limestone even farther below the surface, confining the aquifer between the Del Rio Clay above and the Upper Glen Rose Limestone below. This part of the aquifer is identified as the artesian zone of the Edwards Aquifer. Here the Edwards Aquifer produces freshwater from depths as great as 3,400 feet below the surface. The southern boundary of the *artesian zone* (Figure 1) marks the aquifer's transition from freshwater to brackish water (water with a total dissolved solids [TDS] concentration greater than 1,000 mg/L).

Water circulates through the freshwater parts of the Edwards Aquifer as part of the hydrologic cycle from recharge areas to discharge points (springs and wells). Approximately 1,220 square miles of Edwards Limestone is exposed at the ground surface and composes the recharge zone where water enters the aquifer. Streams flow south or east from the drainage area (the Texas Hill Country and Edwards Plateau) and lose all or most of their baseflow as they cross the recharge zone. In addition, part of the rain that falls directly on the recharge zone also enters the aquifer. Groundwater moves through the aquifer and ultimately discharges from a number of locations, such as Leona Springs in Uvalde County, San Pedro and San Antonio springs in Bexar County, Hueco and Comal springs in Comal County, and San Marcos Springs in Hays County. In addition, domestic, livestock, municipal, agricultural, and industrial wells withdraw water from the aquifer. The residence time of water in the aquifer ranges from a few hours or days to many years, depending on depth of circulation, location, and other aquifer parameters.

The Edwards Aquifer is a karst aquifer, characterized by the presence of sinkholes, sinking streams, caves, large springs, and a well-integrated subsurface drainage system. Within the artesian zone, it is one of the most productive groundwater systems in the United States, characterized by extremely high capacity water wells and high spring discharges. The aquifer exhibits extremely high (cavernous) porosity and permeability, characteristic of many karst aquifers. In contrast, aquifers that occur in sand and gravel or in other rock types, such as sandstone, have a much lower permeability. Because the Edwards Aquifer has many areas of high permeability, it transmits large volumes of water, and groundwater levels respond quickly to rainfall (recharge) events. In addition, a highly developed aquifer ecology of more than 40 endemic species has been identified within the aquifer.

Historically, water quality in the Edwards Aquifer Artesian Zone has been protected by its great depth below population centers, and the recharge zone and drainage area were largely undeveloped. However, there are potential threats to the quality of water in the aquifer from various sources, including the transport, storage, and use of hazardous substances and other chemicals on the recharge zone, abandoned or poorly completed water wells, and urban non-point runoff. The high porosity and permeability of the Edwards Aquifer allow inflow of contaminants from the ground surface with little or no filtration.

# GROUNDWATER LEVELS

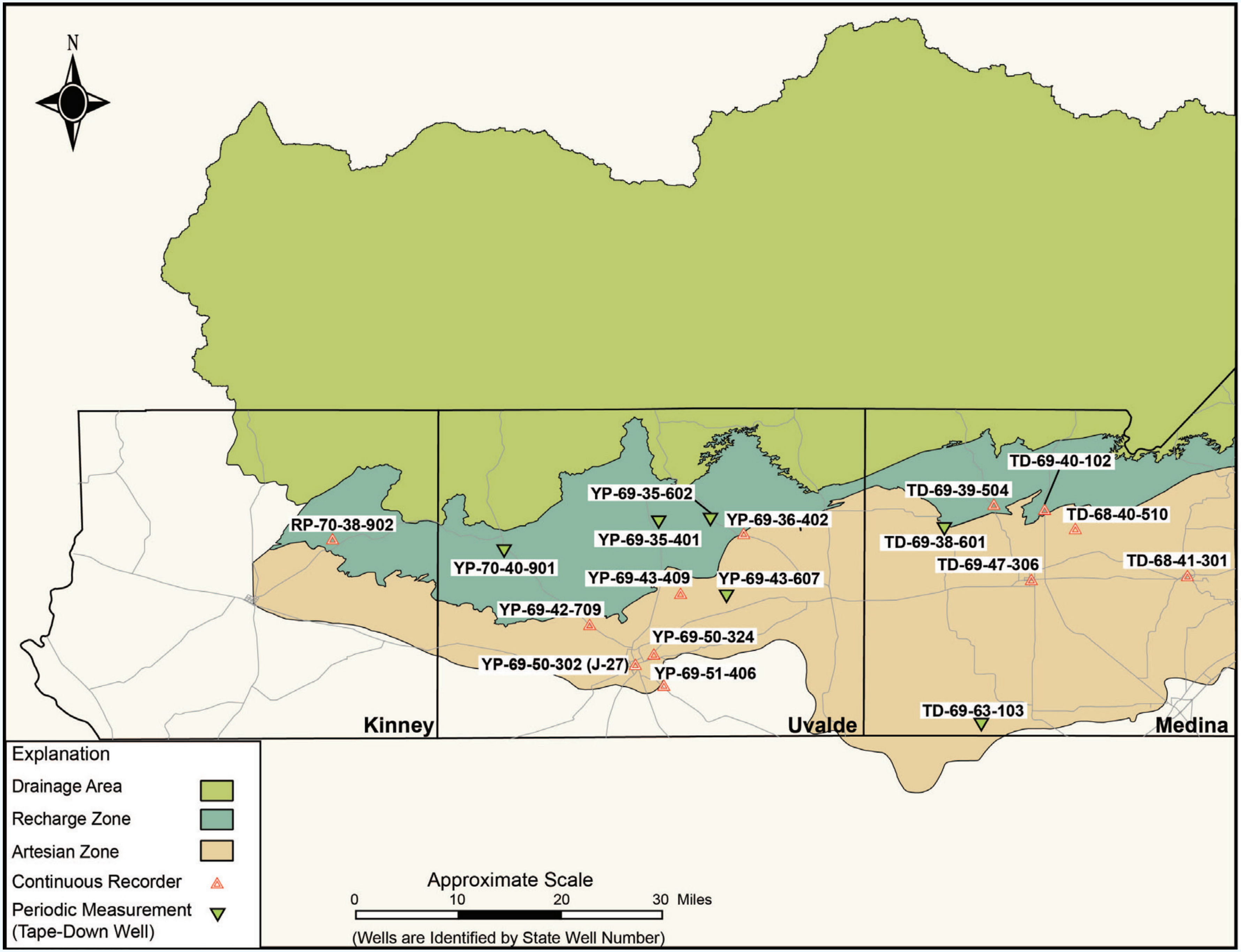
The EAA currently maintains a groundwater level monitoring network from eastern Kinney County to central Hays County. Figures 2a–c indicate the location of wells in the EAA's observation network within the Edwards Aquifer region. The water level observation network includes the recharge (unconfined) and artesian (confined) zones of the Edwards Aquifer and wells within the Trinity and Leona Gravel aquifers. Water levels are monitored through periodic manual measurements (tape down) or electronic data loggers and recorded in feet above mean sea level (msl). Many of the wells have at least partial historical records dating back several decades.

In 2013, the EAA's Water Level Data Collection Program consisted of 48 electronic data-logger-equipped observation wells and 18 tape-down wells. EAA staff also measure over 150 additional wells as part of a regional synoptic water level monitoring program each year. Focused synoptic measurements have been collected episodically in Comal and Hays counties since 2006, with the goal of improving understanding of aquifer behavior in this area. Synoptic measurements are generally obtained with steel-tape or electric-line measuring devices. Water level data collected by the EAA are forwarded to interested Federal, State, and regional agencies.

The EAA and its predecessor, the EUWD, have also collected water level data from the Trinity Aquifer in northern Bexar County since 1991 and the Leona Aquifer in southern Uvalde County since 1966. Water level monitoring of the Edwards Aquifer and associated hydrogeologic units adds to the base of scientific knowledge and helps in the management of this regional water resource. Table 1 lists the annual records of high, low, mean, and median water levels measured in five selected Edwards Aquifer observation wells across the region. For the period of record, water levels are typically highest in the spring and lowest in the summer, before rebounding in the fall and winter. During 2013, water levels across the region were below the historical mean and median values. For calendar year 2013, the Bexar County index well J-17 (AY-68-37-203) water level was below the historical mean value the entire year (Figure 3). The maximum and minimum water levels at J-17 for 2013 were 658.4 and 631.5 feet above msl, respectively. The maximum value occurred in May, whereas the minimum occurred in September. The highest water level on record at J-17 is 703.3 feet above msl in June 1992, and the lowest is 612.5 feet above msl in August 1956. Figure 3b shows the 2013 hydrograph for Uvalde County index well J-27 (YP-69-50-302). Since February 2012, J-27 water levels have been imputed from a nearby Edwards Aquifer well to avoid drawdown interference from adjacent water supply wells. The imputed levels are calculated from a regression equation with a high degree of correlation. However, to determine daily high water levels used for regulatory purposes at J-27 (critical-period restrictions), the adjacent wells are turned off for one hour each day, allowing water levels at J-27 to recover to a static level. This shutdown procedure is continued for a period of ten consecutive days so that ten-day averages at J-27 can be determined to implement critical-period (drought) reductions for Uvalde County. Figure 3b depicts historical average water levels (for the period of record), as well as imputed daily high water levels at J-27 for the year. Water levels in Uvalde were below the historical mean for the entire year, with the maximum imputed water level for the year of 841.4 feet above msl occurring from January 18 through January 25, and the minimum imputed water level of 833.9 feet above msl occurring on May 23. The highest water level on record at J-27, 889.1 feet above msl, occurred in June 1987, and the lowest, 811.0 feet above msl, occurred in April 1957.

Additional water level data are presented in Appendices A and B of this report. Appendix A contains summary tables for selected observation wells, and Appendix B shows well hydrographs and precipitation measurements for wells in Bexar, Medina, and Uvalde counties. Hydrographs for Comal and San Marcos springs are also included in Appendix B.

Figure 2a. Year 2013 Edwards Aquifer Authority Water Level Observation Network—Kinney, Uvalde, and Medina Counties



## Figure 2b. Year 2013 Edwards Aquifer Authority Water Level Observation Network—Bexar County

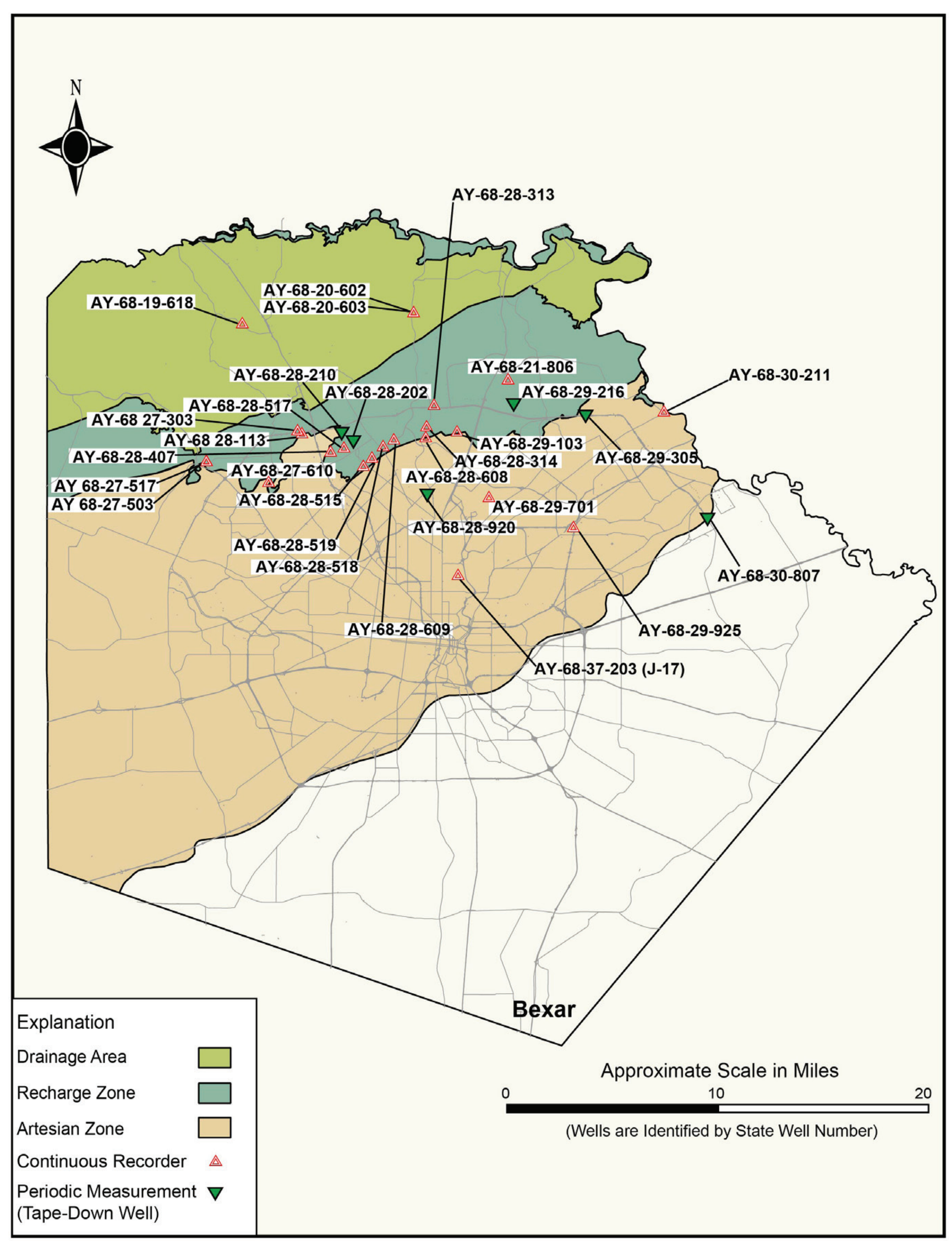
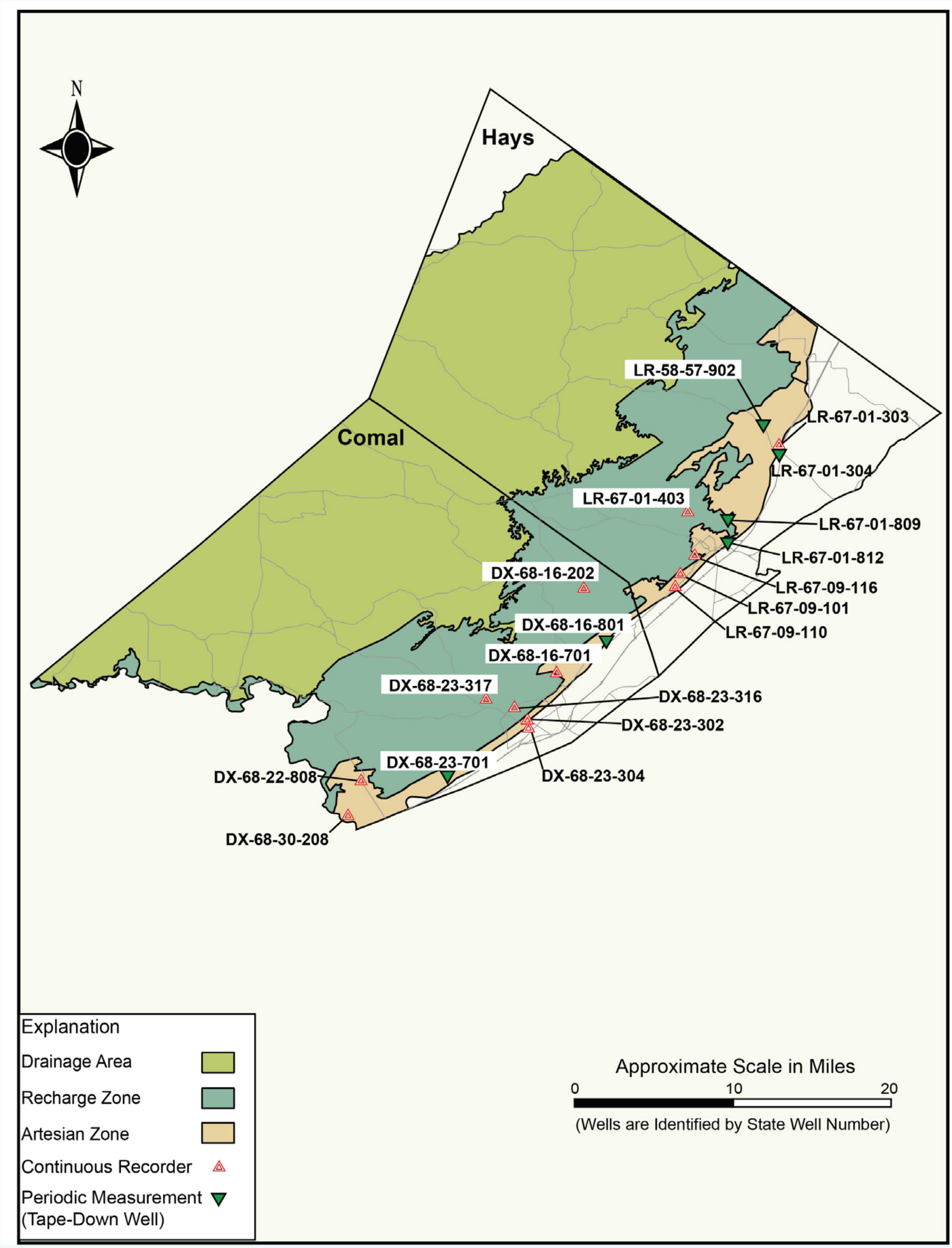


Figure 2c. Year 2013 Edwards Aquifer Authority Water Level Observation Network—Comal and Hays Counties



## Table 1. Highest and Lowest Recorded Water Levels for Selected Observation Wells in the San Antonio Segment of the Edwards Aquifer, 1934–2013 (measured in feet above msl).

| | J-27 Uvalde Uvalde County YP-69-50-302[a] | | Castroville Medina County TD-68-41-301[b] | | J-17 San Antonio Bexar County AY-68-37-203[c] | | New Braunfels Comal County DX-68-23-302[d] | | Kyle Hays County LR-67-01-304[e] | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | High | Low | High | Low | High | Low | High | Low | High | Low |
| 1934 | ---- | ---- | ---- | ---- | 675.2 | 666.8 | ---- | ---- | ---- | ---- |
| 1935 | ---- | ---- | ---- | ---- | 681.3 | 666.8 | ---- | ---- | ---- | ---- |
| 1936 | 876.6 | 876.5 | ---- | ---- | 683.0 | 676.6 | ---- | ---- | ---- | ---- |
| 1937 | 878.1 | 877.1 | ---- | ---- | 682.1 | 674.9 | ---- | ---- | 583.4 | 581.6 |
| 1938 | 875.8 | 874.0 | ---- | ---- | 681.4 | 673.6 | ---- | ---- | 590.6 | 581.5 |
| 1939 | 873.4 | 869.6 | ---- | ---- | 674.1 | 665.7 | ---- | ---- | 580.6 | 569.6 |
| 1940 | 872.3 | 868.5 | ---- | ---- | 671.4 | 661.0 | ---- | ---- | 572.2 | 568.7 |
| 1941 | 875.7 | 867.7 | ---- | ---- | 682.5 | 668.3 | ---- | ---- | 587.7 | 578.6 |
| 1942 | 875.8 | 871.9 | ---- | ---- | 685.4 | 669.7 | ---- | ---- | 580.8 | 573.7 |
| 1943 | 874.5 | 868.0 | ---- | ---- | 679.6 | 668.5 | ---- | ---- | 578.2 | 574.6 |
| 1944 | 869.3 | 866.8 | ---- | ---- | 677.6 | 667.1 | ---- | ---- | 580.5 | 579.3 |
| 1945 | 870.1 | 865.2 | ---- | ---- | 681.9 | 668.8 | ---- | ---- | ---- | ---- |
| 1946 | 867.1 | 862.9 | ---- | ---- | 681.2 | 663.6 | ---- | ---- | ---- | ---- |
| 1947 | 870.7 | 867.1 | ---- | ---- | 680.7 | 665.8 | ---- | ---- | 577.3 | 577.0 |
| 1948 | 868.4 | 860.5 | ---- | ---- | 667.7 | 653.7 | 624.4 | 624.3 | 560.5 | 559.4 |
| 1949 | 871.2 | 859.1 | ---- | ---- | 671.6 | 655.6 | 626.7 | 624.1 | 562.3 | 561.8 |
| 1950 | 871.2 | 861.8 | 687.0 | 674.9 | 665.4 | 653.8 | 625.2 | 624.0 | 575.8 | 575.2 |
| 1951 | 861.8 | 846.8 | 675.2 | 659.9 | 656.0 | 640.6 | 624.2 | 622.5 | 575.3 | 569.4 |
| 1952 | 846.8 | 834.9 | 663.8 | 649.9 | 650.5 | 633.4 | 623.0 | 621.5 | 573.0 | 569.1 |
| 1953 | 835.2 | 817.8 | 665.1 | 647.7 | 651.5 | 630.5 | 623.6 | 621.1 | 584.5 | 573.2 |
| 1954 | 836.7 | 823.1 | 660.3 | 642.4 | 646.3 | 628.9 | 623.1 | 620.5 | 581.8 | 562.8 |
| 1955 | 834.3 | 824.1 | 649.1 | 635.6 | 638.5 | 624.2 | 621.9 | 619.8 | 575.7 | 558.4 |
| 1956 | 834.2 | 814.2 | 641.6 | 622.3 | 632.2 | 612.5 | 621.0 | 613.3 | 569.8 | 542.2 |
| 1957 | 840.9 | 811.0 | 666.1 | 633.0 | 653.8 | 624.4 | 624.7 | 620.1 | 584.9 | 568.3 |
| 1958 | 866.1 | 840.8 | 704.4 | 665.7 | 679.6 | 653.3 | 626.6 | 624.6 | 593.6 | 580.8 |
| 1959 | 876.1 | 866.2 | 703.8 | 689.0 | 677.7 | 661.5 | 627.1 | 625.1 | 591.4 | 580.5 |
| 1960 | 876.9 | 873.1 | 706.3 | 686.0 | 679.4 | 657.9 | 627.1 | 624.9 | 589.4 | 584.3 |
| 1961 | 878.5 | 875.6 | 710.3 | 693.4 | 681.2 | 663.9 | 627.3 | 625.7 | 591.6 | 573.2 |
| 1962 | 878.3 | 867.7 | 703.6 | 676.3 | 675.5 | 646.9 | 626.3 | 623.2 | 584.1 | 565.0 |
| 1963 | 869.7 | 860.9 | 689.1 | 659.2 | 665.8 | 635.0 | 625.0 | 621.7 | 581.6 | 560.0 |
| 1964 | 860.9 | 849.0 | 676.3 | 654.8 | 657.1 | 632.8 | 624.1 | 621.6 | 578.2 | 562.8 |
| 1965 | 865.8 | 860.3 | 689.6 | 666.8 | 675.0 | 645.6 | 626.6 | 623.5 | 590.1 | 573.4 |
| 1966 | 867.2 | 860.2 | 686.1 | 665.0 | 668.8 | 642.7 | 625.9 | 623.1 | 589.0 | 566.6 |
| 1967 | 867.4 | 856.4 | 679.4 | 645.2 | 659.7 | 624.9 | 624.6 | 620.0 | 582.8 | 556.6 |
| 1968 | 873.3 | 864.8 | 702.0 | 679.2 | 678.3 | 655.9 | 627.2 | 624.6 | 593.8 | 574.4 |
| 1969 | 875.0 | 866.5 | 694.8 | 670.5 | 676.1 | 642.8 | 626.3 | 623.4 | 588.7 | 567.7 |
| 1970 | 876.1 | 871.3 | 700.7 | 678.8 | 677.1 | 650.4 | 627.2 | 624.3 | 593.2 | 575.0 |
| 1971 | 877.7 | 864.0 | 701.3 | 646.4 | 674.6 | 627.9 | 626.2 | 621.0 | 577.1 | 551.3 |
| 1972 | 877.8 | 874.6 | 704.6 | 676.7 | 679.0 | 651.2 | 626.7 | 624.1 | 579.7 | 576.3 |
| 1973 | 881.6 | 874.5 | 731.2 | 690.1 | 696.5 | 665.9 | 629.8 | 626.1 | 589.9 | 572.3 |
| 1974 | 881.4 | 876.0 | 723.8 | 696.0 | 689.2 | 660.9 | 629.1 | 625.8 | 593.6 | 558.5 |
| 1975 | 882.1 | 879.4 | 721.0 | 708.2 | 686.9 | 672.0 | 629.3 | 626.5 | 589.8 | 571.4 |
| 1976 | 884.9 | 876.0 | 732.4 | 694.9 | 693.1 | 663.8 | 629.4 | 625.8 | 584.6 | 571.2 |
| 1977 | 886.2 | 881.3 | 737.8 | 715.3 | 696.0 | 675.6 | 630.2 | 627.6 | 587.4 | 562.1 |
| 1978 | 882.6 | 875.6 | 722.4 | 681.7 | 684.1 | 650.1 | 628.1 | 624.5 | 572.0 | 540.4 |
| 1979 | 882.0 | 876.1 | 728.2 | 710.3 | 690.5 | 676.4 | 629.0 | 627.3 | 584.9 | 572.0 |
| 1980 | 879.1 | 868.0 | 716.1 | 666.8 | 680.3 | 640.8 | 627.5 | 623.0 | 572.0 | 551.8 |
| 1981 | 881.8 | 867.9 | 723.2 | 698.8 | 686.0 | 668.6 | 628.0 | 625.5 | 586.2 | 565.5 |
| 1982 | 881.8 | 876.4 | 717.1 | 682.8 | 680.5 | 645.3 | 627.3 | 623.6 | 584.7 | 544.7 |
| 1983 | 877.1 | 871.3 | 698.2 | 667.7 | 670.0 | 642.1 | 625.6 | 623.0 | 588.7 | 560.4 |
| 1984 | 873.3 | 856.9 | 684.5 | 642.0 | 657.0 | 623.3 | 624.4 | 619.6 | 582.5 | 544.3 |
| 1985 | 876.9 | 862.2 | 699.0 | 670.7 | 674.5 | 644.1 | 626.8 | 623.3 | 591.4 | 561.8 |
| 1986 | 877.8 | 872.2 | 704.6 | 674.2 | 685.6 | 649.8 | 627.7 | 624.1 | 595.0 | 576.3 |
| 1987 | 889.1 | 877.9 | 743.5 | 711.1 | 699.2 | 676.9 | 630.4 | 627.2 | 595.9 | 583.5 |
| 1988 | 887.0 | 878.0 | 725.3 | 679.9 | 684.9 | 647.7 | 627.9 | 623.9 | 593.2 | 585.9 |
| 1989 | 879.0 | 866.6 | 695.3 | 650.5 | 663.9 | 626.4 | 624.9 | 620.5 | 571.7 | 571.5 |

## (Table 1. continued)

| | J-27 Uvalde<br>Uvalde County<br>YP-69-50-302[a] | | Castroville<br>Medina County<br>TD-68-41-301[b] | | J-17<br>San Antonio<br>Bexar County<br>AY-68-37-203[c] | | New Braunfels<br>Comal County<br>DX-68-23-302[d] | | Kyle<br>Hays County<br>LR-67-01-304[e] | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **High** | **Low** | **High** | **Low** | **High** | **Low** | **High** | **Low** | **High** | **Low** |
| 1990 | 872.9 | 861.6 | 679.5 | 640.8 | 658.1 | 622.7 | 624.3 | 620.3 | 577.6 | 561.2 |
| 1991 | 873.8 | 865.4 | 703.8 | 666.1 | 680.3 | 640.5 | 627.0 | 623.3 | 593.8 | 575.1 |
| 1992 | 885.2 | 872.9 | 743.6 | 704.3 | 703.3 | 680.7 | 630.9 | 627.0 | 595.4 | 586.2 |
| 1993 | 884.9 | 877.3 | 730.2 | 706.6 | 692.8 | 672.0 | 629.4 | 626.9 | 593.7 | 575.9 |
| 1994 | ---- | ---- | 718.6 | 684.1 | 679.2 | 652.1 | 627.2 | 624.7 | 575.0 | 545.3 |
| 1995 | 877.2 | 871.1 | 703.0 | 681.8 | 676.5 | 651.1 | 626.8 | 624.5 | 575.4 | 552.4 |
| 1996 | 874.2 | 859.0 | 693.0 | 650.2 | 664.9 | 627.5 | 625.3 | 621.2 | 573.2 | 551.3 |
| 1997 | 882.3 | 868.2 | 700.5 | 672.7 | 677.9 | 648.7 | 626.4 | 623.6 | 575.8 | 559.0 |
| 1998 | 880.6 | 868.7 | 717.1 | 669.1 | 688.9 | 640.0 | 629.6 | 622.9 | 575.6 | 552.4 |
| 1999 | 880.7 | 876.8 | 716.4 | 682.9 | 686.4 | 656.9 | 628.7 | 624.9 | 588.6 | 537.9 |
| 2000 | 878.3 | 868.0 | 700.4 | 662.5 | 676.7 | 635.5 | 626.8 | 622.2 | 549.2 | 544.6 |
| 2001 | 877.2 | 872.7 | 713.4 | 685.9 | 682.8 | 652.8 | 628.3 | 624.5 | 563.9 | 544.6 |
| 2002 | 883.2 | 876.3 | 732.7 | 685.8 | 697.9 | 650.0 | 630.2 | 624.6 | 589.3 | 554.4 |
| 2003 | 883.3 | 877.9 | 729.5 | 696.7 | 694.8 | 671.6 | 629.9 | 627.5 | 604.2 | 537.6 |
| 2004 | 884.9 | 879.2 | 740.9 | 706.3 | 702.1 | 677.6 | 632.6 | 627.4 | 609.5 | 542.6 |
| 2005 | 885.6 | 880.2 | 740.4 | 687.8 | 699.8 | 675.4 | 631.3 | 627.7 | 590.2 | 561.8 |
| 2006 | 879.3 | 868.6 | 689.7 | 675.1 | 678.1 | 647.6 | 627.7 | 623.8 | 603.4 | 513.7 |
| 2007 | 882.7 | 867.8 | 740.7 | 686.8 | 700.7 | 661.9 | 631.2 | 625.9 | 592.4 | 547.3 |
| 2008 | 882.6 | 873.4 | 727.3 | 682.2 | 689.2 | 657.3 | 629.3 | 625.5 | 587.6 | 536.9 |
| 2009 | 873.3 | 860.1 | 697.7 | 661.6 | 671.2 | 640.3 | 626.6 | 613.5 | 570.3 | 553.8 |
| 2010 | 867.0 | 862.2 | 708.3 | 689.5 | 682.7 | 667.1 | 630.4 | 626.3 | * | * |
| 2011 | 864.3 | 847.4 | 701.0 | 657.1 | 674.5 | 639.9 | 627.3 | 622.6 | * | * |
| 2012 | 848.1** | 840.1** | 694.9 | 664.3 | 666.8 | 637.6 | 628.4 | 622.5 | 595.2[f] | 554.4[f] |
| 2013 | 841.4** | 833.9** | 681.2 | 650.6 | 658.4 | 631.5 | 624.1 | 621.2 | 582.5[f] | 550.4[f] |
| | High | Low | High | Low | High | Low | High | Low | High | Low |
| **Mean** | 872.7 | 863.8 | 704.2 | 673.6 | 677.0 | 652.2 | 623.5 | 623.6 | * | * |
| **Median** | 876.9 | 703.7 | 675.0 | 679.1 | 652.5 | 627.1 | 624.0 | 624.1 | * | * |
| **Record** | High | Low | High | Low | High | Low | High | Low | High | Low |
| **Level** | 889.1 | 811.0 | 743.6 | 622.3 | 703.3 | 612.5 | 632.6 | 613.3 | 609.5 | 513.7 |
| **Month Year** | June 1987 | April 1957 | June 1992 | Aug. 1956 | June 1992 | Aug. 1956 | Nov. 2004 | Aug. 1956 | Nov. 2004 | Sept. 2006 |

Data source: EAA unpublished data (2014).

[a] = Continuous monitoring equipment established on October 24, 1940.

[b] = Continuous monitoring equipment established on May 25, 1950.

[c] = Continuous monitoring equipment established on January 1, 1963.

[d] = Continuous monitoring equipment established on November 4, 1948.

[e] = Values based on monthly tape-down measurements (no continuous monitoring equipment installed in this well).

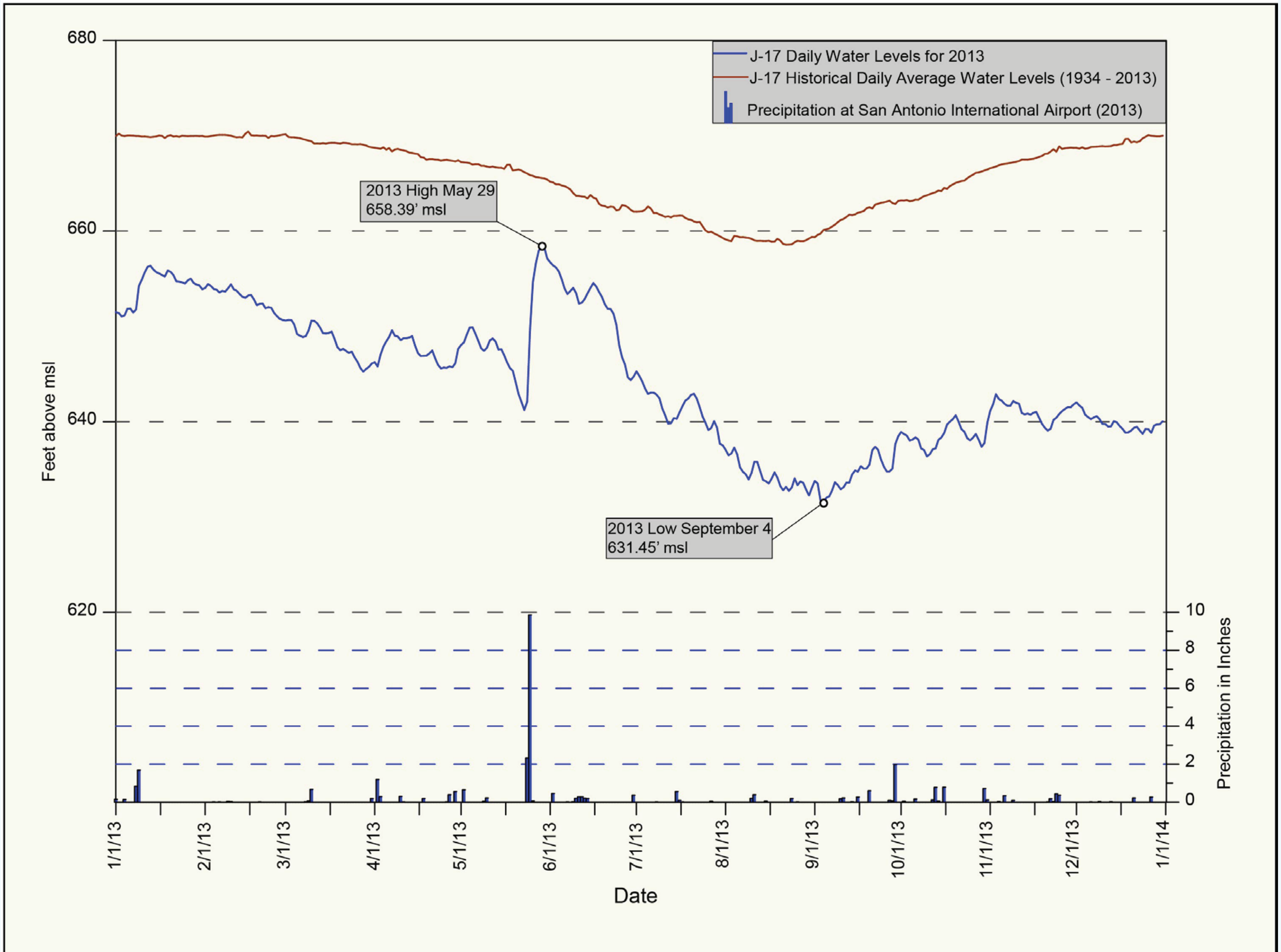
[f] = LR-67-01-304 was out of service, replaced by nearby LR-67-01-303.

* = Well damaged; measurements for 2010, 2011, 2012, and 2013 impacted by damage and not reported for year (mean/median shown through 2009).

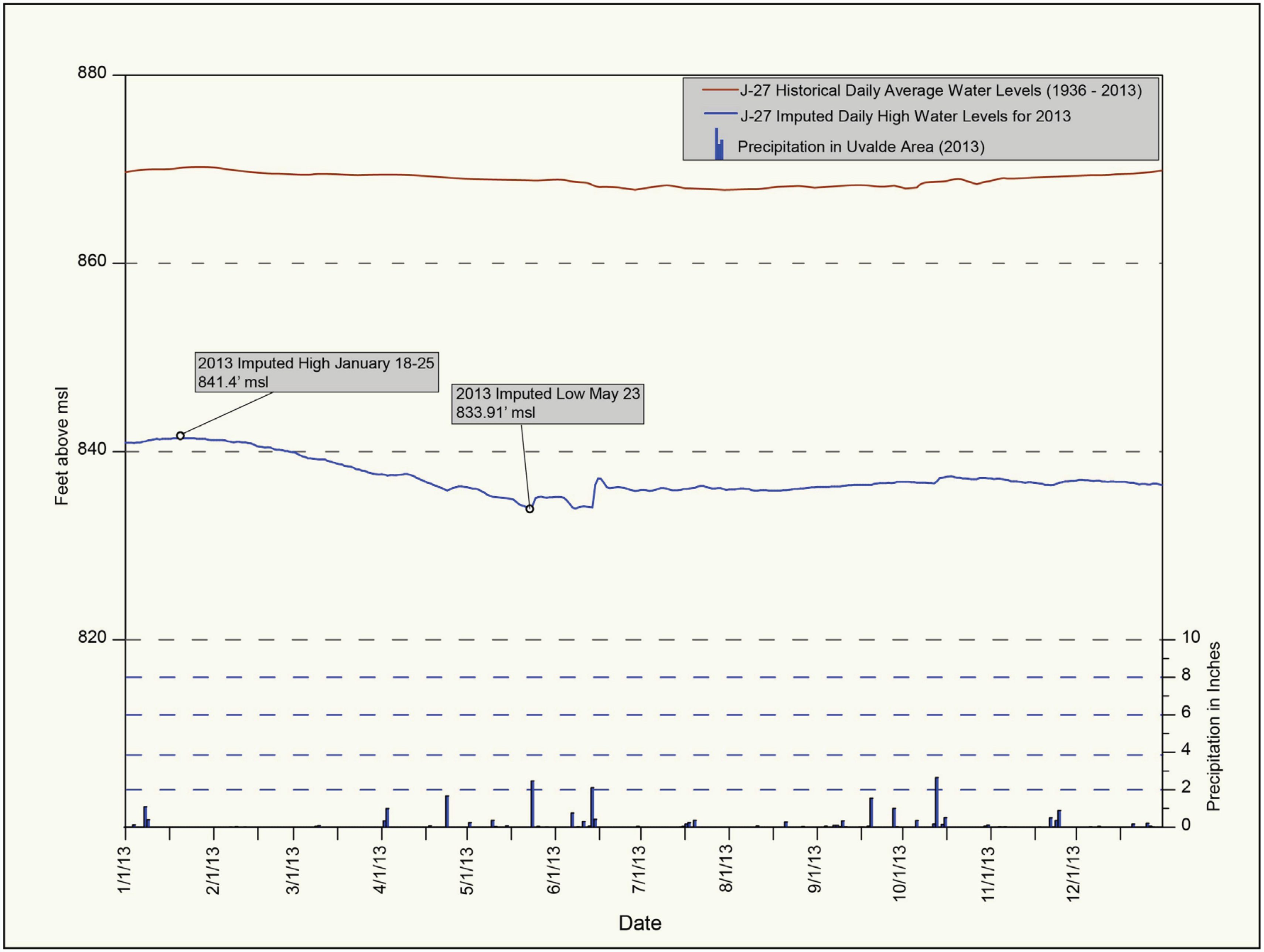
** = Values based on imputed value of Uvalde County Index well (J-27).

Note: Median and mean values based on data in Table 1 for period of record.

## Figure 3a. Comparison of Historical Daily Mean Water Level for the Period of Record 1934–2013 and the Daily High Water Level at the Bexar County Index Well, J-17 (AY-68-37-203)



## Figure 3b. Comparison of Historical Daily Mean Water Level for the Period of Record 1936–2013 and the Daily High Water Level at the Uvalde County Index Well, J-27 (YP-69-50-302)



# PRECIPITATION

## Precipitation in the Edwards Aquifer Region

Precipitation varies significantly across the Edwards Aquifer region. Mean annual precipitation ranges from approximately 23 inches in the western part of the region to just under 35 inches in the eastern part of the region. The mean annual precipitation for San Antonio from 1934 through 2013 is approximately 30.37 inches, although annual precipitation has ranged from 13.70 to 52.28 inches since 1934 (U.S. Department of Commerce, 2014).

Precipitation data are used to calculate recharge to the Edwards Aquifer, monitor any precipitation trends that may affect recharge to the aquifer, and help evaluate the effectiveness of the EAA's Precipitation Enhancement Program (see Precipitation Enhancement Program, p. 21). Precipitation data are gathered from EAA's network of rain-gauge stations and National Oceanic and Atmospheric Administration (NOAA) weather stations located throughout the region. Figure 4 shows the locations of precipitation gauging stations used by the EAA to monitor precipitation in 2013.

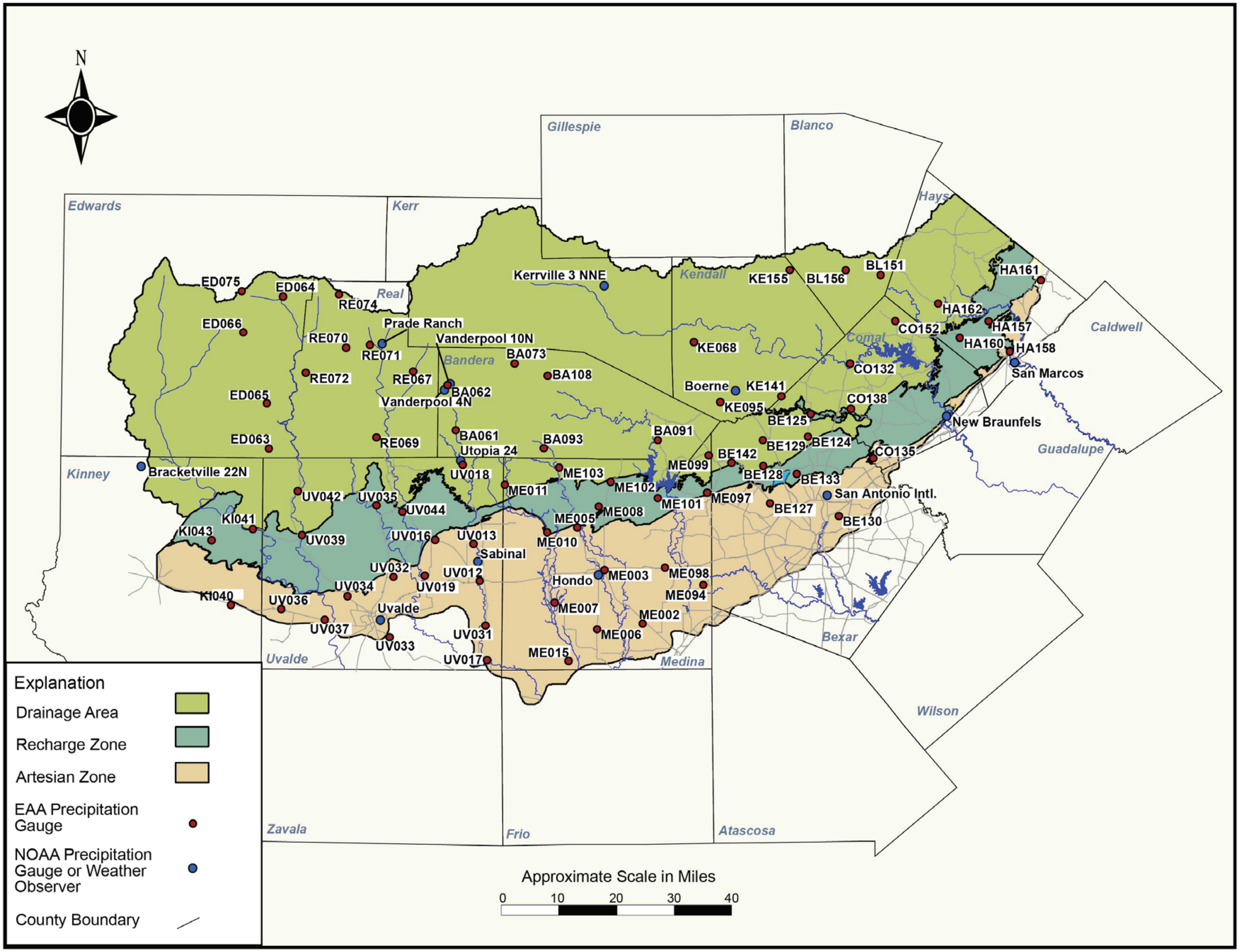
Annual precipitation data are summarized by city in Table 2. Monthly precipitation data are summarized by NOAA station in Tables 3a and 3b, and additional monthly data for EAA's real-time network rain-gauge station totals are summarized in Table 4. In 2013, EAA's real-time network consisted of 75 operational rain-gauge sites (Figure 4).

Median annual precipitation ranges from 19.88 inches in the west to 33.69 inches in the east. Hondo recorded the largest deviation below the median, with only 19.48 inches of rainfall recorded for 2013, compared with a median of 28.56. Hondo was below the median from 2008 through 2012 as well. San Antonio rainfall was just over 1.5 inch above the median value of 30.43 inches for the year.

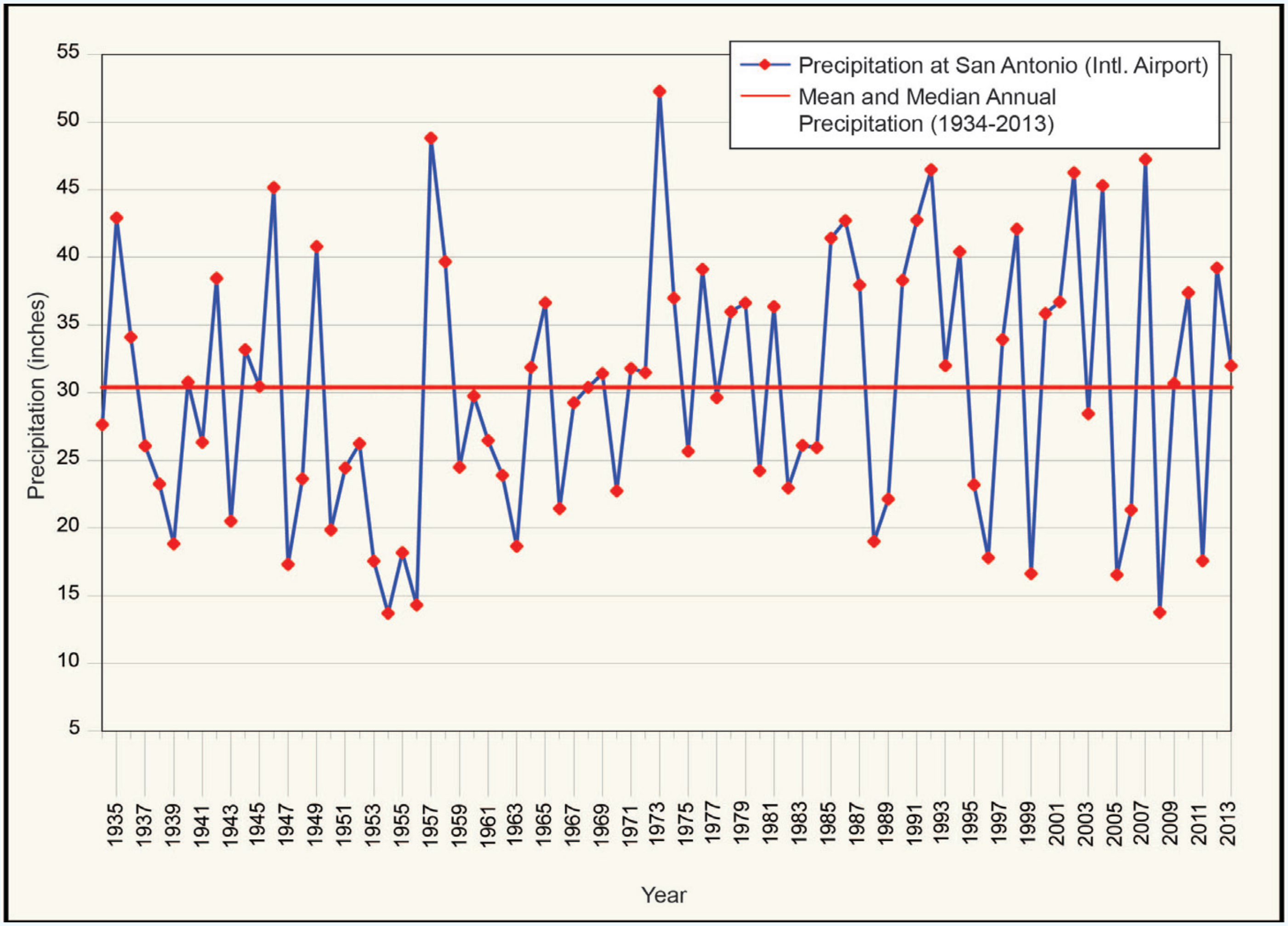
In 2013, total precipitation measured at the San Antonio International Airport was 31.99 inches. Mean precipitation in San Antonio for the period between 1934 and 2013 was 30.37 inches. Annual and mean precipitation data for San Antonio from 1934 through 2013 are shown graphically in Figure 5. Regional rainfall by city (Table 2) for 2013 was below the mean in the entire Edwards Aquifer region, with the exception of San Antonio. For example, San Marcos recorded only 31.30 inches of rainfall for the year, which is 3.61 inches below the mean rainfall for the period of record, 1934–2013.

Regional rainfalls are summarized graphically in Figure 6. The data in Figure 6 represent annual rainfall totals for the region developed by calibrating NEXRAD radar imagery with ground-based measurements to develop an annual rainfall summary for the region. Each grid square in Figure 6 represents a 16-square-kilometer (approximately 6.25 square miles) area. Shades of blue indicate higher relative rainfall amounts, whereas orange and red shades indicate less relative rainfall. Each shade increment represents approximately 2.5 inches of increased rainfall compared with that of the adjacent color. Given these data, regional rainfall volumes were highest in Hays and Bexar counties. Hays County, north of San Marcos, received large amounts of precipitation in May and October 2013. Comal, Kinney, Uvalde, and Real counties generally received the lowest rainfall volumes of the region.

## Figure 4. Locations of Precipitation Gauging Stations Used by the EAA and Other Agencies to Monitor Precipitation in 2013



## Figure 5. Annual Precipitation and Mean Precipitation for San Antonio, 1934–2013



## Table 2. Annual Precipitation from Selected Rain Gauges in the Edwards Aquifer Region, 1934–2013 (in inches).

| Year | Brackettville | Uvalde | Sabinal | Hondo | San Antonio | Boerne | New Braunfels | San Marcos |
|---|---|---|---|---|---|---|---|---|
| 1934 | --- | 16.70 | 18.07 | 23.97 | 27.65 | 26.78 | 30.80 | 35.67 |
| 1935 | --- | 41.17 | 48.21 | 58.73 | 42.93 | 52.93 | 41.67 | 41.09 |
| 1936 | 22.34 | 24.53 | 26.53 | 35.27 | 34.11 | 47.59 | 30.41 | 33.48 |
| 1937 | 16.85 | 17.88 | 9.57[a] | 22.93 | 26.07 | 32.81 | 29.19 | 26.03a |
| 1938 | 19.97 | 13.12 | 15.39 | 27.56 | 23.26 | 24.14 | 28.32 | 28.17 |
| 1939 | 18.38 | 25.30 | 13.98[b] | 23.14 | 18.83 | 26.20 | 13.35 | 18.59 |
| 1940 | 22.43 | 27.66 | 27.51 | 28.13 | 30.79 | 32.29 | 38.11 | 43.57 |
| 1941 | 21.52 | 31.79 | 33.74[a] | 44.07 | 26.34 | 41.60 | 42.99 | 48.41 |
| 1942 | 21.01 | 19.01 | 11.37[a] | 34.83 | 38.46 | 31.12 | 42.08 | 44.65 |
| 1943 | 23.39[b] | 20.63 | 17.21 | 31.43 | 20.51 | 26.33 | 29.93 | 25.45 |
| 1944 | 24.76 | 32.76 | 27.62[a] | 32.46 | 33.19 | 42.98 | 43.14 | 47.42 |
| 1945 | 15.69 | 22.37 | 26.60 | 29.57 | 30.46 | 33.50 | 39.38 | 31.74[b] |
| 1946 | 19.10 | 26.41 | 14.16[a] | 29.65 | 45.17 | 45.62 | 61.60 | 52.24 |
| 1947 | 22.92[b] | 22.67 | --- | 18.98 | 17.32 | 21.89 | 27.52 | 27.53 |
| 1948 | 20.02[a] | 18.31 | --- | 28.82 | 23.64 | 23.77 | 19.88[b] | 21.27[a] |
| 1949 | 31.32 | 34.41 | --- | 39.90 | 40.81 | 41.15 | 43.21 | 36.22 |
| 1950 | 17.70 | 18.27 | 15.28[a] | 24.91 | 19.86 | 24.94 | 21.13 | 21.10 |
| 1951 | 14.71 | 16.07 | 15.63 | 24.05[a] | 24.44 | 18.76 | 24.84 | 30.88 |
| 1952 | 12.26 | 18.24 | 23.16 | 25.56 | 26.24 | 37.54 | 33.87 | 39.91 |
| 1953 | 10.12 | 18.34 | 21.44 | 20.61 | 17.56 | 21.42 | 30.06 | 33.39 |
| 1954 | 19.38 | 15.60 | 14.72 | 11.92 | 13.70 | 10.29 | 10.12 | 13.42 |
| 1955 | 26.55 | 18.36 | 20.87 | 21.21 | 18.18 | 19.27 | 23.12 | 26.44 |
| 1956 | 7.58 | 9.29 | 11.29 | 15.54 | 14.31 | 12.05 | 18.41 | 18.37 |
| 1957 | 34.21 | 39.30 | 40.03 | 35.09 | 48.83 | 52.55 | 51.88 | 46.51 |
| 1958 | 45.37 | 39.03 | 41.18 | 41.60 | 39.69 | 40.94 | 36.40 | 39.08 |
| 1959 | 27.51 | 31.51 | 27.02 | 30.68 | 24.50 | 35.64 | 40.45 | 43.47 |
| 1960 | 19.12 | 23.98 | 26.24 | 32.37 | 29.76 | 32.55 | 34.28 | 45.48 |
| 1961 | 17.91 | 26.26 | 27.24 | 27.36 | 26.47 | 25.45 | 15.70[a] | 30.02 |
| 1962 | 10.87 | 14.12 | 13.58 | 17.85 | 23.90 | 25.26 | 27.40 | 28.47 |
| 1963 | 15.07 | 16.70 | 18.99 | 18.90 | 18.65 | 20.66 | 23.41 | 19.90 |
| 1964 | 20.75 | 22.30 | 23.78 | 28.29 | 31.88 | 27.36 | 30.65 | 30.27 |
| 1965 | 21.48 | 26.21 | 29.41 | 30.80 | 36.65 | 42.41 | 45.16 | 45.00 |
| 1966 | 21.63 | 20.87 | 21.54 | 29.46 | 21.44 | 29.05 | 25.98 | 27.12 |
| 1967 | 21.95 | 20.10 | 23.89 | 30.33 | 29.26 | 26.75 | 31.74 | 26.41 |
| 1968 | 17.26 | 25.20 | 29.88[b] | 31.91 | 30.40 | 35.14 | 35.97 | 37.13 |
| 1969 | 28.53 | 33.38 | 33.05 | 32.30 | 31.42 | 38.07 | 33.01 | 36.59 |
| 1970 | 16.50 | 13.59 | 22.13 | 30.96 | 22.74 | 27.79 | 35.23 | 32.30 |
| 1971 | 29.46 | 31.01 | 31.00 | 32.96 | 31.80 | 45.24 | 29.43 | 31.10 |
| 1972 | 21.21 | 15.49 | 21.10 | 25.43 | 31.49 | 35.09 | 42.02 | 31.90 |
| 1973 | 30.61 | 30.85 | 35.14[b] | 47.82 | 52.28 | 50.93 | 51.66 | 47.91 |
| 1974 | 18.25 | 30.94 | 20.93[b] | 36.41[b] | 37.00 | 41.80 | 42.85 | 37.28[a] |
| 1975 | 26.62 | 24.92 | 23.65 | 25.84[a] | 25.67 | 33.49 | 35.82 | 48.64 |
| 1976 | 34.40 | 46.04 | 40.82 | 45.21 | 39.13 | 45.24 | 49.06 | 47.46 |
| 1977 | 15.06 | 19.90 | 17.06 | 19.40 | 29.64 | 32.43 | 24.83 | 29.69 |
| 1978 | 19.04 | 18.48 | 21.28 | 24.64 | 35.99 | 35.17 | 36.35[b] | 33.08 |
| 1979 | 16.34 | 32.35 | 31.44 | 28.83 | 36.64 | 39.97 | 36.72 | 38.74 |
| 1980 | 18.33 | 23.05 | 22.67 | 21.27 | 24.23 | 39.02 | 33.69 | 29.56 |
| 1981 | 28.73 | 26.24 | 30.19 | 27.40 | 36.37 | 41.05 | 43.23 | 49.62 |
| 1982 | 19.10 | 23.35 | 18.44 | 21.99 | 22.96 | 27.64 | 21.04 | 22.47[b] |
| 1983 | 19.35 | 24.45[a] | 23.33 | 20.92[b] | 26.11 | 34.60 | 34.13 | 36.95 |
| 1984 | 16.24 | 15.33[b] | 20.67 | 21.19[a] | 25.95 | 26.97 | 20.90 | 8.26[b] |
| 1985 | 18.93 | 5.76[a] | 23.67 | 21.94 | 41.43 | 37.77 | 37.26 | 33.54 |
| 1986 | 27.44 | 29.86[b] | 29.62[b] | 36.01[b] | 42.73 | 43.52 | 47.14 | 42.20 |
| 1987 | 39.45 | 36.39 | 38.36 | 40.09 | 37.96 | 39.86 | 37.33[a] | 37.94 |
| 1988 | 12.08 | 15.20 | 13.52 | 9.81[b] | 19.01 | 19.49 | 16.27[b] | 21.50 |
| 1989 | 16.98 | 18.65 | 17.26 | 16.10 | 22.14 | 25.14 | 20.99 | 25.46 |
| 1990 | 38.24[b] | 24.73 | 30.06 | 27.01 | 38.31 | 42.51 | 24.58[a] | 35.14[b] |
| 1991 | 23.11 | 21.77 | 31.12 | 34.55 | 42.76 | 48.22 | 56.55 | 51.07 |
| 1992 | 22.22 | 27.85[a] | 37.73 | 45.34 | 46.49 | 64.17 | 38.84[b] | 40.33[b] |
| 1993 | 15.18 | 9.32[c] | 13.20 | 16.60 | 32.00 | 24.02 | 19.54[b] | 24.01[b] |
| 1994 | 22.85[a] | 39.61 | 29.32 | 22.38[b] | 40.42 | 40.98 | 35.76[a] | 40.85 |
| 1995 | 25.87 | 19.47 | 27.55 | 24.55 | 23.20 | 30.29 | 23.29 | 32.57 |
| 1996 | 20.32[b] | 16.20 | 14.20 | 15.50 | 17.80 | 24.57 | 19.00 | 28.20 |
| 1997 | --- | 27.77 | 35.74 | 37.54 | 33.94 | --- | 41.65 | 43.56 |
| 1998 | 24.15 | 27.40[b] | 20.66[b] | 30.44[a] | 42.10 | 45.74 | 52.98 | 58.51 |
| 1999 | 19.88 | 19.08 | 2.55[b] | 16.94 | 16.63 | 18.67 | 21.07 | 19.38 |
| 2000 | 18.11[b] | 23.84 | 22.87 | 32.49 | 35.86 | 46.30[a] | 36.34[b] | 40.56 |
| 2001 | 18.40 | 26.02 | 25.87 | 30.59 | 36.72 | 53.91 | 37.91 | 42.41 |
| 2002 | --- | 36.79 | 35.75 | 44.70 | 46.27 | 63.20 | 43.60 | 46.16 |
| 2003 | 25.19[c] | 23.39 | 24.86 | 34.70 | 28.45 | 28.55 | 23.42 | 25.74 |
| 2004 | 40.23 | 27.76 | 37.99 | 44.76 | 45.32 | 60.50 | 50.55 | 52.68 |
| 2005 | 25.13 | 16.48 | 20.24 | 28.90 | 16.54 | 25.31 | 21.01 | 22.42 |
| 2006 | 14.62 | 7.85 | 11.06 | 12.15 | 21.34 | 24.24 | 28.51 | 26.36 |
| 2007 | 39.93 | 28.89 | 37.55 | 57.58 | 47.25 | 59.00 | 45.40 | 41.59 |
| 2008 | 12.59 | 11.23 | 14.66 | 16.18 | 13.76 | 14.74 | 16.70 | 15.79 |
| 2009 | 14.26 | 16.19 | 20.86 | 25.00 | 30.69 | 32.65 | 28.10 | 33.10 |
| 2010 | 23.78 | 18.86 | 27.13 | 27.32 | 37.39 | 42.06 | 37.03 | 27.58[b] |
| 2011 | 12.98 | 9.91 | 13.81 | 15.27 | 17.58 | 17.76 | 19.25 | 19.39 |
| 2012 | 20.35 | 13.97 | 18.70 | 25.96 | 39.30 | 29.78 | 35.49 | 34.26 |
| 2013 | 21.18[a] | 22.75 | 22.87 | 19.48[a] | 31.99 | 28.95 | 32.88 | 31.30 |
| Years of Record (shown) | 76 | 80 | 77 | 80 | 80 | 78 | 79 | 80 |
| Mean | 21.49 | 23.09 | 24.72 | 29.05 | 30.37 | 33.84 | 33.57 | 34.91 |
| Median | 19.88 | 22.67 | 23.49 | 28.56 | 30.43 | 32.65 | 33.69 | 33.51 |

Data source: U.S. Department of Commerce (2014); Uvalde data: Texas A&M AgriLIFE Extension Service (2014)
a = Partial record not included in long-term mean; missing one month.
b = Partial record not included in long-term mean; missing more than one month.
c = Change in gauge location from previous years.
--- = No data available.
Mean values calculated using only years with full records. Years with partial or missing records discarded from data set. (NOAA records may exceed the period of record shown in Table 2 for some locations.)

## Table 3a. Monthly Precipitation Data from Selected National Oceanic and Atmospheric Administration Precipitation-Gauging Stations, 2013 (measured in inches).

| Gauge | County | Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| San Antonio Intl. Airport | Bexar | 2.83 | 0.10 | 0.95 | 2.77 | 13.18 | 2.02 | 0.73 | 0.85 | 3.70 | 2.40 | 1.50 | 0.55 | 31.99 |
| Vanderpool 10N | Bandera | 1.10* | 0.00 | 0.32 | 0.88 | 3.13 | 0.00 | M | M | M | 2.30 | 3.37 | 0.60 | 11.70* |
| Vanderpool 4N | Bandera | 3.52* | 0.28 | 0.58 | 1.38 | 4.75* | 2.83 | 1.28 | 1.01 | 2.76 | 3.18 | 2.91 | 1.09 | 25.57* |
| New Braunfels | Comal | 3.82 | 0.41 | 0.11 | 4.32 | 5.09 | 0.78 | 5.49 | 1.01 | 6.17 | 3.40 | 1.53 | 0.75 | 32.88 |
| San Marcos | Hays | 2.66 | 0.53 | 1.63 | 3.12 | 2.66 | 0.68 | 2.30 | 0.86 | 6.48 | 7.66 | 1.48 | 1.24 | 31.30 |
| Kerrville 3 NNE | Kerr | 2.83 | 0.13 | 0.55 | 2.55 | 4.97 | 2.45 | 1.10 | 1.93 | 3.44 | 3.54 | 1.73 | 0.77 | 25.99 |
| Hondo | Medina | 2.53 | 0.25 | 0.45* | 1.50* | 2.66 | 3.14 | 0.89 | 0.26 | 3.69* | 2.74* | 0.77* | 0.60 | 19.48* |
| Brackettville 22N | Kinney | 0.90 | 0.02* | 0.49 | 0.30 | 3.36 | 3.63 | 1.60 | 1.54 | 3.74 | 3.26* | 1.65 | 0.69 | 21.18* |
| Prade Ranch | Real | 2.30* | M | 0.35 | 1.80 | 7.01 | 2.82 | 2.42 | 0.77 | 3.80* | 4.57 | 1.85 | 0.78* | 28.47* |
| Sabinal | Uvalde | 2.21 | 0.11 | 0.74 | 1.41 | 1.94 | 4.31 | 0.68 | 1.06 | 5.02 | 3.12 | 1.87 | 0.40 | 22.87 |
| Uvalde | Uvalde | 1.61 | 0.05 | 0.14 | 3.08 | 3.26 | 3.73 | 0.84 | 0.39 | 3.30 | 4.01 | 1.82 | 0.52 | 22.75 |
| Boerne | Kendall | 3.31 | 0.22 | 0.64 | 2.33 | 6.32 | 1.77 | 1.02 | 0.61 | 6.03 | 2.84 | 3.44 | 0.42 | 28.95 |

M = Missing data.
* = Incomplete data set.

## Table 3b. Deviation from Mean Rainfall Values, 2013.

| Gauge | County | Mean | Total | Deviation from Mean |
|---|---|---|---|---|
| San Antonio Intl. Airport | Bexar | 30.37 | 31.99 | 1.62 |
| New Braunfels | Comal | 32.87 | 32.88 | 0.01 |
| San Marcos* | Hays | 33.98 | 31.30 | -2.68 |
| Hondo | Medina | 28.50 | 19.48* | -9.02 |
| Uvalde | Uvalde | 23.09 | 22.75 | -0.34 |
| Boerne | Kendall | 34.00 | 28.95 | -5.05 |
| Brackettville | Kinney | 21.74 | 21.18* | -0.56 |

* = Incomplete data set for current year, not representative of annual values.
(Rainfall amounts shown in inches.)

## Table 4. 2013 Monthly Precipitation Totals from EAA Rain Gauges (Rain-Gauge Locations Shown in Figure 4).

| | BA061 | BA062 | BA073 | BA091 | BA093 | BA108 | BE124 | BE125 | BE127 | BE128 | BE129 | BE130 | BE133 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **January** | 0.01 | 0.31 | 1.24 | 2.51 | 2.78 | 2.62 | 2.14 | 2.65 | 2.34 | 2.58 | 2.83 | 1.55 | 0 |
| **February** | 0.03 | 0.03 | 0.02 | 0.02 | 0.05 | 0.04 | 0.36 | 0.15 | 0 | 0.07 | 0.21 | 0 | 0 |
| **March** | 0.58 | 0.37 | 1.23 | 0.76 | 0.73 | 0.64 | 1.31 | 1.14 | 0.68 | 0.92 | 1.19 | 1.02 | 0 |
| **April** | 0.73 | 1.28 | 0.88 | 2.85 | 0.93 | 1.36 | 1.54 | 1.93 | 2.37 | 3.66 | 2.81 | 1.79 | 0.59 |
| **May** | 5.22 | 3.79 | 2.83 | 2.26 | 2.44 | 3.06 | 3.99 | 3.31 | 6.92 | 5.21 | 4.06 | 3.38 | 1.61 |
| **June** | 1.50 | 1.97 | 0.88 | 1.18 | 1.79 | 1.25 | 2.01 | 2.09 | 2.11 | 2.79 | 1.96 | 2.45 | 1.39 |
| **July** | 0.28 | 0.87 | 0.80 | 0.44 | 1.67 | 1.23 | 0.81 | 0.47 | 0.62 | 0.09 | 0 | 2.40 | 0.06 |
| **August** | 0.98 | 1.04 | 0.57 | 0.01 | 1.59 | 0.06 | 0.61 | 0.30 | 0.53 | 0.30 | 0.20 | 0 | 0.31 |
| **September** | 2.45 | 1.85 | 1.62 | 0.89 | 2.21 | 1.36 | 4.43 | 4.58 | 1.82 | 3.29 | 3.48 | 2.78 | 3.90 |
| **October** | 1.97 | 2.66 | 0.96 | 0.93 | 1.99 | 1.99 | 6.59 | 6.73 | 2.62 | 5.58 | 3.89 | 2.20 | 2.65 |
| **November** | 2.98 | 2.30 | 1.75 | 0.47 | 1.19 | 2.14 | 1.19 | 1.61 | 0.20 | 1.33 | 0.83 | 0.81 | 0.13 |
| **December** | 0.52 | 0.62 | 0.48 | 0.41 | 0.49 | 0.46 | 0.41 | 0.45 | 0.43 | 0.49 | 0.60 | 0.41 | 0.85 |
| **2013 totals** | **17.25** | **17.09** | **13.26** | **12.73** | **17.86** | **16.21** | **25.39** | **25.41** | **20.64** | **26.31** | **22.06** | **18.79** | **11.49** |

| | BE142 | BL151 | BL156 | CO132 | CO135 | CO138 | CO152 | ED063 | ED064 | ED065 | ED066 | ED075 | HA157 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **January** | 1.49 | 1.83 | * | 1.58 | 2.54 | 2.74 | 1.85 | 0.21 | 0.38 | 0.34 | 0.35 | 1.68 | 1.30 |
| **February** | 0.20 | 0.09 | * | 0.21 | 0.02 | 0.21 | 0.19 | 0 | 0 | 0.06 | 0.01 | 0 | 0.43 |
| **March** | 1.11 | 1.10 | * | 0.72 | 0.91 | 1.72 | 0.63 | 0.37 | 1.49 | 0.71 | 0.20 | 0.70 | 0.96 |
| **April** | 2.54 | 1.14 | * | 1.25 | 4.01 | 2.14 | 1.07 | 0.44 | 0.26 | 2.67 | 0.91 | 0.36 | 2.02 |
| **May** | 3.07 | 5.56 | * | 3.16 | 5.45 | 6.80 | 0.85 | 4.21 | 2.54 | 1.88 | 2.87 | 2.94 | 4.25 |
| **June** | 1.79 | 1.64 | * | 1.70 | 1.30 | 1.70 | 0.76 | 3.69 | 2.58 | 3.17 | 3.03 | 0.52 | 1.00 |
| **July** | 0.75 | 1.59 | * | 1.80 | 2.00 | 1.65 | 2.05 | 0.43 | 2.38 | 1.11 | 1.85 | 1.01 | 2.54 |
| **August** | 0.18 | 0.08 | * | 0.75 | 0 | 0.30 | 0.17 | 0.26 | 0.75 | 0.80 | 1.14 | 0.60 | 0.32 |
| **September** | 3.68 | 1.89 | 3.38 | 3.08 | 1.58 | 3.08 | 2.25 | 4.11 | 2.03 | 3.98 | 2.46 | 1.83 | 4.08 |
| **October** | 1.83 | 4.55 | 5.57 | 5.56 | 1.12 | 0.01 | 4.02 | 2.02 | 1.98 | 2.18 | 1.78 | 0.95 | 5.49 |
| **November** | 1.02 | 1.08 | 2.39 | 0.64 | 1.63 | 1.35 | 0.79 | 1.15 | 1.07 | 1.31 | 0.97 | 1.62 | 1.51 |
| **December** | 0.68 | 0.31 | 0.48 | 0.50 | 0.70 | 0.53 | 0.25 | 0.64 | 0.47 | 0.49 | 0.47 | 0.38 | 0.87 |
| **2013 totals** | **18.34** | **20.86** | **11.82** | **20.95** | **21.26** | **22.23** | **14.88** | **17.53** | **15.93** | **18.7** | **16.04** | **12.59** | **24.77** |

* = Incomplete data set.

ND = Annual total not provided; annual data set not complete.

# (Table 4. continued)

| | BE142 | BL151 | BL156 | CO132 | CO135 | CO138 | CO152 | ED063 | ED064 | ED065 | ED066 | ED075 | HA157 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 1.49 | 1.83 | * | 1.58 | 2.54 | 2.74 | 1.85 | 0.21 | 0.38 | 0.34 | 0.35 | 1.68 | 1.30 |
| February | 0.20 | 0.09 | * | 0.21 | 0.02 | 0.21 | 0.19 | 0 | 0 | 0.06 | 0.01 | 0 | 0.43 |
| March | 1.11 | 1.10 | * | 0.72 | 0.91 | 1.72 | 0.63 | 0.37 | 1.49 | 0.71 | 0.20 | 0.70 | 0.96 |
| April | 2.54 | 1.14 | * | 1.25 | 4.01 | 2.14 | 1.07 | 0.44 | 0.26 | 2.67 | 0.91 | 0.36 | 2.02 |
| May | 3.07 | 5.56 | * | 3.16 | 5.45 | 6.80 | 0.85 | 4.21 | 2.54 | 1.88 | 2.87 | 2.94 | 4.25 |
| June | 1.79 | 1.64 | * | 1.70 | 1.30 | 1.70 | 0.76 | 3.69 | 2.58 | 3.17 | 3.03 | 0.52 | 1.00 |
| July | 0.75 | 1.59 | * | 1.80 | 2.00 | 1.65 | 2.05 | 0.43 | 2.38 | 1.11 | 1.85 | 1.01 | 2.54 |
| August | 0.18 | 0.08 | * | 0.75 | 0 | 0.30 | 0.17 | 0.26 | 0.75 | 0.80 | 1.14 | 0.60 | 0.32 |
| September | 3.68 | 1.89 | 3.38 | 3.08 | 1.58 | 3.08 | 2.25 | 4.11 | 2.03 | 3.98 | 2.46 | 1.83 | 4.08 |
| October | 1.83 | 4.55 | 5.57 | 5.56 | 1.12 | 0.01 | 4.02 | 2.02 | 1.98 | 2.18 | 1.78 | 0.95 | 5.49 |
| November | 1.02 | 1.08 | 2.39 | 0.64 | 1.63 | 1.35 | 0.79 | 1.15 | 1.07 | 1.31 | 0.97 | 1.62 | 1.51 |
| December | 0.68 | 0.31 | 0.48 | 0.50 | 0.70 | 0.53 | 0.25 | 0.64 | 0.47 | 0.49 | 0.47 | 0.38 | 0.87 |
| **2013 totals** | **18.34** | **20.86** | **11.82** | **20.95** | **21.26** | **22.23** | **14.88** | **17.53** | **15.93** | **18.7** | **16.04** | **12.59** | **24.77** |

| | HA158 | HA160 | HA161 | HA162 | KE068 | KE095 | KE141 | KE155 | KI040 | KI041 | KI043 | ME002 | ME003 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 2.56 | 1.74 | 2.74 | 2.03 | 1.11 | 2.49 | 3.07 | 3.41 | 1.12 | 1.18 | 0.95 | 1.66 | 2.18 |
| February | 0.06 | 0.46 | 0.35 | 0.09 | 0.03 | 0.05 | 0.08 | 0.06 | 0 | 0.01 | 0 | 0.01 | 0.08 |
| March | 0.55 | 1.25 | 1.22 | 0.71 | 1.26 | 0.72 | 0.73 | 0.54 | 0.20 | 0.86 | 1.17 | 0.11 | 0.33 |
| April | 2.02 | 2.03 | 2.87 | 2.68 | 1.36 | 0.56 | 2.06 | 1.80 | 0.71 | 0.46 | 0.25 | 1.61 | 1.36 |
| May | 0.78 | 4.46 | 2.98 | 3.74 | 6.41 | 3.14 | 4.55 | 6.44 | 3.11 | 1.18 | 3.90 | 0.68 | 2.03 |
| June | 0.08 | 1.46 | 0.24 | 1.21 | 1.28 | 0.89 | 2.12 | 2.87 | 6.53 | 6.11 | 7.58 | 1.63 | 2.42 |
| July | 0.50 | 3.79 | 1.38 | 2.95 | 1.33 | 0.14 | 0.87 | 0.45 | 0.65 | 1.25 | 0.32 | 0.74 | 0.36 |
| August | 0 | 0.44 | 0.32 | 0.49 | 1.17 | 0.40 | 0.82 | 0.33 | 0.41 | 0.98 | 1.46 | 0.12 | 0.12 |
| September | 0 | 3.48 | 6.29 | 2.75 | 1.83 | 3.40 | 2.92 | 1.43 | 3.61 | 2.72 | 2.57 | 2.37 | 3.86 |
| October | 7.23 | 4.74 | 10.06 | 8.22 | 1.62 | 1.88 | 3.43 | 4.21 | 3.66 | 2.80 | 1.60 | 2.48 | 2.48 |
| November | 1.41 | 1.62 | 1.79 | 1.59 | 1.32 | 1.34 | 1.29 | 4.22 | 1.96 | 1.50 | 0.67 | 0.91 | 0.90 |
| December | 0.48 | 0.50 | 0.58 | 0.38 | 0.66 | 0.46 | 0.46 | 0.60 | 0.72 | 0.64 | 0.54 | 0.36 | 0.35 |
| **2013 totals** | **15.67** | **25.97** | **30.82** | **26.84** | **19.38** | **15.47** | **22.4** | **26.36** | **22.68** | **19.69** | **21.01** | **12.68** | **16.47** |

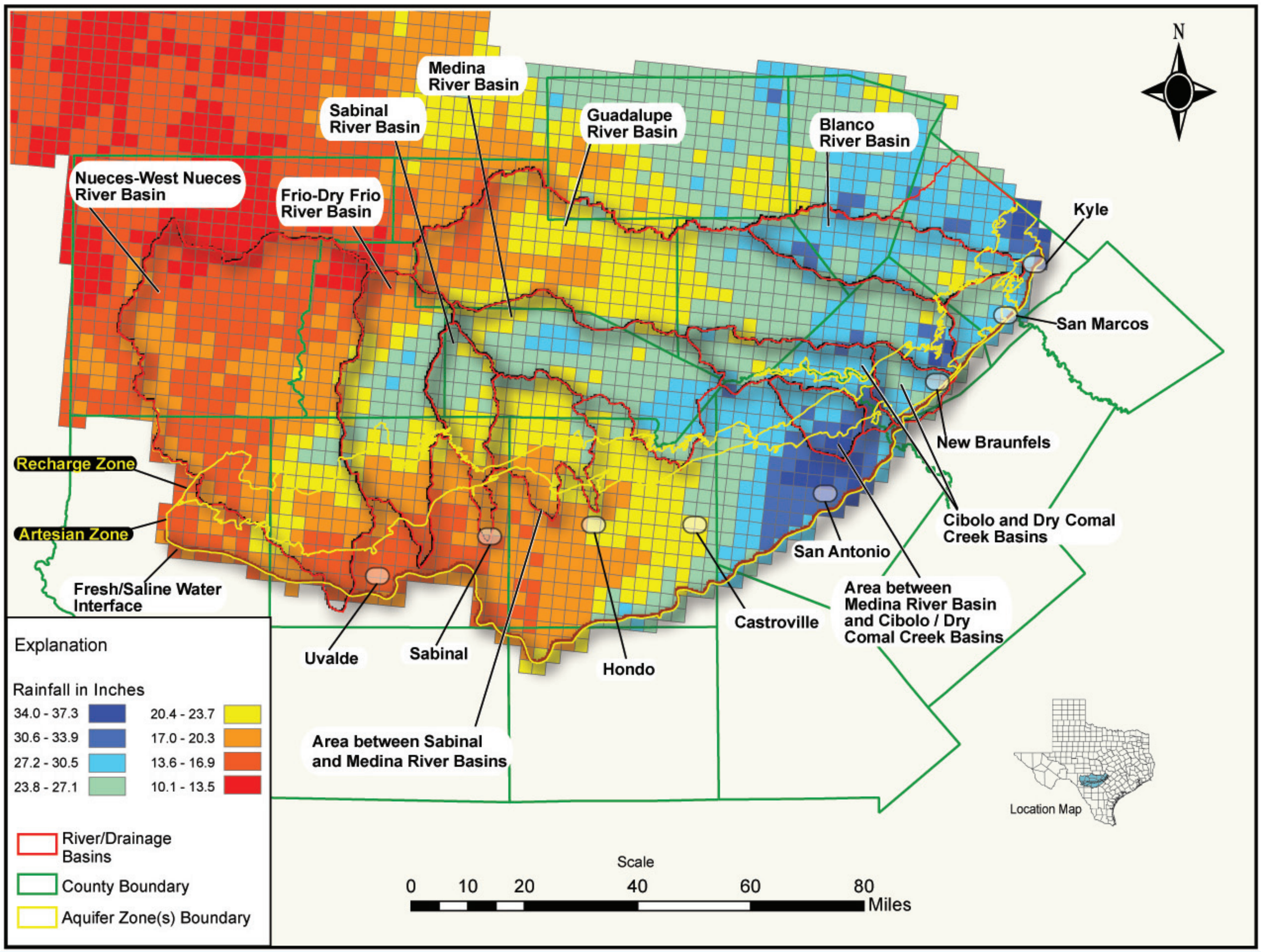
| | ME005 | ME006 | ME007 | ME008 | ME010 | ME011 | ME015 | ME094 | ME097 | ME098 | ME099 | ME101 | ME102 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 0.34 | 1.76 | 1.29 | 1.59 | 1.83 | 2.29 | 0.10 | 0.02 | 2.12 | 2.10 | 2.16 | 0.18 | 2.05 |
| February | 0.07 | 0.01 | 0.07 | 0.08 | 0.06 | 0.05 | 0 | 0.04 | 0.06 | 0.01 | 0.08 | 0.04 | 0.04 |
| March | 0.48 | 0.12 | 0.19 | 0.55 | 0.39 | 0.28 | 0.22 | 0.11 | 0.93 | 0.24 | 0.51 | 0.33 | 0.72 |
| April | 1.79 | 1.36 | 1.52 | 2.50 | 1.72 | 0.57 | 2.00 | 3.80 | 1.78 | 2.02 | 1.36 | 0.59 | 1.31 |
| May | 1.96 | 1.65 | 1.93 | 2.51 | 2.39 | 3.53 | 0.97 | 3.24 | 3.68 | 1.07 | 3.89 | 1.10 | 3.46 |
| June | 1.10 | 2.39 | 1.84 | 1.96 | 2.74 | 2.94 | 2.94 | 2.11 | 1.54 | 1.94 | 0.91 | 2.15 | 2.26 |
| July | 0.10 | 2.02 | 2.80 | 0.70 | 0.50 | 0.59 | 1.48 | 0.73 | 0.63 | 0.62 | 0.32 | 0.30 | 0.37 |
| August | 0.08 | 0.39 | 0.37 | 0.04 | 0.06 | 0.40 | 0.12 | 0.71 | 0.62 | 1.48 | 0.65 | 0 | 0.04 |
| September | 2.62 | 3.79 | 1.95 | 4.03 | 3.83 | 1.51 | 4.73 | 2.89 | 2.65 | 3.57 | 0.39 | 2.68 | 2.55 |
| October | 1.45 | 2.38 | 2.34 | 2.22 | 2.49 | 1.02 | 2.44 | 2.92 | 2.66 | 2.71 | 1.38 | 2.08 | 1.82 |
| November | 1.42 | 0.68 | 0.88 | 0.93 | 1.10 | 0.79 | 0.64 | 1.25 | 1.04 | 0.97 | 1.45 | 0.86 | 1.31 |
| December | 0.48 | 0.42 | 0.44 | 0.52 | 0.47 | 0.23 | 0.25 | 0.43 | 0.79 | 0.57 | 0.61 | 0.46 | 0.51 |
| **2013 totals** | **11.89** | **16.97** | **15.62** | **17.63** | **17.58** | **14.2** | **15.89** | **18.25** | **18.5** | **17.3** | **13.71** | **10.77** | **16.44** |

| | ME103 | RE067 | RE069 | RE070 | RE071 | RE072 | RE074 | UV012 | UV013 | UV016 | UV017 | UV018 | UV019 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 2.36 | 1.68 | 1.52 | 2.20 | 1.58 | 2.00 | 1.81 | 2.17 | 2.08 | 2.12 | 2.20 | 4.00 | 3.21 |
| February | 0.09 | 0.05 | 0.02 | 0.07 | 0 | 0 | 0 | 0.06 | 0 | 0.02 | 0.03 | 0.02 | 0.02 |
| March | 0.53 | 0.45 | 0.90 | 0.54 | 0.45 | 0.66 | 0.66 | 1.11 | 0.75 | 0.55 | 0.58 | 0.96 | 0.92 |
| April | 1.31 | 1.08 | 0.28 | 0.82 | 0.59 | 1.85 | 0.66 | 0.99 | 1.31 | 0.82 | 0.92 | 0.69 | 0.97 |
| May | 4.03 | 4.25 | 3.20 | 3.45 | 6.62 | 4.94 | 4.87 | 1.30 | 0.05 | 4.13 | 1.71 | 4.87 | 4.73 |
| June | 2.29 | 2.31 | 1.34 | 2.51 | 1.93 | 3.04 | 2.84 | 2.87 | 2.09 | 3.20 | 1.41 | 2.02 | 3.06 |
| July | 1.89 | 0.48 | 0.21 | 0.30 | 1.14 | 0.24 | 1.76 | 0.54 | 1.10 | 0.76 | 0.12 | 0.57 | 0.25 |
| August | 0.14 | * | 0.69 | 0.42 | 0.35 | 0.57 | 0.79 | 0.51 | 0.12 | 0.14 | 0.94 | 1.25 | 0.14 |
| September | 2.06 | * | 3.00 | 2.30 | 2.26 | 2.80 | 2.02 | 4.56 | 1.52 | 2.97 | 1.92 | 3.58 | 2.23 |
| October | 2.02 | * | 2.06 | 2.82 | 1.61 | 1.50 | 1.15 | 2.84 | 1.54 | 1.44 | 3.46 | 2.03 | 2.88 |
| November | 1.39 | * | 2.28 | 1.13 | 1.21 | 1.25 | 1.66 | 1.02 | 2.57 | 2.98 | 0.42 | 1.92 | 2.00 |
| December | 0.46 | * | 0.54 | 0.71 | 0.70 | 0.57 | 0.85 | 0.25 | 0.38 | 0.32 | 0.30 | 0.33 | 0.35 |
| **2013 totals** | **18.57** | **10.3** | **16.04** | **17.27** | **18.44** | **19.42** | **19.07** | **18.22** | **13.51** | **19.45** | **14.01** | **22.24** | **20.76** |

| | UV031 | UV032 | UV033 | UV034 | UV035 | UV036 | UV037 | UV039 | UV042 | UV044 |
|---|---|---|---|---|---|---|---|---|---|---|
| January | 0.26 | 0.61 | 0.90 | 1.55 | 0.87 | 1.37 | 1.00 | 1.07 | 1.92 | 0.26 |
| February | 0.75 | 0.94 | 0.51 | 1.46 | 1.10 | 1.18 | 0.30 | 1.42 | 1.66 | 0.75 |
| March | 2.72 | 2.17 | 1.67 | 3.04 | 2.56 | 1.80 | 4.00 | 2.38 | 1.36 | 2.72 |
| April | 0.04 | 0.00 | 0.02 | 0.02 | 0.37 | 0.06 | 0.14 | 0.19 | 0.07 | 0.04 |
| May | 1.58 | 4.09 | 3.84 | 5.25 | 6.62 | 4.58 | 2.75 | 6.73 | 4.64 | 1.58 |
| June | 0.00 | 0.18 | 0.19 | 0.01 | 0.00 | 0.05 | 0.00 | 0.00 | 0.29 | 0.00 |
| July | 0.58 | 1.77 | 1.59 | 1.63 | 1.83 | 0.71 | 1.26 | 5.17 | 2.52 | 0.58 |
| August | 0.50 | 1.47 | 0.34 | 0.43 | 0.77 | 0.65 | 1.79 | 1.42 | 0.47 | 0.50 |
| September | 3.97 | 8.37 | 4.59 | 4.27 | 3.65 | 4.45 | 3.18 | 1.18 | 3.70 | 3.97 |
| October | 0.30 | 0.34 | 0.00 | 0.03 | 0.20 | 0.00 | 0.00 | 0.09 | 0.34 | 0.30 |
| November | 0.01 | 0.18 | 0.03 | 0.06 | 0.18 | 0.01 | 0.01 | 0.04 | 0.03 | 0.01 |
| December | 0.10 | 0.08 | 0.09 | 0.24 | 0.12 | 0.00 | 0.11 | 0.09 | 0.33 | 0.10 |
| **2013 totals** | **15.49** | **19.88** | **19.83** | **16.11** | **25.2** | **14.81** | **18.15** | **23.43** | **18.92** | **25.66** |

* = Incomplete data set.

## Figure 6. Ground-Calibrated NEXRAD Radar Rainfall Distribution for 2013



## Precipitation Enhancement Program (PEP)

Since 1998, the EAA has funded a Precipitation Enhancement Program (PEP) in an effort to enhance rainfall in strategic parts of the EAA jurisdiction. Specifically, the goals of the PEP are to

- Enhance rainfall in a targeted area by using state-of-the-art cloud-seeding technology and procedures to seed suitable convective clouds,
- Increase aquifer recharge,
- Increase the annual mean quantity of water that may be withdrawn from the aquifer,
- Reduce demands from the aquifer by increasing precipitation, and
- Reduce periods of low water levels and protect threatened springflows.

On the basis of reports prepared by the South Texas Weather Modification Association (STWMA) and the Southwest Texas Rain Enhancement Association (SWTREA), EAA's PEP contractors, program analyses for 2013 indicate an increase of 129,200 acre-feet of rainfall within the four-county target area. The area is just over 3.1 million acres in size, resulting in an average increased rainfall amount of approximately 0.5 inch per acre. The EAA continues to monitor the effectiveness of PEP activities.

# GROUNDWATER RECHARGE

Recharge to the Edwards Aquifer originates as precipitation over the drainage area and recharge zone of the aquifer or as interformational flow from adjacent aquifers. The EAA maintains a joint funding agreement with the U.S. Geological Survey (USGS) to provide recharge estimates by drainage basin (Figure 7). Recharge is estimated using a water-balance method that relies on precipitation and streamflow measurements across the region.

Table 5 lists estimated annual recharge by drainage basin from 1934 through 2013 on the basis of USGS calculations. The USGS estimates that annual recharge for the period of record (1934–2013) ranged from 43,700 acre-feet at the height of the drought of record in 1956 to 2,486,000 acre-feet in 1992. In 2013, estimated recharge was 182,600 acre-feet. The median annual recharge for 1934 through 2013 is 556,950 acre-feet. Recharge estimates shown in Table 5 do not include the Guadalupe River Basin because the historical method of estimating recharge is based on the interpretation that the basin does not recharge the aquifer.

The 2013 estimated recharge volume of 182,600 acre-feet was below the period of record (1934–2013) median recharge value of 556,950 acre-feet; the corresponding mean value is 699,380 acre-feet. Figure 8 provides a graphical representation of annual estimated recharge compared with the most recent ten-year median and period-of-record median for the San Antonio segment of the Balcones Fault Zone Edwards Aquifer from 1934 through 2013.

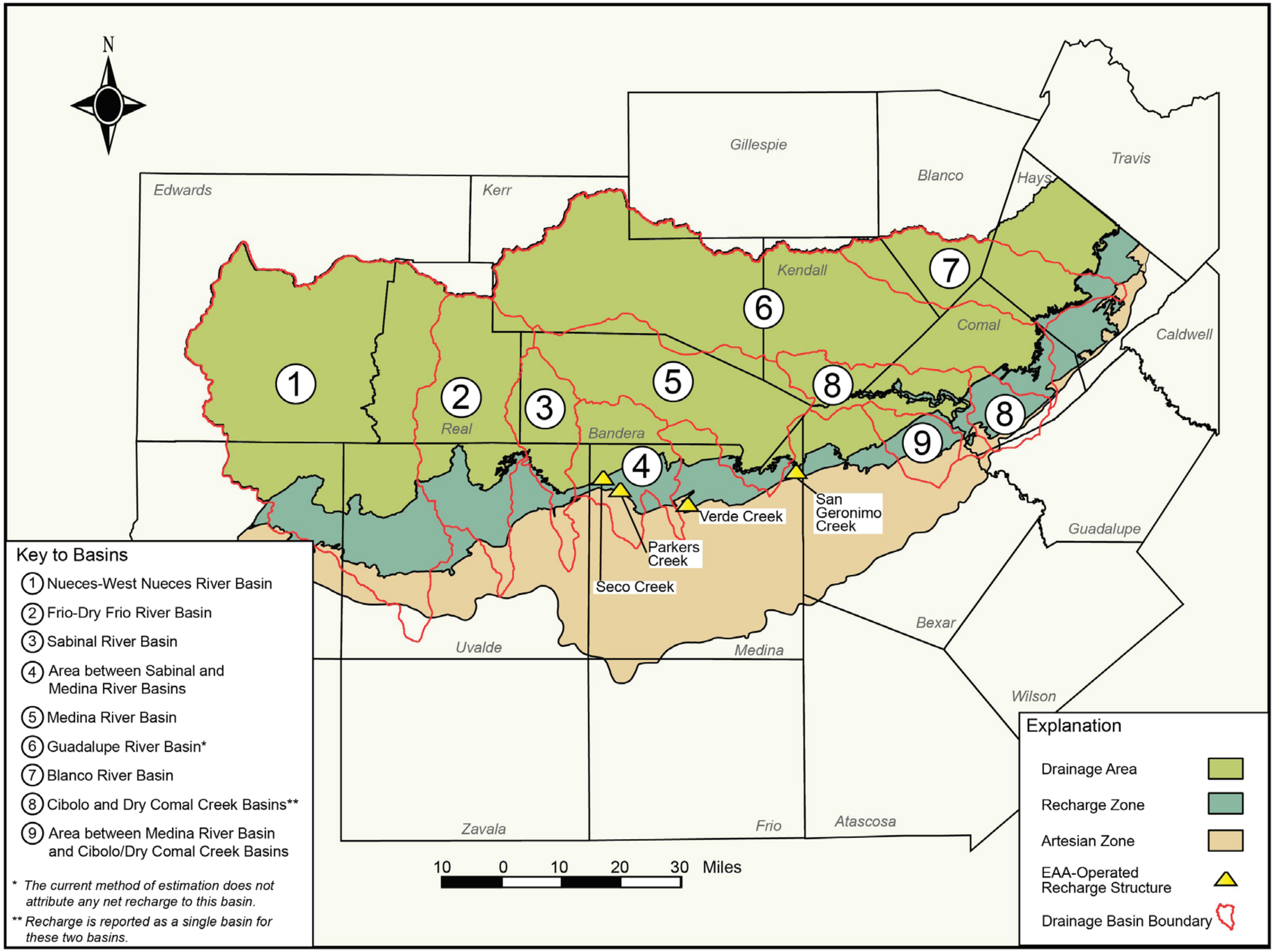
The EAA operates four recharge structures in Medina County on the Edwards Aquifer Recharge Zone (Figure 7). Total recharge for each site is calculated using data from stage recorders near these structures. Table 6 shows the annual recharge (total recharge) for each site since construction. Combined recharge for these structures was 1.0 acre-foot in 2013.

Historical median and mean annual recharge attributed to the recharge structures is based on a period of record that reflects the date of construction through 2013. The approximate historical median annual recharge contributed by the combined structures is 848 acre-feet, whereas the approximate historical mean annual recharge contributed by the combined structures is 4,845 acre-feet.

The methodology for calculating recharge is being refined using the Hydrologic Simulation Program Fortran (HSPF) model. HSPF modeling performed to date indicates similar historical total recharge relative to the traditional USGS method; however, differences by basin are noteworthy. As additional HSPF output data are generated and refined, results will be incorporated into future versions of this report.

Recharge resulting from interformational flow in adjacent aquifers such as the Trinity Aquifer is not estimated annually. Estimates associated with interformational flow are highly variable and range from 5,000 to 100,000 acre-feet per year in different publications. Estimated interformational recharge is not included in recharge values provided in this report.

## Figure 7. Major Drainage Basins and Edwards Aquifer Authority-Operated Recharge Structures in the San Antonio Segment of the Balcones Fault Zone Edwards Aquifer



## Table 5. Estimated Annual Groundwater Recharge to Edwards Aquifer by Drainage Basin, 1934–2013 (measured in thousands of acre-feet).

| Year | Nueces River/ West Nueces River basin | Frio River/ Dry Frio River basin | Sabinal River Basin | Area between Sabinal River and Medina River basins | Medina River Basin | Area between Medina River and Cibolo Creek/ Dry Comal Creek basins | Cibolo Creek/ Dry Comal Creek basin | Blanco River Basin | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1934 | 8.6 | 27.9 | 7.5 | 19.9 | 46.5 | 21.0 | 28.4 | 19.8 | 179.6 |
| 1935 | 411.3 | 192.3 | 56.6 | 166.2 | 71.1 | 138.2 | 182.7 | 39.8 | 1,258.2 |
| 1936 | 176.5 | 157.4 | 43.5 | 142.9 | 91.6 | 108.9 | 146.1 | 42.7 | 909.6 |
| 1937 | 28.8 | 75.7 | 21.5 | 61.3 | 80.5 | 47.8 | 63.9 | 21.2 | 400.7 |
| 1938 | 63.5 | 69.3 | 20.9 | 54.1 | 65.5 | 46.2 | 76.8 | 36.4 | 432.7 |
| 1939 | 227.0 | 49.5 | 17.0 | 33.1 | 42.4 | 9.3 | 9.6 | 11.1 | 399.0 |
| 1940 | 50.4 | 60.3 | 23.8 | 56.6 | 38.8 | 29.3 | 30.8 | 18.8 | 308.8 |
| 1941 | 89.9 | 151.8 | 50.6 | 139.0 | 54.1 | 116.3 | 191.2 | 57.8 | 850.7 |
| 1942 | 103.5 | 95.1 | 34.0 | 84.4 | 51.7 | 66.9 | 93.6 | 28.6 | 557.8 |
| 1943 | 36.5 | 42.3 | 11.1 | 33.8 | 41.5 | 29.5 | 58.3 | 20.1 | 273.1 |
| 1944 | 64.1 | 76.0 | 24.8 | 74.3 | 50.5 | 72.5 | 152.5 | 46.2 | 560.9 |
| 1945 | 47.3 | 71.1 | 30.8 | 78.6 | 54.8 | 79.6 | 129.9 | 35.7 | 527.8 |
| 1946 | 80.9 | 54.2 | 16.5 | 52.0 | 51.4 | 105.1 | 155.3 | 40.7 | 556.1 |
| 1947 | 72.4 | 77.7 | 16.7 | 45.2 | 44.0 | 55.5 | 79.5 | 31.6 | 422.6 |
| 1948 | 41.1 | 25.6 | 26.0 | 20.2 | 14.8 | 17.5 | 19.9 | 13.2 | 178.3 |
| 1949 | 166.0 | 86.1 | 31.5 | 70.3 | 33.0 | 41.8 | 55.9 | 23.5 | 508.1 |
| 1950 | 41.5 | 35.5 | 13.3 | 27.0 | 23.6 | 17.3 | 24.6 | 17.4 | 200.2 |
| 1951 | 18.3 | 28.4 | 7.3 | 26.4 | 21.1 | 15.3 | 12.5 | 10.6 | 139.9 |
| 1952 | 27.9 | 15.7 | 3.2 | 30.2 | 25.4 | 50.1 | 102.3 | 20.7 | 275.5 |
| 1953 | 21.4 | 15.1 | 3.2 | 4.4 | 36.2 | 20.1 | 42.3 | 24.9 | 167.6 |
| 1954 | 61.3 | 31.6 | 7.1 | 11.9 | 25.3 | 4.2 | 10.0 | 10.7 | 162.1 |
| 1955 | 128.0 | 22.1 | 0.6 | 7.7 | 16.5 | 4.3 | 3.3 | 9.5 | 192.0 |
| 1956 | 15.6 | 4.2 | 1.6 | 3.6 | 6.3 | 2.0 | 2.2 | 8.2 | 43.7 |
| 1957 | 108.6 | 133.6 | 65.4 | 129.5 | 55.6 | 175.6 | 397.9 | 76.4 | 1,142.6 |
| 1958 | 266.7 | 300.0 | 223.8 | 294.9 | 95.5 | 190.9 | 268.7 | 70.7 | 1,711.2 |
| 1959 | 109.6 | 158.9 | 61.6 | 96.7 | 94.7 | 57.4 | 77.9 | 33.6 | 690.4 |
| 1960 | 88.7 | 128.1 | 64.9 | 127.0 | 104.0 | 89.7 | 160.0 | 62.4 | 824.8 |
| 1961 | 85.2 | 151.3 | 57.4 | 105.4 | 88.3 | 69.3 | 110.8 | 49.4 | 717.1 |
| 1962 | 47.4 | 46.6 | 4.3 | 23.5 | 57.3 | 16.7 | 24.7 | 18.9 | 239.4 |
| 1963 | 39.7 | 27.0 | 5.0 | 10.3 | 41.9 | 9.3 | 21.3 | 16.2 | 170.7 |
| 1964 | 126.1 | 57.1 | 16.3 | 61.3 | 43.3 | 35.8 | 51.1 | 22.2 | 413.2 |
| 1965 | 97.9 | 83.0 | 23.2 | 104.0 | 54.6 | 78.8 | 115.3 | 66.7 | 623.5 |
| 1966 | 169.2 | 134.0 | 37.7 | 78.2 | 50.5 | 44.5 | 66.5 | 34.6 | 615.2 |
| 1967 | 82.2 | 137.9 | 30.4 | 64.8 | 44.7 | 30.2 | 57.3 | 19.0 | 466.5 |
| 1968 | 130.8 | 176.0 | 66.4 | 198.7 | 59.9 | 83.1 | 120.5 | 49.3 | 884.7 |
| 1969 | 119.7 | 113.8 | 30.7 | 84.2 | 55.4 | 60.2 | 99.9 | 46.6 | 610.5 |
| 1970 | 112.6 | 141.9 | 35.4 | 81.6 | 68.0 | 68.8 | 113.8 | 39.5 | 661.6 |
| 1971 | 263.4 | 212.4 | 39.2 | 155.6 | 68.7 | 81.4 | 82.4 | 22.2 | 925.3 |
| 1972 | 108.4 | 144.6 | 49.0 | 154.6 | 87.9 | 74.3 | 104.2 | 33.4 | 756.4 |
| 1973 | 190.6 | 256.9 | 123.9 | 286.4 | 97.6 | 237.2 | 211.7 | 82.2 | 1,486.5 |

## (Table 5. continued)

| Year | Nueces River/ West Nueces River basin | Frio River/ Dry Frio River basin | Sabinal River Basin | Area between Sabinal River and Medina River basins | Medina River Basin | Area between Medina River and Cibolo Creek/ Dry Comal Creek basins | Cibolo Creek/ Dry Comal Creek basin | Blanco River Basin | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1974 | 91.1 | 135.7 | 36.1 | 115.3 | 96.2 | 68.1 | 76.9 | 39.1 | 658.5 |
| 1975 | 71.8 | 143.6 | 47.9 | 195.9 | 93.4 | 138.8 | 195.7 | 85.9 | 973.0 |
| 1976 | 150.7 | 238.6 | 68.2 | 182.0 | 94.5 | 47.9 | 54.3 | 57.9 | 894.1 |
| 1977 | 102.9 | 193.0 | 62.7 | 159.5 | 77.7 | 97.9 | 191.6 | 66.7 | 952.0 |
| 1978 | 69.8 | 73.1 | 30.9 | 103.7 | 76.7 | 49.6 | 72.4 | 26.3 | 502.5 |
| 1979 | 128.4 | 201.4 | 68.6 | 203.1 | 89.4 | 85.4 | 266.3 | 75.2 | 1,117.8 |
| 1980 | 58.6 | 85.6 | 42.6 | 25.3 | 88.3 | 18.8 | 55.4 | 31.8 | 406.4 |
| 1981 | 205.0 | 365.2 | 105.6 | 252.1 | 91.3 | 165.0 | 196.8 | 67.3 | 1,448.4 |
| 1982 | 19.4 | 123.4 | 21.0 | 90.9 | 76.8 | 22.6 | 44.8 | 23.5 | 422.4 |
| 1983 | 79.2 | 85.9 | 20.1 | 42.9 | 74.4 | 31.9 | 62.5 | 23.2 | 420.1 |
| 1984 | 32.4 | 40.4 | 8.8 | 18.1 | 43.9 | 11.3 | 16.9 | 25.9 | 197.7 |
| 1985 | 105.9 | 186.9 | 50.7 | 148.5 | 64.7 | 136.7 | 259.2 | 50.7 | 1,003.3 |
| 1986 | 188.4 | 192.8 | 42.2 | 173.6 | 74.7 | 170.2 | 267.4 | 44.5 | 1,153.7 |
| 1987 | 308.5 | 473.3 | 110.7 | 405.5 | 90.4 | 229.3 | 270.9 | 114.9 | 2,003.6 |
| 1988 | 59.2 | 117.9 | 17.0 | 24.9 | 69.9 | 12.6 | 28.5 | 25.5 | 355.5 |
| 1989 | 52.6 | 52.6 | 8.4 | 13.5 | 46.9 | 4.6 | 12.3 | 23.6 | 214.4 |
| 1990 | 479.3 | 255.0 | 54.6 | 131.2 | 54.0 | 35.9 | 71.8 | 41.3 | 1,123.2 |
| 1991 | 325.2 | 421.0 | 103.1 | 315.2 | 52.8 | 84.5 | 109.7 | 96.9 | 1,508.4 |
| 1992 | 234.1 | 586.9 | 201.1 | 566.1 | 91.4 | 290.6 | 286.6 | 226.9 | 2,485.7 |
| 1993 | 32.6 | 78.5 | 29.6 | 60.8 | 78.5 | 38.9 | 90.9 | 37.8 | 447.6 |
| 1994 | 124.6 | 151.5 | 29.5 | 45.1 | 61.1 | 34.1 | 55.6 | 36.6 | 538.1 |
| 1995 | 107.1 | 147.6 | 34.7 | 62.4 | 61.7 | 36.2 | 51.1 | 30.6 | 531.3 |
| 1996 | 130.0 | 92.0 | 11.4 | 9.4 | 42.3 | 10.6 | 14.7 | 13.9 | 324.3 |
| 1997 | 176.9 | 209.1 | 57.0 | 208.4 | 63.3 | 193.4 | 144.2 | 82.3 | 1,134.6 |
| 1998 | 141.5 | 214.8 | 72.5 | 201.4 | 80.3 | 86.2 | 240.9 | 104.7 | 1,142.3 |
| 1999 | 101.4 | 136.8 | 30.8 | 57.2 | 77.1 | 21.2 | 27.9 | 21.0 | 473.5 |
| 2000 | 238.4 | 123.0 | 33.1 | 55.2 | 53.4 | 28.6 | 48.6 | 34.1 | 614.5 |
| 2001 | 297.5 | 126.7 | 66.2 | 124.1 | 90.0 | 101.5 | 173.7 | 89.7 | 1,069.4 |
| 2002 | 83.6 | 207.3 | 70.6 | 345.2 | 93.7 | 175.5 | 447.8 | 150.0 | 1,573.7 |
| 2003 | 149.8 | 112.2 | 31.7 | 67.4 | 86.6 | 56.2 | 105.0 | 59.9 | 669.0 |
| 2004 | 481.9 | 424.5 | 116.0 | 343.9 | 95.5 | 213.4 | 315.0 | 185.8 | 2,176.1 |
| 2005 | 105.5 | 147.2 | 50.1 | 79.1 | 82.8 | 84.8 | 140.4 | 74.1 | 764.0 |
| 2006 | 45.5 | 60.2 | 9.0 | 5.0 | 47.7 | 5.1 | 11.2 | 17.9 | 201.6 |
| 2007 | 471.8 | 474.4 | 104.0 | 406.4 | 75.2 | 227.6 | 306.1 | 96.9 | 2,162.3 |
| 2008 | 48.2 | 44.5 | 5.9 | 9.8 | 53.6 | 9.6 | 22.8 | 18.5 | 212.9 |
| 2009 | 58.5 | 30.3 | 1.8 | 13.5 | 45.6 | 7.3 | 26.4 | 27.5 | 210.9 |
| 2010 | 135.4 | 104.9 | 31.5 | 186.3 | 68.2 | 81.4 | 148.2 | 57.5 | 813.5 |
| 2011 | 15.3 | 13.7 | 1.0 | 2.0 | 43.3 | 3.0 | 15.3 | 18.3 | 112.0 |
| 2012 | 78.3 | 82.6 | 8.9 | 14.4 | 41.6 | 3.9 | 32.2 | 51.6 | 313.5 |
| 2013 | 67.7 | 26.7 | 0.5 | 2.8 | 10.8 | 3.3 | 28.7 | 42.1 | 182.6 |
| **Recharge for period of record 1934–2013:** | | | | | | | | | |
| Median | 99.7 | 115.9 | 31.2 | 76.3 | 60.5 | 49.9 | 77.4 | 36.0 | 557.0 |
| Mean | 124.8 | 135.6 | 41.2 | 109.5 | 61.9 | 70.3 | 109.3 | 46.6 | 699.4 |
| **Recharge for period of record 2003–2013 (last ten years):** | | | | | | | | | |
| Median | 73.0 | 71.4 | 9.0 | 14.0 | 50.7 | 8.5 | 30.5 | 46.9 | 263.2 |
| Mean | 150.8 | 140.9 | 32.9 | 106.3 | 56.4 | 63.9 | 104.6 | 59.0 | 714.9 |

Data source: USGS Unpublished Report (April 2014).

## Table 6. Estimated Annual Edwards Aquifer Recharge from Edwards Aquifer Authority-Operated Recharge Structures (measured in acre-feet).

| Year | Parker (April 1974) | Verde (April 1978) | San Geronimo (November 1979) | Seco (October 1982) | Annual Total |
|---|---|---|---|---|---|
| 1974 | 160 | --- | --- | --- | 160 |
| 1975 | 620 | --- | --- | --- | 620 |
| 1976 | 2,018 | --- | --- | --- | 2,018 |
| 1977 | 6 | --- | --- | --- | 6 |
| 1978 | 98 | 150 | --- | --- | 248 |
| 1979 | 2,315 | 1,725 | 0 | --- | 4,040 |
| 1980 | 0 | 371 | 903 | --- | 1,274 |
| 1981 | 772 | 1,923 | 1,407 | --- | 4,102 |
| 1982 | 3 | 112 | 91 | 0 | 206 |
| 1983 | 0 | 254 | 0 | 0 | 254 |
| 1984 | 251 | 246 | 0 | 143 | 640 |
| 1985 | 232 | 440 | 1,097 | 643 | 2,412 |
| 1986 | 217 | 889 | 963 | 1,580 | 3,649 |
| 1987 | 2,104 | 4,141 | 1,176 | 12,915 | 20,336 |
| 1988 | 0 | 0 | 0 | 0 | 0 |
| 1989 | 0 | 0 | 0 | 0 | 0 |
| 1990 | 49 | 176 | 41 | 479 | 745 |
| 1991 | 647 | 966 | 1,647 | 2,160 | 5,420 |
| 1992 | 723 | 2,775 | 2,874 | 14,631 | 21,003 |
| 1993 | 0 | 0 | 334 | 508 | 842 |
| 1994 | 159 | 0 | 0 | 5 | 164 |
| 1995 | 18 | 79 | 51 | 880 | 1,028 |
| 1996 | 0 | 0 | 0 | 0 | 0 |
| 1997 | 2,941[a] | 2,154[b] | 1,579[b] | 7,515[b] | 14,189[b] |
| 1998 | 1,469[a/b] | 1,160[b] | 872[b] | 3,796[b] | 7,297[b] |
| 1999 | 0[b] | 0[b] | 0[b] | 50[c] | 50[b/c] |
| 2000 | 901[b] | 1,371[b] | 1,023[b] | 4,606[b] | 7,901[b] |
| 2001 | 526[b] | 657[b/d] | 1,085[b/d] | 2,154[b/d] | 4,422[b/d] |
| 2002 | 1,811 | 1,511 | 4,350 | 18,872 | 26,544 |
| 2003 | 665 | 184 | 0 | 465 | 1,314 |
| 2004 | 2,363 | 170 | 4,778 | 14,682 | 21,993 |
| 2005 | 795 | 0 | 0 | 58 | 853 |
| 2006 | 0 | 0 | 0 | 0 | 0 |
| 2007 | 5,998 | 2,091 | 7,268 | 10,645 | 26,002 |
| 2008 | 2.6 | 2.5 | 0 | 0 | 5 |
| 2009 | 630.3 | 30.5 | 0.1 | 27.5 | 688.4 |
| 2010 | 1,356.4 | 1,324 | 4,375.1 | 6,170.7 | 13,226.2 |
| 2011 | 10.1 | 4.5 | 1.0 | 0 | 15.6 |
| 2012 | 1.0 | 51.2 | 0 | 97.5 | 149.7 |
| 2013 | 0.6 | 0 | 0 | 0.4 | 1.0 |
| **Total** | 29,861 | 24,958 | 35,915 | 103,083 | 193,818 |
| **Median** | 225 | 180 | 51 | 472 | 848 |
| **Mean** | 747 | 693 | 1,026 | 3,221 | 4,845 |

Data source: Unpublished EAA files (2014).

a = Written communication from USGS, San Antonio Subdistrict Office.

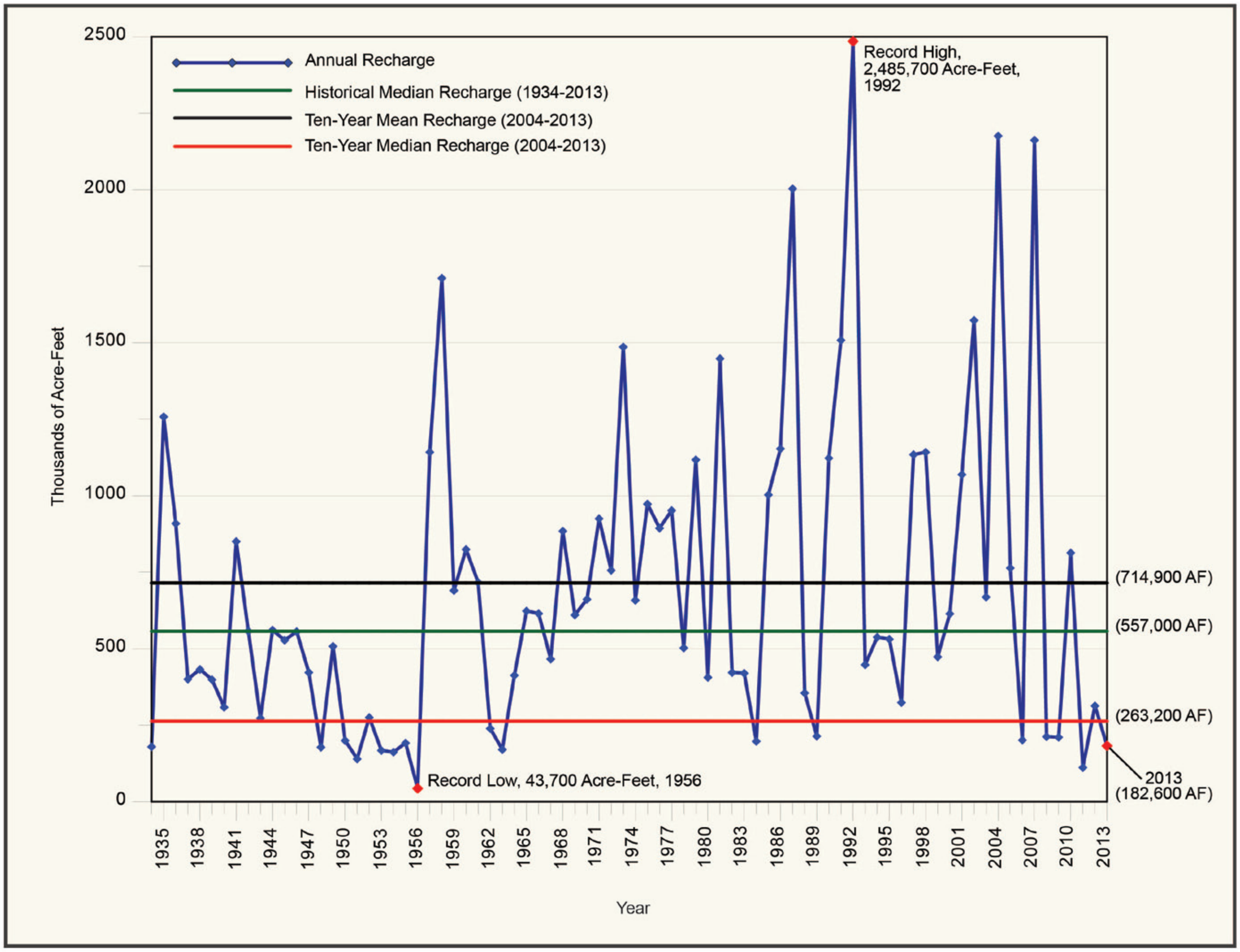
b = Determined by linear-regression analysis using rainfall data and historical recharge data.

c = Linear-regression analysis indicates zero recharge; however, one recharge event was observed that was estimated to have recharged 50 acre-feet.

d = Part of 2001 recharge estimate provided by HDR Engineering, Inc. (unpublished report).

--- = Years prior to construction of recharge structure.

## Figure 8. Estimated Annual Recharge and Ten-Year Floating Median Estimated Recharge for the San Antonio Segment of the Balcones Fault Zone Edwards Aquifer, 1934–2013



# GROUNDWATER DISCHARGE AND USAGE

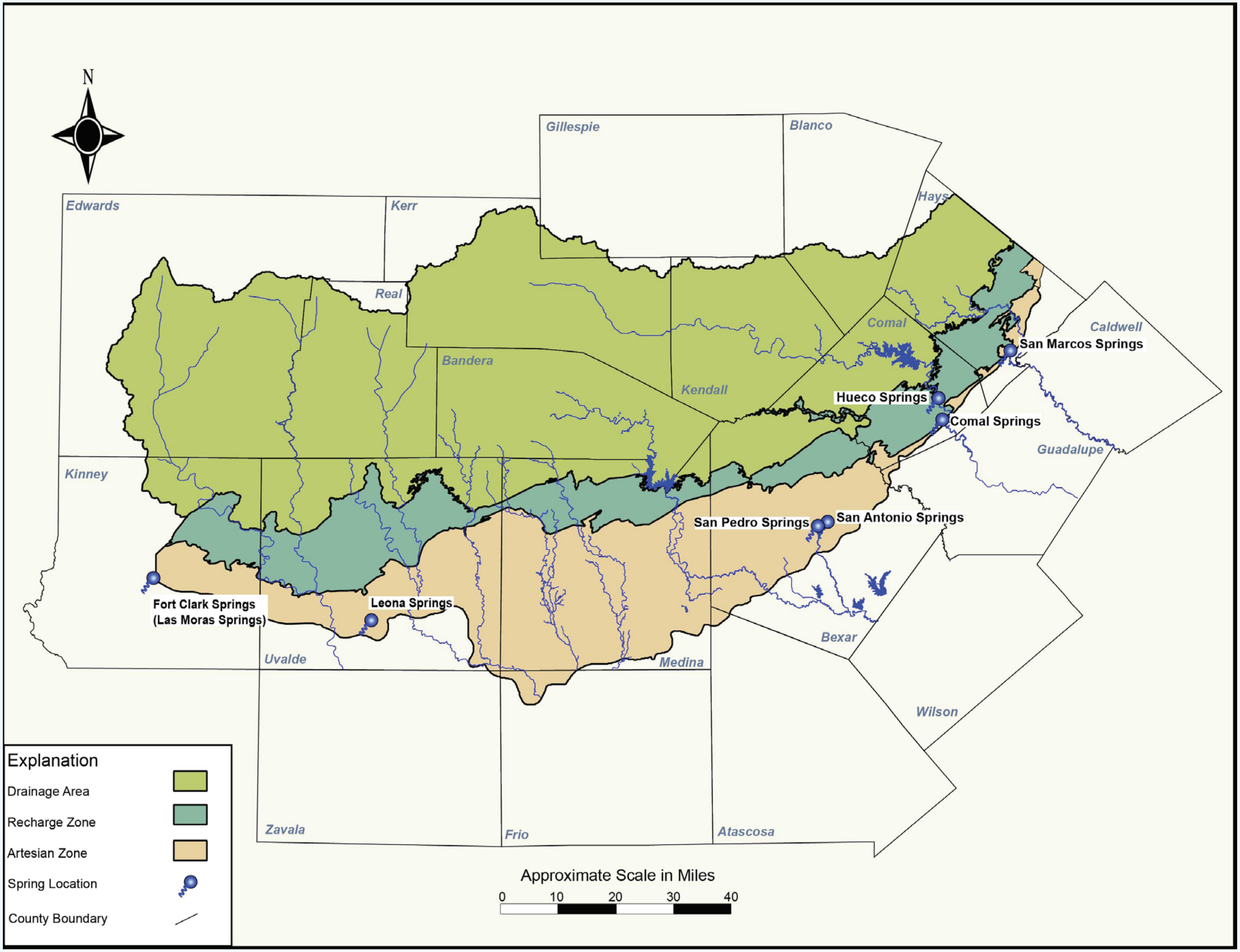
Groundwater discharges from the Edwards Aquifer as springflow or as pumping from wells. Comal and San Marcos springs, the largest and second-largest springs in Texas, respectively, are fed by the Edwards Aquifer. This springflow is the primary basis of the recreational economies in New Braunfels and San Marcos, and both springs provide habitat for threatened and endangered animal and plant species. Figure 9 shows locations of the major springs in the Edwards Aquifer region. Wells drilled into the Edwards Aquifer provide water for many diverse uses in south central Texas, including irrigation, municipal water supplies, industrial applications, and domestic/livestock consumption. The amount of groundwater discharged as springflow has historically been greater than the amount discharged through wells.

Estimates of annual total groundwater discharge from springflow and pumping for the Edwards Aquifer are provided in Table 7 for the period of record (1934–2013) by county. Annual total groundwater discharge estimates range from a low of 388,800 acre-feet in 1955 to a high of 1,130,000 acre-feet in 1992. In 2013, the total groundwater discharged from the Edwards Aquifer from wells and springs was estimated at 588,630 acre-feet.

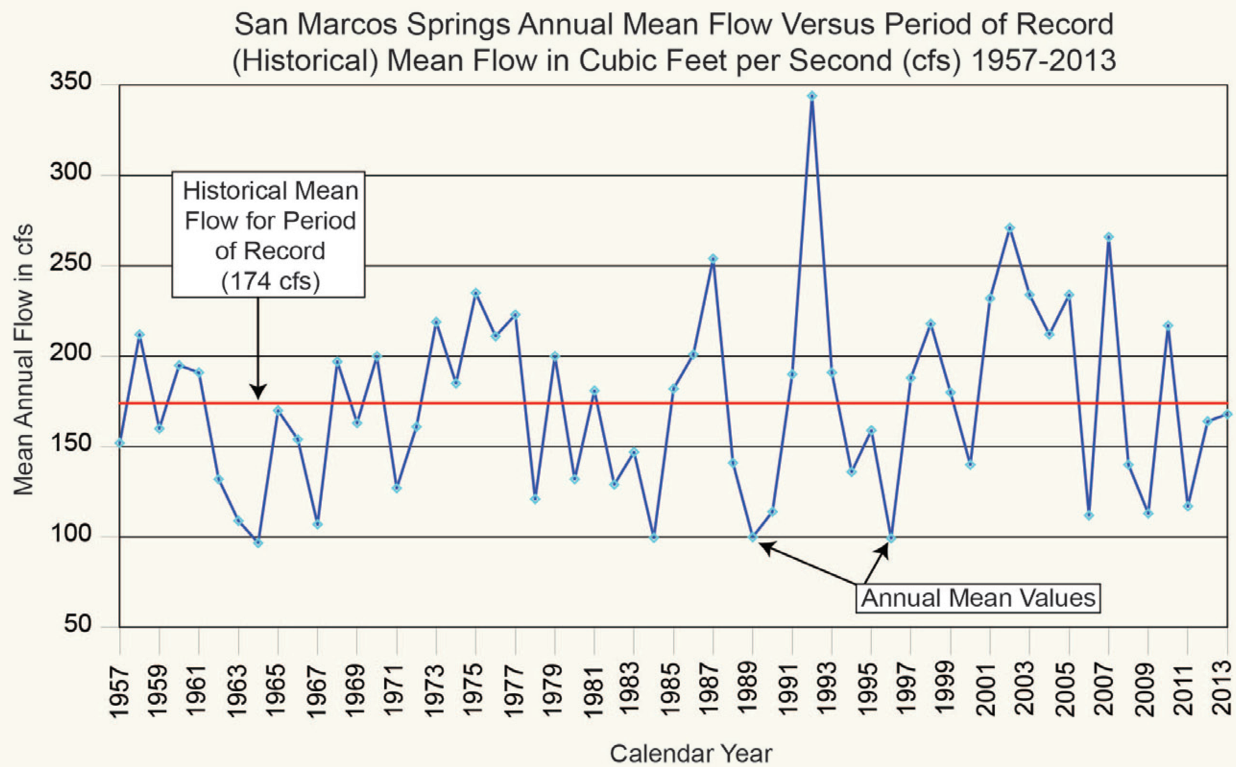
Springflow is calculated by measuring streamflow downstream of the springs and converting the streamflow measurements to spring discharge. Electronic data loggers are used to record streamflow at Leona, Hueco, Comal, and San Marcos springs, whereas periodic flow measurements are taken at San Pedro and San Antonio springs. Springflow from 1934 through 2013 varied from a low of 69,800 acre-feet in 1956 to a high of 802,800 acre-feet in 1992 (Table 7). Monthly springflow estimates for 2013 at each of the six major Edwards Aquifer springs is provided in Table 8. Total springflow from the Edwards Aquifer for 2013 was calculated at 232,806 acre-feet. Las Moras Springs flow is not measured by the EAA because it is outside the EAA's jurisdictional area. Furthermore, recent studies indicate that in Kinney County, groundwater contribution to the Uvalde or San Antonio pools of the Edwards Aquifer is limited.

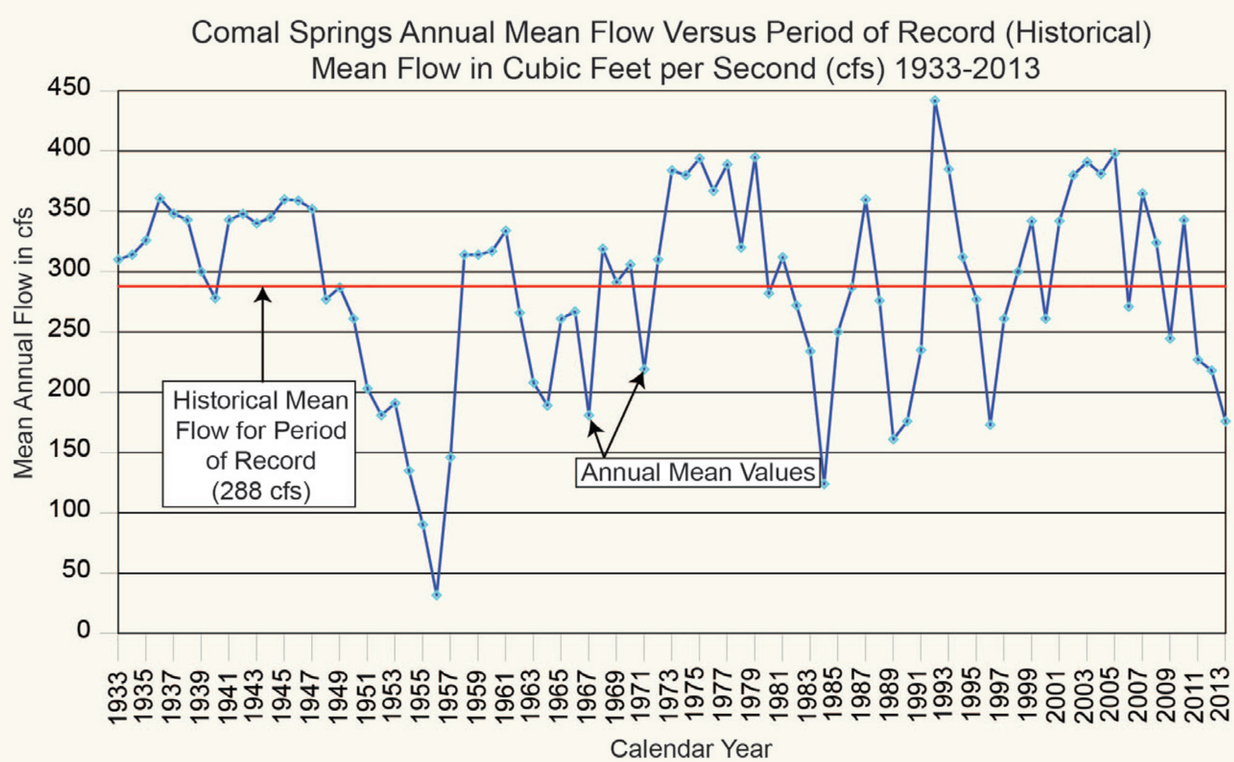
In Figure 10, flows at Comal and San Marcos springs are shown as annual flows in cubic feet per second (cfs) for each year of record, compared with mean flow for the entire period represented on the graph. Generally, wet years plot above the period of record mean line, whereas dry years plot below the line. For 2013, both springs had annual mean flow values below the period-of-record mean discharge.

## Figure 9. Major Springs in the Southern Segment of the Balcones Fault Zone Edwards Aquifer



## Figure 10. Annual Versus Period of Record Mean Springflow, San Marcos and Comal Springs



## Table 7. Annual Estimated Groundwater Discharge Data by County for Edwards Aquifer, 1934–2013 (measured in thousands of acre-feet).

| Year | Uvalde[a] | Medina | Bexar[b] | Comal[c] | Hays | Total | Total Wells | Total Springs |
|---|---|---|---|---|---|---|---|---|
| 1934 | 12.6 | 1.3 | 109.3 | 229.1 | 85.6 | 437.9 | 101.9 | 336.0 |
| 1935 | 12.2 | 1.5 | 171.8 | 237.2 | 96.9 | 519.6 | 103.7 | 415.9 |
| 1936 | 26.6 | 1.5 | 215.2 | 261.7 | 93.2 | 598.2 | 112.7 | 485.5 |
| 1937 | 28.3 | 1.5 | 201.8 | 252.5 | 87.1 | 571.2 | 120.2 | 451.0 |
| 1938 | 25.2 | 1.6 | 187.6 | 250.0 | 93.4 | 557.8 | 120.1 | 437.7 |
| 1939 | 18.2 | 1.6 | 122.5 | 219.4 | 71.1 | 432.8 | 118.9 | 313.9 |
| 1940 | 16.1 | 1.6 | 116.7 | 203.8 | 78.4 | 416.6 | 120.1 | 296.5 |
| 1941 | 17.9 | 1.6 | 197.4 | 250.0 | 134.3 | 601.2 | 136.8 | 464.4 |
| 1942 | 22.5 | 1.7 | 203.2 | 255.1 | 112.2 | 594.7 | 144.6 | 450.1 |
| 1943 | 19.2 | 1.7 | 172.0 | 249.2 | 97.2 | 539.3 | 149.1 | 390.2 |
| 1944 | 11.6 | 1.7 | 166.3 | 252.5 | 135.3 | 567.4 | 147.3 | 420.1 |
| 1945 | 12.4 | 1.7 | 199.8 | 263.1 | 137.8 | 614.8 | 153.3 | 461.5 |
| 1946 | 6.2 | 1.7 | 180.1 | 261.9 | 134.0 | 583.9 | 155.0 | 428.9 |
| 1947 | 13.8 | 2.0 | 193.3 | 256.8 | 127.6 | 593.5 | 167.0 | 426.5 |
| 1948 | 9.2 | 1.9 | 159.2 | 203.0 | 77.3 | 450.6 | 168.7 | 281.9 |
| 1949 | 13.2 | 2.0 | 165.3 | 209.5 | 89.8 | 479.8 | 179.4 | 300.4 |
| 1950 | 17.8 | 2.2 | 177.3 | 191.1 | 78.3 | 466.7 | 193.8 | 272.9 |
| 1951 | 16.9 | 2.2 | 186.9 | 150.5 | 69.1 | 425.6 | 209.7 | 215.9 |
| 1952 | 22.7 | 3.1 | 187.1 | 133.2 | 78.8 | 424.9 | 215.4 | 209.5 |
| 1953 | 27.5 | 4.0 | 193.7 | 141.7 | 101.4 | 468.3 | 229.8 | 238.5 |
| 1954 | 26.6 | 6.3 | 208.9 | 101.0 | 81.5 | 424.3 | 246.2 | 178.1 |
| 1955 | 28.3 | 11.1 | 215.2 | 70.1 | 64.1 | 388.8 | 261.0 | 127.8 |
| 1956 | 59.6 | 17.7 | 229.6 | 33.6 | 50.4 | 390.9 | 321.1 | 69.8 |
| 1957 | 29.0 | 11.9 | 189.4 | 113.2 | 113.0 | 456.5 | 237.3 | 219.2 |
| 1958 | 23.7 | 6.6 | 199.5 | 231.8 | 155.9 | 617.5 | 219.3 | 398.2 |
| 1959 | 43.0 | 8.3 | 217.5 | 231.7 | 118.5 | 619.0 | 234.5 | 384.5 |
| 1960 | 53.7 | 7.6 | 215.4 | 235.2 | 143.5 | 655.4 | 227.1 | 428.3 |
| 1961 | 56.5 | 6.4 | 230.3 | 249.5 | 140.8 | 683.5 | 228.2 | 455.3 |
| 1962 | 64.6 | 8.1 | 220.0 | 197.5 | 98.8 | 589.0 | 267.9 | 321.1 |
| 1963 | 51.4 | 9.7 | 217.3 | 155.7 | 81.9 | 516.0 | 276.4 | 239.6 |
| 1964 | 49.3 | 8.6 | 201.0 | 141.8 | 73.3 | 474.0 | 260.2 | 213.8 |
| 1965 | 46.8 | 10.0 | 201.1 | 194.7 | 126.3 | 578.9 | 256.1 | 322.8 |
| 1966 | 48.5 | 10.4 | 198.0 | 198.9 | 115.4 | 571.2 | 255.9 | 315.3 |
| 1967 | 81.1 | 15.2 | 239.7 | 139.1 | 82.3 | 557.4 | 341.3 | 216.1 |
| 1968 | 58.0 | 9.9 | 207.1 | 238.2 | 146.8 | 660.0 | 251.7 | 408.3 |
| 1969 | 88.5 | 13.6 | 216.3 | 218.2 | 122.1 | 658.7 | 307.5 | 351.2 |
| 1970 | 100.9 | 16.5 | 230.6 | 229.2 | 149.9 | 727.1 | 329.4 | 397.7 |
| 1971 | 117.0 | 32.4 | 262.8 | 168.2 | 99.1 | 679.5 | 406.8 | 272.7 |
| 1972 | 112.6 | 28.8 | 247.7 | 234.3 | 123.7 | 747.1 | 371.3 | 375.8 |
| 1973 | 96.5 | 14.9 | 273.0 | 289.3 | 164.3 | 838.0 | 310.4 | 527.6 |
| 1974 | 133.3 | 28.6 | 272.1 | 286.1 | 141.1 | 861.2 | 377.4 | 483.8 |
| 1975 | 112.0 | 22.6 | 259.0 | 296.0 | 178.6 | 868.2 | 327.8 | 540.4 |
| 1976 | 136.4 | 19.4 | 253.2 | 279.7 | 164.7 | 853.4 | 349.5 | 503.9 |
| 1977 | 156.5 | 19.9 | 317.5 | 295.0 | 172.0 | 960.9 | 380.6 | 580.3 |
| 1978 | 154.3 | 38.7 | 269.5 | 245.7 | 99.1 | 807.3 | 431.8 | 375.5 |
| 1979 | 130.1 | 32.9 | 294.5 | 300.0 | 157.0 | 914.5 | 391.5 | 523.0 |
| 1980 | 151.0 | 39.9 | 300.3 | 220.3 | 107.9 | 819.4 | 491.1 | 328.3 |
| 1981 | 104.2 | 26.1 | 280.7 | 241.8 | 141.6 | 794.4 | 387.1 | 407.3 |
| 1982 | 129.2 | 33.4 | 305.1 | 213.2 | 105.5 | 786.4 | 453.1 | 333.3 |
| 1983 | 107.7 | 29.7 | 277.6 | 186.6 | 118.5 | 720.1 | 418.5 | 301.6 |
| 1984 | 156.9 | 46.9 | 309.7 | 108.9 | 85.7 | 708.1 | 529.8 | 178.3 |
| 1985 | 156.9 | 59.2 | 295.5 | 200.0 | 144.9 | 856.5 | 522.5 | 334.0 |
| 1986 | 91.7 | 41.9 | 294.0 | 229.3 | 160.4 | 817.3 | 429.3 | 388.0 |
| 1987 | 94.9 | 15.9 | 326.6 | 286.2 | 198.4 | 922.0 | 364.1 | 557.9 |
| 1988 | 156.7 | 82.2 | 317.4 | 236.5 | 116.9 | 909.7 | 540.0 | 369.7 |

## (Table 7. continued)

| Year | Uvalde[a] | Medina | Bexar[b] | Comal[c] | Hays | Total | Total Wells | Total Springs |
|---|---|---|---|---|---|---|---|---|
| 1989 | 156.9 | 70.5 | 305.6 | 147.9 | 85.6 | 766.5 | 542.4 | 224.1 |
| 1990 | 118.1 | 69.7 | 276.8 | 171.3 | 94.1 | 730.0 | 489.4 | 240.6 |
| 1991 | 76.6 | 25.6 | 315.5 | 221.9 | 151.0 | 790.6 | 436.0 | 354.6 |
| 1992 | 76.5 | 9.3 | 370.5 | 412.4 | 261.3 | 1130.0 | 327.2 | 802.8 |
| 1993 | 107.5 | 17.8 | 371.0 | 349.5 | 151.0 | 996.7 | 407.3 | 589.4 |
| 1994 | 95.5 | 41.1 | 297.7 | 269.8 | 110.6 | 814.8 | 424.6 | 390.2 |
| 1995 | 90.8 | 35.2 | 272.1 | 235.0 | 127.8 | 761.0 | 399.6 | 361.3 |
| 1996 | 117.6 | 66.3 | 286.8 | 150.2 | 84.7 | 705.6 | 493.6 | 212.0 |
| 1997 | 77.0 | 31.4 | 260.2 | 243.3 | 149.2 | 761.1 | 377.1 | 383.9 |
| 1998 | 113.1 | 51.3 | 312.4 | 271.8 | 168.8 | 917.6 | 453.5 | 464.1 |
| 1999 | 104.0 | 49.2 | 307.1 | 295.5 | 143.0 | 898.8 | 442.7 | 456.1 |
| 2000 | 89.1 | 45.1 | 283.6 | 226.1 | 108.4 | 752.3 | 414.8 | 337.5 |
| 2001 | 68.6 | 33.9 | 291.6 | 327.7 | 175.4 | 890.0 | 367.7 | 529.6 |
| 2002 | 76.2 | 40.6 | 311.9 | 350.4 | 202.1 | 981.2 | 371.3 | 609.9 |
| 2003 | 89.4 | 34.8 | 331.7 | 344.7 | 176.3 | 976.9 | 362.1 | 621.5 |
| 2004 | 91.3 | 22.5 | 331.9 | 341.4 | 153.1 | 940.3 | 317.4 | 622.9 |
| 2005 | 107.4 | 37.3 | 366.1 | 349.3 | 175.6 | 1035.7 | 388.5 | 647.1 |
| 2006 | 107.5 | 64.9 | 289.5 | 216.7 | 87.9 | 766.5 | 454.5 | 312.0 |
| 2007 | 64.6 | 18.4 | 330.2 | 331.7 | 196.0 | 940.9 | 319.9 | 621.0 |
| 2008 | 102.0 | 48.8 | 320.4 | 266.6 | 108.0 | 845.7 | 428.6 | 417.1 |
| 2009 | 76.9 | 47.3 | 265.2 | 206.6 | 87.8 | 683.7 | 395.7 | 287.9 |
| 2010 | 53.1 | 36.4 | 298.5 | 312.1 | 162.5 | 862.6 | 372.6 | 490.0 |
| 2011 | 79.6 | 57.4 | 277.2 | 187.7 | 91.0 | 692.9 | 427.7 | 265.2 |
| 2012 | 57.6 | 44.3 | 267.5 | 193.4 | 124.2 | 687.0 | 384.7 | 302.3 |
| 2013 | 43.6 | 42.8 | 251.0 | 13.5 | 4.9 | 588.6 | 355.8 | 232.8 |
| **For period of record 1934–2013:** | | | | | | | | |
| Median | 76.4 | 17.8 | 256.1 | 233.1 | 117.7 | 690.0 | 328.6 | 379.9 |
| Mean | 72.5 | 23.4 | 248.6 | 227.6 | 121.3 | 696.2 | 315.1 | 381.3 |
| **For period of record 2003–2013 (last ten years):** | | | | | | | | |
| Median | 78.3 | 43.6 | 294.0 | 241.7 | 116.1 | 806.1 | 386.6 | 364.6 |
| Mean | 78.4 | 42.0 | 299.8 | 241.9 | 119.1 | 804.4 | 384.5 | 419.8 |

Data source: USGS and EAA files (2014).

a = As of 2008, no longer includes Kinney County discharge; prior years include 1,900 acre-feet of discharge for Kinney County.

b = Includes reports of Edwards Aquifer irrigators in Atascosa County.

c = Includes reports of Edwards Aquifer industrial and municipal users in Guadalupe County.

Differences in totals may occur as a result of rounding.

## Table 8. Estimated Spring Discharge from Edwards Aquifer, 2013 (measured in acre-feet).

| Month | Leona Springs and Leona River Underflow | San Pedro Springs | San Antonio Springs | Comal Springs | Hueco Springs | San Marcos Springs | Total Monthly Discharge from Springs |
|---|---|---|---|---|---|---|---|
| January | 78 | 8 | 0 | 13,500 | 772 | 7,380 | 21,788 |
| February | 50 | 3 | 0 | 12,180 | 415 | 6,350 | 18,998 |
| March | 5 | 0 | 0 | 12,530 | 469 | 6,660 | 19,664 |
| April | 0 | 0 | 0 | 11,610 | 507 | 6,400 | 18,517 |
| May | 0 | 13 | 0 | 11,970 | 1,380 | 6,390 | 19,753 |
| June | 0 | 27 | 0 | 12,010 | 1,710 | 7,180 | 20,927 |
| July | 0 | 0 | 0 | 10,250 | 516 | 6,980 | 17,746 |
| August | 0 | 0 | 0 | 7,740 | 67 | 6,580 | 14,387 |
| September | 0 | 0 | 0 | 7,110 | 466 | 6,130 | 13,706 |
| October | 0 | 0 | 0 | 8,900 | 1,840 | 7,180 | 17,920 |
| November | 0 | 0 | 0 | 9,990 | 3,700 | 12,600 | 26,290 |
| December | 0 | 0 | 0 | 9,990 | 1,830 | 11,380 | 23,110 |
| **Total** | **133** | **51** | **0** | **127,740** | **13,672** | **91,210** | **232,806** |

Data source: USGS unpublished report (2014).

For the purposes of this report, well discharge is either non-reported discharge or reported discharge. Non-reported discharge refers to use that does not require a groundwater withdrawal permit from the EAA, such as domestic, livestock, or federal facility use. Reported discharge refers to water pumped from the aquifer by a person or entity holding a groundwater withdrawal permit. These users, who are typically larger quantity users, meter their withdrawals and report the totals to the EAA. Non-reported discharge is estimated rather than metered. In 2013, total non-reported discharge was estimated at 19,190 acre-feet. Reported discharge totaled 336,634 acre-feet. As such, total estimated well discharge for the year was 355,824 acre-feet.

Table 9 provides a comprehensive summary of well and spring discharge information from the Edwards Aquifer for 2013. The table reports discharge that is based on type of use by county in acre-feet. Well discharge and springflow totals for the period of record are compared graphically in Figure 11, which shows the variability in well discharge and springflow over the period of record. Well discharge is generally highest in dry years, whereas springflow is highest in wet years. Figure 12 shows discharge that is based on percentages for wells versus springs and discharge by type of use for wells versus springs. Table 10 shows total discharge data by use for the period 1955–2013 for counties in the region.

In 2001, the EAA implemented a well-construction permitting system requiring a well-construction permit for all new wells drilled in the Edwards Aquifer. Well-construction permitting data were used to develop updated estimates for the domestic/livestock use category in Tables 7, 9, 10, and 12. On the basis of the permitted installation of 78 domestic/livestock wells in 2013, domestic/livestock use was increased by approximately 49.3 acre-feet for 2013. The estimated mean per-well domestic/livestock usage of 564 gallons per well per day is based on the methodology outlined in William F. Guyton Associates (1992). New domestic/livestock wells, by county, installed in calendar year 2013 are:

- Uvalde: 37 wells
- Medina: 27 wells
- Bexar: seven wells
- Comal: four wells
- Hays: three wells
- Atascosa, Caldwell, and Guadalupe: none

Reported withdrawal estimates, which are based on metered use throughout the region, provide the most accurate estimates of well discharge. Non-reported discharge estimates are generally less accurate than reported discharge because domestic and livestock numbers are not based on metered use. Prior to 1999, well-discharge estimates were provided to the EAA by

## Table 9. Comprehensive Discharge Summary for Calendar Year 2013 (in acre-feet).

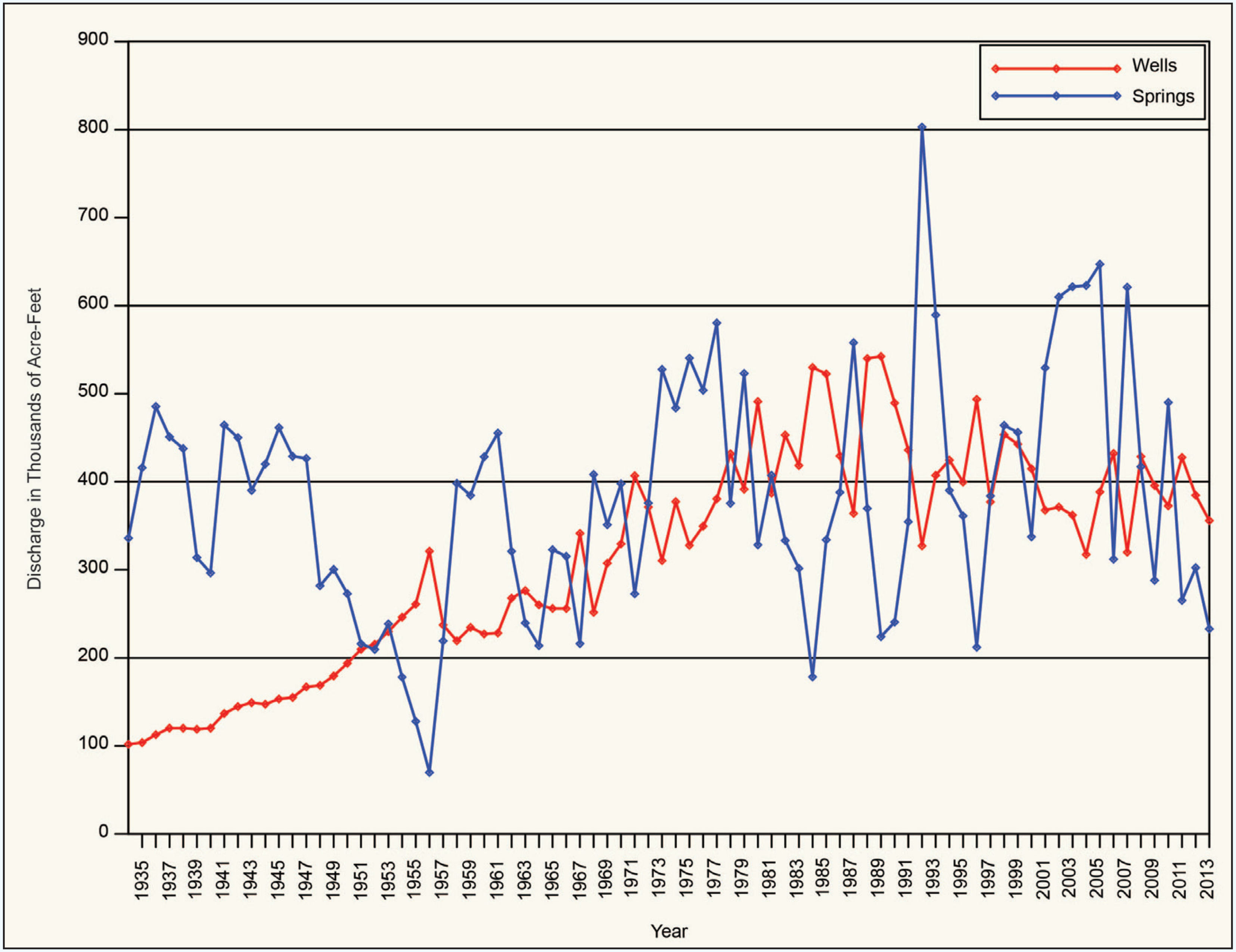
| | Reported Use (permitted wells) | | | Unreported Use | | | | |
|---|---|---|---|---|---|---|---|---|
| County | Irrigation | Municipal | Industrial | Domestic or Livestock* | Nonreporting Facilities* | Total Well Discharge | Spring Discharge | Total Wells and Springs |
| Atascosa | 1,208 | 0 | 0 | 0 | 0 | 1,208 | 0 | 1,208 |
| Bexar | 4,179 | 216,051 | 15,648 | 8,893 | 5,046** | 249,817 | 51 | 249,868 |
| Comal | 63 | 5,781 | 7,061 | 390 | 0 | 13,295 | 141,412 | 154,707 |
| Guadalupe | 0 | 69 | 167 | 0 | 0 | 236 | 0 | 236 |
| Hays | 177 | 2,341 | 1,292 | 858 | 195 | 4,863 | 91,210 | 96,073 |
| Medina | 33,755 | 5,911 | 2,007 | 1,089 | 0 | 42,762 | 0 | 42,762 |
| Uvalde | 36,959 | 3,870 | 95 | 2,510 | 209 | 43,643 | 133 | 43,776 |
| Totals | **76,341** | **234,023** | **26,270** | **13,740** | **5,450** | **355,824** | **232,806** | **588,630** |

* Federal facilities, domestic and livestock wells do not report annual use (non-reporting); quantities estimated. Differences in totals may occur as a result of rounding.

** Estimated

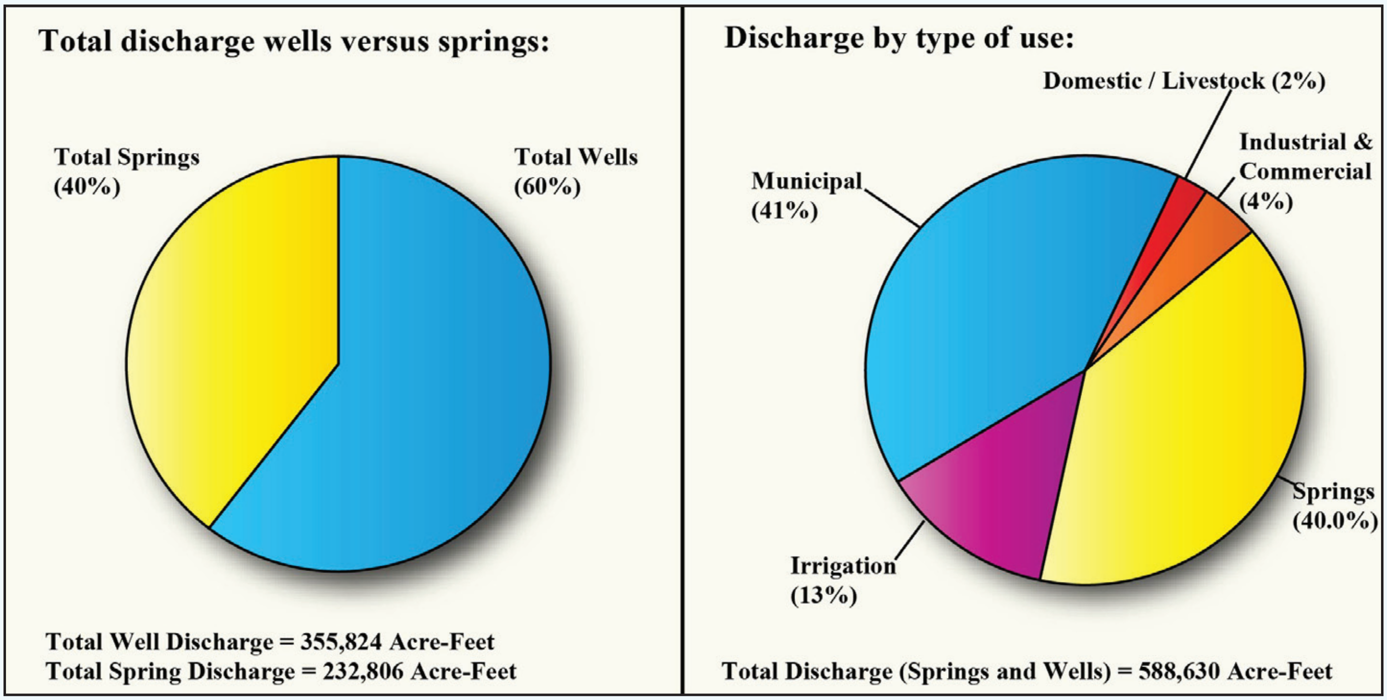
*(continued on p. 35)*

Figure 11. Groundwater Pumping Compared with Springflow from the Edwards Aquifer, 1934–2013 (measured in thousands of acre-feet)



the USGS as estimates that were based on various methodologies representing the best available technology at the time. However, in 1998 the EAA adopted rules requiring all irrigation, industrial, and municipal wells to be metered, which improved estimates of well discharge from 1999 forward. Tables 11 and 12 show reported withdrawals (actual metered discharge from wells) within the jurisdictional area of the EAA. Table 11 summarizes actual reported groundwater withdrawal totals by year and type of use. Table 12 summarizes actual reported groundwater withdrawals by county and type of use, as well as estimated domestic use and measured springflows for calendar years 1999 through 2013.

**Figure 12. Distribution of Total Discharge from the Edwards Aquifer by Springs and Wells for Calendar Year 2013**



## Table 10. Annual Estimated Edwards Aquifer Groundwater Discharge by Use, 1955–2013 (measured in thousands of acre-feet).

| Year | Irrigation | Municipal | Domestic/ Stock | Industrial/ Commercial | Springs |
|---|---|---|---|---|---|
| 1955 | 85.2 | 120.5 | 30.1 | 25.1 | 127.8 |
| 1956 | 127.2 | 138.3 | 28.9 | 22.4 | 69.8 |
| 1957 | 68.8 | 116.1 | 29.8 | 22.6 | 219.2 |
| 1958 | 47.2 | 113.7 | 33.4 | 25.1 | 398.2 |
| 1959 | 60.0 | 118.9 | 31.5 | 24.2 | 384.5 |
| 1960 | 54.9 | 121.1 | 29.1 | 23.3 | 428.3 |
| 1961 | 52.1 | 124.5 | 29.6 | 22.2 | 455.3 |
| 1962 | 72.7 | 143.7 | 28.8 | 22.8 | 321.1 |
| 1963 | 75.4 | 151.8 | 27.8 | 21.8 | 239.6 |
| 1964 | 72.6 | 140.2 | 26.3 | 21.7 | 213.8 |
| 1965 | 68.0 | 138.8 | 27.0 | 22.3 | 322.8 |
| 1966 | 68.2 | 141.8 | 23.3 | 22.6 | 315.3 |
| 1967 | 119.4 | 171.0 | 25.1 | 25.8 | 216.1 |
| 1968 | 59.3 | 146.9 | 25.5 | 20.0 | 408.3 |
| 1969 | 95.2 | 162.0 | 29.2 | 21.1 | 351.2 |
| 1970 | 110.1 | 167.5 | 29.3 | 22.5 | 397.7 |
| 1971 | 159.4 | 196.2 | 28.6 | 22.6 | 272.7 |
| 1972 | 128.8 | 190.5 | 30.8 | 21.1 | 375.8 |
| 1973 | 82.2 | 177.1 | 32.3 | 18.8 | 527.6 |
| 1974 | 140.4 | 174.6 | 33.5 | 15.1 | 483.3 |
| 1975 | 96.4 | 182.5 | 33.6 | 15.3 | 540.4 |
| 1976 | 118.2 | 182.1 | 34.6 | 14.7 | 503.9 |
| 1977 | 124.2 | 205.3 | 38.1 | 13.0 | 580.3 |
| 1978 | 165.8 | 214.2 | 40.3 | 11.5 | 375.5 |
| 1979 | 126.8 | 208.9 | 40.7 | 15.2 | 523.0 |
| 1980 | 177.9 | 256.2 | 43.3 | 13.7 | 328.3 |
| 1981 | 101.8 | 231.8 | 40.9 | 12.6 | 407.3 |
| 1982 | 130.0 | 268.6 | 39.5 | 15.0 | 333.3 |
| 1983 | 115.9 | 249.2 | 38.8 | 14.7 | 301.5 |
| 1984 | 191.2 | 287.2 | 36.2 | 15.2 | 178.3 |
| 1985 | 203.1 | 263.7 | 39.2 | 16.5 | 334.0 |
| 1986 | 104.2 | 266.3 | 42.0 | 16.8 | 388.0 |
| 1987 | 40.9 | 260.9 | 43.5 | 18.7 | 557.9 |
| 1988 | 193.1 | 286.2 | 41.9 | 18.8 | 369.7 |
| 1989 | 196.2 | 285.2 | 38.2 | 22.9 | 224.1 |
| 1990 | 172.9 | 254.9 | 37.9 | 23.7 | 240.6 |
| 1991 | 88.5 | 240.5 | 39.5 | 67.5 | 354.6 |
| 1992 | 27.1 | 236.5 | 34.8 | 29.0 | 802.8 |
| 1993 | 69.3 | 252.0 | 49.9 | 36.1 | 589.4 |
| 1994 | 104.5 | 247.0 | 33.9 | 39.3 | 390.2 |
| 1995 | 95.6 | 255.0 | 11.6 | 37.3 | 361.3 |
| 1996 | 181.3 | 261.3 | 12.3 | 38.8 | 212.0 |
| 1997 | 77.4[a, b] | 253.0 | 12.3 | 34.4 | 383.9 |
| 1998 | 131.9[a] | 266.5 | 13.4 | 41.7[b] | 464.1 |
| 1999 | 113.6 | 273.3 | 13.4 | 42.4 | 456.1 |
| 2000 | 106.3 | 261.3 | 13.4 | 33.8 | 337.5 |
| 2001 | 79.0 | 245.9 | 13.4 | 29.4 | 529.4 |
| 2002 | 97.1 | 228.4 | 13.6 | 32.3 | 609.9 |
| 2003 | 79.6 | 237.2 | 13.7 | 31.7 | 621.5 |
| 2004 | 55.4 | 220.3 | 13.8 | 28.1 | 622.9 |
| 2005 | 85.3 | 255.1 | 13.8 | 34.3 | 647.1 |
| 2006 | 149.1 | 259.1 | 13.8 | 34.5 | 312.0 |
| 2007 | 42.5 | 236.0 | 13.8 | 27.6 | 620.6 |
| 2008 | 112.7 | 273.6 | 13.5** | 28.8 | 417.1 |
| 2009 | 108.9 | 247.5 | 13.6** | 25.7 | 288.0 |
| 2010 | 72.7 | 259.9 | 13.6** | 26.4 | 490.0 |
| 2011 | 124.9 | 265.5 | 13.6** | 23.6 | 265.2 |
| 2012 | 90.6 | 257.9 | 13.7** | 22.6 | 302.3 |
| 2013 | 76.3 | 239.5 | 13.7** | 26.3 | 232.8 |
| **For period of record 1955–2013:** | | | | | |
| Median | 97.1 | 236.5 | 29.2 | 22.8 | 375.8 |
| Mean | 104.7 | 214.1 | 27.5 | 25.0 | 390.3 |
| **For period of record 2004–2013 (last ten years):** | | | | | |
| Median | 88.0 | 256.5 | 13.7 | 27.0 | 364.6 |
| Mean | 91.8 | 251.4 | 13.7 | 27.8 | 419.8 |

Data source: USGS unpublished report and EAA files (2014).

a = Includes estimates from Atascosa County discharge by Edwards Aquifer users.

b = Includes estimates from Guadalupe County discharge by Edwards Aquifer users.

* = In 1995 the USGS revised the method of calculation domestic/livestock pumpage, which significantly decreased the estimate for 1995 and 1996.

** = Revision based on number of new wells permitted annually and discontinuation of Kinney County estimates in total.

Differences in totals may occur as a result of rounding.

## Table 11. Groundwater Withdrawals Attributed to Permit Holders (Reported Withdrawals) and Type of Use within EAA Jurisdictional Area, 1999–2013 (in acre-feet).

| Year | Industrial/ Commercial | Irrigation | Municipal | Total |
|---|---|---|---|---|
| 1999 | 42,933 | 109,156 | 277,101 | 429,190 |
| 2000 | 33,473 | 104,970 | 260,291 | 398,734 |
| 2001 | 30,307 | 78,088 | 250,781 | 359,176 |
| 2002 | 32,328 | 96,445 | 227,362 | 356,135 |
| 2003 | 31,688 | 79,015 | 229,455 | 340,158 |
| 2004 | 28,072 | 54,793 | 212,630 | 295,495 |
| 2005 | 34,327 | 84,733 | 247,344 | 366,404 |
| 2006 | 34,472 | 148,480 | 251,390 | 434,342 |
| 2007 | 27,575 | 41,864 | 228,121 | 297,559 |
| 2008 | 28,815 | 112,708 | 266,655 | 408,178 |
| 2009 | 25,326 | 108,886 | 243,043 | 377,255 |
| 2010 | 26,187 | 72,690 | 255,204 | 354,081 |
| 2011 | 23,393 | 124,905 | 260,332 | 408,630 |
| 2012 | 22,560 | 90,557 | 252,550 | 365,668 |
| 2013 | 26,270 | 6,341 | 234,023 | 336,634 |

Data source: Unpublished EAA files (2014).

## Table 12. Groundwater Discharge Attributed to Permit Holders (Reported Withdrawals) by Type of Use, Domestic Use, and Springflow within EAA Jurisdictional Area by County, 1999–2013 (reported in acre-feet).

### Uvalde County

| Year | Domestic Stock Use | Industrial/ Commercial | Irrigation | Municipal | Total Well Use | Spring-flow |
|---|---|---|---|---|---|---|
| 1999 | 2,300 | 2,046 | 58,857 | 7,106 | 70,309 | 33,100 |
| 2000 | 2,300 | 1,636 | 57,910 | 7,137 | 68,983 | 19,100 |
| 2001 | 2,300 | 921 | 43,160 | 4,790 | 51,171 | 51,200 |
| 2002 | 2,333 | 624 | 54,855 | 4,361 | 62,173 | 12,200 |
| 2003 | 2,369 | 488 | 44,765 | 4,023 | 51,645 | 35,900 |
| 2004 | 2,386 | 218 | 34,364 | 3,834 | 40,802 | 48,700 |
| 2005 | 2,400 | 940 | 46,428 | 4,248 | 54,016 | 51,570 |
| 2006 | 2,346 | 307 | 79,076 | 5,250 | 86,979 | 20,480 |
| 2007 | 2,411 | 198 | 26,090 | 3,728 | 32,427 | 30,290 |
| 2008 | 2,422 | 126 | 63,715 | 4,768 | 71,031 | 30,937 |
| 2009 | 2,430 | 107 | 58,814 | 4,797 | 66,148 | 10,530 |
| 2010 | 2,442 | 119 | 38,118 | 3,975 | 44,654 | 8,249 |
| 2011 | 2,457 | 151 | 68,171 | 4,862 | 75,641 | 3,949 |
| 2012 | 2,487 | 143 | 49,163 | 4,356 | 56,149 | 1,498 |
| 2013 | 2,510 | 95 | 36,959 | 4,080 | 43,643 | 133 |

### Medina County

| Year | Domestic Stock Use | Industrial/ Commercial | Irrigation | Municipal | Total Well Use | Spring-flow |
|---|---|---|---|---|---|---|
| 1999 | 900 | 1,354 | 39,004 | 7,727 | 48,985 | na |
| 2000 | 900 | 839 | 36,759 | 6,564 | 45,062 | na |
| 2001 | 900 | 768 | 26,407 | 6,433 | 34,508 | na |
| 2002 | 925 | 1,050 | 33,112 | 5,497 | 40,584 | na |
| 2003 | 947 | 727 | 27,217 | 5,922 | 34,813 | na |
| 2004 | 971 | 731 | 15,148 | 5,738 | 22,588 | na |
| 2005 | 985 | 1,295 | 29,066 | 5,957 | 37,303 | na |
| 2006 | 1,002 | 1,421 | 55,372 | 7,089 | 64,884 | na |
| 2007 | 1,017 | 550 | 11,180 | 5,651 | 18,398 | na |
| 2008 | 1,033 | 1,327 | 40,185 | 6,290 | 48,835 | na |
| 2009 | 1,046 | 1,456 | 38,348 | 6,409 | 47,259 | na |
| 2010 | 1,052 | 1,210 | 28,478 | 5,860 | 36,600 | na |
| 2011 | 1,063 | 1,978 | 47,608 | 6,740 | 57,389 | na |
| 2012 | 1,072 | 2,018 | 35,137 | 6,104 | 44,331 | na |
| 2013 | 1,089 | 2,007 | 33,755 | 5,911 | 42,762 | NA |

### Bexar County

| Year | Domestic Stock Use | Industrial/ Commercial | Irrigation | Municipal | Total Well Use | Spring-flow |
|---|---|---|---|---|---|---|
| 1999 | 8,800 | 25,464 | 9,421 | 241,437 | 285,122 | 17,400 |
| 2000 | 8,800 | 21,849 | 8,903 | 233,983 | 273,535 | 3,400 |
| 2001 | 8,814 | 20,192 | 7,229 | 227,370 | 263,605 | 29,400 |
| 2002 | 9,000 | 20,084 | 7,633 | 205,897 | 242,614 | 68,600 |
| 2003 | 8,833 | 19,692 | 6,157 | 209,972 | 244,654 | 86,200 |
| 2004 | 8,849 | 18,608 | 4,849 | 195,462 | 227,768 | 97,000 |
| 2005 | 8,855 | 23,418 | 7,942 | 227,544 | 267,759 | 90,270 |
| 2006 | 8,861 | 24,654 | 11,716 | 228,757 | 273,988 | 6,650 |
| 2007 | 8,870 | 19,330 | 3,902 | 211,083 | 243,185 | 79,600 |
| 2008 | 8,875 | 19,231 | 7,265 | 244,622 | 279,993 | 32,292 |
| 2009 | 8,879 | 16,766 | 10,233 | 221,633 | 257,511 | 2,045 |
| 2010 | 8,883 | 17,882* | 5,107 | 236,185 | 268,057* | 25,028 |
| 2011 | 8,885 | 15,269 | 7,436 | 237,620 | 269,210 | 1,624 |
| 2012 | 8,889 | 14,165 | 4,703 | 237,954 | 265,711 | 516 |
| 2013 | 8,893 | 15,648 | 4,179 | 221,097 | 249,817 | 51 |

### Comal County

| Year | Domestic Stock Use | Industrial/ Commercial | Irrigation | Municipal | Total Well Use | Spring-flow |
|---|---|---|---|---|---|---|
| 1999 | 300 | 12,242 | 129 | 10,511 | 23,182 | 275,300 |
| 2000 | 300 | 7,514 | 137 | 7,733 | 15,684 | 213,400 |
| 2001 | 300 | 6,556 | 44 | 7,289 | 14,189 | 316,700 |
| 2002 | 315 | 8,533 | 55 | 8,093 | 16,996 | 333,200 |
| 2003 | 325 | 9,549 | 92 | 4,174 | 14,140 | 330,400 |
| 2004 | 339 | 7,421 | 41 | 3,658 | 11,459 | 329,800 |

## (Table 12. continued)

### (Comal County continued)

| Year | Domestic Stock Use | Industrial/ Commercial | Irrigation | Municipal | Total Well Use | Spring-flow |
|---|---|---|---|---|---|---|
| 2005 | 347 | 7,528 | 57 | 5,275 | 13,207 | 335,910 |
| 2006 | 356 | 6,925 | 53 | 5,362 | 12,696 | 203,990 |
| 2007 | 363 | 6,281 | 15 | 4,092 | 10,751 | 320,643 |
| 2008 | 369 | 6,563 | 61 | 6,463 | 13,456 | 252,766 |
| 2009 | 375 | 5,409 | 65 | 6,620 | 12,469 | 193,740 |
| 2010 | 378 | 5,486* | 33 | 5,782 | 11,679* | 300,060 |
| 2011 | 383 | 4,296 | 72 | 7,880 | 12,631 | 174,684 |
| 2012 | 387 | 4,849 | 78 | 6,235 | 11,549 | 181,704 |
| 2013 | 390 | 7,061 | 63 | 5,781 | 13,295 | 141,412 |

### Hays County

| Year | Domestic Stock Use | Industrial/ Commercial | Irrigation | Municipal | Total Well Use | Spring-flow |
|---|---|---|---|---|---|---|
| 1999 | 800 | 1,646 | 19 | 10,320 | 11,985 | 130,300 |
| 2000 | 800 | 1,447 | 57 | 4,874 | 6,378 | 101,600 |
| 2001 | 800 | 1,650 | 77 | 4,899 | 6,626 | 167,900 |
| 2002 | 814 | 1,851 | 61 | 3,479 | 5,391 | 195,900 |
| 2003 | 825 | 1,050 | 107 | 5,324 | 6,481 | 169,000 |
| 2004 | 830 | 910 | 54 | 3,900 | 4,864 | 147,400 |
| 2005 | 833 | 928 | 120 | 4,320 | 5,368 | 169,400 |
| 2006 | 837 | 1,123 | 123 | 4,932 | 6,186 | 80,910 |
| 2007 | 841 | 1,066 | 139 | 3,413 | 4,618 | 190,510 |
| 2008 | 843 | 1,332 | 314 | 4,380 | 6,026 | 105,152 |
| 2009 | 845 | 1,378 | 275 | 3,423 | 5,921 | 81,660 |
| 2010 | 850 | 1,293 | 244 | 3,252 | 5,639 | 156,680 |
| 2011 | 854 | 1,482 | 384 | 3,097 | 5,817 | 84,960 |
| 2012 | 856 | 1,357 | 215 | 3,115 | 5,543 | 118,630 |
| 2013 | 858 | 1,292 | 177 | 2,535 | 4,862 | 91,210 |

### Guadalupe County

| Year | Domestic Stock Use | Industrial/ Commercial | Irrigation | Municipal | Total Well Use | Spring-flow |
|---|---|---|---|---|---|---|
| 1999 | na | 181 | 0 | 0 | 181 | 0 |
| 2000 | na | 188 | 0 | 0 | 188 | 0 |
| 2001 | na | 220 | 0 | 0 | 220 | 0 |
| 2002 | na | 186 | 0 | 35 | 221 | 0 |
| 2003 | na | 182 | 0 | 40 | 222 | 0 |
| 2004 | na | 184 | 0 | 38 | 222 | 0 |
| 2005 | na | 218 | 0 | 0 | 218 | 0 |
| 2006 | na | 42 | 6 | 0 | 48 | 0 |
| 2007 | na | 151 | 1 | 153 | 305 | 0 |
| 2008 | na | 236 | 3 | 132 | 371 | 0 |
| 2009 | na | 210 | 1 | 161 | 372 | 0 |
| 2010 | na | 197 | 1 | 150 | 348 | 0 |
| 2011 | na | 216 | 1 | 132 | 349 | 0 |
| 2012 | na | 28 | 1 | 114 | 143 | 0 |
| 2013 | NA | 167 | 0 | 69 | 236 | 0 |

### Atascosa County

| Year | Domestic Stock Use | Industrial/ Commercial | Irrigation | Municipal | Total Well Use | Spring-flow |
|---|---|---|---|---|---|---|
| 1999 | na | 0 | 1,726 | 0 | 1,726 | 0 |
| 2000 | na | 0 | 1,204 | 0 | 1,204 | 0 |
| 2001 | na | 0 | 1,171 | 0 | 1,171 | 0 |
| 2002 | na | 0 | 729 | 0 | 729 | 0 |
| 2003 | na | 0 | 677 | 0 | 677 | 0 |
| 2004 | na | 0 | 337 | 0 | 337 | 0 |
| 2005 | na | 0 | 1,120 | 0 | 1,120 | 0 |
| 2006 | na | 0 | 2,125 | 0 | 2,125 | 0 |
| 2007 | na | 0 | 537 | 0 | 537 | 0 |
| 2008 | na | 0 | 1,165 | 0 | 1,165 | 0 |
| 2009 | na | 0 | 1,150 | 0 | 1,150 | 0 |
| 2010 | na | 0 | 709 | 0 | 709 | 0 |
| 2011 | na | 0 | 1,233 | 0 | 1,233 | 0 |
| 2012 | na | 0 | 1,259 | 0 | 1,259 | 0 |
| 2013 | NA | 0 | 1,208 | 0 | 1,208 | 0 |

Data source: Unpublished EAA files (2014).
na = Not applicable or no information.
Domestic/Stock Use estimates incorporate new wells on the basis of drilling permits beginning in 2002, discharge quantity adjusted yearly afterward.
Total Well Use includes only categories of well use listed in table (Domestic/Stock, Municipal, Industrial, and Irrigation).

# WATER QUALITY

The EAA and its predecessor agency, the EUWD, in cooperation with the USGS and TWDB, have conducted a program of water quality data collection since 1968. Analyses of these data have been used by the EAA to assess aquifer water quality.

Each year the EAA monitors the quality of water in the aquifer by sampling wells, springs, and streams across the region. Analyses of these data enable the EAA to assess water quality before it enters the aquifer. Five major spring groups are sampled annually on a quarterly or more frequent basis, depending on springflows: San Antonio, San Pedro, Hueco, Comal, and San Marcos springs. The EAA occasionally collects additional samples from other springs in the region. For example, in 2013, the EAA also collected samples from Las Moras (Fort Clark) Spring in Kinney County and from a spring in Government Canyon State Natural Area in Bexar County.

Because of the large areal extent of the aquifer, the large number of wells, and the distance between wells, the annual data set provides only limited resolution with regard to aquiferwide conditions. Therefore, the sampling program provides a representative "snapshot" of water quality conditions relative to the location, time, and date the sample was collected. As such, some sample locations are sampled at a greater frequency than in the past so that resolution of the water quality data set might improve over time. In 2013, the EAA sampled 73 wells, five spring groups, and ten streams. Many of the wells, springs, and surface waters were sampled multiple times so that temporal changes in water quality might be evaluated at select locations. The EAA water quality program includes testing for a variety of different types of compounds. Whereas not all sample points were tested for each of the analyses listed below, cumulative results of the annual testing program are intended to be representative of general water quality across the region. Analytical testing for the following compounds was performed: bacteria, nutrients, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), metals, pesticides, herbicides, and polychlorinated biphenyls (PCBs), as well as analyses for pharmaceuticals and personal care products (PPCPs) at a limited number of locations.

Although most sample results did not indicate anthropogenic impacts at the sample point, some compounds of concern were detected at what are considered low levels at various locations. In wells, the compounds detected with the highest frequency were SVOCs and VOCs. None of the VOC detections was at a concentration in excess of a regulatory standard. SVOC detections that are not suspected of being post-collection contaminants were also detected at concentrations far below regulatory standards. Well samples collected for herbicides and pesticides resulted in one detection, again below the regulatory standard. Nitrate sampling in wells resulted in four wells testing positive for elevated nitrates (above five milligrams per liter, or mg/L). The regulatory standard for nitrate as N is ten mg/L. Several metals were noted above the regulatory standard at seven different wells across the region.

Samples collected at springs indicated some detections of VOCs, SVOCs, herbicides, pesticides, and a few metals. Samples analyzed for VOCs had two positive results out of 74 spring samples collected, and these detections were below the associated regulatory standards. Of the 74 spring samples collected for SVOC analyses, 45 detections were noted; however, all of these detections were for phthalate compounds—most, if not all of which were probable post-collection contaminants. Analyses for PCBs did not indicate the presence of any PCB compounds in the 74 spring samples collected and analyzed. Herbicide and pesticide compounds were detected in four of the 74 samples collected at springs. All compounds were reported at extremely low levels, and none of the herbicide and pesticide detections exceeded regulatory standards. The metal thallium was detected above the regulatory standard in three of the 74 samples collected at springs during 2013.

Samples collected at surface water sites across the region are generally not tested for VOC compounds because of the low probability of these compounds being detected in normal surface water. However, four of the 12 surface water sample locations from 2013 were tested for VOC compounds, and no VOC detections were reported. Samples were collected for SVOCs in all 12 surface water sample locations, resulting in one detection. Analyses for PCBs in surface waters indicated no detections in the 19 samples collected across the 12 surface water sample locations. Surface water analyses indicated no herbicide or pesticide compounds in the 19 samples collected.

PPCP sampling performed in 2013 provided additional insight into the presence of these compounds in groundwater, surface water, and springflow. At the 13 sample sites tested for PPCPs in 2013, 17 compounds were detected. Unlike other analyses discussed herein, PPCP compounds are analyzed at the nanogram per liter (ng/L) level, (parts per trillion). Consequently, all detections were at extremely low levels. The types of compounds detected were generally trace quantities of antibiotics, estrogen compounds, caffeine, nicotine metabolites, and other medications.

Water quality sample locations are shown in Figures 13a–e. Spring and stream samples are discussed in detail in the following section.

Sample-Collection Summary Calendar Year 2013

Bacteria Samples

- 83 samples collected at 73 wells
- 71 samples collected at five spring groups
- 19 samples collected from ten streams

Metals Samples

- 78 samples collected at 62 wells
- 74 samples collected at five spring groups
- 19 samples collected from ten streams

Nitrate-Nitrite as Nitrogen

- 91 samples collected at 72 wells
- 74 samples collected at five spring groups
- 19 samples collected from ten streams

Volatile Organic Compounds

- 91 samples collected at 72 wells
- 74 samples collected at five spring groups
- Four samples collected from two streams

Semivolatile Organic Compounds

- 69 samples collected at 52 wells
- 73 samples collected at five spring groups
- 19 samples collected from ten streams

Pesticide and/or Herbicide Compounds

- 50 samples collected at 49 wells
- 73 samples collected at five spring groups
- 20 samples collected from ten streams

Polychlorinated Bi-Phenyls

- 32 samples collected at 32 wells
- 72 samples collected at five spring groups
- 16 samples collected from nine streams

Pharmaceuticals and Personal Care Products

- Five samples collected at five wells
- Four samples collected at four spring groups
- Five samples collected from four streams

For water quality samples, a general listing of the parameters analyzed, their drinking-water standards, and typical concentrations in the Edwards Aquifer are listed in Table 13. Routine water quality data collected from wells in 2013 are listed in Appendix C, Tables C-1 through C-7. Routine water quality data collected from streams and springs in 2013 are listed in Appendix C, Tables C-8 through C-14. Results for PPCP compounds for wells, springs, and surface water are listed in Table C-15. These tables are available at http://www.edwardsaquifer.org/scientific-research-and-reports/hydrologic-data-reports. As applicable, analytical results discussed herein are compared with water quality standards to determine whether any concentrations exceed health-based levels. For samples taken from locations such as private or municipal wells, a copy of analytical results for the location was forwarded to the owner or appropriate entity as a courtesy for allowing the EAA access to these locations.

**Primary Drinking-Water Standards**—Primary drinking-water standards are enforceable for public water supply systems and are also referred to as maximum contaminant levels (MCLs). The MCL for a contaminant is the maximum permissible level in water that is delivered to any user of a public water system. MCLs protect drinking water quality by limiting levels of specific contaminants

*(continued on page 47)*

## Table 13. Comparison of Drinking-Water Quality Standards with Range of Concentrations from Water Quality Results, 2013.

| Parameter and Method | Maximum Contaminant Levels or Secondary Standards | Range of Concentrations Detected in 2013 | Typical Range of Concentrations for the Freshwater Edwards Aquifer |
|---|---|---|---|
| **Field** | | | |
| Temperature (**˚C**) EPA 170.1 | NE | 14.2–32.06 | 20–23 |
| pH measured at 25 ˚C EPA 150.1 | >7.0* | 6.64–7.73 | 6.5–8.0 |
| Turbidity **(NTU)** | NE | 0.05–42.4 | 0.05–2 |
| Dissolved oxygen (DO) **(mg/L)** | NE | 0.21–11.37 | 2–4 |
| Alkalinity total as $CACO_3$ SM 2320 B **(mg/L)** | NE | 190–480 | 200–400 |
| Specific conductance uS/cm | NE | 404–990 | 500–600 |
| | | | |
| **Laboratory** | | | |
| Alkalinity total as $CACO_3$ SM 2320 B | NE | 99–590 | 200–400 |
| Bicarbonate ($HCO_3$) SM 2320 B | NE | 99–590 | 200–400 |
| Carbonate (CO3) SM 2320B | NE | ND–112 | ND |
| E. Coli (MPN/100 mL) | 0 MCLG[1] | <1-3–700 | 0–3 |
| pH measured at 25 ˚C EPA 150.1 | >7.0* | 6.45–8.28 | 6.5–8.0 |
| Specific conductance uS/cm | NE | 432–884 | 500–600 |
| | | | |
| **Nutrients (mg/L)** | | | |
| Nitrate as N E300 | 10 | ND–19.7 | ND–2.5 |
| Orthophosphate EPA 365.3 | NE | <0.02–0.023 | ND–0.03 |
| Ammonia as N SM 4500 | NE | ND–0.373 | ND |
| Phosphorus | NE | ND–1.71 | ND |
| | | | |
| **Major Ions (mg/L)** | | | |
| Sulfate ($SO_4$) EPA 300.0 | 300* | 3.79–136 | 30–60 |
| Solids total dissolved (TDS) EPA 160.1 | 1,000* | 182–616 | 200–400 |
| Solids total suspended (TSS) EPA 160.2 | NE | ND–45.6 | ND–2 |
| Bromide (Br) EPA 300.0 | NE | ND–0.718 | ND–0.2 |
| Chloride (Cl) EPA 300.0 | 300* | 5.19–154 | 15–50 |
| Fluoride (F) EPA 340.2 | 2.0* | 0.0442–1.97 | 0.02–0.4 |
| | | | |
| **Metals by EPA 200.7 and 200.8 (µg/L)** | | | |
| Aluminum | 24,000** | ND–924 | ND–40 |
| Antimony | 6.0 | ND–8.18 | ND–1 |
| Arsenic | 10.0 | ND–5.73 | ND–1 |
| Barium | 2,000 | 17.7–137 | 10–100 |
| Beryllium | 4.0 | ND | ND–1 |
| Boron | 4,900** | ND–454 | ND–60 |
| Cadmium | 5.0 | ND | ND–0.6 |
| Chromium | 100 | ND-6.56 | ND–3 |
| Cobalt | 7.3** | ND | ND–1 |
| Copper | 1,000** | ND–72.5 | ND–4 |
| Iron | 300* | ND–2910 | ND–6 |
| Lead | 15.0 | ND–20.7 | ND–3 |
| Lithium | 49.0** | ND–9.41 | ND–5 |
| Manganese | 50.0* | ND–78.1 | ND–4 |
| Molybdenum | 120** | ND–37.9 | ND–10 |
| Nickel | 490** | ND–9.8 | ND-3 |
| Selenium | 50.0 | ND–16.7 | ND–30 |
| Silver | 100* | ND | ND–0.001 |
| Strontium | 15,000** | 0.965–3,740 | 200–500 |
| Thallium | 2.0 | ND–6.23 | ND–1 |
| Uranium | 30.0 | ND–.46 | ND |
| Vanadium | 44.0** | 2.06–7.26 | ND–4 |
| Zinc | 5,000* | ND–199 | ND–20 |
| | | | |
| **Metals by E200.8 (mg/L)** | | | |
| Calcium | NE | 45.7–146 | 0.05–0.10 |
| Magnesium | NE | 1.58–32.4 | ND-0.004 |
| Potassium | NE | 0.49–12.5 | 5–15 |
| Sodium | NE | 3.21–81.6 | 0.005–0.015 |
| | | | |
| **Metals by SW-7470A (mg/L)** | | | |
| Mercury | 0.002 | ND–0.00229 | ND–0.0001 |
| | | | |
| **Total Organic Carbon by E415.1 (mg/L)** | | | |
| TOC | NE | ND–6.62 | ND |

## (Table 13. continued)

| Parameter and Method | Maximum Contaminant Levels or Secondary Standards | Range of Concentrations Detected in 2013 | Typical Range of Concentrations for the Freshwater Edwards Aquifer |
|---|---|---|---|
| **Herbicides by SW-8141 (µg/L)** | | | |
| Azinphosmethyl | 37.0** | ND | ND |
| Bolstar (Sulprofos) | 73.0** | ND | ND |
| Chlorpyrifos | 73.0** | ND | ND |
| Coumaphos | 170** | ND | ND |
| Demeton-O | 0.98** | ND–0.0882 | ND |
| Demeton-S | 22.0** | ND | ND |
| Diazinon | 3.1** | ND | ND |
| Dichlorvos | 4.9** | ND | ND |
| Dimethoate | 0.98** | ND | ND |
| Disulfoton | 0.24** | ND | ND |
| EPN | 2.4** | ND–0.0858 | ND |
| Ethoprop | 0.73** | ND | ND |
| Famphur | 24.0** | ND | ND |
| Fensulfothion | 1.7** | ND | ND |
| Fenthion | 490** | ND | ND |
| Malathion | 0.73** | ND | ND |
| Merphos | 6.1** | ND | ND |
| Methyl parathion | 0.61** | ND | ND |
| Mevinphos (Phosdrin) | 15.0** | ND | ND |
| Mononcrotophos | 49.0** | ND | ND |
| Naled | 150** | ND | ND |
| Parathion | 4.9** | ND | ND |
| Phorate | 1,200** | ND | ND |
| Ronnel | 1000** | ND | ND |
| Stirophos (Tetrachlorvinphos) | 12.0** | ND | ND |
| Sulfotepp (Tetraethyl dithiopyrophosphate) | 2.4** | ND | ND |
| Tokuthion (Prothiofos) | 73.0** | ND | ND |
| Trichloronate | 1.7** | ND | ND |
| Thionazin | 1.7** | ND | ND |
| | | | |
| **Herbicides by SW-8151 (µg/L)** | | | |
| 2,4,5-T | 240** | ND | ND |
| 2,4,5-TP (Silvex) | 50.0 | ND | ND |
| 2,4- D | 70.0 | ND–10.4 | ND |
| 2,4-DB | 200** | ND | ND |
| Dalapon | 200 | ND | ND |
| Dicamba | 730** | ND | ND |
| Dichoroprop | 240** | ND | ND |
| Dinoseb | 7.0 | ND | ND |
| MCPA | 12.0** | ND | ND |
| MCPP (mecoprop) | 24.0** | ND | ND |
| Pentachlorophenol | 1.0 | ND | ND |
| | | | |
| **Pesticides by SW-8081 (µg/L)** | | | |
| 4, 4'-DDD | 3.8** | ND | ND |
| 4, 4'-DDE | 2.7** | ND–0.00212 | ND |
| 4, 4'-DDT | 2.7** | ND | ND |
| Aldrin | 0.05** | ND–0.0151 | ND |
| Alpha-bhc (Alpha-hexachlorocyclohexane) | 0.1** | ND–0.0033 | ND |
| Alpha-chlordane | 2.6** | ND | ND |
| Beta-bhc (Beta-hexachlorocyclohexane) | 0.5** | ND | ND |
| Chlordane | 2.0** | ND | ND |
| Chlorobenzilate | NE | ND | ND |
| Delta-bhc (Delta-hexachlorocyclohexane) | 0.5** | ND–0.00329 | ND |
| Dieldrin | 0.57** | ND | ND |
| Endosulfan I | 49** | ND | ND |
| Endosulfan II | 150** | ND | ND |
| Endosulfan sulfate | 150** | ND | ND |
| Endrin | 2.0** | ND | ND |
| Endrin aldehyde | 7.3** | ND | ND |
| Endrin ketone | 7.3** | ND | ND |
| Gamma-bhc (Lindane) | 0.2 | ND–0.00219 | ND |
| Gamma-chlordane | 2.6** | ND | ND |
| Heptachlor | 0.4 | ND | ND |
| Heptachlor epoxide | 0.2 | ND | ND |
| Methoxychlor | 40.0 | ND | ND |
| Toxaphene | 3.0 | ND | ND |

## (Table 13. continued)

| Parameter and Method | Maximum Contaminant Levels or Secondary Standards | Range of Concentrations Detected in 2013 | Typical Range of Concentrations for the Freshwater Edwards Aquifer |
|---|---|---|---|
| **PCBs by SW-8082 (µg/L)** | | | |
| Aroclor 1016 | 0.5 | ND | ND |
| Aroclor 1221 | 0.5 | ND | ND |
| Aroclor 1232 | 0.5 | ND | ND |
| Aroclor 1242 | 0.5 | ND | ND |
| Aroclor 1248 | 0.5 | ND | ND |
| Aroclor 1254 | 0.5 | ND | ND |
| Aroclor 1260 | 0.5 | ND | ND |
| Aroclor 1262 | 0.5 | ND | ND |
| Aroclor 1268 | 0.5 | ND | ND |
| | | | |
| **SVOCs by SW-8270C (µg/L)** | | | |
| 1,2- dichlorobenzene | 600** | ND | ND |
| 1,2,4- trichlorobenzene | 70** | ND | ND |
| 1,3- diclorobenzene | NE | ND | ND |
| 1,3- dimethylnaphthalene | NE | ND–0.0572 | ND |
| 1,4- dichlorobenzene | NE | ND | ND |
| 1- methylnaphthalene | NE | ND | ND |
| 2, 4, 5-trichlorophenol | 2,400** | ND | ND |
| 2, 4, 6-trichlorophenol | 24** | ND | ND |
| 2, 4-dichlorophenol | 73** | ND | ND |
| 2, 4-dimethylphenol | 490** | ND | ND |
| 2, 4-dinitrophenol | 49** | ND | ND |
| 2-chlorophenol | 120** | ND | ND |
| 2-methylnaphthalene | 98** | ND–0.109 | ND |
| 2-methylphenol (o-cresol) | 1,200** | ND | ND |
| 2-nitroaniline | 7.3** | ND | ND |
| 2-nitrophenol | 49** | ND | ND |
| 3 & 4 methylphenol (m&p cresol) | 1,200** | ND | ND |
| 3-nitroaniline | 7.3** | ND | ND |
| 4, 6-dinitro-2-methylphenol | 2.4** | ND | ND |
| 4-chloro-3-methylphenol | 120** | ND | ND |
| 4- chloroaniline | 4.6** | ND | ND |
| 4-nitroaniline | 46** | ND | ND |
| 4-nitrophenol | 49** | ND | ND |
| Naphthalene | 490** | ND | ND |
| Nitrobenzene | 49** | ND–0.109 | ND |
| Pentachlorophenol | 1.0 | ND | ND |
| Phenanthrene | 730** | ND | ND |
| Phenol | 7,300** | ND | ND |
| Pyrene | 730** | ND | ND |
| N-nitrosodi-n-propylamine | 0.13** | ND–0.0488 | ND |
| N-nitrosodiphenylamine | 190** | ND | ND |
| Acenaphthene | 1,500** | ND | ND |
| Acenaphthylene | 1,500** | ND | ND |
| Anthracene | 7,300** | ND | ND |
| Benzo(a)anthracene (1 2-benzanthracene) | 1.3** | ND | ND |
| Benzo(b)fluoranthene | 1.3** | ND–0.0431 | ND |
| Benzo(k)fluoranthene | 13** | ND–0.0441 | ND |
| Benzo(ghi)perylene | 730** | ND–0.0281 | ND |
| Benzo(a)pyrene | 0.2 | ND–0.0316 | ND |
| Benzyl Alcohol | 2,400** | ND–0.0379 | ND |
| Butyl benzyl phthalate | 480** | ND | ND |
| Bis(2-chloroethoxy)methane | 0.83** | ND–2.24 | ND |
| Bis(2-chloroethyl)ether | 0.83** | ND | ND |
| Bis(2-ethylhexyl)phthalate | 6.0 | ND | ND |
| 4-bromophenyl phenyl ether | 0.061** | ND–34.8 | ND |
| 4-chloroaniline | 4.6** | ND | ND |
| 2-chloronaphthalene | 2,000** | ND | ND |
| 4-chlorophenyl phenyl ether | 0.061** | ND | ND |
| Chrysene | 130** | ND | ND |
| Dibenz(a,h)anthracene | 0.2** | ND | ND |
| Dibenzofuran | 98** | ND | ND |
| 3 3-dichlorobenzidine | 2** | ND–2.64 | ND |
| Diethyl phthalate | 20,000** | ND | ND |
| Dimethyl phthalate | 20,000** | ND–0.910 | ND |
| Di-n-butyl phthalate | 2,400** | ND | ND |
| Di-n-octyl phthalate | 980** | ND | ND |
| 2 4-dinitrotoluene | 1.3** | ND | ND |

## (Table 13. continued)

| Parameter and Method | Maximum Contaminant Levels or Secondary Standards | Range of Concentrations Detected in 2013 | Typical Range of Concentrations for the Freshwater Edwards Aquifer |
|---|---|---|---|
| 2 6-dinitrotoluene | 1.3** | ND | ND |
| Fluoranthene | 980** | ND–0.068 | ND |
| Fluorene | 980** | ND | ND |
| Hexachlorobenzene | 1.0** | ND | ND |
| Hexachlorobutadiene | 12.0** | ND | ND |
| Hexachlorocyclopentadiene | 50.0 | ND | ND |
| Hexachloroethane | 17.0** | ND | ND |
| Indeno(1,2,3-cd)pyrene | 1.3** | ND–0.0301 | ND |
| Isophorone | 960** | ND | ND |
| | | | |
| **VOCs SW-8260b (µg/L)** | | | |
| 1, 1, 1, 2-tetrachloroethane | 35.0** | ND | ND |
| 1, 1, 1-trichloroethane | 200.0 | ND | ND |
| 1, 1, 2, 2-tetrachloroethane | 4.6** | ND | ND |
| 1, 1, 2-trichloroethane | 5.0 | ND | ND |
| 1,1,2- trichlorotrifloroethane | 730,000** | ND | ND |
| 1, 1-dichloroethane | 4,900** | ND | ND |
| 1, 1-dichloropropene | 9.1** | ND | ND |
| 1, 1-dichloroethene (Vinylidene chloride) | 7.0 | ND | ND |
| 1- chlorohexane | 980** | ND | ND |
| 1-octene | NE | ND | ND |
| 1, 2, 3-trichlorobenzene | 73.0** | ND | ND |
| 1, 2, 3-trichloropropane | 0.03** | ND | ND |
| 1, 2, 4-trichlorobenzene | 70.0** | ND | ND |
| 1, 2, 4-trimethylbenzene | 1,200** | ND | ND |
| 1, 2-dibromo-3-chloropropane | 0.2 | ND | ND |
| 1, 2-dibromoethane (EDB) | .05** | ND | ND |
| 1, 2-dichlorobenzene | 600** | ND | ND |
| 1, 2-dichloroethane (EDC) | 5.0 | ND | ND |
| 1,2- dichloroethane, Total | 5.0 | ND | ND |
| 1, 2-dichloropropane | 1,200** | ND | ND |
| 1, 3, 5-trimethylbenzene | NE | ND | ND |
| 1,3- butadiene | 730** | ND | ND |
| 1, 3-dichlorobenzene | 9.1** | ND | ND |
| 1, 3-dichloropropane | 75.0** | ND | ND |
| 1, 4-dichlorobenzene | 9.1** | ND | ND |
| 1, 4-dioxane | 13.0** | ND–0.418 | ND |
| 2, 2-dichloropropane | NE | ND | ND |
| 2-chlorotoluene | 490** | ND | ND |
| 2-hexanone | 120** | ND | ND |
| 2-nitropropane | 3.4** | ND | ND |
| 1,3,5- trichlorobenzene | 73** | ND | ND |
| 4-chlorotoluene | 490** | ND | ND |
| 4-isopropyltoluene | 2,400** | ND | ND |
| 4-methyl-2-pentanone (MIBK) | 2,000** | ND | ND |
| Acetone | 22,000** | ND–33.1 | ND |
| Acetonitrile | 780** | ND | ND |
| Allyl Chloride | 240** | ND | ND |
| Benzene | 5.0 | ND–0.251 | ND |
| Benzyl Chloride | 5.4** | ND | ND |
| Bromobenzene | 200** | ND | ND |
| Bromochloromethane (chlorobromomethane) | 980** | ND | ND |
| Bromodichloromethane | 15.0** | ND–1.26 | ND |
| Bromoform (Tribromomethane) | 120** | ND–3.53 | ND |
| Bromomethane (Methyl bromide) | 34.0** | ND | ND |
| Carbon disulfide | 2,400** | ND–1.10 | ND |
| Carbon tetrachloride | 5.0 | ND–0.409 | ND |
| Chlorobenzene | 100 | ND–0.229 | ND |
| Chloroethane (Ethyl chloride) | 9,800** | ND | ND |
| Chloroform | 240** | ND–5.53 | ND |
| Chloromethane (Methyl chloride) | 70.0** | ND–0.903 | ND |
| Chloroprene | 70.0 | ND | ND |
| Cis-1, 2-dichloroethene | 1.7** | ND | ND |
| Cis-1, 3-dichloropropene | NE | ND | ND |
| Cis-1,4- dichloro-2- butene | 120,000** | ND | ND |
| Cyclohexane | 120,000** | ND–2.36 | ND |
| Cyclohexanone | 11.0** | ND | ND |
| Dibromochloromethane | 120** | ND–2.07 | ND |
| Dibromomethane | NE | ND | ND |
| Dichlorodifluoromethane | 4,900** | ND | ND |
| Ethylbenzene | 700** | ND–0.409 | ND |

## (Table 13. continued)

| Parameter and Method | Maximum Contaminant Levels or Secondary Standards | Range of Concentrations Detected in 2013 | Typical Range of Concentrations for the Freshwater Edwards Aquifer |
|---|---|---|---|
| Ethyl acetate | 22,000** | ND | ND |
| Ethyl ether | 4,900** | ND | ND |
| Ethylene oxide | 0.89** | ND | ND |
| Ethyl methacrylate | 2,200** | ND | ND |
| Hexane | 1,500** | ND | ND |
| Hexachlorobutadiene | 12.0** | ND | ND |
| Iodomethane | 34.0** | ND | ND |
| Isobutyl alcohol | 7,300** | ND | ND |
| Isooctane | NE | ND | ND |
| Isopropylbenzene (Cumene) | 2,400** | ND | ND |
| Methacrylonitrile | 2.4** | ND | ND |
| Methyl ethyl ketone (2-butanone) | 15,000** | ND | ND |
| Methyl methacrylate | 34,000** | ND | ND |
| Methylene chloride (Dichloromethane) | 5.0** | ND | ND |
| Naphthalene | 490** | ND–0.109 | ND |
| n-Butylbenzene | 1,200** | ND | ND |
| n-Heptane | 1,500** | ND | ND |
| n-Propylbenzene | 980** | ND | ND |
| Pentachloroethane | 10.0** | ND | ND |
| Propionitrile | 9.8** | ND | ND |
| sec-Butylbenzene | 980** | ND | ND |
| Styrene | 100 | ND | ND |
| tert-Butylbenzene | 980** | ND | ND |
| Tert-butyl methyl ether (mtbe) | 240** | ND | ND |
| Tetrachloroethene | 5.0 | ND–4.87 | ND |
| Toluene | 1,000 | ND–0.316 | ND |
| Trans-1, 2-dichloroethene | 100 | ND | ND |
| Trans-1, 3-dichloropropene | 9.1** | ND | ND |
| Trans-1,4- dicloro-2- butene | NE | ND | ND |
| Trichloroethene | 5.0 | ND | ND |
| Trichlorofluoromethane | 7,300** | ND | ND |
| Vinyl Acetate | 24,000** | ND | ND |
| Vinyl chloride (Chloroethene) | 2.0 | ND | ND |
| m-p-xylene | 10,000** | ND–1.65 | ND |
| o-xylene | 10,000** | ND–0.572 | ND |

Data source: TCEQ, maximum contaminant levels, 30 TAC, Chapter 290, Subchapter F, and RG-346 Rev. May 2012 (www.sos.state.tx.us/tac/index.shtml.

NE = No established MCL, secondary standard, or PCL.

* = Secondary drinking water standards (30 TAC, 290, Subchapter F).

** = Texas Risk Reduction Program (TRRP) rules, Tier 1, residential PCLs, 30 TAC Chapter 350, updated June 2012 (http://www.tceq.state.tx.us/remediation/trrp/trrppcls.html).

1 = MCLG-Maximum contaminant level goal.

MCL = Maximum contaminant level.

ND = Not detectable.

NA = Not analyzed.

< = Detection limit, and not necessarily the concentration, of the compound in water.

mg/L = Milligram per liter (often referred to as parts per million).

µg/L = Microgram per liter (often referred to as parts per billion).

## Table 14. Secondary Drinking-Water Standards.

| Parameter | Secondary Drinking-Water Standards (mg/L) |
|---|---|
| Aluminum | 0.05–0.2 |
| Chloride | 300 |
| Color | 15 color units |
| Copper | 1.0 |
| Corrosivity | Non-corosive |
| Fluoride | 2.0 |
| Iron | 0.3 |
| Manganese | 0.05 |
| pH | >7.0 |
| Silver | 0.10 |
| Sulfate | 300 |
| Total dissolved solids TDS | 1000 |
| Zinc | 5 |

Data source: 30 TAC Chapter 290, Subchapter F.

Color and corrosivity parameters were not included in the 2013 analytical program.

that can adversely affect public health and are known or anticipated to occur in public water systems. The primary standards are based on concentrations published in Title 30 of the Texas Administrative Code, Chapter 290, Subchapter F (Table 13). For compounds that do not have an established MCL, the protective concentration level (PCL) is provided, which is based on the Texas Risk Reduction Program (TRRP), Tier 1, residential value, as referenced in Title 30, Texas Administrative Code, Chapter 350. This concentration is the value estimated to be protective of human health and the environment.

**Secondary Drinking-Water Standards**—Secondary standards are non-enforceable and are set for contaminants that may affect aesthetic qualities of drinking water, such as odor or appearance. Table 14 is a list of current secondary standards. Concentrations of the secondary standards listed in Table 14 are generally not exceeded in the freshwater part of the Edwards Aquifer, although concentrations of TDS, fluoride, chloride, and iron typically exceed secondary standards in samples from the saline-water zone.

Tables 13 and 14 referenced earlier are updated regularly with revisions to MCL or PCL values for various compounds. The reader is encouraged to check the referenced regulations for updates to MCL and PCL values, as well as secondary standards.

## Routine Water Quality Data from Edwards Aquifer Wells

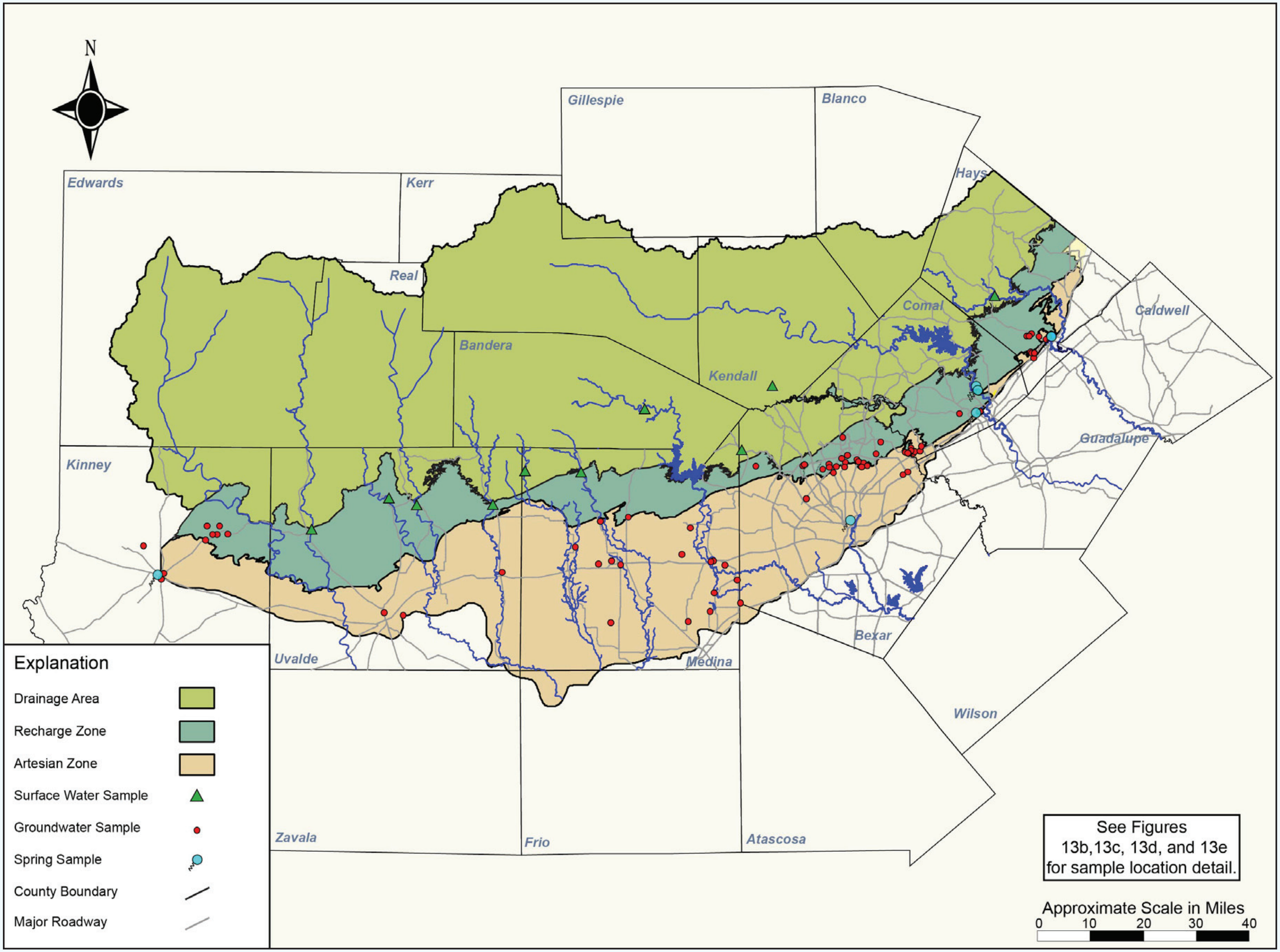
Groundwater samples for calendar year 2013 were analyzed by the EAA's contract laboratories—Test America and the San Antonio River Authority (SARA). In addition, approximately 20 well samples per year are collected by the EAA for analyses by the TWDB contract laboratory for portions of the analyses. In 2013, the Lower Colorado River Authority (LCRA), pursuant to an analytical services contract with the TWDB, provided these analyses.

**Metals**—Of the 62 wells sampled for metals, laboratory analyses indicated the presence of the metal thallium, which is regulated under the primary drinking-water standards, at a concentration exceeding its MCL. Thallium was detected in Hays and Medina counties above the MCL of 2.0 µg/L. Lead was detected in Hays and Medina counties above the MCL of 15 µg/L. Mercury was detected in Bexar County above the MCL of 0.002 µg/L.

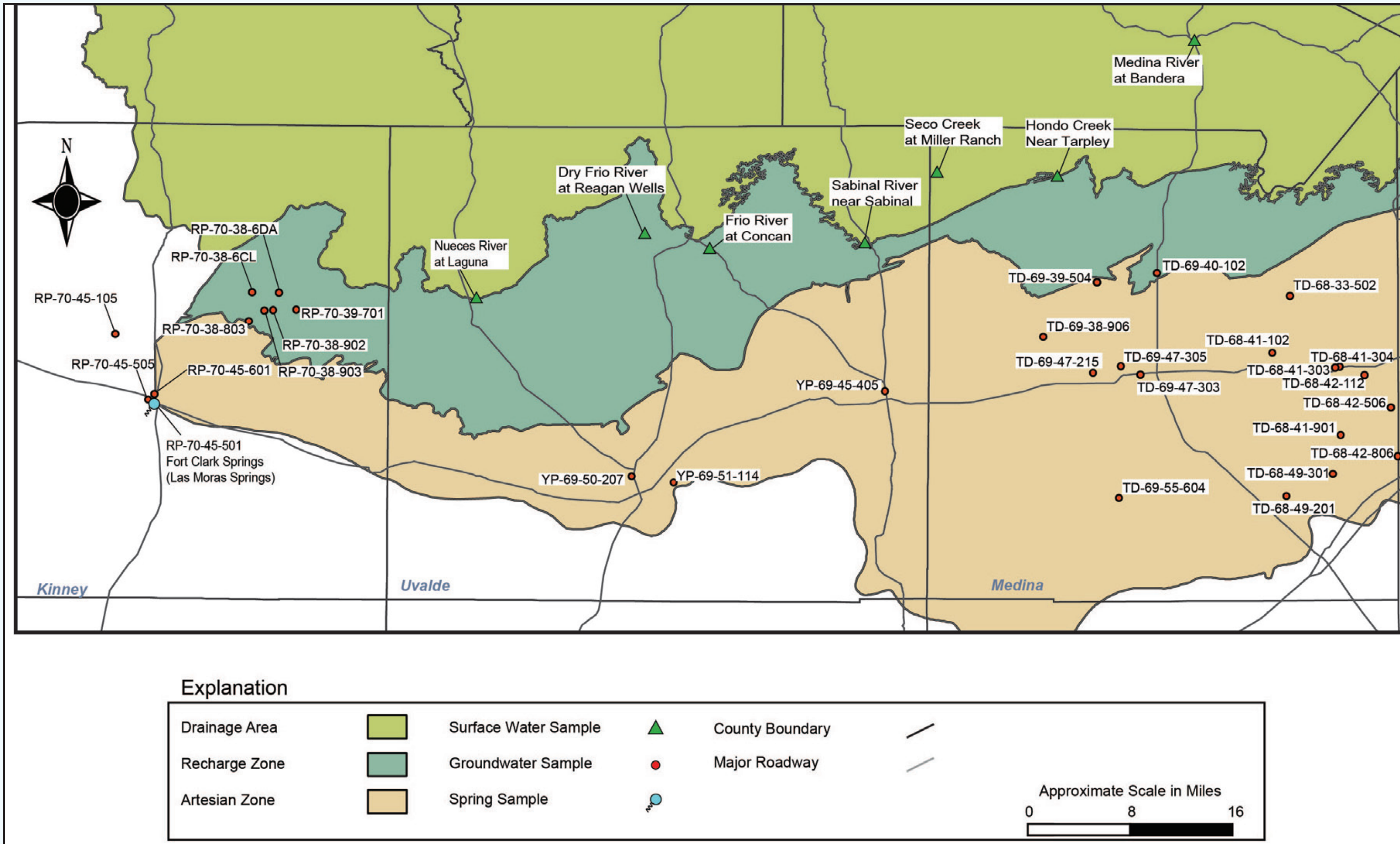
Detections above the secondary standard of 300 µg/L for iron were noted in Kinney and Medina counties. Antimony was detected in Bexar County above the PCL value of 6.0 µg/L. Metal detections above secondary or PCL standards are summarized next (see Figures 13b–d

*(continued on p. 53)*

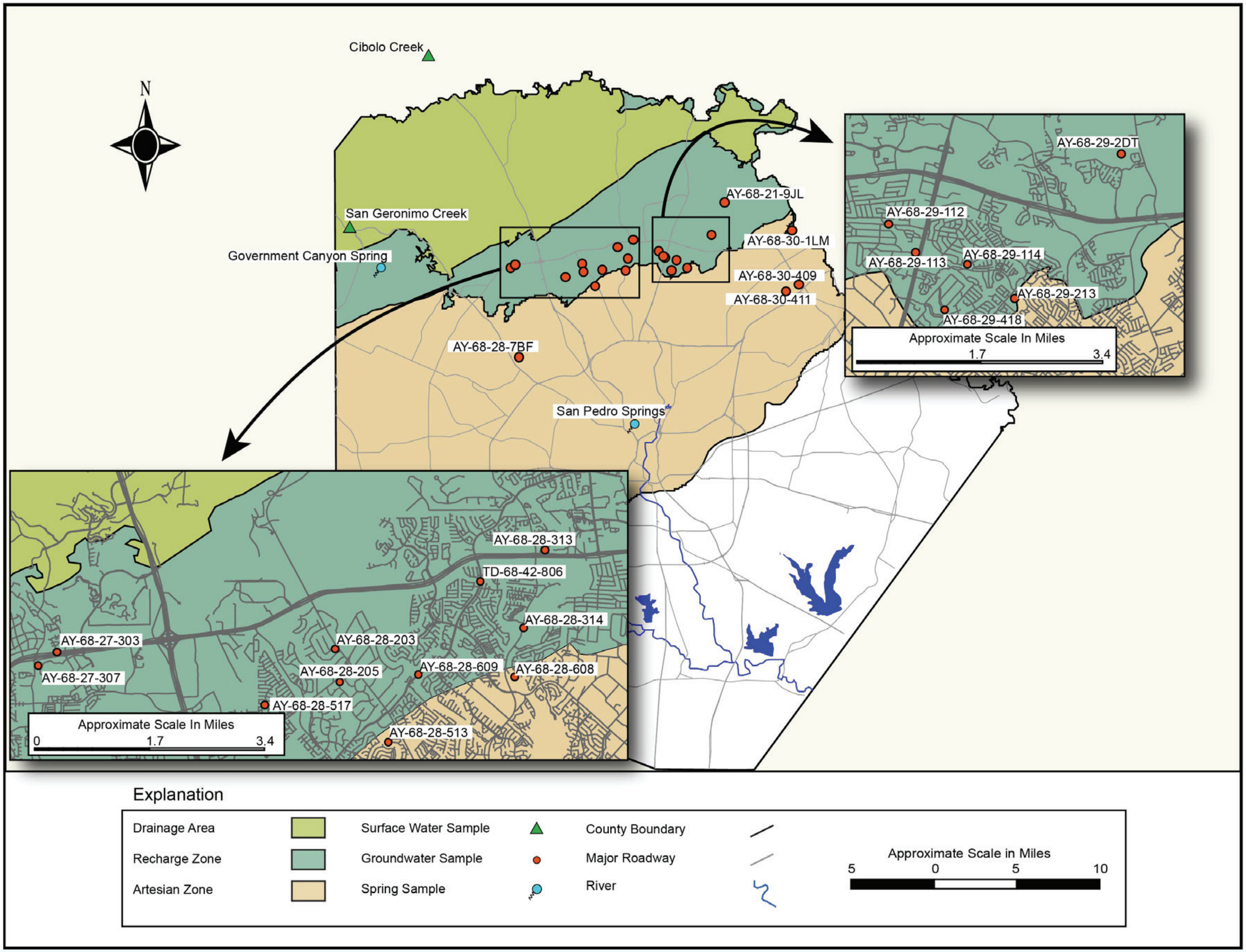
## Figure 13a. Year 2013 Edwards Aquifer Authority Water Quality Sampling Locations—Wells, Springs, and Streams Sampled



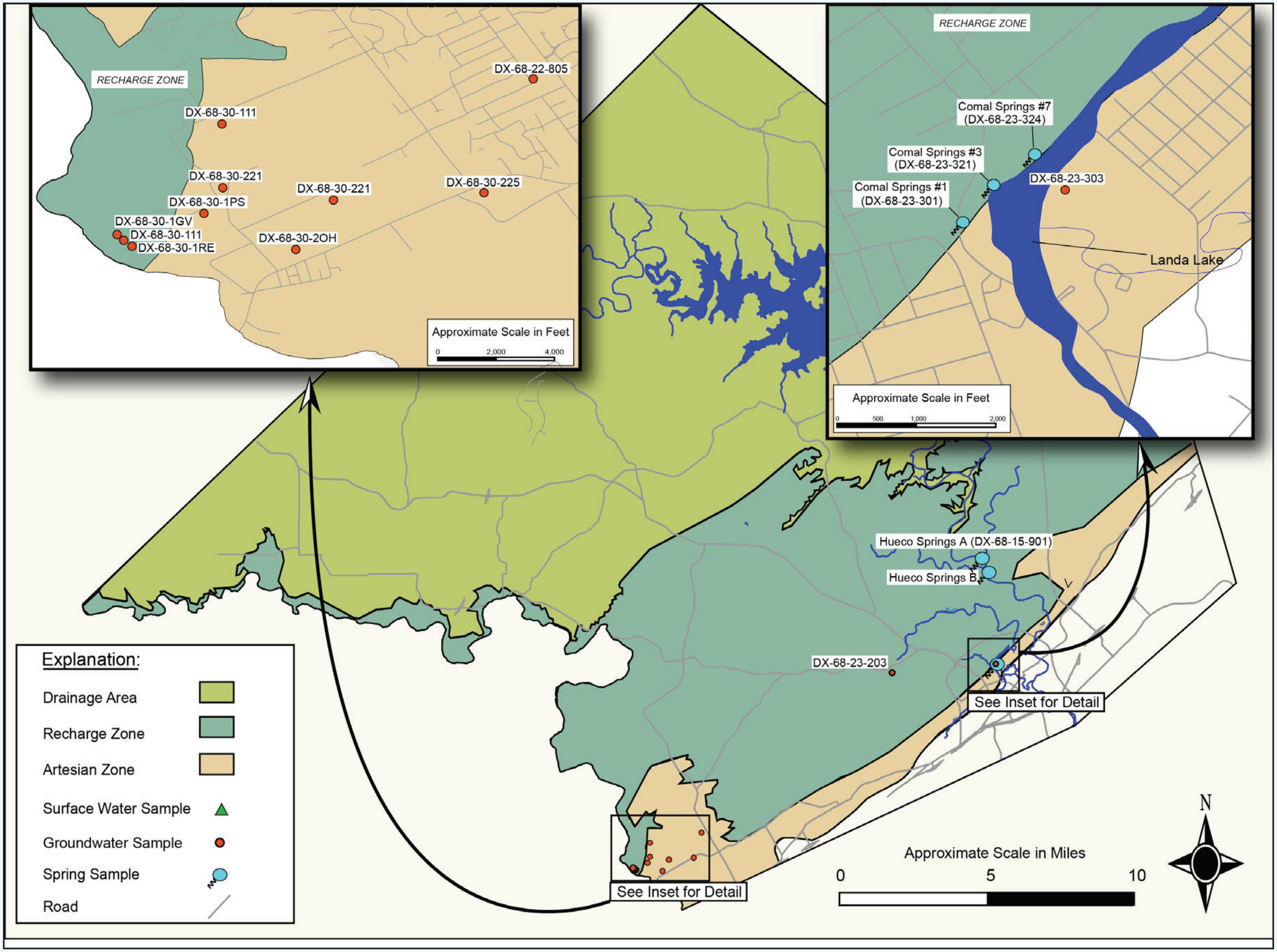
## Figure 13b. Year 2013 Edwards Aquifer Authority Water Quality Sampling Locations, Kinney, Uvalde, and Medina Counties



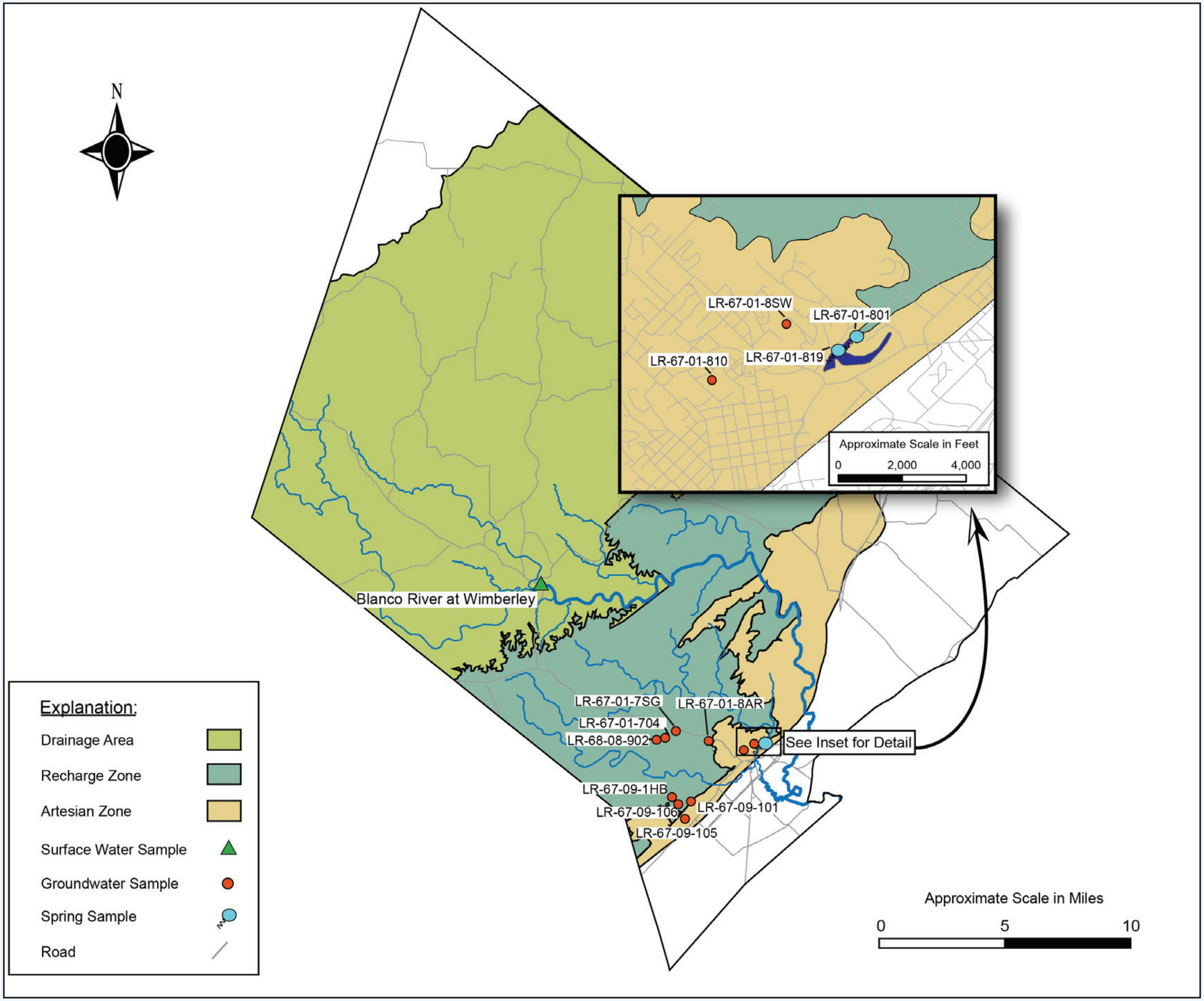
## Figure 13c. Year 2013 Edwards Aquifer Authority Water Quality Sampling Locations, Bexar County



## Figure 13d. Year 2013 Edwards Aquifer Authority Water Quality Sampling Locations, Comal County



## Figure 13e. Year 2013 Edwards Aquifer Authority Water Quality Sampling Locations, Hays County



for map locations and Appendix C for detailed listings of all analytical results for the year).

### Medina County

- Thallium detected in
  TD-68-49-201 at 2.60 µg/L
  (MCL = 2.0 µg/L)
- Lead detected in
  TD-69-35-504 at 20.7 µg/L
  (MCL = 15 µg/L)
- Iron detected in
  TD-69-39-504 at 2,910 µg/L
  (Secondary standard = 300 µg/L)

### Hays County

- Thallium detected in
  LR-67-09-101-4 at 6.23 µg/L
  LR-67-09-101-1 at 4.85 µg/L
  (MCL = 2.0 µg/L)
- Lead detected in
  LR-67-01-101-4 at 15.5 µg/L
  (MCL = 15 µg/L)

### Bexar County

- Mercury detected in
  AY-68-27-303-1 at 0.00229 µg/L
  (MCL = 0.002 µg/L)
- Antimony detected in
  AY-68-28-313 at 8.18 µg/L
  (MCL = six µg/L)

### Kinney County

- Iron detected in
  RP-70-37-7DO at 2,480 µg/L
  (Secondary standard = 300 µg/L)

**Bacteria**—In 2013, 83 bacteria samples were collected from 73 wells. The EAA collects samples from wells upstream of any chlorination equipment in order to assess the presence or absence of bacteria in raw water samples from the aquifer. These sample results are not directly comparable to bacterial samples collected by most public water supply systems because public water supply samples are generally collected downstream of chlorination equipment. Wells were generally sampled for *Escherichia coli* (E. coli). Bacteria results are reported in units of most probable number per 100 milliliters of water (MPN/100 mL). Bacteria samples ranged in concentration from non-detectable numbers to 170 MPN/100 mL. Wells sampled under the routine sampling program with positive bacteria detections are listed below.

### Bexar County

- E. coli detected in
  AY-68-28-315 at one MPN/100 mL
  AY-68-27-303-2 at two MPN/100 mL
  AY-68-29-114 at two MPN/100 mL
  AY-68-29-2DT at two MPN/100 mL
  AY-68-29-418 at 18 MPN/100 mL

### Comal County

- E. coli detected in
  DX-68-23-303 at one MPN/100 mL

### Hays County

- E. coli detected in
  LR-67-01-7SG at one MPN/100 mL
  LR-67-09-101-1 at one MPN/100 mL
  (2/25/2013)
  LR-67-09-101-4 at one MPN/100 mL
  (12/12/2013)
  LR-67-09-101-1 at two MPN/100 mL
  (9/25/2013)
  LR-67-09-101-4 at two MPN/100 mL
  (9/25/2013)
  LR-67-09-101-1 at 150 MPN/100 mL
  (5/28/2013)
  LR-67-09-101-4 at 170 MPN/100 mL
  (5/28/2013)

E. coli bacteria analyses are used to indicate the possible presence of fecal matter in ground- and surface water.

The MCL for coliform bacterial samples is based on the size of a public water supply distribution system and is for treated water at the point of use and not from the point of withdrawal. For example, the number of monthly samples collected increases with the number of connections or size of population served. A public water supply with 100,000 connections would be required to collect 100 samples per month. If more than five percent of the monthly samples are coliform positive, the MCL would be exceeded. For systems that collect fewer than 40 routine bacteria samples per month, the MCL is defined as occurring when more than one sample is coliform positive (Title 30 Texas Administrative Code, 290.109). Note that samples for public water supplies are collected downstream of the chlorination device and generally from public facilities near the ends of the distribution system.

Presence of fecal bacteria may indicate a problem with laboratory or sampling methods, poor wellhead or casing maintenance, or impact to groundwater from human or animal waste. Public water supplies are required by State law to be chlorinated. Domestic wells do not have a chlorination requirement. The EAA's bacteria samples are collected with great care to avoid post-collection contamination.

**Nitrates**—In 2013, 91 nitrate-nitrite as nitrogen (*nitrate* for this report) samples were collected from 72 wells. Nitrate is a highly soluble, naturally occurring compound in both surface water and groundwater. The largest amounts of naturally occurring nitrate in surface water and groundwater are derived from direct absorption from the air and soil during rainfall events. Concentrations of nitrate below one mg/L are generally considered background from natural sources. Concentrations above two mg/L are considered slightly elevated. Potential sources of elevated nitrate include runoff from agricultural and urban sources (fertilizer from farm fields and yards), septic systems, leaking sewer lines, and animal waste. Concentrations of nitrate above the MCL of ten mg/L pose an increased risk for methemoglobinemia or *blue baby syndrome*, which results from nitrates interfering with the ability of blood to carry oxygen in infants usually younger than six months. Methemoglobinemia can also affect senior adults.

Of the 72 wells sampled for nitrate, two wells exceeded the MCL of ten mg/L. Four samples indicated concentrations above five mg/L, but less than ten mg/L. Results from a total of 37 wells indicated nitrate concentrations at or above two mg/L but less than five mg/L. The EAA is studying historical nitrate concentrations to identify trends that may indicate contamination sources.

Nitrate detections above five mg/L were found in

Comal County

- DX-68-30-111 at 11.2 mg/L (on 5/20)
- DX-68-30-111 at 9.74 mg/L (on 7/16)
- DX-68-30-1GV at 10.0 mg/L (on 5/20 and 7/17)
- DX-68-30-1PS at 6.04 mg/L
- DX-68-30-221 at 5.19 mg/L

Uvalde County

- YP-69-51-114 at 5.94 mg/L

**Volatile Organic Compounds (VOCs)**—In 2013, water samples collected from 72 wells were analyzed for VOCs. A total of 91 VOC analyses were performed from these wells. Eighteen positive detections across seven different wells were noted for several different VOC analytes. None of the compounds exceeded their respective regulatory limits (statement applies to compounds for which a regulatory limit is established). Detections are summarized below by county.

Uvalde County

- YP-69-51-114, tetrachloroethene (PCE), detected at 3.30 µg/L (MCL = 5.0 µg/L)

Medina County

- TD-68-42-806, ethylbenzene, detected at 0.513 J µg/L (PCL = 700 µg/L)
- TD-68-42-806, m,p-xylene, detected at 1.08 J, and 1.65 J µg/L (PCL = 10,000 µg/L)
- TD-68-42-806, naphthalene, detected at 0.109 J µg/L (PCL = 490 µg/L)
- TD-68-42-806, o-xylene, detected at 0.572 J µg/L (PCL = 10,000 µg/L)
- TD-68-42-806, toluene, detected at 0.316 J µg/L (PCL = 100 µg/L)

Bexar County

- AY-68-27-303-1, chloroform, detected at 0.519 J and 0.544 J µg/L (PCL = 240 µg/L)
- AY-68-27-303-2, chloroform, detected at 0.699 J and 0.628 J µg/L (PCL = 240 µg/L)
- AY-68-28-313, chloroform, detected at 1.19 and 1.28 µg/L (PCL = 240 µg/L)
- AY-68-29-112, naphthalene, detected at 0.0585 J µg/L (PCL = 490 µg/L)
- AY-68-29-418, chloroform, detected at 0.292 J µg/L (PCL = 240 µg/L)

- AY-68-30-409, chloroform, detected at 0.240 J µg/L (PCL = 240 µg/L)
- AY-68-29-418, tetrachloroethene (PCE), detected at 4.33 µg/L, 4.59 µg/L, and 4.87 µg/L (MCL = 5.0 µg/L)

*Note:*
*J = Detection above method detection limit but below reporting limit.*

The detected compounds can be problematic with regard to resolution of their actual source. Chloroform, for example, was the most frequently detected VOC in 2013, with eight detections in well samples. Chloroform is a common byproduct associated with chlorination of water; however, the samples herein are not collected from a chlorinated source. The USGS indicates that many potential sources for chloroform in groundwater exist and include septic effluent, leaking sewer lines, and irrigation using chlorinated water (Ivahnenko and Zogorski, 2006). These detections may also be associated with collecting samples influenced by a nearby well that had recently been "shocked" or disinfected with chlorine by the well owner.

The second most frequently detected VOC in 2013 was tetrachloroethene (PCE), which was detected in four wells in 2013. This compound is a common organic solvent used in the dry cleaning industry, as well as degreasing processes for mechanical parts.

The PCE detections in Bexar County are from an unknown source; however, the matter is currently being investigated. The PCE detection in Uvalde County is from a release associated with a dry-cleaning facility.

**Semivolatile Organic Compounds (SVOCs)**—In 2013, SVOCs were detected in 11 samples from a total of eight wells for the year. Each well had at least one detection, significantly below the applicable regulatory limits, of one or more SVOCs. Two of the wells (TD-68-42-806 and TD-68-49-201) were resampled after the initial detections and produced similar analytical results for both the compounds detected and their concentrations. Two wells in Bexar County also tested positive for suspected post-collection phthalate contaminants. One SVOC compound, naphthalene, which can also be detected as a VOC compound, was detected in Bexar County well AY-68-29-112. Naphthalene was detected at 0.0585 J µg/L, far below the PCL of 490 µg/L. The concentration of naphthalene in this particular well, and the respective PCL limit, is a fair representation of the regulatory limits and type of SVOC levels detected in the other wells.

**Pesticides, Herbicides, and Polychlorinated Biphenyls (PCBs)**—In 2013, water samples collected from 49 wells were analyzed for pesticides and herbicides, and 32 well samples were analyzed for PCBs. Herbicide compounds were detected in two wells, whereas no pesticides or PCB compounds were detected. The herbicide detection did not exceed the respective regulatory limit. Detections are summarized by county below.

### Hays County

- LR-67-01-08PS, 2,4-D, detected at 0.0861 J µg/L (MCL = 70 µg/L)

### Bexar County

- AY-68-29-418, EPN, detected at 0.0858 J µg/L (MCL = 0.24 µg/L)

*Note:*
*J = Detection above method detection limit but below reporting limit.*

**Pharmaceuticals and Personal Care Products**—Water samples collected from five wells were analyzed for pharmaceutical and personal care products (PPCPs) in 2013. None of the wells tested positive for PPCP compounds.

Detections of non-naturally occurring compounds in a karst system such as the Edwards Aquifer are problematic because contaminants may pass through the system quickly. As such, periodic sample-collection events occurring every several months may not coincide with the flux of a contaminant at the sample point. Therefore, ascertaining whether the sample result reflects the low, middle, or high end of the contaminant flux is impossible. Water tracing compounds, injected into the aquifer as part of the EAA's research program, are good surrogates for the behavior of contaminants in groundwater. Most tracers exhibit transient detections at specific monitoring locations in the aquifer and help explain why a contaminant may be detected once but may not be detected during subsequent sampling several weeks or months later.

Karst properties of the Edwards Aquifer require collection of multiple samples from a single point during the year so that a representative perspective of water quality can be obtained. The EAA sampling program has therefore been modified to collect multiple samples from select wells during the year while maintaining annual sampling at many wells aquiferwide. For example, wells with more than one detection listed for a single compound were sampled more than once during the year.

In summary, water samples from the Edwards Aquifer indicate the presence of anthropogenic compounds generally in limited areas and predominantly at concentrations below the MCL or regulatory limit. However, the presence of multiple anthropogenic compounds at various well-sample locations indicates a sensitivity of the aquifer to the introduction of contaminants. The number of chloroform detections provides a good example of these anthropogenic impacts in certain areas.

## Routine Water Quality Data from Streams and Springs in the Edwards Aquifer Area

Water quality data from streams are generally collected within the drainage area of the aquifer (see Figure 13a) at USGS gauging stations located upstream of the Edwards Aquifer Recharge Zone. The primary surface water data collection sites are located within eight major stream basins that flow across the recharge zone and contribute significant groundwater recharge to the Edwards Aquifer. The streams monitored (historically), from west to east, are the Nueces River, Dry Frio River, Frio River, Sabinal River, Seco Creek, Hondo Creek, Medina River, and Blanco River. In 2013, surface or stream water samples were collected from each of these eight historically sampled rivers and creeks. In addition, San Geronimo Creek in Bexar and Medina counties was sampled once at three different locations, as well as Cibolo Creek in Kendall County. Data from most of these sites can be used as a baseline to evaluate the quality of water recharging the aquifer and to provide a measure of the potential fluctuations in water quality due to land use changes in the Edwards Aquifer region.

Water quality data are also routinely collected from five major spring groups discharging from the aquifer because they provide composite samples of the vast underground drainage network that makes up the aquifer. In 2013, multiple spring orifices were sampled at Comal, Hueco, and San Marcos springs. Major springs were sampled quarterly or more frequently. Two sample-collection events were conducted at Las Moras (Fort Clark) Springs in Kinney County, and one sample-collection event was conducted at Government Canyon Spring in Bexar County for a total of five spring sample locations in 2013. The aggregate number of samples (due to multiple sampling events) collected at all springs was 74 across the region.

**Summary of Analytical Results**—Water samples from the stream locations and spring groups discussed previously were analyzed for the following metals: aluminum, antimony, arsenic, barium, beryllium, boron, bromide, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, vanadium, and zinc. Detectable metal concentrations in surface and spring water are common at trace amounts. Samples from streams and springs were also analyzed for nitrates, pesticides, herbicides, PCBs, and bacteria. Additional analyses for VOCs, SVOCs, and PPCPs were performed at surface water locations and spring locations in 2013.

**Metals**—Of the 12 surface water collection sites and five spring groups sampled for metals, one metal was detected at concentrations in excess of an MCL value. Thallium was detected in Comal and Hays counties above an MCL of 2.0 µg/L. These detections are summarized below. (See Figures 13b–e for map locations and Appendix C for detailed listings of all analytical results for the year.)

### Comal County

- Thallium detected in Comal Spring # 1 (DX-68-23-301) at 2.89 µg/L (MCL = 2.0 µg/L)

### Hays County

- Thallium detected in San Marcos Springs-Hotel (LR-67-01-801) at 3.10 µg/L (MCL = 2.0 µg/L)
- Thallium detected in San Marcos Springs-Deep (LR-67-01-819) at 2.30 µg/L (MCL = 2.0 µg/L)

Thallium is not commonly detected above the MCL in the aquifer. Potential sources of thallium include leaching from ore processing or discharge from electronics, glass, or drug factories (http://water.epa.gov/drink/contaminants/basicinformation/thallium.cfm).

**Nitrates**—Laboratory analyses indicated a limited range of nitrate (nitrate-nitrite as nitrogen) concentrations in spring water and a fairly wide range in surface water samples in 2013. Of the 19 surface water samples collected and analyzed for nitrate, concentrations ranged from less than 0.5 to 19.7 mg/L. Of the 74 spring water samples collected and analyzed for nitrate, concentrations ranged from less than 0.720 to 2.11 mg/L. Cibolo Creek near the Nature Center in Kendall County was the only surface water location that exceeded an MCL of ten mg/L for drinking water, with a concentration of 19.7 mg/L in 2013. The maximum nitrate concentration of 2.11 mg/L in spring water was collected at Comal Springs #1 (DX-68-23-301) in Comal County.

**Bacteria**—In 2013, most surface water and spring samples were tested for bacteria. It is not unusual for surface water and spring samples to have positive detections of bacteria, especially in wet years (for example, in 2007 counts ranged to “too numerous to count” during periods of heavy runoff). Bacteria counts for surface streams in 2013 ranged from two MPN/100 mL through 3,700 MPN/100 mL for E. coli. The high sample was from the Blanco River at Wimberley in Hays County. Spring water samples for bacteria ranged from less than one to 820 MPN/100 mL for E. coli. The high sample was from Hueco A Springs (DX-68-15-901) in Comal County.

**Volatile Organic Compounds (VOCs)**—In 2013, water samples collected from four surface water sites and all five spring groups were analyzed for VOCs, and no VOCs were detected in surface waters. A total of 74 VOC analyses were performed on spring samples. Laboratory analyses indicated the presence of the VOCs in one spring group. None of the compounds exceeds its respective regulatory limits. Detections are summarized by spring group below.

### Springs VOCs

- Hueco Springs A (DX-68-15-901) 2,2-Dichloropropane, detected at 0.418 µg/L (PCL = 13 µg/L)

  Acetone, detected at 8.49 J µg/L (PCL = 22,000 µg/L)

Note:

J = Detection is above the method detection limit, but below the reporting limit.

**Semivolatile Organic Compounds (SVOCs), Herbicides, Pesticides, and Polychlorinated Biphenyls (PCBs)**—Widespread detections of organic compounds in surface and spring water are generally not common in the Edwards Aquifer region. However, the EAA analyzes samples for these compounds because their detection can indicate the presence of chemicals originating from anthropogenic sources. Streams sampled in 2013 did not contain any SVOC, herbicide, pesticide, or PCB compounds. However, several SVOCs and herbicides were detected in spring samples, and one pesticide compound was detected in two spring samples. No PCBs were detected in spring samples.

The most common SVOC detected in spring samples for the year was bis(2-ethylhexyl)phthalate (DEHP), which was detected in 62 percent of the samples. Some of the sample-collection equipment (specific to spring sampling) utilizes plastic tubing containing DEHP, although not all spring samples are exposed to that equipment. Whether DEHP detections are false positives or representative of actual conditions is difficult to determine because DEHP is ubiquitous in most plastics, as well as cosmetics, inks, adhesives, and pesticides, and it is also used as lubricating oil for vacuum pumps and as a dielectric fluid. The validity of DEHP detections in spring samples has been assessed by analyzing various blank samples and duplicate samples and experimenting with alternative sampling equipment. Generally the compound was present in laboratory blank samples for the springs. In fact, only a few DEHP detections had no accompanying blank detection. Unfortunately, alternative equipment is not viable for all sample sites (specifically San Marcos Springs-Deep LR-67-01-819 and Hueco B Springs). On the basis of continued evaluation of this compound, however, the EAA has concluded that some detections are valid, and it will continue to evaluate the validity of DEHP detections in samples.

Detected compounds for surface water and springwater samples are summarized below. Detections of DEHP that are potentially valid are included in the summary, whereas detections considered to be false positives are omitted from the summary.

### Springs SVOCs

- Comal Springs #1 (DX-68-23-301)
  DEHP, detected at 34.8 µg/L (MCL = 6.0 µg/L)
  Butyl benzyl phthalate, detected at 2.24 J µg/L (MCL = 480 µg/L)
- Comal Springs #7 (DX-68-23-324)
  DEHP, detected at 5.94 J µg/L (MCL = 6.0 µg/L)
  Butyl benzyl phthalate, detected at 2.14 J µg/L (MCL = 480 µg/L)
- Hueco B Springs
  DEHP, detected at 5.21 J µg/L (MCL = 6.0 µg/L)
- San Marcos Springs—Hotel (LR-67-01-801)
  DEHP, detected at 5.05 J µg/L (MCL = 6.0 µg/L)
  Butyl benzyl phthalate, detected at 2.21 J µg/L (MCL = 480 µg/L)
  Di-n-octyl phthalate, detected at 2.95 J µg/L (MCL = 980 µg/L)
- San Marcos Springs—Deep (LR-67-01-819)
  Di-n-octyl phthalate, detected at 3.04 J µg/L (PCL = 980 µg/L)

Note: J = Detection above method detection limit but below reporting limit.

### Springs Herbicides

- Comal Springs #3 (DX-68-23-321)
  Coumaphos, detected at 0.0882 J µg/L (PCL = 170 µg/L)
  EPN, detected at 0.0671 J µg/L (PCL = 0.24 µg/L)

### Springs Pesticides

- Government Canyon Springs
  Gamma-BHC, detected at 0.00219 JH µg/L (MCL = 0.2 µg/L)
- San Marcos Springs—Deep (LR-67-01-819)
  Gamma-BHC, detected at 0.00130 JP µg/L (MCL = 0.2 µg/L)

Note:

J = Detection above method detection limit but below reporting limit.

H = Compound detected in associated laboratory blank sample.

P = Duplicate analyses outside of laboratory control limits.

The compound gamma-BHC (Lindane) is a pesticide that has not been used agriculturally since 2007 in the United States; however, it is still used as a pharmaceutical for lice treatment in limited cases. Detections occurred in Bexar and Hays counties. Because of the extremely limited use of this compound, each detection may be a *false positive*, although such an assessment has not been confirmed. Although trace quantities of this compound are detected in a small percentage of samples, positive confirmation of their presence is problematic.

**Pharmaceuticals and Personal Care Products (PPCPs)**—Water samples collected from four surface water sites and four springs were analyzed for PPCPs in 2013. PPCP compounds were detected in all four surface sites, and none of the spring samples tested positive for PPCP compounds. These detections are in the nanogram per liter (ng/L) range. Currently, PPCP compounds detected in environmental samples do not have a regulatory limit. Detections are summarized by sample site below.

### Surface Water PPCPs

- Blanco River at Wimberley
  Dilitiazem—(blood pressure medication) detected at 0.829 J ng/L
  Thiabendazole—(fungicide and parasiticide) detected at 10.5 ng/L
  Caffeine—(stimulant) detected at 17.4 J ng/L
  Trimethoprim—(antibiotic) detected at 5.45 J ng/L

- Cibolo Creek (near the Nature Center in Kendall County)
  17a-Estradiol—(synthetic estrogen hormone) detected at 1.57 J ng/L
  Trimethoprim—(antibiotic) detected at 10.6 ng/L
  Thiabendazole—(fungicide and parasiticide) detected at 12.8 ng/L
  Caffeine—(stimulant) detected at 133 ng/L
  Triclocarban—(ingredient in antibacterial soaps) detected at 3.95 J ng/L
  Sulfamethoxazole—(antibiotic) detected at 391 ng/L
  Cotinine—(metabolite of nicotine) detected at 49.3 ng/L
  DEET—(insecticide) detected at 59.4 ng/L
  Diltiazem—(blood pressure medication) detected at 7.87 HB ng/L
  Triclosan—(ingredient in antibacterial soaps) detected at 9.41 J ng/L

- Frio River at Concan
  Diltiazem—(blood pressure medication) detected at 0.997 J ng/L

- San Geronimo Creek
  17a-Estradiol—(synthetic estrogen hormone) detected at 1.27 J ng/L
  Thiabendazole—(fungicide and parasiticide) detected at 8.42 J ng/L

Note:

J = Detection above method detection limit but below reporting limit.

H = Sample prepped or analyzed beyond specified holding time.

B = Compound found in blank and sample.

Some anthropogenic compounds detected in stream and spring samples are designated as *false positives*, which means that they were introduced during sample collection or analysis. Detections are invalid if the compound occurs in the accompanying laboratory blank. If a compound is detected in an associated blank sample, the presence and concentration of the compound in the parent sample are not considered representative of the sample location.

## Lorence Creek Water Quality Monitoring Site

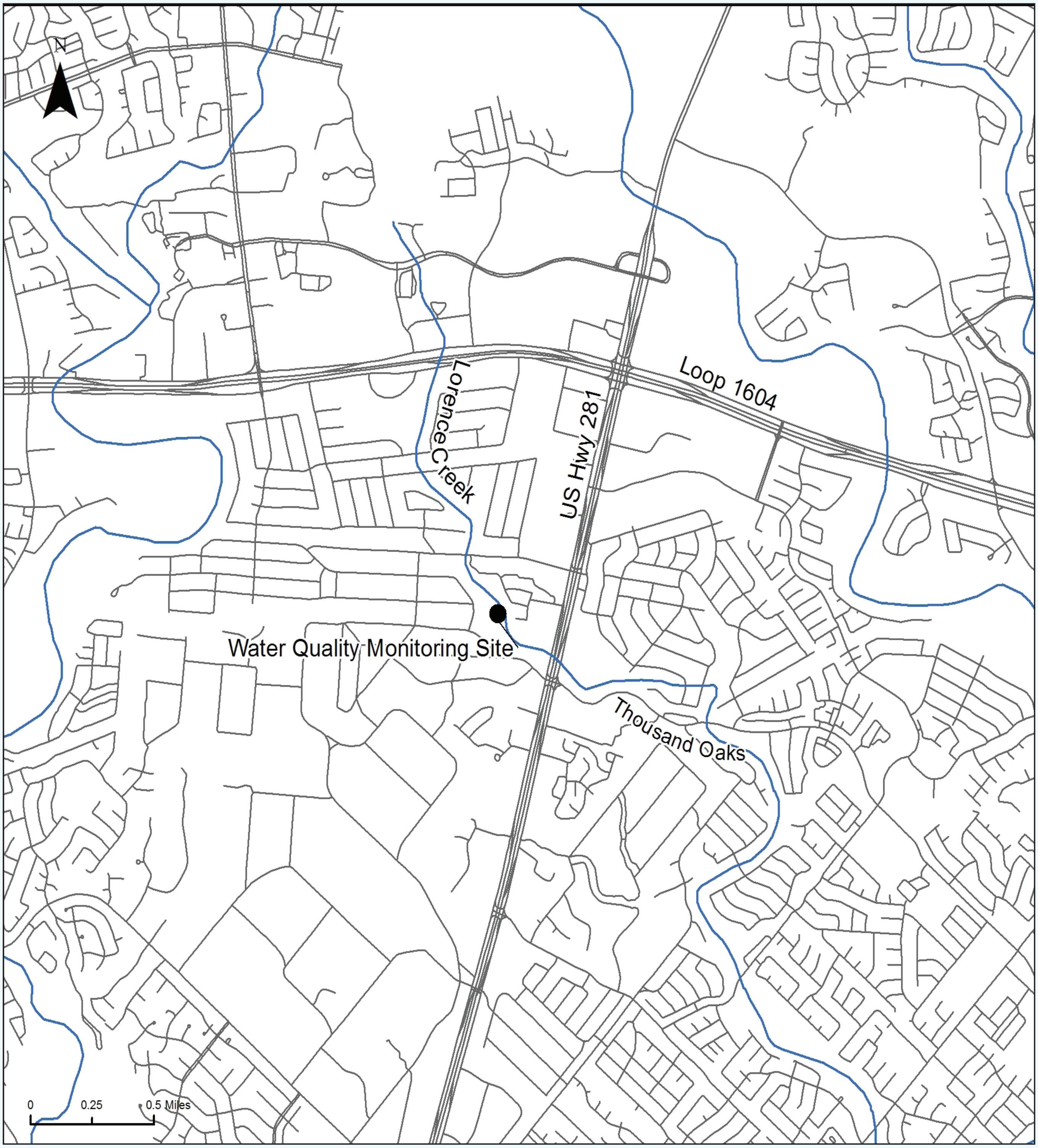
The Lorence Creek Water Quality Monitoring Site is a pilot study aimed at improving water quality in the Edwards Aquifer by excluding "first flush" flows of potentially contaminated stormwater into an existing sinkhole located in Lorence Creek (Figure 14). The site is located in northern Bexar County in Hollywood Park near U.S. Highway 281 and Thousand Oaks Drive (Figure 15). The system utilizes an engineered structure with a 24-inch diameter valve that automatically closes and opens at specific times during a precipitation or recharge event (Figure 16). A schematic diagram of the system is shown in Figure 17. The system monitors water quality continuously in Lorence Creek, and the valve is triggered on the basis of water quality data. The valve closes when the stormwater is turbid, typically during the first flush of a flow event, to prevent potentially polluted water from entering the recharge feature. Once the initial pulse of stormwater has passed the recharge feature and turbidity has decreased to an acceptable level, the 24-inch-diameter valve reopens to accept cleaner water (Figure 18).

The project required retrofitting an existing static stormwater-exclusion device, installing continuous water quality monitoring instruments, and installing the automated valve system to exclude first-flush stormwater. In addition, a small rental storage room was secured close by to house the electronic equipment and power source to operate the system. The instruments for continuous monitoring of water quality record pH, temperature, conductivity, water height, water flow, and turbidity. In addition to these monitoring instruments, the system has the potential to collect automated stormwater grab samples for further laboratory analyses.

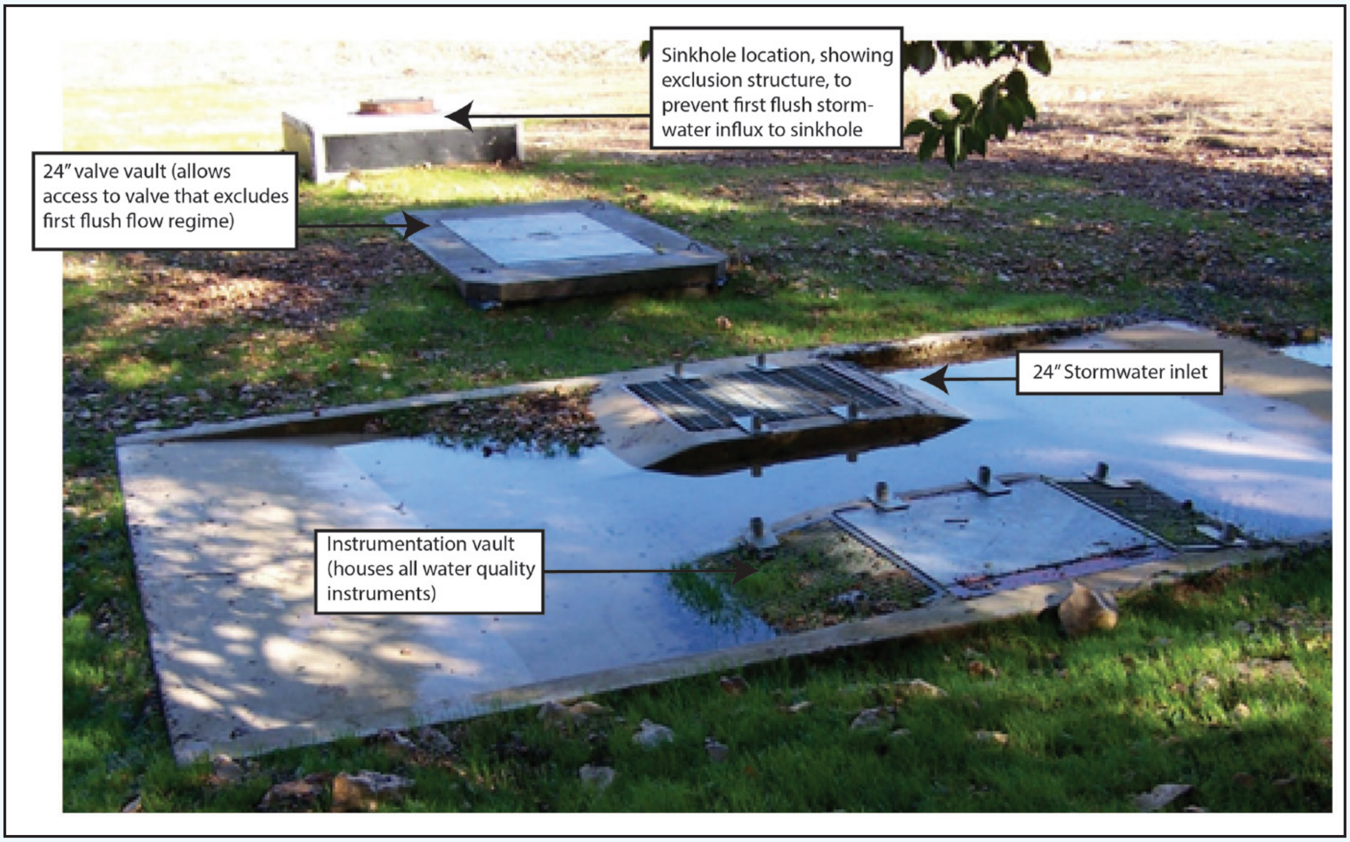
*(continued on p. 64)*

## Figure 14. Exploration of the Lorence Creek Sinkhole

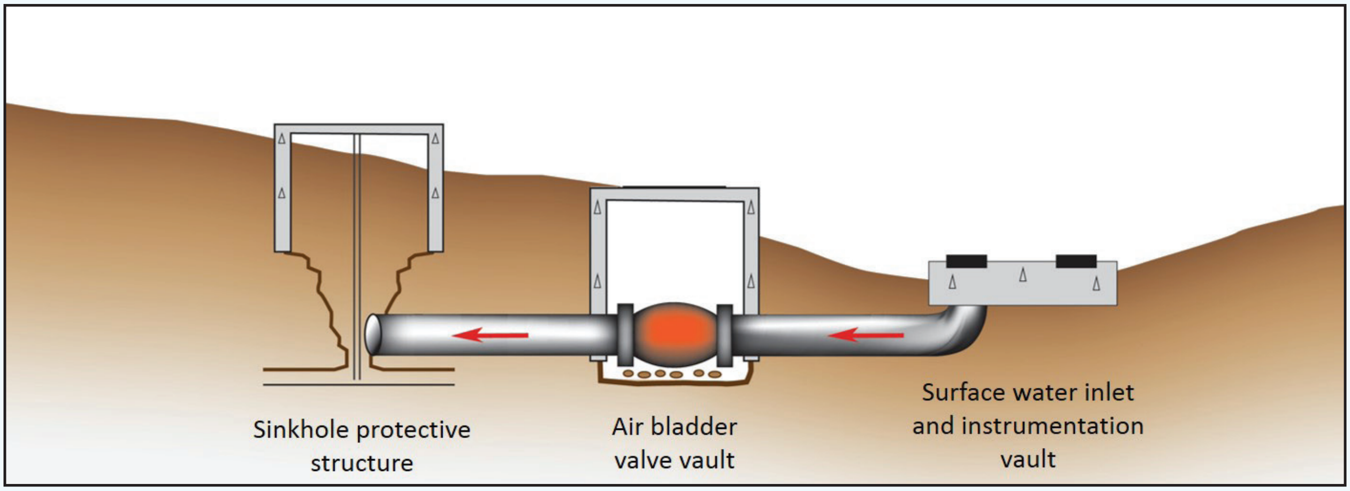
## Figure 15. Lorence Creek Water Quality Monitoring Site Location



## Figure 16. Stormwater Inlet and Instrumentation Vault




## Figure 17. Schematic Diagram of Inlet Valve (not to scale)



## Figure 18. Lorence Creek Stormwater Event

## Freshwater/Saline-Water Interface Studies

The regional boundary between fresh and saline parts of the Edwards Aquifer is defined by a mapped iso-concentration line representing 1,000 mg/L of total dissolved solids (TDS). Groundwater is commonly classified according to TDS concentrations (Table 15).

The interface varies both laterally and vertically in the aquifer, as determined from several wells near the boundary. Locally this line is referred to as the *freshwater/saline-water interface*, or bad-water line, which defines the farthest downdip extent of potable water (Pavilicek and others, 1987). The approximate location of the freshwater/saline-water interface is shown in Figure 1. Water quality concerns related to the position and stability of the freshwater/saline-water interface have been expressed by some researchers. However, water quality data collected during and since the drought of record in the 1950s do not indicate any significant movement of the interface during the range of observed aquifer conditions.

South and southeast of the interface, water from the aquifer is slightly to moderately saline and contains moderate to large concentrations of dissolved sodium chloride and sulfate. The interface varies both laterally and vertically, as determined in several wells near the boundary. Water from some wells north of the interface, and from all wells south of the interface, contains dissolved hydrogen sulfide gas. In most wells along the interface, freshwater has been encountered in the upper part and saline water in the lower part of the Edwards Aquifer (Reeves, 1971; Groschen, 1993). A few wells along the interface have encountered the opposite vertical distribution, with saline-water zones overlying freshwater zones, particularly in southern Medina County.

### Table 15. Classification of Groundwater Quality on the Basis of Total Dissolved Solids

| Description | TDS Concentration (mg/L) |
|---|---|
| Fresh | Less than 1,000 |
| Slightly saline | 1,000 to 3,000 |
| Moderately saline | 3,000 to 10,000 |
| Very saline | 10,000 to 35,000 |
| Brine | More than 35,000 |

*Source: Winslow and Kister, 1956.*

In 1985 the USGS, in cooperation with the Edwards Underground Water District (EUWD), TWDB, and the City Water Board—now San Antonio Water System (SAWS) —initiated a research study of the freshwater/saline-water interface. A series of seven wells were drilled in the area of the Freeman Coliseum in San Antonio, which transects the freshwater/saline-water interface, to detect changes in water quality as the hydraulic head in the aquifer changes. This program was implemented in response to the concern that increased aquifer withdrawals might result in encroachment of saline water into the aquifer's freshwater zone.

Additional water quality monitor-well transects across the freshwater/saline water interface were installed by the EUWD between 1989 and 1993.

SAWS, working with the USGS, TWDB, and the EAA, installed additional transects of freshwater/saline-water interface monitoring wells through 2005. To date, the following transects of monitoring wells have been installed:

- Artesia Pump Station (San Antonio) Transect (installed in 1986)
- New Braunfels (Comal Springs area) Transect (installed in 1989)
- San Marcos (San Marcos Springs area) Transect (installed in 1991)
- South Medina Well (installed in 1993)
- Kyle Transect (installed in 1998)
- East Uvalde "Knippa Gap" Transect (installed in 1999)
- "Tri-County" (Bexar-Comal-Guadalupe) Transect (installed in 2000)
- Hays–Fish Hatchery Transect (installed in 2001)
- Mission Road Transect (installed in 2002)
- Pitluk Transect Bexar County (installed in 2005).

Studies conducted to date indicate that, over the historical range, changes in aquifer water levels have little effect on water quality in wells adjacent to the freshwater/saline-water interface. The EAA, USGS, and SAWS will continue to monitor water quality in the freshwater/saline-water interface monitoring wells.

# SIGNIFICANT EVENTS AFFECTING THE EDWARDS AQUIFER IN CALENDAR YEAR 2013

Calendar year 2013 brought no relief from drought conditions that have persisted in the Central Texas region for the past several years. With the exception of year 2010, total annual recharge to the Edwards Aquifer has been significantly below the long-term (1934–2013) average of almost 700,000 acre-feet each year since 2008. The 2013 estimated total annual recharge of 182,600 acre-feet was the ninth-lowest estimate on record since 1934. On March 28, 2013, the Uvalde pool of the aquifer reached the Stage V critical-period management trigger for the first time since its inception, as the 10-day average water level in Uvalde Index Well J-27 fell below 840 feet above mean sea level (msl). The Uvalde pool remained in Stage V for the rest of 2013 and into 2014. The San Antonio pool fared marginally better and finished the year with San Antonio Index Well J-17 below the Stage III critical-period management trigger of 640 feet msl.

The general declining trend of water levels since late 2007 in Uvalde, Medina, and Bexar counties can be seen in Figures 19 through 21, which also show the estimated total monthly recharge for that period. A very wet summer in 2007 brought water levels in the Uvalde and San Antonio pools to nearly record high levels. Water levels began to decline sharply, however, because years 2008 and 2009 brought abnormally dry conditions to the region. Water levels recovered with moderately wet conditions in the first half of 2010 but fell sharply again during a period of record drought conditions. According to the Texas Office of the State Climatologist, the period from October 2010 through September 2011 was the driest 12-month period on record, with statewide rainfall totals far below the previous record low set in 1956 (Nielsen-Gammon, 2011). To compound these dry conditions, June through August 2011 average temperatures across Texas were about 2.5°F warmer than any previous Texas summer and over 5°F above the long-term summer average. Below-average rainfall in 2012 and 2013 resulted in continued low recharge rates, which lowered water levels in both the Uvalde and San Antonio Pools.

Figures 22 through 24 show a comparison of the past seven years with the seven-year drought of record from 1950 through 1957 for Uvalde Index Well J-27, San Antonio Index Well J-17, and springflow at Comal Springs, respectively. The estimated total monthly recharge for these two periods, shown at the bottom of each figure, indicates the relationship between recharge and these index-well water levels and springflow at Comal Springs. Although the last seven years had extended periods of low recharge similar to those experienced in the drought of the 1950s, the water levels and springflows benefitted from high recharge in 2007 and slightly above-average recharge in 2010. Just as important, the critical-period management rules instituted by the EAA since 2002 have helped to sustain springflow. As a result, effects of the current drought on the aquifer are not yet as severe as those experienced during the drought of record. Below-average recharge in 2014 and 2015, however, could lower water levels and springflows that might rival the drought of record. Conversely, a single wet year like 2007 could return aquifer levels to above-average conditions. Ultimately, the Edwards Aquifer system depends on rainfall to maintain water levels and sustain springflow.

## Figure 19. Water Levels in Selected Uvalde County Wells, September 2007–December 2013

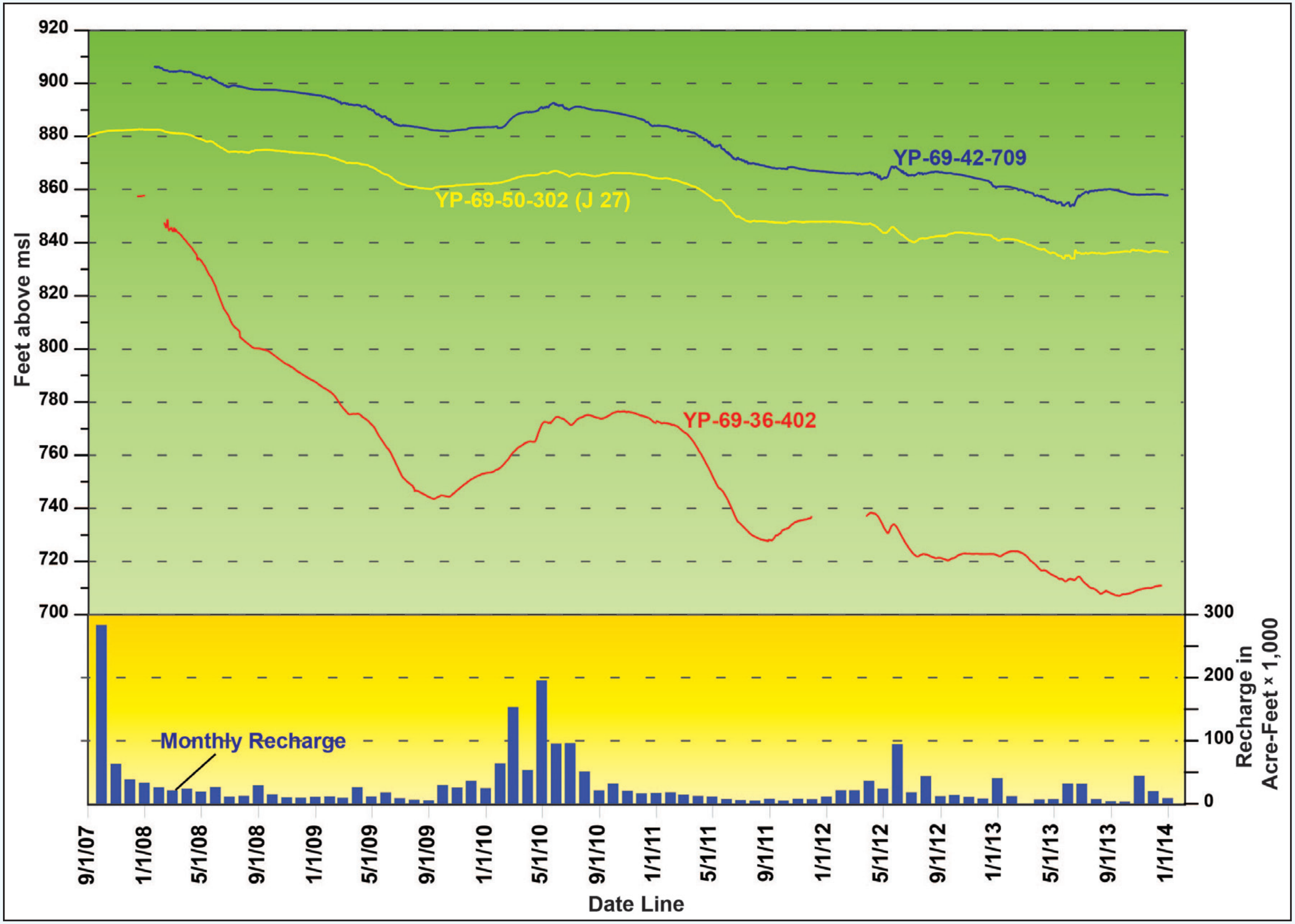
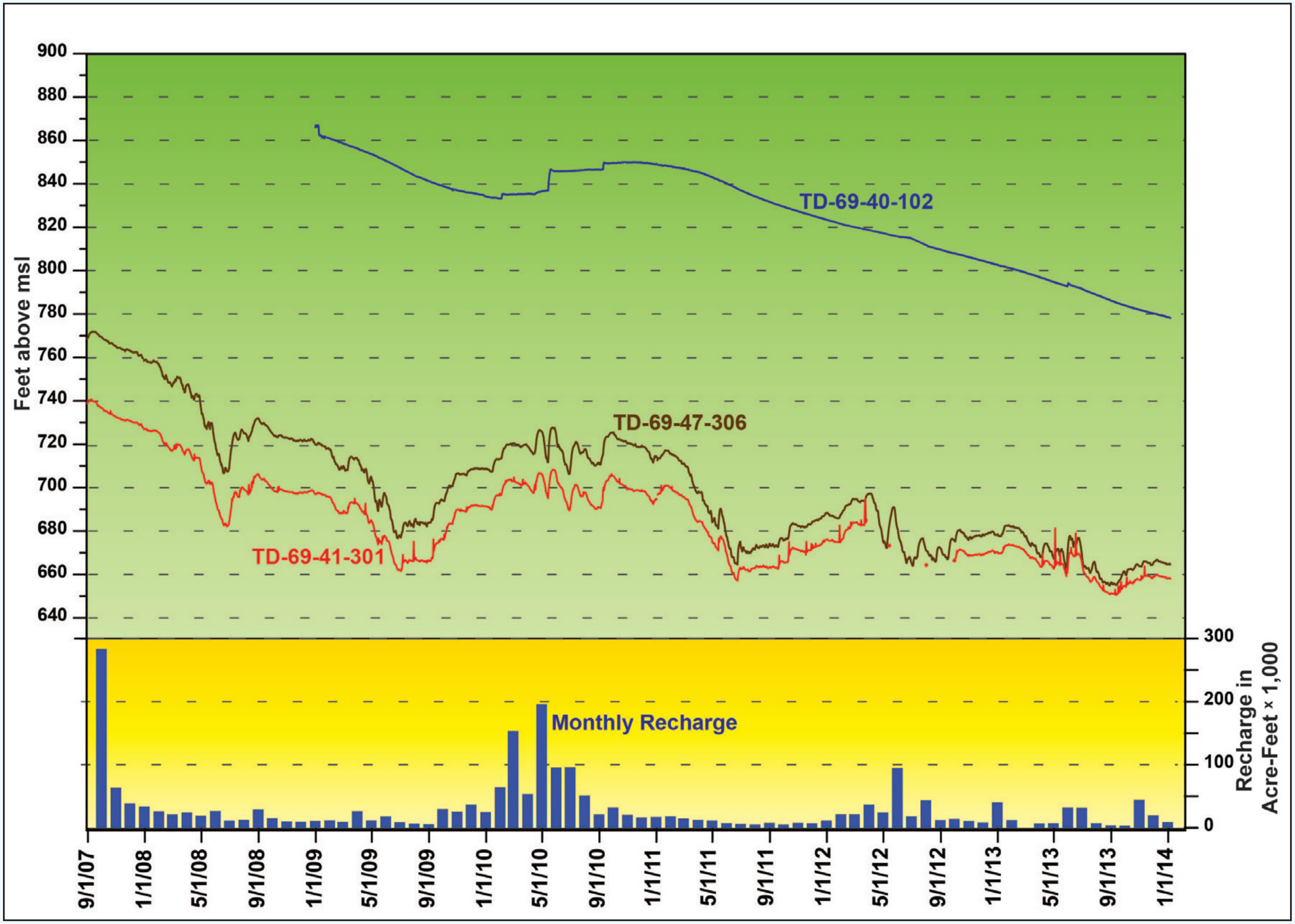


Figure 20. Water Levels in Selected Medina County Wells, September 2007–December 2013



## Figure 21. Water Levels in Selected Bexar County Wells, September 2007–December 2013

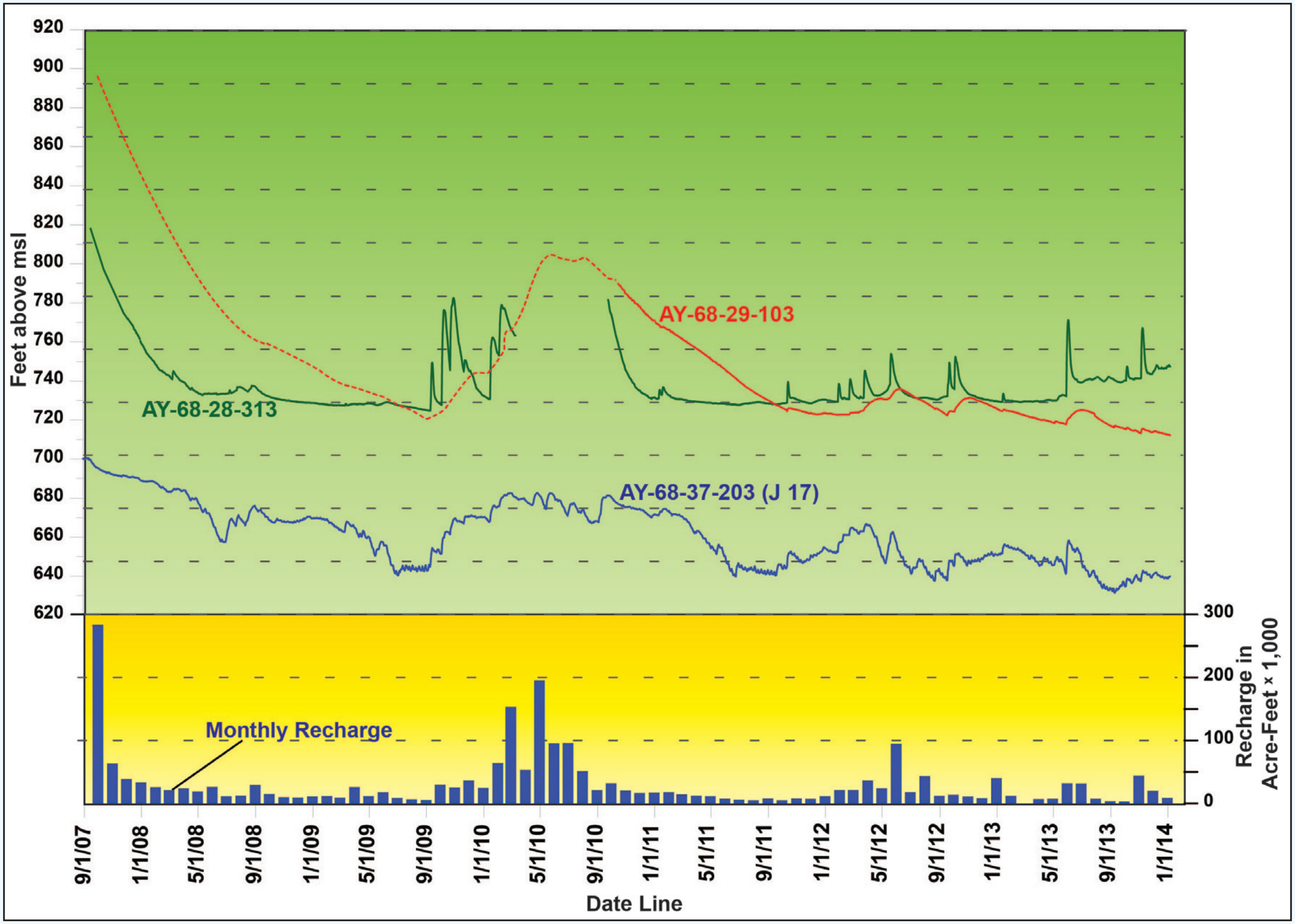


Figure 22. Comparison of Recharge and Water Levels in Uvalde Index Well J-27 for the Most Recent Seven Years with Those of the Drought of Record 1950–1957

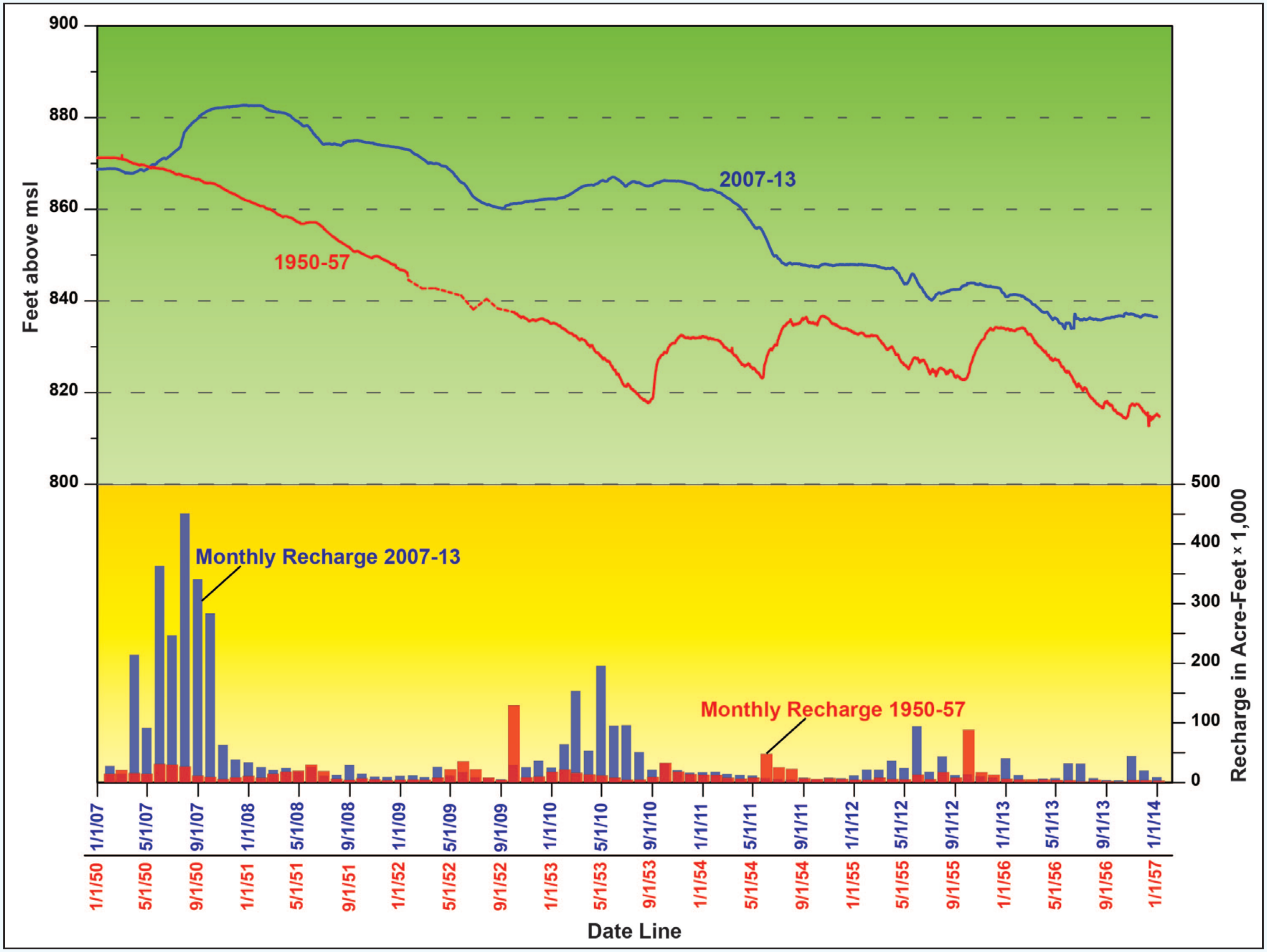


**Figure 23. Comparison of Recharge and Water Levels in San Antonio Index Well J-17 for the Most Recent Seven Years with Those of the Drought of Record 1950–1957**

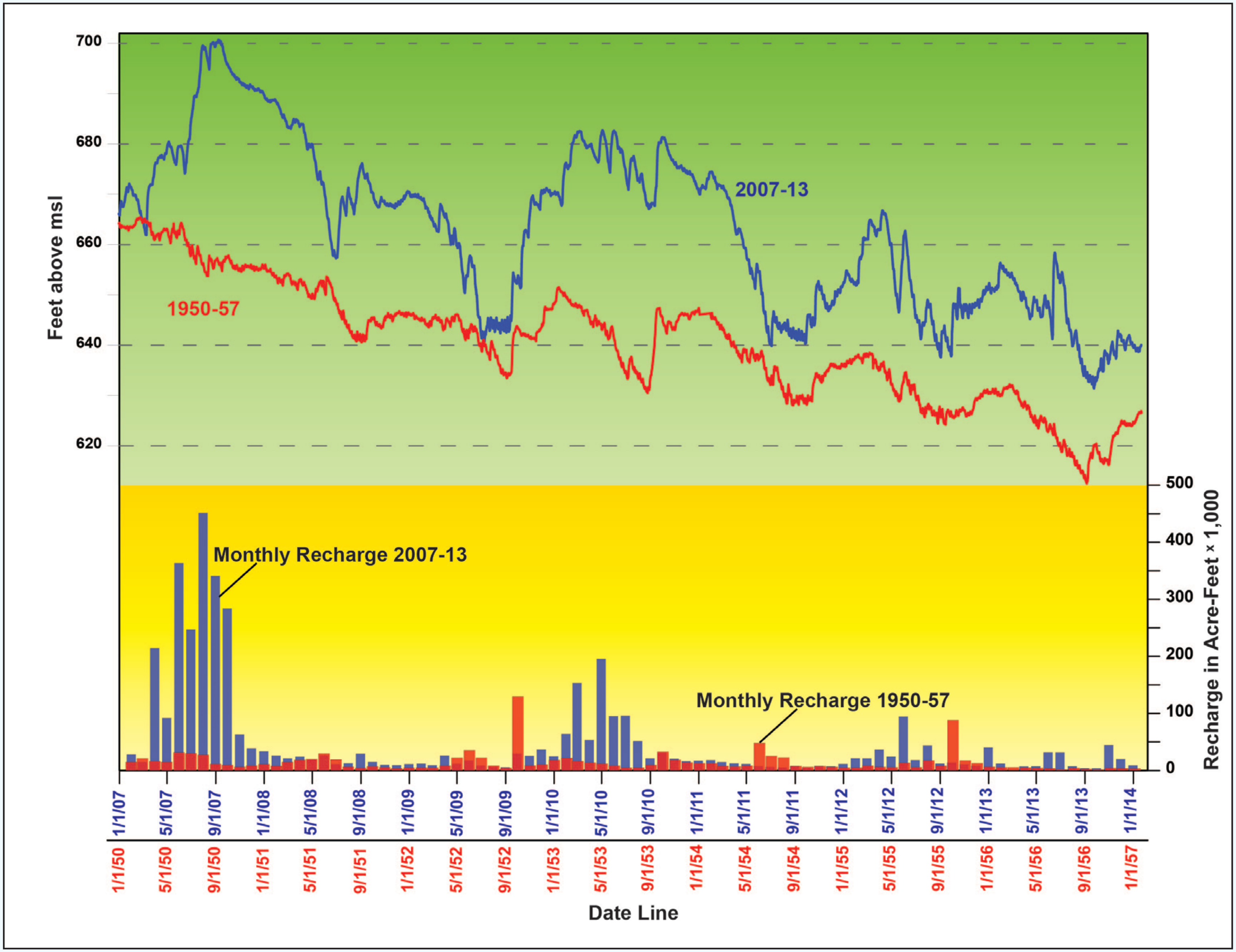
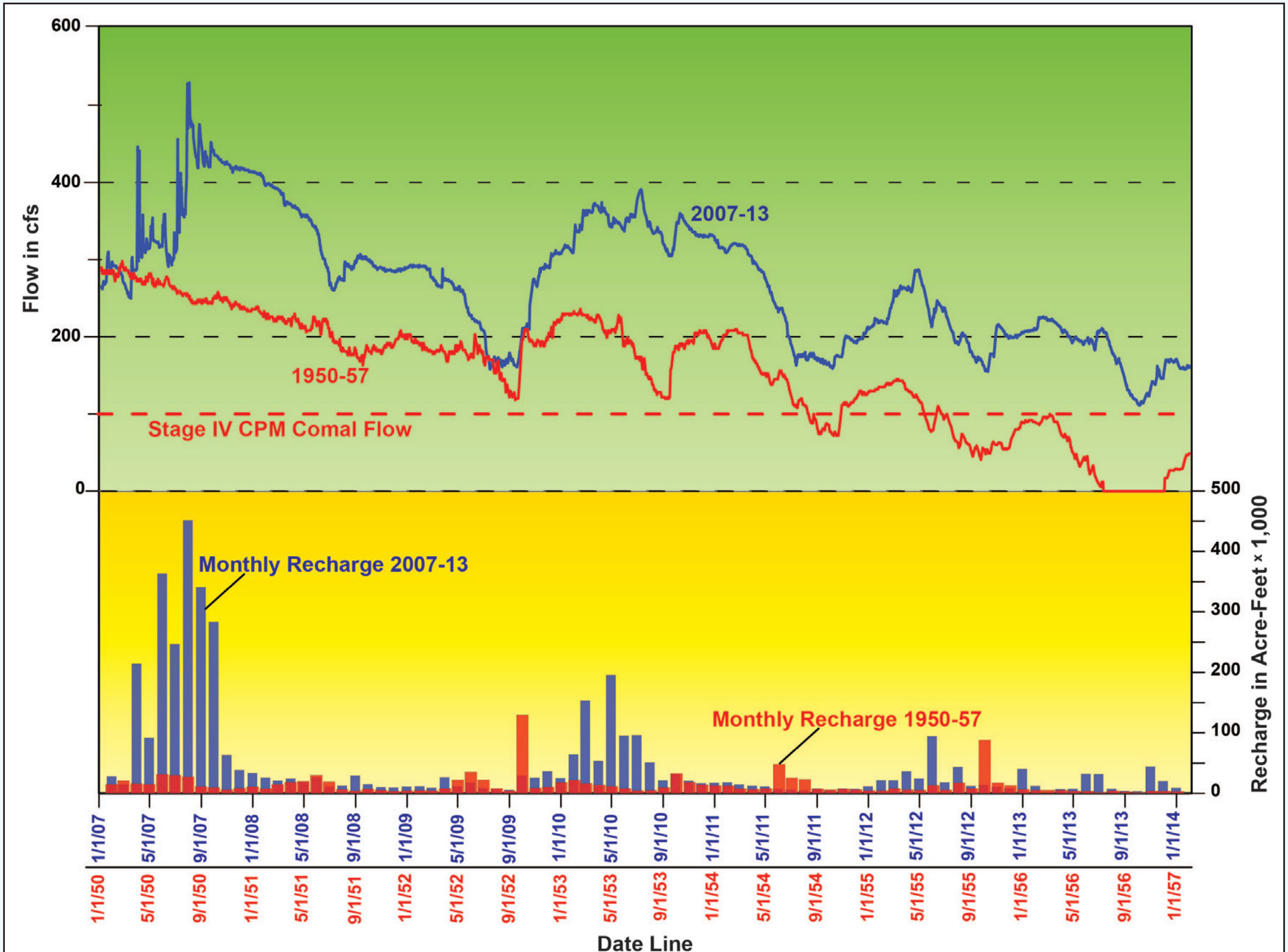


**Figure 24. Comparison of Recharge and Springflow at Comal Springs for the Most Recent Seven Years with Those of the Drought of Record 1950–1957**



# DEFINITIONS

Technical terms and abbreviations used in this report are defined below.

| | |
|---|---|
| **acre-foot** | Quantity of water required to cover one acre to a depth of one foot, equivalent to 43,560 $ft^3$ (cubic feet), about 325,851 gal (gallons), or 1,233 $m^3$ (cubic meters). |
| **aquifer** | A body of rock that contains sufficient saturated permeable material to conduct groundwater and to yield economically significant quantities of groundwater to wells and springs. |
| **artesian well** | A well tapping confined groundwater. Water in the well rises above the level of the confined water-bearing strata under artesian pressure but does not necessarily reach the land surface. |
| **artesian zone** | An area where the water level from a confined aquifer stands above the top of the strata in which the aquifer is located. |
| **average** | A number representing the sum of a group of added figures divided by the number of figures. |
| **bacteria** | Microscopic unicellular organisms, typically spherical, rodlike, or spiral and threadlike in shape, often clumped in colonies. Some bacteria are pathogenic (causing disease), whereas others perform an essential role in nature in the recycling of materials (measured in colonies/100 mL). |
| **conductivity** | A measure of the ease with which an electrical current can be caused to flow through an aqueous solution under the influence of an applied electric field. Expressed as the algebraic reciprocal of electrical resistance (measured in microsiemens per centimeter (µS/cm) at ambient temperature). Generally, in water, the greater the TDS content, the greater the value of conductivity. See also *specific conductance*. |
| **confined aquifer** | An artesian aquifer or an aquifer bound above and below by impermeable strata or by strata with lower permeability than the aquifer itself. |
| **domestic or livestock use** | Use of water for drinking, washing, or culinary purposes; or irrigation of a family garden or orchard, the produce of which is for household consumption only or watering animals. |
| **discharge** | Volume of water that passes a given point within a given period of time. |
| **drainage area** | Area or watershed where runoff from precipitation flows downgradient to the recharge zone of the Edwards Aquifer. Also known as the *Texas Hill Country*. |

**drainage basin**
An area bounded by a divide and occupied by a drainage system. It consists of a surface stream or a body of impounded surface water together with all tributary surface streams and bodies of impounded surface water.

**drinking water**
All water distributed by any agency or individual, public or private, for the purpose of human consumption or that may be used in the preparation of foods or beverages or for the cleaning of any utensil or article used in the course of preparation or consumption of food or beverages for human beings. The term *drinking water* shall also include all water supplied for human consumption or used by any institution catering to the public.

**Edwards Aquifer Authority (EAA)**
Regional governmental entity established by the Texas Legislature in 1993 to "manage, enhance, and protect the Edwards Aquifer system."

**Edwards Underground Water District (EUWD)**
Regional governmental entity that preceded the Edwards Aquifer Authority.

**freshwater/saline-water interface**
Interface or boundary that separates TDS values less than 1,000 mg/L (freshwater) from TDS values greater than 1,000 mg/L (saline water). Commonly referred to as the *bad water line*.

**gauging station**
A particular site that systematically collects hydrologic data such as streamflow, springflow, or precipitation.

**groundwater divide**
A ridge or mound in the water table or potentiometric surface from which the groundwater moves in opposite directions.

**Mean**
Arithmetic average of a population of numbers. Described mathematically as mean = $X_1+X_2+X_3+\ldots+X_n / n$.

**Median**
Numerical value at the "center" or "middle" of a data set, where one-half of the sample population is less than, and one-half is greater than, the median value.

**method blank**
Laboratory-grade water taken through the entire sample preparation and analytical procedure as part of a batch of samples to determine the presence or absence of target constituents or interferents. The blank is used to assess possible background contamination from the analytical process. This blank is also referred to as a *laboratory blank*.

**method detection limit**
The minimum concentration of a substance that can be measured and reported with 99-percent confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte. The method detection limit (MDL) is estimated in accordance with 40 CFR 136, Appendix B.

**micrograms per liter (µg/L)** — A unit for expressing the concentration of chemical constituents in solution as mass (micrograms) of solute per unit volume (liter) of water; 1,000 micrograms per liter is equal to 1 milligram per liter.

**milligrams per liter (mg/L)** — A unit for expressing the concentration of chemical constituents in solution as mass (milligrams) of solute per unit volume (liter) of water; 1,000 milligrams per liter is equal to 1 gram per liter.

**potentiometric surface** — An imaginary surface representing the total head of groundwater and defined by the level to which water will rise in a well. Under confined conditions, the water level will rise above the producing aquifer.

**public water system** — A system for the provision to the public of water for human consumption through pipes or other constructed conveyances, which includes all uses described under the definition for *drinking water*.

**real-time data** — Instantaneous or near-instantaneous information used to monitor a current condition such as precipitation, streamflow, spring discharge, etc.

**recharge** — Process involved in absorption and addition of water to the zone of saturation.

**recharge zone** — Area in which water infiltrates into the ground and eventually reaches the zone of saturation in one or more aquifers.

**semivolatile organic compounds (SVOCs)** — Class of naturally occurring and synthetic organic compounds such as polynuclear aromatic hydrocarbons and chlorinated hydrocarbons and pesticides; typically analyzed using gas chromatograph/mass spectrometers.

**specific conductance** — A measure of the ability of an aqueous solution to conduct an electrical current. Specific conductance is the given value of conductivity adjusted to a standard temperature of 25$^{o}$C. Expressed in microsiemens per centimeter (µS/cm). See also *conductivity*.

**ten-year floating average** — Calculated mean of the current year plus the previous nine years in a graph.

**total dissolved solids (TDS)** — Concentration of dissolved minerals in water, usually expressed in units of milligrams per liter (mg/L).

**transect wells** — A group of Edwards Aquifer monitoring wells positioned in a linear transect to monitor for changes in water quality along the freshwater/saline-water interface.

**trip blank**
Laboratory-grade water taken from the laboratory to the sampling site and returned to the laboratory unopened whenever samples are collected for analyses of volatile organic compounds. This blank is used to measure cross-contamination from the container and preservative during transport, field handling, and storage. It is analyzed for volatile organic compounds.

**unconfined aquifer**
An aquifer, or part of an aquifer, with a water table and containing groundwater that is not under pressure beneath relatively impermeable rocks.

**underflow**
Movement of water flowing beneath the land surface within the bed or alluvial plain of a surface stream.

**volatile organic compounds (VOCs)**
Class of naturally occurring and synthetic organic compounds with boiling points below 200˚C, typically analyzed using gas chromatograph/mass spectrometers; includes solvents such as trichloroethene or benzene.

**water level observation well**
A water well used to measure the water level or potentiometric surface of water-bearing strata such as the Edwards Aquifer, Leona Gravel Aquifer, and Lower Glen Rose (Trinity) Aquifer.

**water table**
Interface between the zone of saturation and the zone of aeration, where the surface pressure of unconfined groundwater is equal to the atmospheric pressure. Also known as the *piezometric surface*.

**zone of aeration**
Subsurface zone where the voids and pore spaces may contain water under less pressure than that of the atmosphere. Also known as the *vadose zone*.

**zone of saturation**
Subsurface zone in which all voids and pore spaces are filled with water under pressure greater than that of the atmosphere. Also known as the *phreatic zone*.

# ACKNOWLEDGMENTS

The EAA extends its appreciation to municipalities, agencies (Federal, State, and local), and other well owners who participated in this data compilation by granting access to their wells, land, and records. The EAA also extends its gratitude to the United States Geological Survey, Water Resources Division, San Antonio Subdistrict, for its work in compiling and calculating recharge and springflow discharge from the Edwards Aquifer.

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## Internet Resources:

MCL Information and Tables:
http://info.sos.state.tx.us/pls/pub/readtac$ext.ViewTAC?tac_view=5&ti=30&pt=1&ch=290&sch=F&rl=Y

TRRP Rules and PCL Tables:
http://www.tceq.state.tx.us/assets/public/remediation/trrp/trrptbls1_5_042308.xls

Population and Census Data:
http://quickfacts.census.gov/qfd/

# APPENDIX A

## Year 2013 Water Level Data for Selected Wells

**Table A-1. City of Uvalde Index Well J-27 (YP-69-50-302) Daily High Water Levels, imputed (in feet above msl), 2013.**

| Day | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 840.94 | 841.22 | 839.92 | 837.59 | 836.22 | 835.19 | 835.92 | 835.98 | 836.25 | 836.78 | 837.15 | 836.92 |
| 2 | 840.94 | 841.22 | 839.83 | 837.54 | 836.13 | 835.19 | 835.93 | 835.98 | 836.25 | 836.78 | 837.06 | 837.00 |
| 3 | 840.94 | 841.22 | 839.65 | 837.46 | 836.05 | 835.17 | 835.89 | 835.98 | 836.25 | 836.78 | 837.11 | 837.00 |
| 4 | 840.91 | 841.22 | 839.52 | 837.50 | 836.05 | 835.08 | 835.80 | 836.02 | 836.25 | 836.75 | 837.11 | 836.95 |
| 5 | 840.96 | 841.17 | 839.43 | 837.50 | 835.96 | 834.81 | 835.84 | 836.07 | 836.25 | 836.75 | 837.06 | 836.95 |
| 6 | 840.96 | 841.09 | 839.29 | 837.49 | 835.78 | 834.45 | 835.93 | 836.07 | 836.29 | 836.70 | 837.02 | 836.91 |
| 7 | 841.05 | 841.04 | 839.29 | 837.52 | 835.65 | 834.05 | 836.02 | 836.02 | 836.29 | 836.70 | 836.97 | 836.86 |
| 8 | 841.09 | 841.00 | 839.25 | 837.55 | 835.43 | 833.96 | 836.11 | 836.02 | 836.29 | 836.70 | 836.83 | 836.91 |
| 9 | 841.18 | 841.04 | 839.20 | 837.61 | 835.29 | 834.05 | 836.11 | 835.89 | 836.29 | 836.70 | 836.83 | 836.91 |
| 10 | 841.23 | 841.04 | 839.16 | 837.61 | 835.20 | 834.14 | 836.06 | 835.84 | 836.34 | 836.66 | 836.83 | 836.82 |
| 11 | 841.32 | 841.00 | 839.16 | 837.52 | ND | 834.19 | 835.97 | 835.84 | 836.38 | 836.66 | 836.78 | 836.82 |
| 12 | 841.36 | 841.00 | 839.16 | 837.43 | ND | 834.14 | 835.89 | 835.89 | 836.43 | 836.61 | 836.74 | 836.77 |
| 13 | 841.32 | 840.91 | 839.02 | 837.25 | ND | 834.10 | 835.89 | 835.89 | 836.43 | 836.84 | 836.70 | 836.82 |
| 14 | 841.36 | 840.86 | 838.93 | 837.11 | ND | 834.05 | 835.89 | 835.89 | 836.47 | 837.19 | 836.74 | 836.82 |
| 15 | 841.36 | 840.77 | 838.85 | 836.98 | ND | 836.47 | 835.93 | 835.84 | 836.47 | 837.24 | 836.74 | 836.77 |
| 16 | 841.36 | 840.59 | 838.76 | 836.84 | 834.99 | 837.14 | 836.02 | 835.84 | 836.47 | 837.28 | 836.70 | 836.77 |
| 17 | 841.36 | 840.55 | 838.67 | 836.71 | 834.95 | 837.10 | 836.02 | 835.84 | 836.47 | 837.33 | 836.65 | 836.77 |
| 18 | 841.40 | 840.50 | 838.62 | 836.62 | 834.72 | 836.69 | 836.06 | 835.84 | 836.47 | 837.37 | 836.61 | 836.77 |
| 19 | 841.40 | 840.41 | 838.48 | 836.49 | 834.45 | 836.24 | 836.11 | 835.84 | 836.47 | 837.28 | 836.56 | 836.73 |
| 20 | 841.40 | 840.46 | 838.44 | 836.35 | 834.27 | 836.10 | 836.15 | 835.89 | 836.47 | 837.24 | 836.47 | 836.68 |
| 21 | 841.40 | 840.41 | 838.39 | 836.26 | 834.23 | 836.15 | 836.29 | 835.89 | 836.56 | 837.24 | 836.47 | 836.68 |
| 22 | 841.40 | 840.28 | 838.30 | 836.13 | 834.05 | 836.19 | 836.33 | 835.93 | 836.61 | 837.15 | 836.43 | 836.59 |
| 23 | 841.40 | 840.19 | 838.12 | 835.99 | 833.92 | 836.24 | 836.33 | 835.98 | 836.65 | 837.15 | 836.47 | 836.51 |
| 24 | 841.40 | 840.19 | 838.08 | 835.86 | 834.27 | 836.19 | 836.24 | 836.02 | 836.64 | 837.10 | 836.56 | 836.55 |
| 25 | 841.40 | 840.14 | 837.99 | 835.99 | 835.04 | 836.15 | 836.15 | 836.02 | 836.64 | 837.06 | 836.70 | 836.55 |
| 26 | 841.36 | 840.05 | 837.94 | 836.13 | 835.17 | 836.06 | 836.06 | 836.07 | 836.69 | 837.06 | 836.74 | 836.51 |
| 27 | 841.36 | 840.05 | 837.81 | 836.22 | 835.22 | 835.97 | 836.06 | 836.07 | 836.64 | 837.06 | 836.83 | 836.51 |
| 28 | 841.36 | 839.97 | 837.73 | 836.31 | 835.13 | 835.88 | 836.11 | 836.11 | 836.69 | 837.20 | 836.83 | 836.60 |
| 29 | 841.36 | | 837.63 | 836.31 | 835.10 | 835.79 | 836.11 | 836.16 | 836.78 | 837.20 | 836.87 | 836.59 |
| 30 | 841.27 | | 837.59 | 836.26 | 835.14 | 835.83 | 836.02 | 836.20 | 836.78 | 837.20 | 836.87 | 836.52 |
| 31 | 841.23 | | 837.56 | | 835.14 | | 835.93 | 836.20 | | 837.15 | | 836.46 |

ND = No data available

**Table A-2. City of Hondo Well (TD-69-47-306) Daily High Water Levels (in feet above msl), 2013.**

| Day | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 677.73 | 681.60 | 675.64 | 669.07 | 670.52 | 677.07 | 664.11 | 659.42 | 655.81 | 662.19 | 664.62 | 666.71 |
| 2 | 677.65 | 681.51 | 675.28 | 669.10 | 670.94 | 675.98 | 663.87 | 658.49 | 655.89 | 662.28 | 665.04 | 666.80 |
| 3 | 677.48 | 681.51 | 674.70 | 670.77 | 671.45 | 676.54 | 663.53 | 657.91 | 655.72 | 662.36 | 665.63 | 666.77 |
| 4 | 677.82 | 681.60 | 674.44 | 672.20 | 671.78 | 676.54 | 662.86 | 658.24 | 655.48 | 662.28 | 666.04 | 666.68 |
| 5 | 678.49 | 681.60 | 673.94 | 672.96 | 671.95 | 675.95 | 662.86 | 658.16 | 655.14 | 662.44 | 666.04 | 666.35 |
| 6 | 678.57 | 681.51 | 673.61 | 673.71 | 671.70 | 674.27 | 662.78 | 657.74 | 655.06 | 662.44 | 666.04 | 665.93 |
| 7 | 678.91 | 681.43 | 673.27 | 674.13 | 670.77 | 672.84 | 662.86 | 657.57 | 655.31 | 662.60 | 665.87 | 665.76 |
| 8 | 679.67 | 681.34 | 673.02 | 674.13 | 669.35 | 674.61 | 663.03 | 656.65 | 655.48 | 662.60 | 665.79 | 665.93 |
| 9 | 680.25 | 681.34 | 673.94 | 674.22 | 668.59 | 674.94 | 663.03 | 656.31 | 655.98 | 662.44 | 665.87 | 666.01 |
| 10 | 681.09 | 681.43 | 674.53 | 674.13 | 670.04 | 675.03 | 662.27 | 656.40 | 656.23 | 662.27 | 665.87 | 665.84 |
| 11 | 681.93 | 681.26 | 674.36 | 674.30 | 671.03 | 674.35 | 661.60 | 656.65 | 656.40 | 662.02 | 665.79 | 665.68 |
| 12 | 682.35 | 681.01 | 674.11 | 674.13 | 671.61 | 673.43 | 661.01 | 656.73 | 656.99 | 662.10 | 665.62 | 665.51 |
| 13 | 682.35 | 680.59 | 673.69 | 673.38 | 671.78 | 673.60 | 660.59 | 656.48 | 657.32 | 662.18 | 665.20 | 665.68 |
| 14 | 682.44 | 680.42 | 673.61 | 672.96 | 670.94 | 674.77 | 661.35 | 656.48 | 657.49 | 662.60 | 665.37 | 665.68 |
| 15 | 682.52 | 680.09 | 673.19 | 672.71 | 670.52 | 675.78 | 661.77 | 656.14 | 657.66 | 663.02 | 665.29 | 665.51 |
| 16 | 682.52 | 679.33 | 673.10 | 672.03 | 670.19 | 676.45 | 662.27 | 655.64 | 657.91 | 663.28 | 665.29 | 665.42 |
| 17 | 682.52 | 679.58 | 673.44 | 671.11 | 668.59 | 676.87 | 663.11 | 655.98 | 658.75 | 663.78 | 665.37 | 665.42 |
| 18 | 682.44 | 679.67 | 673.35 | 670.61 | 666.91 | 676.79 | 664.37 | 656.06 | 659.26 | 664.28 | 665.04 | 665.17 |
| 19 | 682.52 | 679.41 | 672.43 | 670.61 | 665.82 | 676.79 | 665.04 | 656.14 | 659.84 | 664.45 | 664.45 | 665.17 |
| 20 | 682.60 | 679.16 | 671.17 | 670.77 | 665.15 | 675.87 | 665.46 | 655.98 | 660.26 | 664.70 | 664.28 | 665.09 |
| 21 | 682.60 | 678.74 | 670.42 | 670.69 | 664.06 | 675.03 | 665.80 | 655.22 | 660.93 | 664.70 | 664.36 | 665.17 |
| 22 | 682.27 | 678.07 | 669.74 | 670.27 | 662.88 | 673.77 | 665.80 | 655.14 | 661.27 | 664.62 | 664.36 | 665.09 |
| 23 | 682.18 | 677.65 | 669.58 | 669.10 | 661.88 | 672.59 | 665.13 | 655.14 | 661.35 | 664.37 | 664.62 | 664.75 |
| 24 | 682.02 | 677.23 | 669.74 | 668.34 | 663.64 | 670.91 | 664.12 | 654.97 | 661.35 | 664.20 | 664.95 | 664.59 |
| 25 | 682.10 | 677.57 | 670.00 | 668.17 | 667.58 | 669.32 | 662.53 | 655.64 | 660.85 | 663.95 | 665.45 | 664.75 |
| 26 | 682.02 | 677.73 | 669.58 | 667.33 | 671.45 | 667.05 | 661.69 | 656.23 | 660.10 | 663.78 | 665.79 | 664.75 |
| 27 | 681.93 | 677.06 | 668.82 | 667.99 | 674.30 | 665.37 | 661.10 | 656.31 | 659.76 | 663.86 | 665.87 | 664.59 |
| 28 | 681.93 | 676.22 | 668.15 | 669.63 | 676.06 | 663.94 | 661.27 | 656.23 | 659.76 | 663.78 | 666.04 | 664.75 |
| 29 | 682.27 | | 667.90 | 669.85 | 677.24 | 663.36 | 661.27 | 655.89 | 660.77 | 663.70 | 666.13 | 664.92 |
| 30 | 682.18 | | 668.23 | 670.19 | 677.74 | 663.86 | 660.85 | 655.39 | 661.69 | 663.61 | 666.46 | 664.84 |
| 31 | 681.85 | | 668.65 | | 677.66 | | 660.34 | 655.56 | | 663.86 | | 664.59 |

# Appendix A (cont.)

**Table A-3. City of Castroville Well (TD-68-41-301) Daily High Water Levels (in feet above msl), 2013.**

| Day | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 669.9 | 673.1 | 669.1 | 663.6 | 664.3 | 669.9 | 660.6 | 655.4 | 651.1 | 655.6 | 658.1 | 659.8 |
| 2 | 669.8 | 673.1 | 668.9 | 669.4 | 665.9 | 672.3 | 660.3 | 655.0 | 651.1 | 655.8 | 658.4 | 660.0 |
| 3 | 669.6 | 672.9 | 668.8 | 666.4 | 665.0 | 669.8 | 660.0 | 654.4 | 650.9 | 656.1 | 658.9 | 660.0 |
| 4 | 669.7 | 673.1 | 668.7 | 664.4 | 665.5 | 669.8 | 659.5 | 654.3 | 653.0 | 656.1 | 659.2 | 659.8 |
| 5 | 670.1 | 673.0 | 668.4 | 665.0 | 665.6 | 669.5 | 659.1 | 654.1 | 650.6 | 656.0 | 659.4 | 659.6 |
| 6 | 670.2 | 672.9 | 667.8 | 665.6 | 665.6 | 668.9 | 658.8 | 653.8 | 650.6 | 657.0 | 663.8 | 659.3 |
| 7 | 670.4 | 672.8 | 667.7 | 666.1 | 665.3 | 668.4 | 658.7 | 653.5 | 650.6 | 656.1 | 659.2 | 659.1 |
| 8 | 671.0 | 672.7 | 667.5 | 666.2 | 664.8 | 668.4 | 658.7 | 653.0 | 651.2 | 656.1 | 659.3 | 659.3 |
| 9 | 672.6 | 672.7 | 667.8 | 666.4 | 664.3 | 668.6 | 658.5 | 652.7 | 650.9 | 656.1 | 659.5 | 659.3 |
| 10 | 672.0 | 672.9 | 668.0 | 666.3 | 669.7 | 668.6 | 658.0 | 655.1 | 651.1 | 656.0 | 659.4 | 659.1 |
| 11 | 672.6 | 672.7 | 668.0 | 666.2 | 664.7 | 668.3 | 657.5 | 652.4 | 654.7 | 655.9 | 659.5 | 659.0 |
| 12 | 673.2 | 672.6 | 667.9 | 666.2 | 665.0 | 679.0 | 657.1 | 652.4 | 651.7 | 655.9 | 659.3 | 658.9 |
| 13 | 673.2 | 672.3 | 667.6 | 666.0 | 665.0 | 672.6 | 656.6 | 652.3 | 651.9 | 656.7 | 659.0 | 659.1 |
| 14 | 673.4 | 672.2 | 667.3 | 666.0 | 664.9 | 669.1 | 656.6 | 652.2 | 652.1 | 656.3 | 659.2 | 659.1 |
| 15 | 673.5 | 672.1 | 667.3 | 665.7 | 664.8 | 668.9 | 656.7 | 652.0 | 652.2 | 656.5 | 659.2 | 658.8 |
| 16 | 673.5 | 671.8 | 667.4 | 665.4 | 664.6 | 669.4 | 656.9 | 651.8 | 656.2 | 657.3 | 659.3 | 658.9 |
| 17 | 673.4 | 671.8 | 667.5 | 664.8 | 664.1 | 669.6 | 657.3 | 651.8 | 656.7 | 657.1 | 659.2 | 658.8 |
| 18 | 673.5 | 671.9 | 667.4 | 664.7 | 663.1 | 669.6 | 657.9 | 651.8 | 653.2 | 657.6 | 659.0 | 658.7 |
| 19 | 673.7 | 671.6 | 666.9 | 664.3 | 662.3 | 669.6 | 658.3 | 651.8 | 653.5 | 657.6 | 658.7 | 658.7 |
| 20 | 673.8 | 671.5 | 666.5 | 664.5 | 661.7 | 669.3 | 658.6 | 651.6 | 653.9 | 658.0 | 658.6 | 658.7 |
| 21 | 673.8 | 671.5 | 666.1 | 664.4 | 660.9 | 668.7 | 658.9 | 651.4 | 654.2 | 658.0 | 658.5 | 658.8 |
| 22 | 673.7 | 671.0 | 666.0 | 664.2 | 660.1 | 668.2 | 658.9 | 651.1 | 654.6 | 657.9 | 658.3 | 658.5 |
| 23 | 673.6 | 670.7 | 665.6 | 663.8 | 659.2 | 667.5 | 658.5 | 651.1 | 654.8 | 657.8 | 658.3 | 658.2 |
| 24 | 673.6 | 670.4 | 665.3 | 663.2 | 662.6 | 666.8 | 658.1 | 650.8 | 654.7 | 657.7 | 659.0 | 658.1 |
| 25 | 673.5 | 670.4 | 665.1 | 663.0 | 660.8 | 665.6 | 657.5 | 651.0 | 654.6 | 657.5 | 659.1 | 658.3 |
| 26 | 673.6 | 670.2 | 664.6 | 662.6 | 663.6 | 664.3 | 657.2 | 651.3 | 654.5 | 657.5 | 658.9 | 658.2 |
| 27 | 673.5 | 669.9 | 664.3 | 663.6 | 666.1 | 663.1 | 656.7 | 651.4 | 654.2 | 657.6 | 659.1 | 658.2 |
| 28 | 673.5 | 669.4 | 663.9 | 663.2 | 668.0 | 662.0 | 656.5 | 651.3 | 656.0 | 657.5 | 659.2 | 658.3 |
| 29 | 673.7 | | 663.5 | 681.2 | 669.4 | 661.1 | 656.4 | 651.2 | 658.7 | 657.4 | 659.3 | 658.4 |
| 30 | 673.5 | | 663.5 | 667.8 | 669.9 | 660.6 | 656.1 | 651.1 | 655.2 | 659.4 | 659.5 | 658.2 |
| 31 | 673.2 | | 663.6 | | 670.0 | | 655.8 | 651.0 | | 658.5 | | 658.1 |

**Table A-4. Bexar County Index Well J-17 (AY-68-37-203) Daily High Water Levels (in feet above msl), 2013.**

| Day | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 651.49 | 654.01 | 650.61 | 646.23 | 648.04 | 656.72 | 645.28 | 637.05 | 633.78 | 638.91 | 641.13 | 642.02 |
| 2 | 651.41 | 654.43 | 650.68 | 645.80 | 648.31 | 656.39 | 644.80 | 636.48 | 633.51 | 638.70 | 641.82 | 641.69 |
| 3 | 651.03 | 654.25 | 650.67 | 647.02 | 649.13 | 656.17 | 644.22 | 636.66 | 631.72 | 638.54 | 642.88 | 641.46 |
| 4 | 651.15 | 653.92 | 650.19 | 647.86 | 649.86 | 655.76 | 643.47 | 637.28 | 631.45 | 638.02 | 642.37 | 640.73 |
| 5 | 651.84 | 653.84 | 649.18 | 648.42 | 649.89 | 654.94 | 642.92 | 636.58 | 632.01 | 638.12 | 642.20 | 640.48 |
| 6 | 651.87 | 653.54 | 649.01 | 648.89 | 649.22 | 653.98 | 643.06 | 635.21 | 632.15 | 638.36 | 641.86 | 640.27 |
| 7 | 651.45 | 653.73 | 648.88 | 649.59 | 648.48 | 653.39 | 643.05 | 634.74 | 632.77 | 638.12 | 641.66 | 640.44 |
| 8 | 651.77 | 653.64 | 648.96 | 649.00 | 647.69 | 653.70 | 642.83 | 634.48 | 633.64 | 637.18 | 641.66 | 640.57 |
| 9 | 654.25 | 653.99 | 649.58 | 648.93 | 647.42 | 654.04 | 642.43 | 633.93 | 633.35 | 637.02 | 642.16 | 640.27 |
| 10 | 654.89 | 654.41 | 650.60 | 648.55 | 647.75 | 653.49 | 641.37 | 634.62 | 632.91 | 636.35 | 641.98 | 639.77 |
| 11 | 655.65 | 653.87 | 650.57 | 648.75 | 648.51 | 652.40 | 640.65 | 635.79 | 633.11 | 636.58 | 641.88 | 639.76 |
| 12 | 656.23 | 653.73 | 650.32 | 648.75 | 648.73 | 652.47 | 639.80 | 635.78 | 633.60 | 637.10 | 640.90 | 639.48 |
| 13 | 656.35 | 653.39 | 649.86 | 648.83 | 648.41 | 652.87 | 639.84 | 634.84 | 633.60 | 637.19 | 640.77 | 639.51 |
| 14 | 655.97 | 653.10 | 649.28 | 648.96 | 647.58 | 653.47 | 640.37 | 633.89 | 634.47 | 638.09 | 640.85 | 640.06 |
| 15 | 655.69 | 652.99 | 649.25 | 647.99 | 647.60 | 654.03 | 640.31 | 633.74 | 634.86 | 638.33 | 640.73 | 639.93 |
| 16 | 655.55 | 653.23 | 649.30 | 647.20 | 646.97 | 654.54 | 640.99 | 633.51 | 634.76 | 638.82 | 640.92 | 639.55 |
| 17 | 655.39 | 653.28 | 649.44 | 646.88 | 646.22 | 654.18 | 641.62 | 634.03 | 635.34 | 639.70 | 641.02 | 639.25 |
| 18 | 655.22 | 652.83 | 648.69 | 646.90 | 645.62 | 653.60 | 642.22 | 634.67 | 635.07 | 640.00 | 640.40 | 638.84 |
| 19 | 655.84 | 652.21 | 647.82 | 646.93 | 645.34 | 653.08 | 642.41 | 634.13 | 635.09 | 640.26 | 639.78 | 638.87 |
| 20 | 655.73 | 652.37 | 647.49 | 647.17 | 644.14 | 652.32 | 642.82 | 633.26 | 635.49 | 640.66 | 639.35 | 639.06 |
| 21 | 655.37 | 652.40 | 647.63 | 647.45 | 642.89 | 651.85 | 642.91 | 632.79 | 637.01 | 640.00 | 639.06 | 639.36 |
| 22 | 654.72 | 651.91 | 647.42 | 646.64 | 642.08 | 651.81 | 642.39 | 633.16 | 637.38 | 639.20 | 639.25 | 639.46 |
| 23 | 654.69 | 652.01 | 647.22 | 645.96 | 641.24 | 651.34 | 641.50 | 632.74 | 637.05 | 638.95 | 640.18 | 639.07 |
| 24 | 654.61 | 651.95 | 647.34 | 645.60 | 642.09 | 650.18 | 640.53 | 633.09 | 636.05 | 638.28 | 640.41 | 638.72 |
| 25 | 654.49 | 651.41 | 646.74 | 645.68 | 649.72 | 648.00 | 639.88 | 634.04 | 635.31 | 638.03 | 640.81 | 639.23 |
| 26 | 654.82 | 651.06 | 646.28 | 645.65 | 654.66 | 646.75 | 639.12 | 633.34 | 634.78 | 638.32 | 641.11 | 639.20 |
| 27 | 655.02 | 650.78 | 645.63 | 645.79 | 656.59 | 646.00 | 639.34 | 633.73 | 634.78 | 638.71 | 641.34 | 638.84 |
| 28 | 654.55 | 650.68 | 645.24 | 645.71 | 657.91 | 644.65 | 640.06 | 633.57 | 635.07 | 638.10 | 641.52 | 639.59 |
| 29 | 654.39 | | 645.53 | 646.12 | 658.39 | 644.36 | 639.38 | 632.86 | 637.64 | 637.37 | 641.51 | 639.72 |
| 30 | 654.29 | | 645.75 | 647.63 | 658.21 | 644.72 | 637.68 | 632.26 | 638.46 | 637.76 | 641.81 | 639.74 |
| 31 | 653.90 | | 646.11 | | 657.10 | | 637.52 | 633.07 | | 639.88 | | 640.06 |

## Appendix A (cont.)

**Table A-5. Landa Park Well (DX-68-23-302) Daily High Water Levels (in feet above msl), 2013.**

| Day | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 623.6 | 623.9 | 623.6 | 623.1 | 623.1 | 623.9 | 623.3 | 622.4 | 621.4 | 622.0 | 622.7 | 622.9 |
| 2 | 623.7 | 624.0 | 623.6 | 623.1 | 623.4 | 623.9 | 623.2 | 622.4 | 621.4 | 622.1 | 622.8 | 622.9 |
| 3 | 623.6 | 624.0 | 623.6 | 623.2 | 623.3 | 623.9 | 623.2 | 622.4 | 621.3 | 622.0 | 622.8 | 622.9 |
| 4 | 623.6 | 624.0 | 623.6 | 623.2 | 623.3 | 623.9 | 623.1 | 622.4 | 621.2 | 622.0 | 622.8 | 622.9 |
| 5 | 623.6 | 623.9 | 623.5 | 623.2 | 623.3 | 623.9 | 623.1 | 622.3 | 621.2 | 622.0 | 622.8 | 622.8 |
| 6 | 623.6 | 623.9 | 623.5 | 623.3 | 623.3 | 623.9 | 623.1 | 622.3 | 621.2 | 622.0 | 622.8 | 622.8 |
| 7 | 623.6 | 623.9 | 623.5 | 623.3 | 623.3 | 623.9 | 623.1 | 622.1 | 621.2 | 622.0 | 622.8 | 622.8 |
| 8 | 623.7 | 623.9 | 623.5 | 623.3 | 623.2 | 623.9 | 623.0 | 622.1 | 621.3 | 621.9 | 622.9 | 622.8 |
| 9 | 624.1 | 623.9 | 623.5 | 623.3 | 623.2 | 623.9 | 622.9 | 622.0 | 621.3 | 621.9 | 622.9 | 622.7 |
| 10 | 623.9 | 623.9 | 623.5 | 623.3 | 623.4 | 623.9 | 622.9 | 622.1 | 621.3 | 621.8 | 622.9 | 622.7 |
| 11 | 623.9 | 623.9 | 623.5 | 623.3 | 623.3 | 623.8 | 622.8 | 622.1 | 621.3 | 621.8 | 622.9 | 622.7 |
| 12 | 624.0 | 623.9 | 623.5 | 623.2 | 623.3 | 623.8 | 622.7 | 622.1 | 621.3 | 621.9 | 622.8 | 622.7 |
| 13 | 624.0 | 623.9 | 623.5 | 623.2 | 623.3 | 623.8 | 622.8 | 622.0 | 621.3 | 622.0 | 622.8 | 622.7 |
| 14 | 624.0 | 623.8 | 623.5 | 623.2 | 623.3 | 623.9 | 622.8 | 622.0 | 621.4 | 622.0 | 622.8 | 622.7 |
| 15 | 624.0 | 623.8 | 623.4 | 623.2 | 623.2 | 623.9 | 623.0 | 621.6 | 621.5 | 622.0 | 622.8 | 622.7 |
| 16 | 624.0 | 623.8 | 623.4 | 623.1 | 623.2 | 624.0 | 623.1 | 621.6 | 621.5 | 622.2 | 622.8 | 622.7 |
| 17 | 624.0 | 623.9 | 623.5 | 623.1 | 623.1 | 624.0 | 623.1 | 621.6 | 621.5 | 622.2 | 622.8 | 622.6 |
| 18 | 624.0 | 623.8 | 623.4 | 623.1 | 623.1 | 624.0 | 622.9 | 621.7 | 621.5 | 622.2 | 622.8 | 622.6 |
| 19 | 624.0 | 623.8 | 623.3 | 623.1 | 623.1 | 623.9 | 622.9 | 621.6 | 621.5 | 622.2 | 622.7 | 622.6 |
| 20 | 624.0 | 623.8 | 623.3 | 623.1 | 623.0 | 623.9 | 623.0 | 621.6 | 621.6 | 622.2 | 622.7 | 622.6 |
| 21 | 624.0 | 623.8 | 623.3 | 623.1 | 622.9 | 623.8 | 623.0 | 621.5 | 621.7 | 622.5 | 622.7 | 622.4 |
| 22 | 624.0 | 623.7 | 623.3 | 623.1 | 622.9 | 623.8 | 622.9 | 621.5 | 621.7 | 622.5 | 622.7 | 622.4 |
| 23 | 624.0 | 623.7 | 623.3 | 623.0 | 622.8 | 623.8 | 622.8 | 621.4 | 621.7 | 622.5 | 622.7 | 622.3 |
| 24 | 624.0 | 623.7 | 623.3 | 623.0 | 623.0 | 623.7 | 622.8 | 621.4 | 621.6 | 622.4 | 622.8 | 622.3 |
| 25 | 624.0 | 623.7 | 623.3 | 623.0 | 623.5 | 623.6 | 622.7 | 621.5 | 621.6 | 622.4 | 622.8 | 622.4 |
| 26 | 624.0 | 623.7 | 623.2 | 622.9 | 623.6 | 623.5 | 622.6 | 621.4 | 621.5 | 622.4 | 622.8 | 622.4 |
| 27 | 624.0 | 623.6 | 623.2 | 623.0 | 623.7 | 623.4 | 622.7 | 621.4 | 621.5 | 622.4 | 622.8 | 622.3 |
| 28 | 624.0 | 623.6 | 623.1 | 623.0 | 623.8 | 623.3 | 622.7 | 621.4 | 621.8 | 622.4 | 622.9 | 622.3 |
| 29 | 624.0 | | 623.1 | 623.0 | 623.9 | 623.3 | 622.6 | 621.4 | 622.0 | 622.3 | 622.9 | 622.4 |
| 30 | 624.0 | | 623.1 | 623.1 | 623.9 | 623.3 | 622.5 | 621.3 | 621.9 | 622.3 | 622.9 | 622.3 |
| 31 | 623.9 | | 623.1 | | 623.9 | | 622.5 | 621.4 | | 622.5 | | 622.4 |

**Table A-6. Knispel Well (LR 67-01-809) Daily high water levels (in feet above msl), 2013.**

| Day | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ND | ND | ND | ND | 574.2 | ND | ND | ND | ND | ND | ND | ND |
| 2 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 3 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 4 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 5 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 6 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 7 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 8 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 9 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 10 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 11 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 12 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 13 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 14 | 574.7 | ND | ND | ND | ND | ND | ND | ND | ND | 574.4 | ND | ND |
| 15 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 16 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 576.9 |
| 17 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 18 | ND | ND | ND | ND | ND | ND | 574.5 | ND | ND | ND | ND | ND |
| 19 | ND | 574.5 | 574.4 | ND | ND | ND | ND | ND | ND | ND | 577.9 | ND |
| 20 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 21 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 22 | ND | ND | ND | ND | 574.7 | ND | ND | ND | ND | ND | ND | ND |
| 23 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 24 | ND | ND | ND | ND | ND | 574.7 | ND | ND | ND | ND | ND | ND |
| 25 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 26 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 27 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 28 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 29 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 30 | ND | | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 31 | ND | | ND | | ND | | ND | ND | | ND | | ND |

ND = No data available

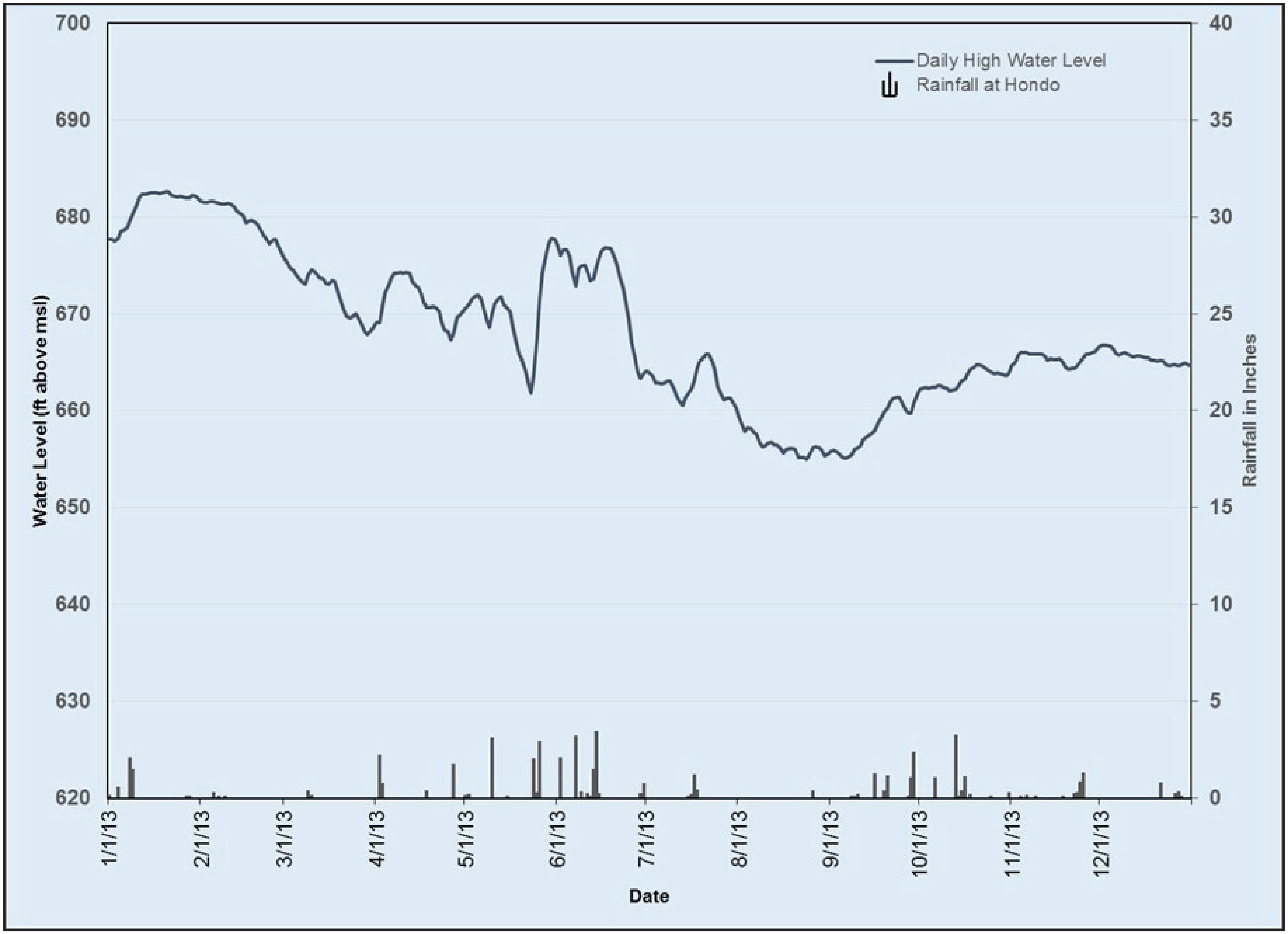
# APPENDIX B

## Year 2013 Hydrographs for Wells and Springs

**Figure B-1.** Bexar County Index Well J-17 (AY-68-37-203)
Hydrograph of Groundwater Elevation vs. Precipitation at San Antonio International Airport

## Appendix B (cont.)

**Figure B-2.** City of Hondo Well (TD-69-47-306)
Hydrograph of Groundwater Elevation vs. Precipitation at Hondo



## Appendix B (cont.)

**Figure B-3.** City of Uvalde Index Well J-27 (YP-69-50-302)
Hydrograph of Groundwater Elevation vs. Precipitation at Uvalde

## Appendix B (cont.)

**Figure B-4.** Comal Springflow Hydrograph of Springflow vs. Precipitation at San Antonio International Airport

## Appendix B (cont.)

**Figure B-5.** San Marcos Springflow
Hydrograph of Springflow vs. Precipitation at San Marcos

# APPENDIX C – Year 2013 Water Quality Data

**Available at EAA's website: www.edwardsaquifer.org**

# APPENDIX D –

## Conversion Factors

| Volume | Equivalent Units |
|---|---|
| 1 cubic foot | 7.48 gallons |
| | 62.41 lbs. of water (1 gal. weighs ~ 8.35 pounds: ~62.45) |
| 1 acre-foot | 43,560 cubic feet |
| | 325,851 gallons |
| | Covers one acre of land<br>(209 feet by 209 feet) one foot deep |
| 1 million gallons | 3.07 acre-feet |
| **Flow Rate** | |
| 1 cubic foot per second (cfs) | 448.80 gallons per minute |
| | 646,272 gallons per day |
| | 1.98 acre-feet per day |
| | 0.65 million gallons per day<br>(0.646272, or approximately 0.65 million gallons per day) |
| | 59.4 acre-feet per month |
| | 236 million gallons per year<br>(0.646272 × 365 = 235.89 million gallons per year) |
| | 724 acre-feet per year<br>(235.89 × 3.07 = 724.18 acre-feet per year) |
| 1 million gallons per day (mgd) | 3.07 acre-feet per day |
| | 1,120.55 acre-feet per year |
| 1,000 gallons per minute (gpm) | 2.23 cfs |
| | 4.42 acre-feet per day |

| Cost | |
|---|---|
| 10 cents per 1,000 gallons | $100.00 per 1 million gallons |
| | $32.59 per acre foot (EAA charges $37.00 for M/I) |
| 0.61 cents per 1,000 gallons | $2.00 per acre foot |
| 7.7 cents per 1,000 gallons | $25.00 per acre foot |

| Metric conversions | |
|---|---|
| 1 acre | 0.4 hectares |
| 1 gallon | 3.8 liters |
| 1 cubic foot | 0.028 cubic meters |
| 1 cubic meter per second | 15,850 gallons per minute<br>951,019 gallons per hour |