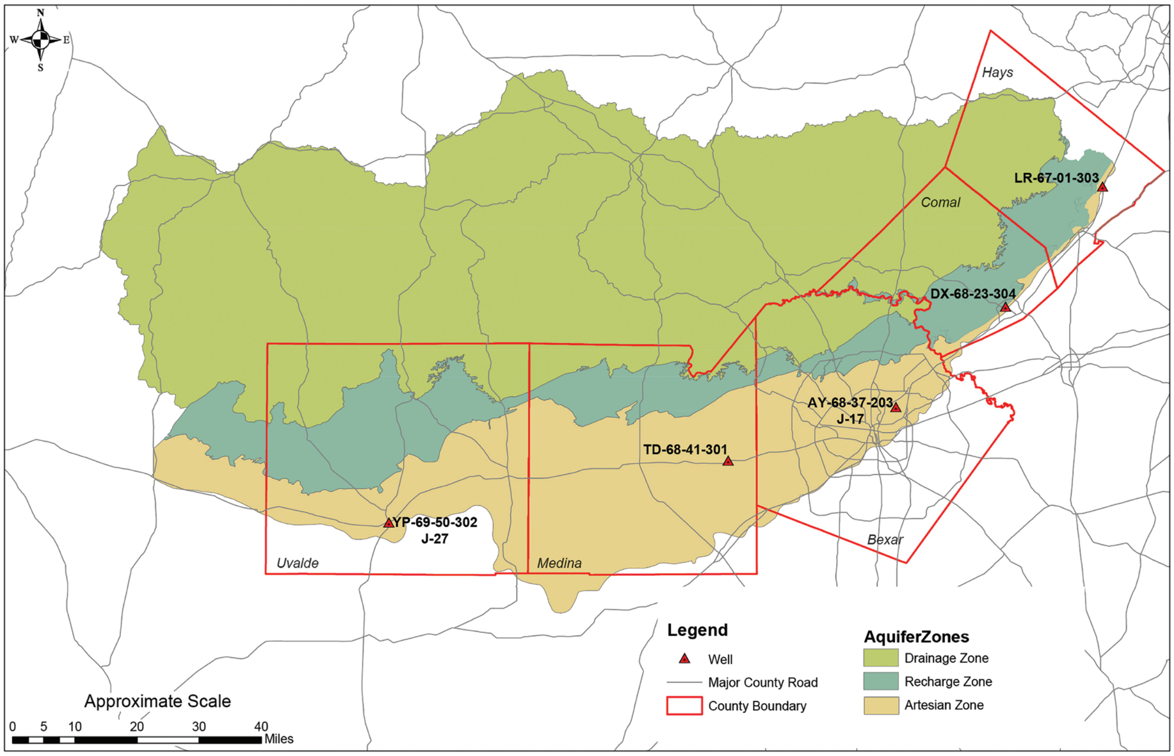
2015 GROUNDWATER LEVELS

The EAA currently maintains a groundwater level monitoring network that extends from eastern Kinney County to central Hays County. A total of 46 wells were monitored for groundwater levels in the Edwards Aquifer during 2015. The water level observation network includes wells in the recharge (unconfined) and artesian (confined) zones of the Edwards Aquifer. Continuous recording equipment was installed in 42 of the monitored wells and 4 of the wells were monitored through periodic manual tape-down measurements. Many of the wells have at least partial historical records dating back several decades.

Throughout the region, Edwards Aquifer water levels began the year well below average, following several years of below-normal recharge to the aquifer. Heavy rains during late spring; however, helped to increase water levels in the aquifer. Following are discussions of water level observations for Uvalde, Medina, Bexar, Comal, and Hays Counties. Figure 1 shows the location of wells included in this document with water level hydrographs that show the general trend of water levels and rainfall across the region in 2015. Rainfall data shown in the well hydrographs are derived from the EAA's calibrated NEXRAD radar dataset. Location for the rainfall data are also indicated on each graphic. The EAA website contains a more detailed listing of water level information for EAA monitored wells not included in this document.
That information can be found at www.edwardsaquifer.org.

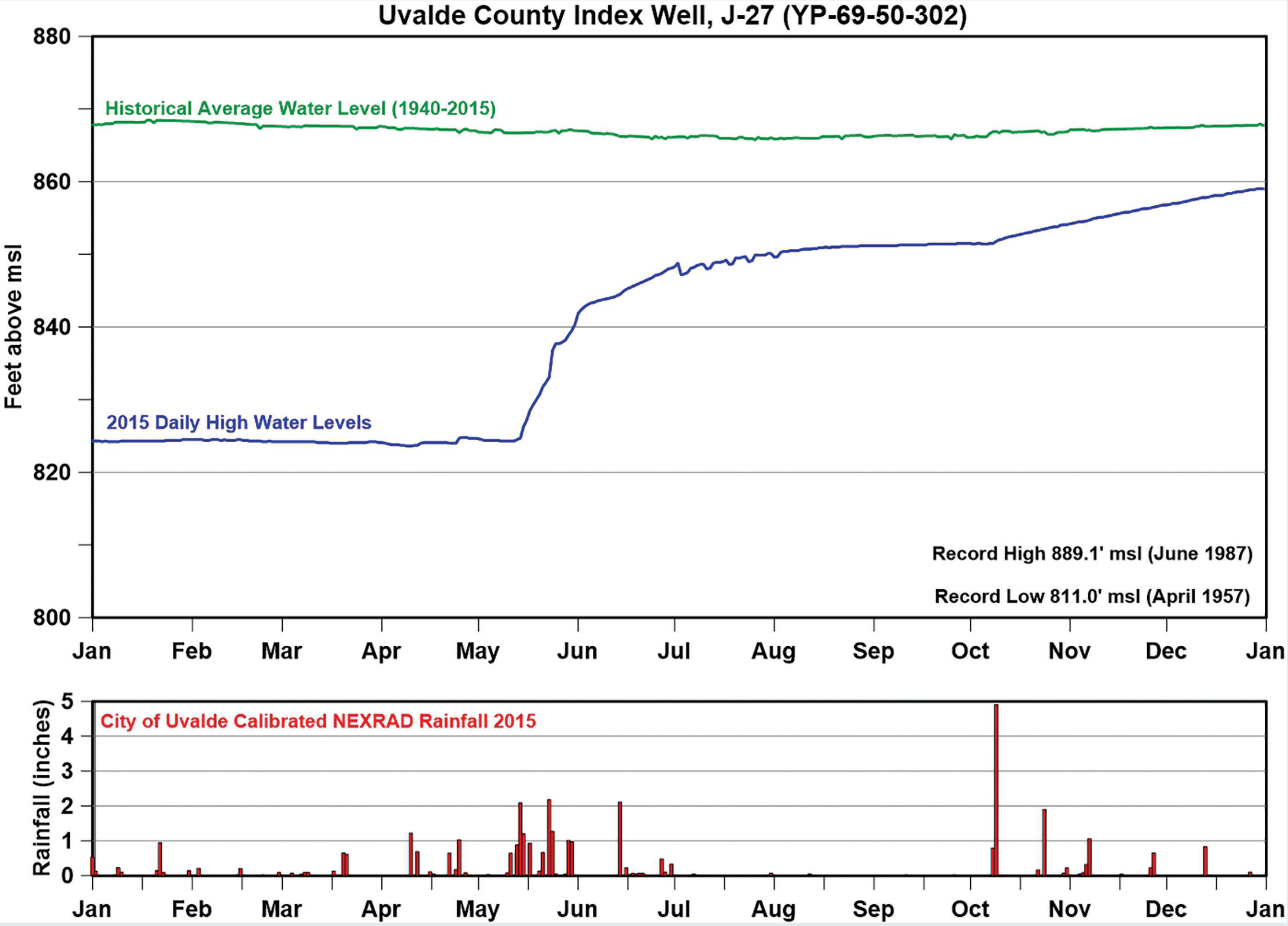
Fig. 1



UVALDE COUNTY

Water levels for wells monitored in Uvalde County generally plot below their historical averages for 2015. Water levels for the Uvalde County Index Well, J-27 are shown in Figure 2. Daily precipitation over the town of Uvalde, estimated from EAA's calibrated NEXRAD radar dataset, are shown at the bottom of Figure 2. Water levels throughout the county began the year flat and increased gradually following the heavy rains that occurred in May. To put these water levels into historical perspective, Figure 2 shows the 2015 response of well YP-69-50-324 (Uvalde Index Well J 27) compared to the historical average water levels for this well. Water levels in this well began the year significantly below-average, then increased following the heavy spring rains. While water levels continued to rise slowly for the remainder of the year, they remained slightly below-average when compared to the period of record average.

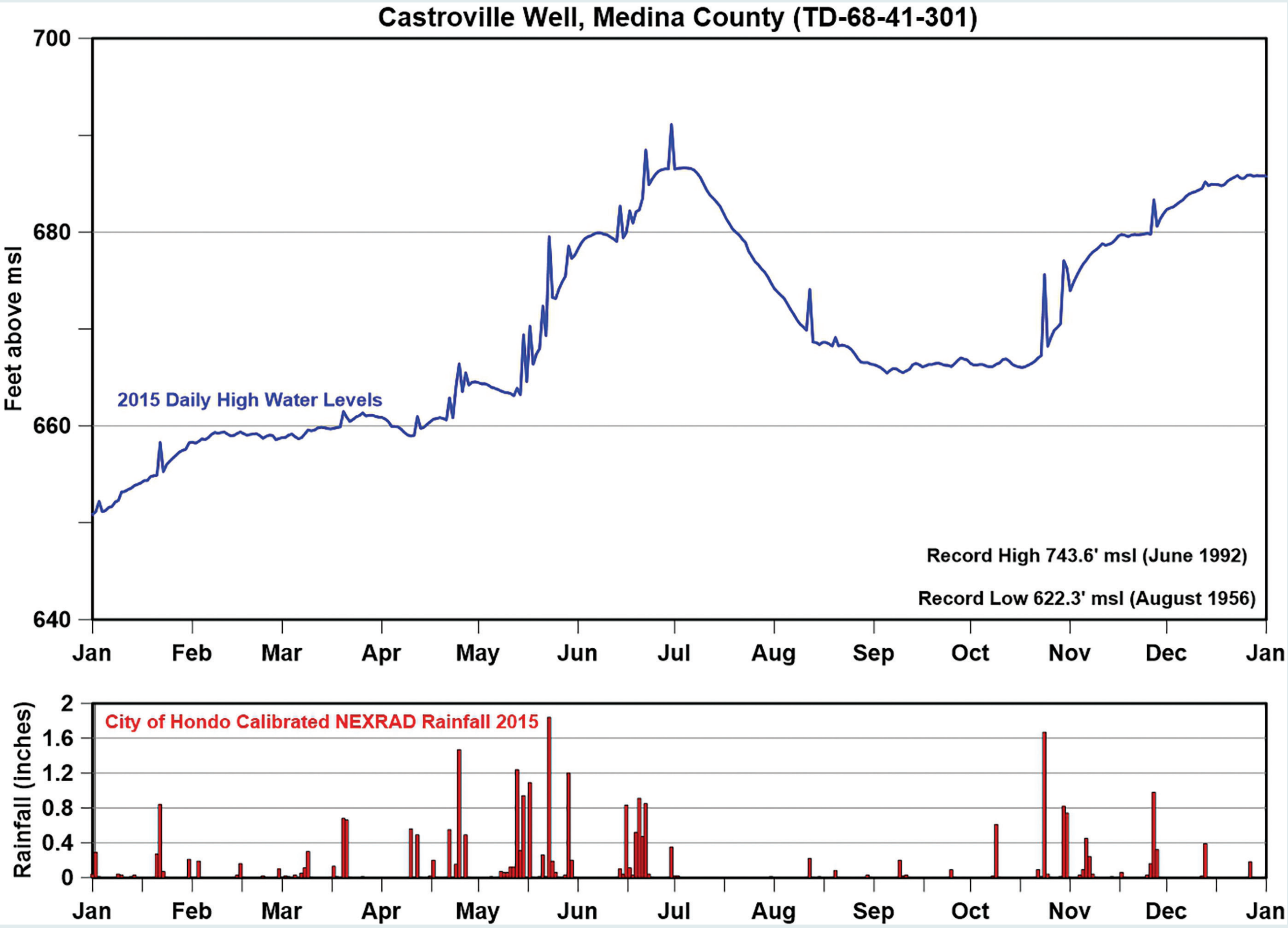
Fig. 2



MEDINA COUNTY

Water levels in Medina County began the year relatively flat and increased following the heavy rains that occurred in the month of May. Water levels in the recharge zone remained relatively flat for the remainder of the year, while wells in the artesian zone declined slightly during the dry summer months and increased again following rains in November and December. Figure 3 shows the response of well TD-68-41-301 (Castroville Well) to 2015 weather conditions. Water levels in this well began the year very low, but responded to rainfall and rose until July when rainfall amounts decreased. Water levels increased again after a relatively wet fall season.

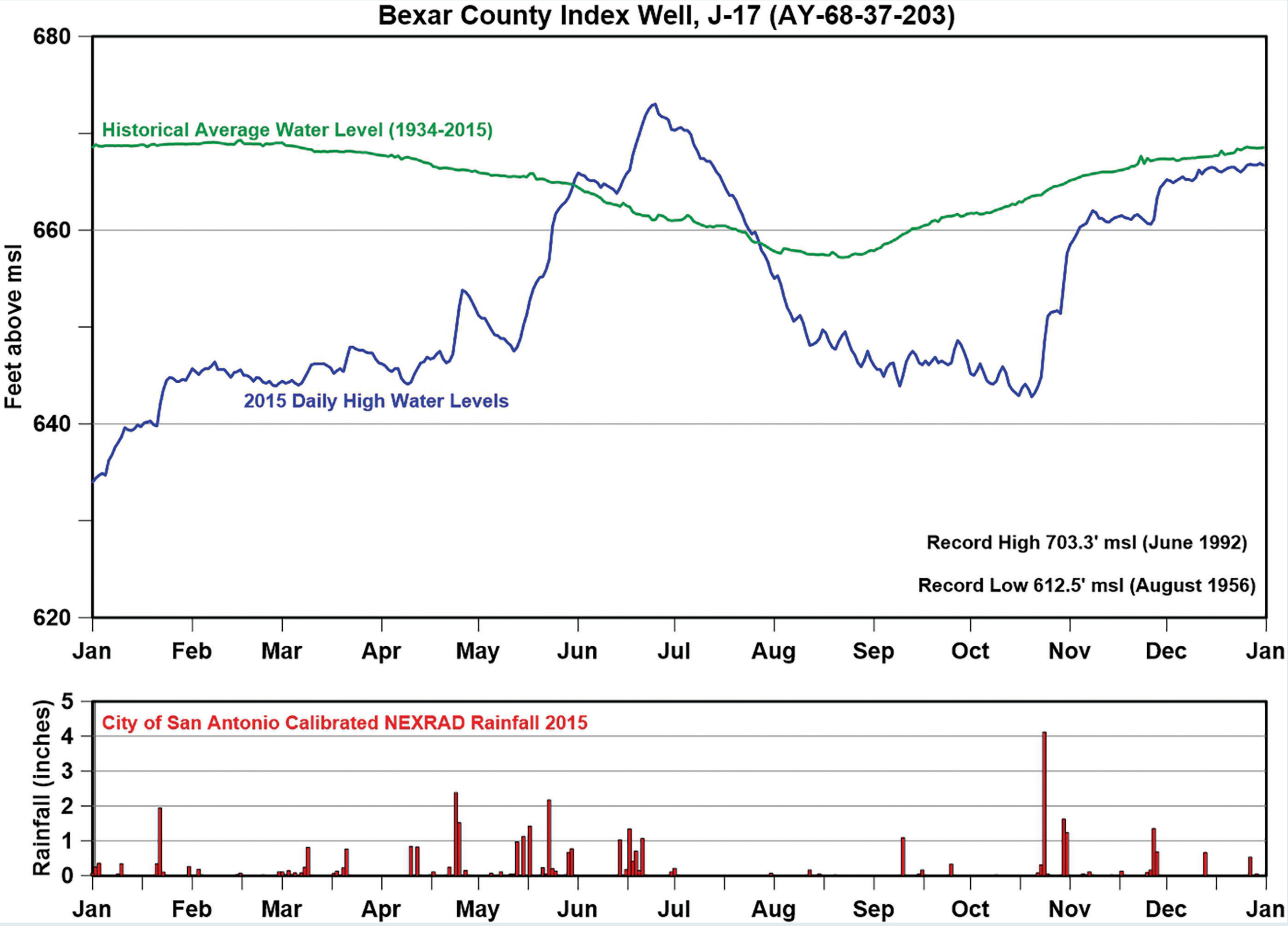
Fig. 3



BEXAR COUNTY

The responses of water levels to rainfall in Bexar County are somewhat more variable compared to Medina and Uvalde Counties, with wells in and near the recharge zone having large and near-instantaneous responses to rainfall events followed by rapid declines. Water-levels in Bexar County were relatively constant from the beginning of the year through late April, increased significantly following heavy rains in May, declined significantly during the dry summer, and increased again following late October rain events. To put these water levels into historical perspective, Figure 4 shows the 2015 response of well AY-68-37-203 (San Antonio Index Well J-17) compared to the historical average water levels. Water levels in this well began the year significantly below average, then recovered to several feet above average following heavy rains in late May and June. Water levels then declined significantly during a dry summer, but recovered to near-average levels by the end of the year.

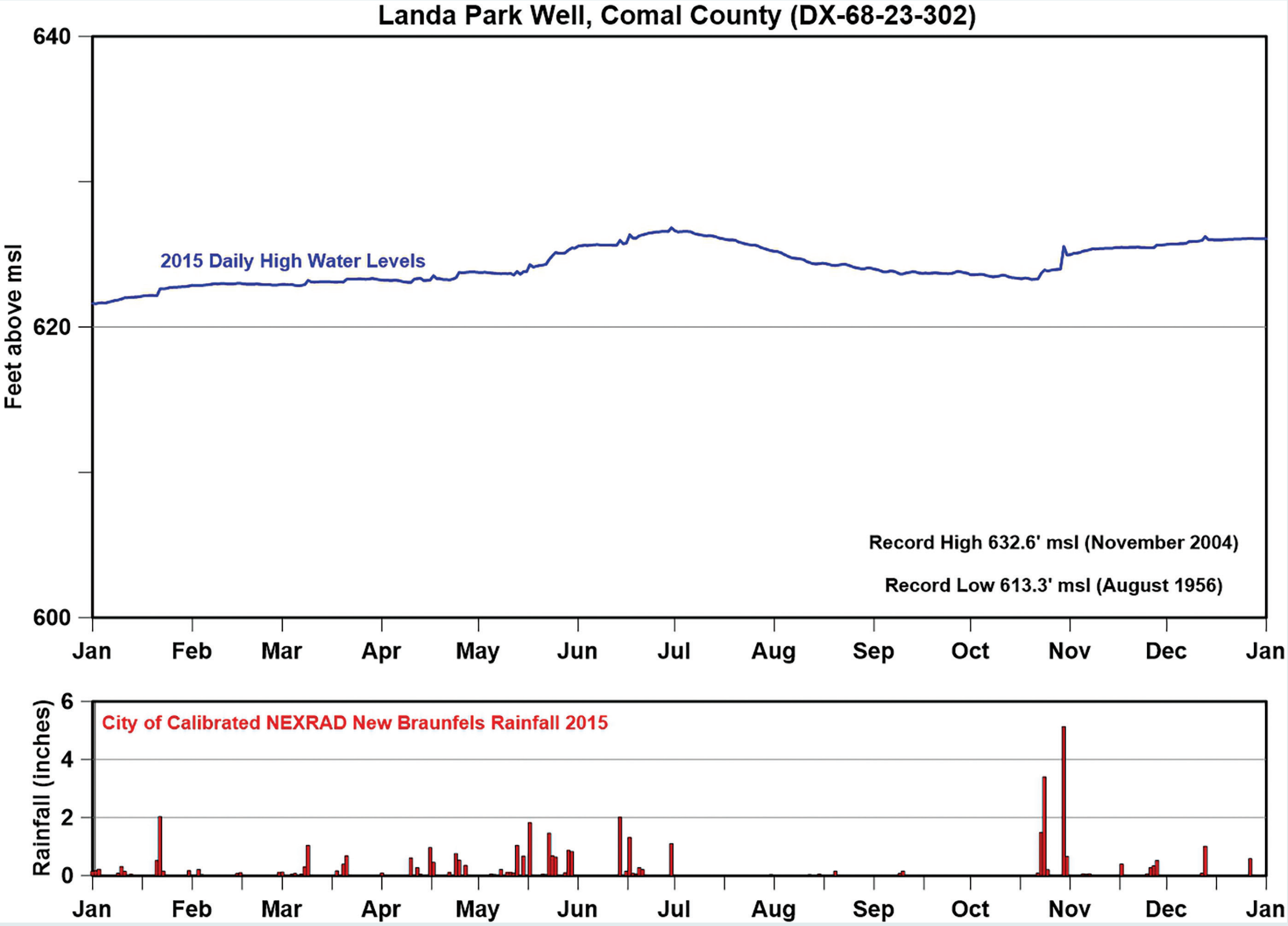
Fig. 4



COMAL COUNTY

Well water level responses to rainfall in Comal County show somewhat higher amplitudes of variability to rainfall for wells in and near the recharge zone, than do wells in the artesian zone. Water-levels were relatively constant from the beginning of the year through late April, with some increase following a January rainfall event. Water levels then increased significantly following a series of heavy rains in May. After declining somewhat during the dry summer, water levels increased again following two closely-spaced rain events in late October. To put these water levels into historical perspective, Figure 5 shows the response of well DX-68-23-302 (Landa Park Well) to 2015 weather conditions. This well, located in the artesian zone, shows less water level fluctuation than a typical recharge zone well. Water levels in this well began the year below normal, then recovered following the heavy rains in late May and June. Water levels then declined slightly during a dry summer, but recovered some by the end of the year.

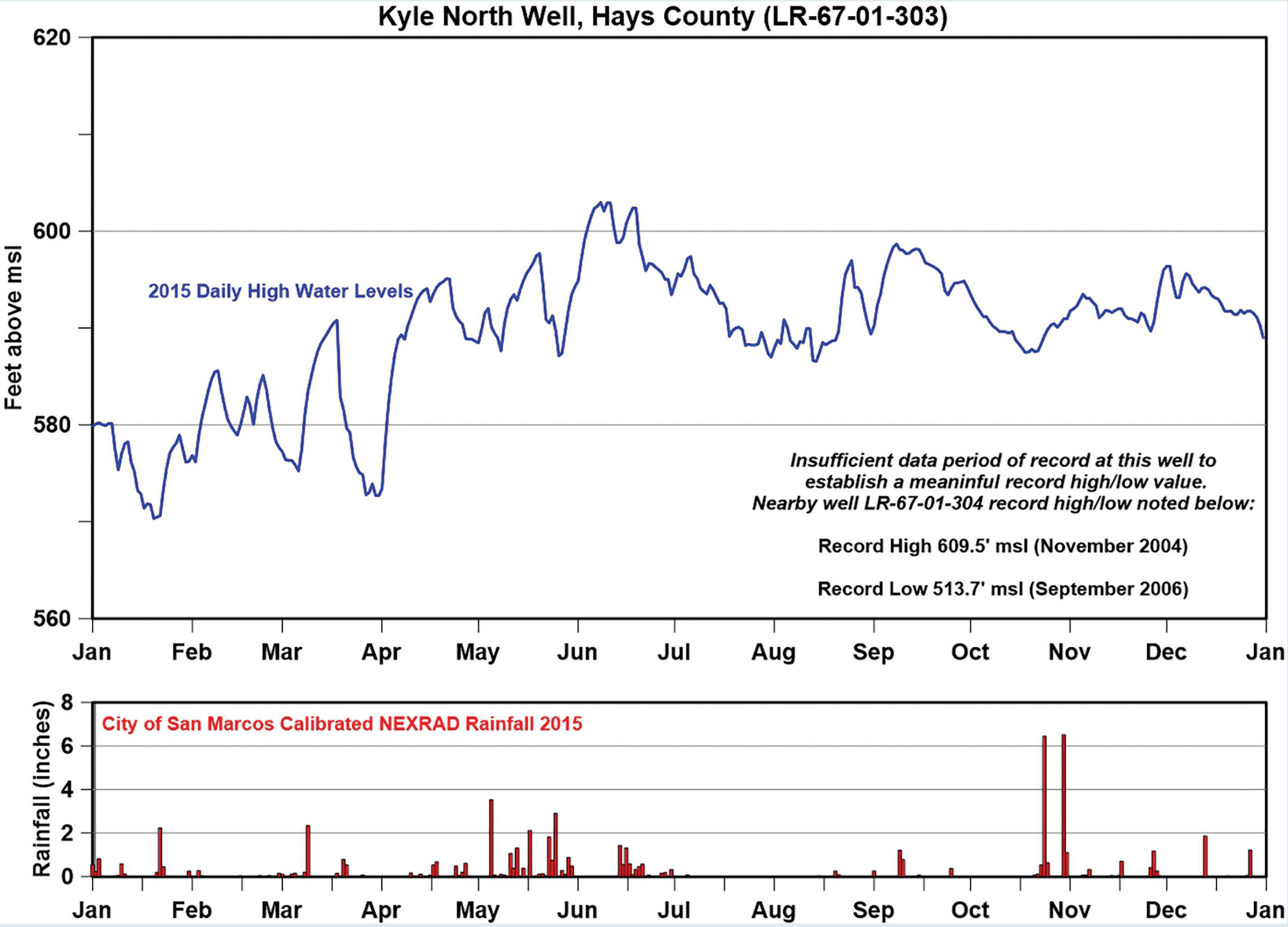
Fig. 5



HAYS COUNTY

Well LR 67 01 303, shown in Figure 5 responds differently than any other well in the Hays County portion of the observation network with frequent large oscillations that are not always associated with rainfall events. The reason for this variability is not known for certain, but is likely a combination of hydrologic compartmentalization (poor hydraulic connection to the rest of the aquifer) and the influence of nearby pumping wells. In general, water-levels in Hays County showed a slight rise following rain in January, then remained relatively constant until a significant increase following the series of rain events in May. After declining during the dry summer, water levels increased again following the late-October rains.

Fig. 6



EAA staff have access to measure over 150 additional wells as part of a regional synoptic water level monitoring program or to support focused studies. Focused synoptic measurements have been collected episodically in Comal and Hays counties since 2006, with the goal of improving overall understanding of aquifer behavior in this area. Synoptic measurements are generally obtained with steel-tape or electric-line measuring devices. Data for numerous other wells throughout the state of Texas can be obtained from Texas Water Development Board's online groundwater database at http://www.waterdatafortexas.org/groundwater.

PRECIPITATION IN THE EDWARDS AQUIFER REGION

The Edwards Aquifer Authority (EAA) monitors precipitation throughout the region using a network of 75 real-time rain gauges. Rainfall data is used as input for watershed computer models that can provide estimates of monthly recharge to the aquifer. Collected over several years or decades, the extensive database of rainfall information can also be useful for monitoring climate trends, evaluating relationships between rainfall and aquifer levels, or for understanding how global-scale phenomena such as "El Nino" (which refers to above-average sea surface temperatures in the equatorial region of the Pacific Ocean) may affect rainfall in Central Texas.

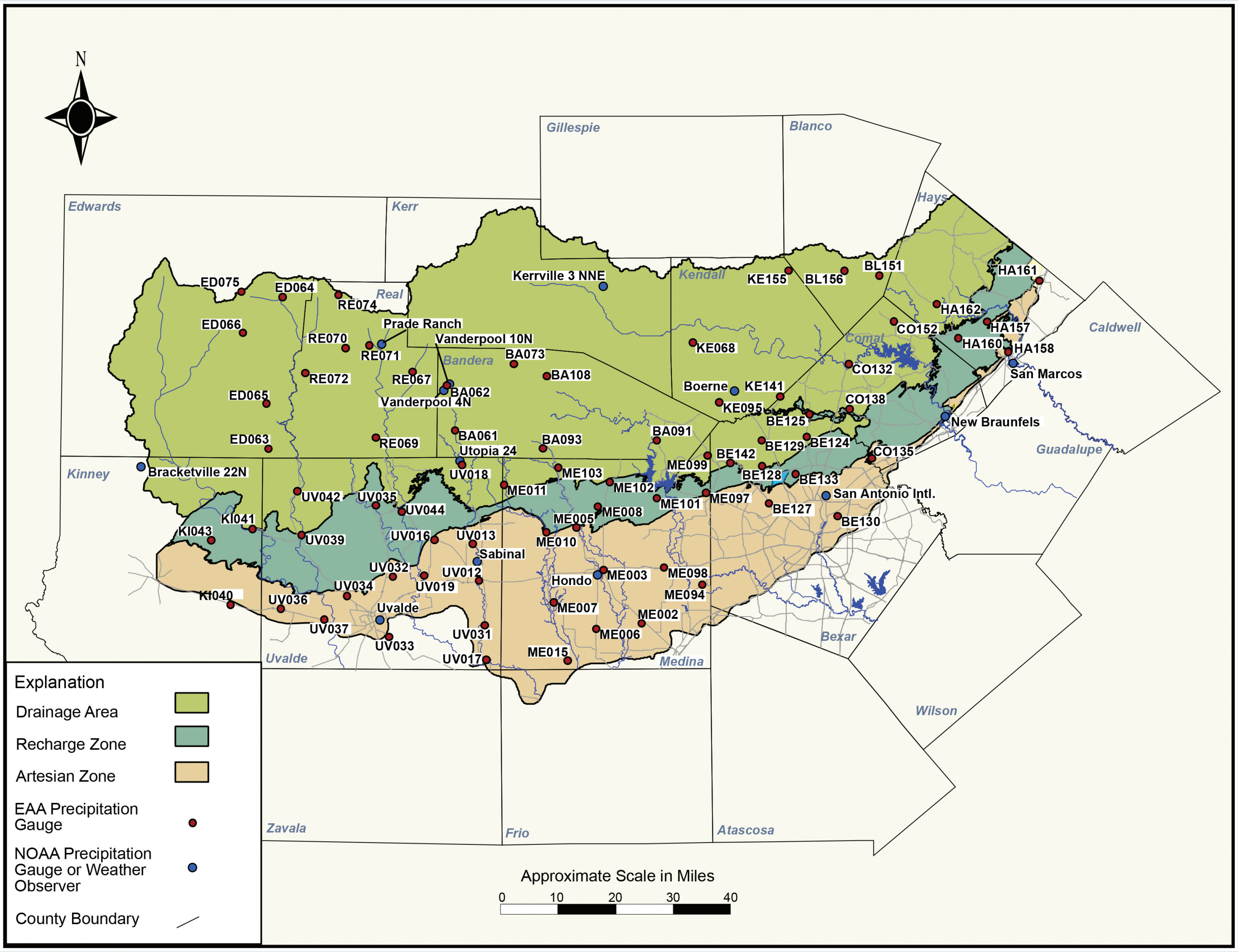


Fig. 1

The locations of the EAA rain gauges are shown in Figure 1. In general, rain gauges are not always reliable indicators of total rainfall over a region. Rainfall can vary greatly over relatively short distances and a gauge only reflects rainfall at a specific point. Additionally, gauges are susceptible to occasional malfunctions. NEXRAD (Next-Generation Radar) data from the National Weather service provides a potential solution to the limitations of individual rain gauges because it provides continuous coverage of the entire region based on overlapping coverage from NEXRAD Doppler radar stations in Brackettville, Corpus Christi, New Braunfels, and Granger, Texas. However, NEXRAD measures reflectivity of precipitation near ground level and not the actual amount of precipitation as measured by rain gauges. For this reason, EAA takes a two-step approach to rainfall data by using the operational rain-gauge data as a "ground-truth" to calibrate the NWS NEXRAD data. The resulting product is a dataset of hourly rainfall totals for a grid of 16-km² pixels over the entire region of interest that extends back to January 1, 2003.

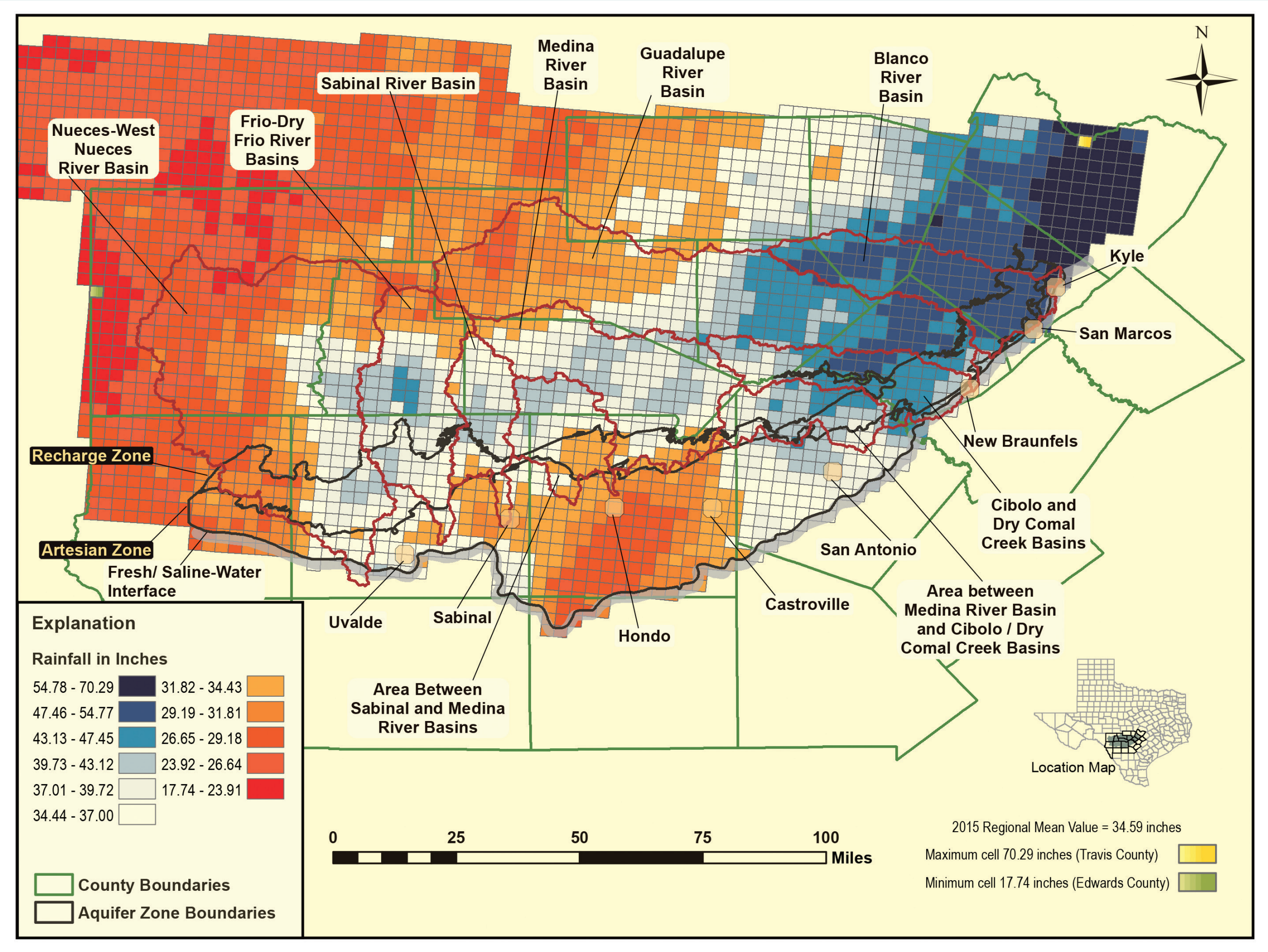


Fig. 2

Figure 2 shows the calibrated NEXRAD coverage area with a color map indicating total 2015 rainfall for each 16-km² pixel. The high degree of spatial variability in rainfall totals can be seen, with the highest rainfall total of 70.3 inches in Travis County at the northeast edge of the coverage area and the lowest total of 17.7 inches in Edwards county on the western edge of the coverage area. Figure 2 also shows delineations of the nine watershed catchment areas that contain streams that cross the Edwards Aquifer recharge zone.

The rainfall over these watersheds is of particular interest because their catchment areas convey water to the Edwards Aquifer recharge zone and the data can be used as input to the EAA's HSPF (Hydrologic Simulation Program—Fortran) models as one method to estimate recharge. Table 1 provides the 2015 area-averaged rainfall total for each of the nine watersheds obtained from the calibrated NEXRAD data. Figures 3 through 12 illustrate the distribution in time of rainfall for each watershed area. It can be seen that the month of May provided much of the cumulative rainfall throughout the region, followed by dry summer months and relatively wet conditions from late October through December.

2015 RAINFALL TOTALS FOR NINE DELINEATED CONTRIBUTING ZONE WATERSHEDS

GAUGE	2015 AREA AVERAGE RAINFALL (INCHES)
Nueces-West Nueces River Basins	31.2
Frio-Dry Frio River Basins	37.1
Sabinal River Basin	36.9
Area Between Sabinal and Medina River Basins	36.2
Medina River Basin	37.2
Area Between Medina and Cibolo River Basins	40.4
Cibolo and Dry Comal Creek Basins	43.6
Guadalupe River Basin	37.7
Blanco River Basin	48.8

Table 1

2015 Daily and Cumulative Rainfall for the Watershed Area of Nueces and West Nueces River Basins

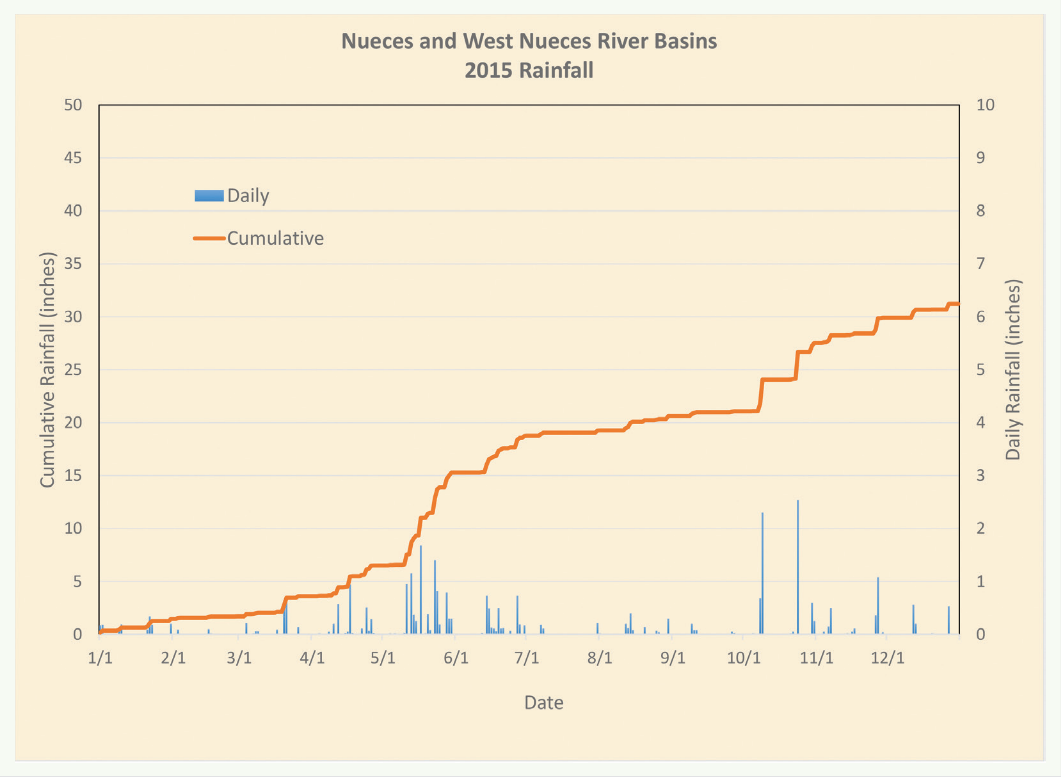


Fig. 3

2015 Daily and Cumulative Rainfall for the Watershed Area of Frio and Dry Frio River Basins

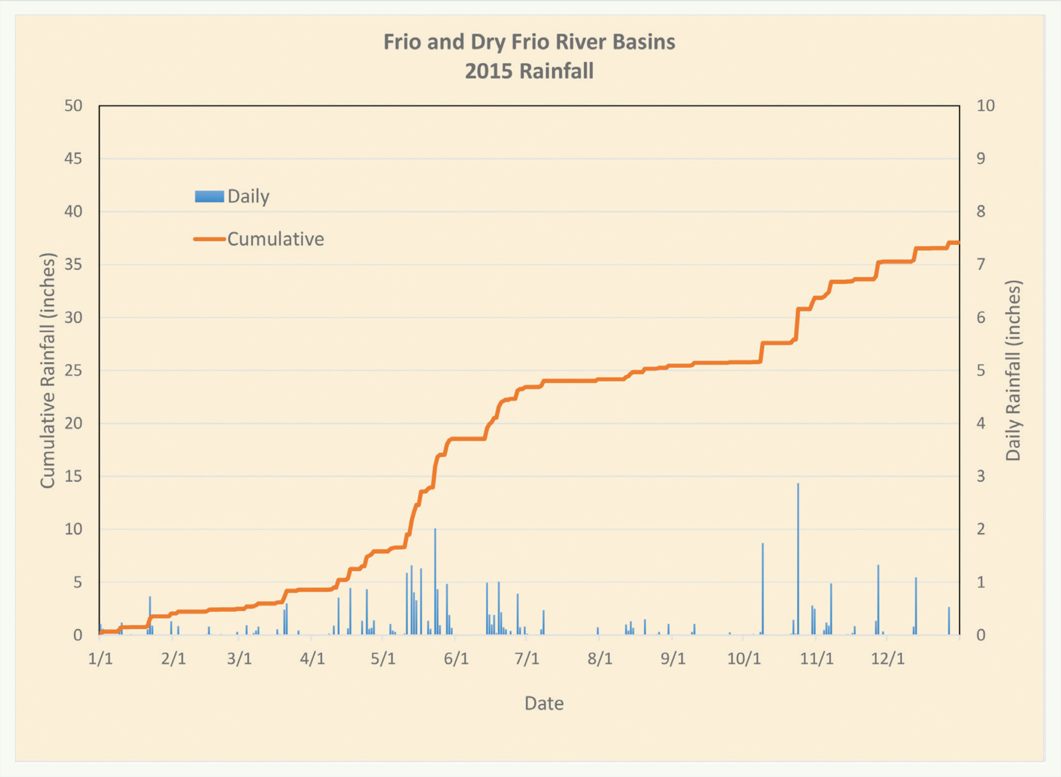


Fig. 4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2015 Daily and Cumulative Rainfall for the Watershed Area of Sabinal River Basin

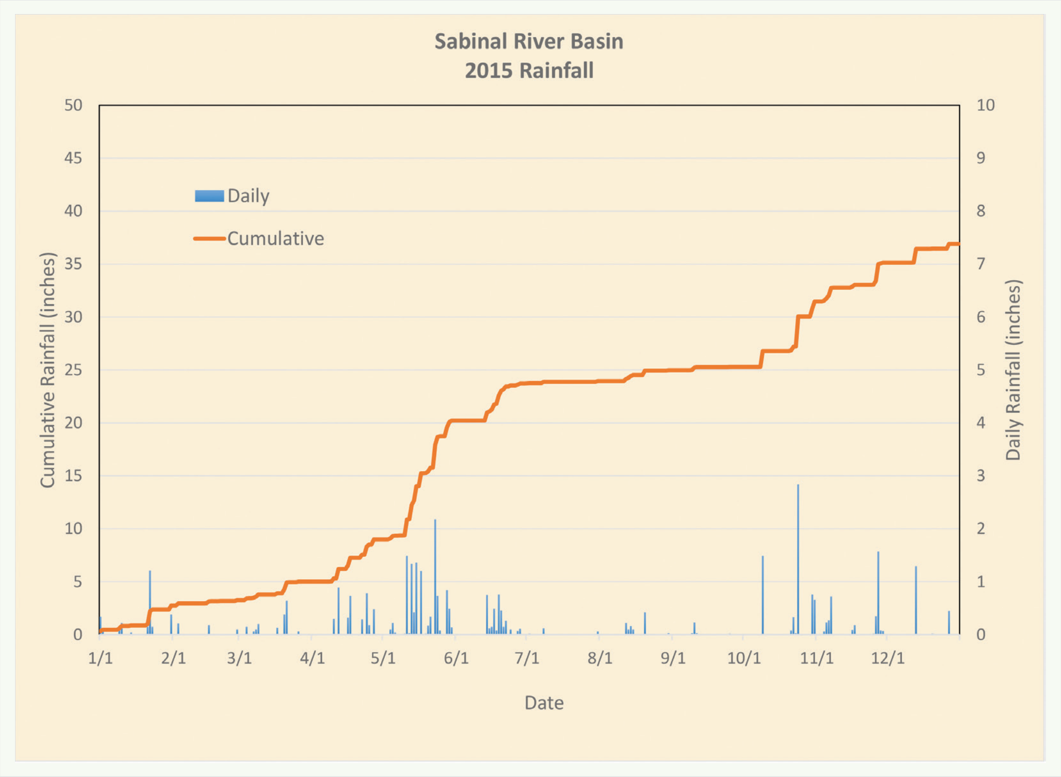

Fig. 5

2015 Daily and Cumulative Rainfall for the Watershed Area Between Sabinal and Medina River Basins

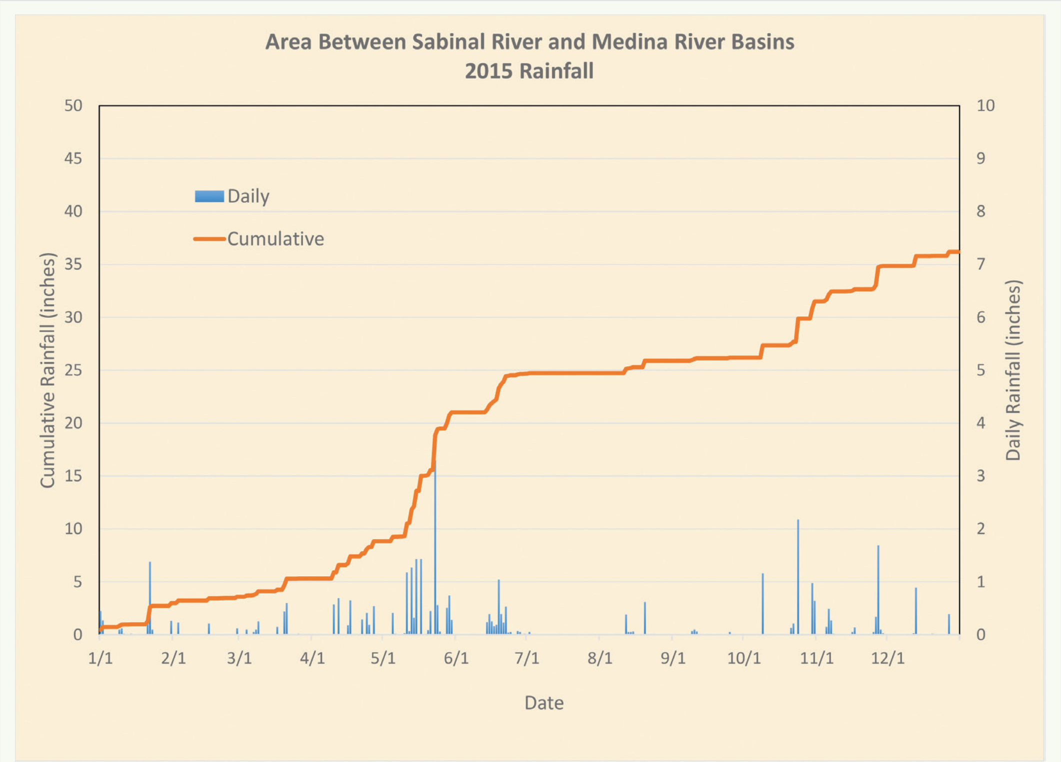

Fig. 6


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2015 Daily and Cumulative Rainfall for the Watershed Area of Medina River Basin

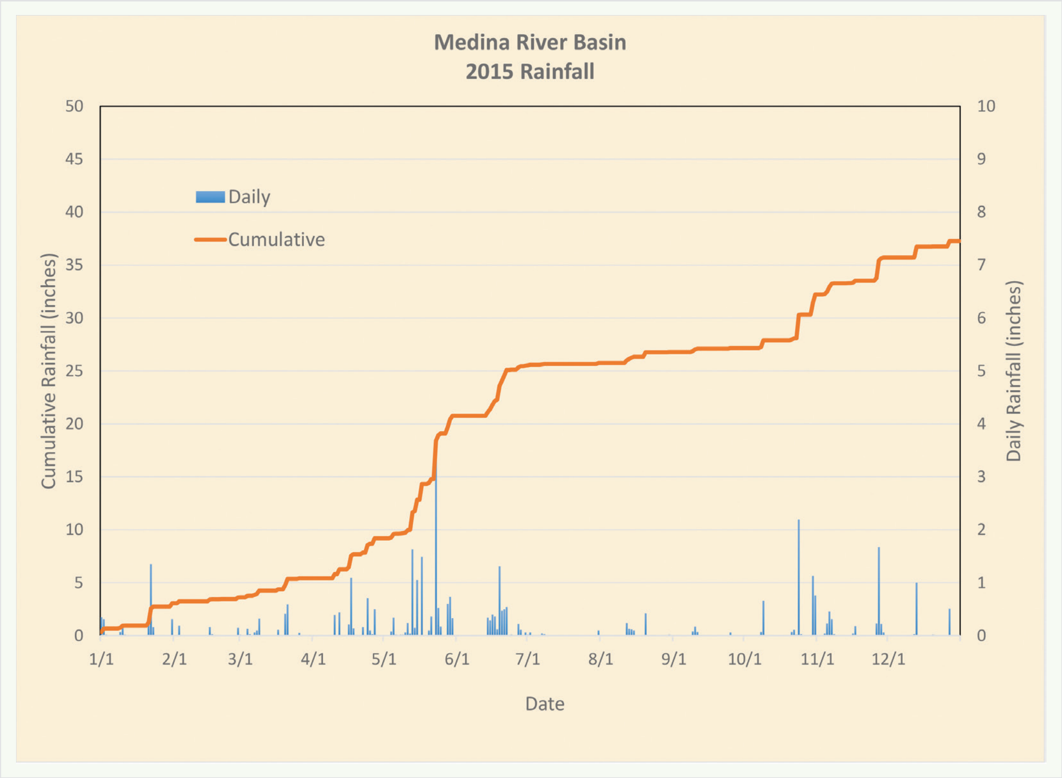

Fig. 7

2015 Daily and Cumulative Rainfall for the Watershed Area Between Medina River and Cibolo Creek Basins

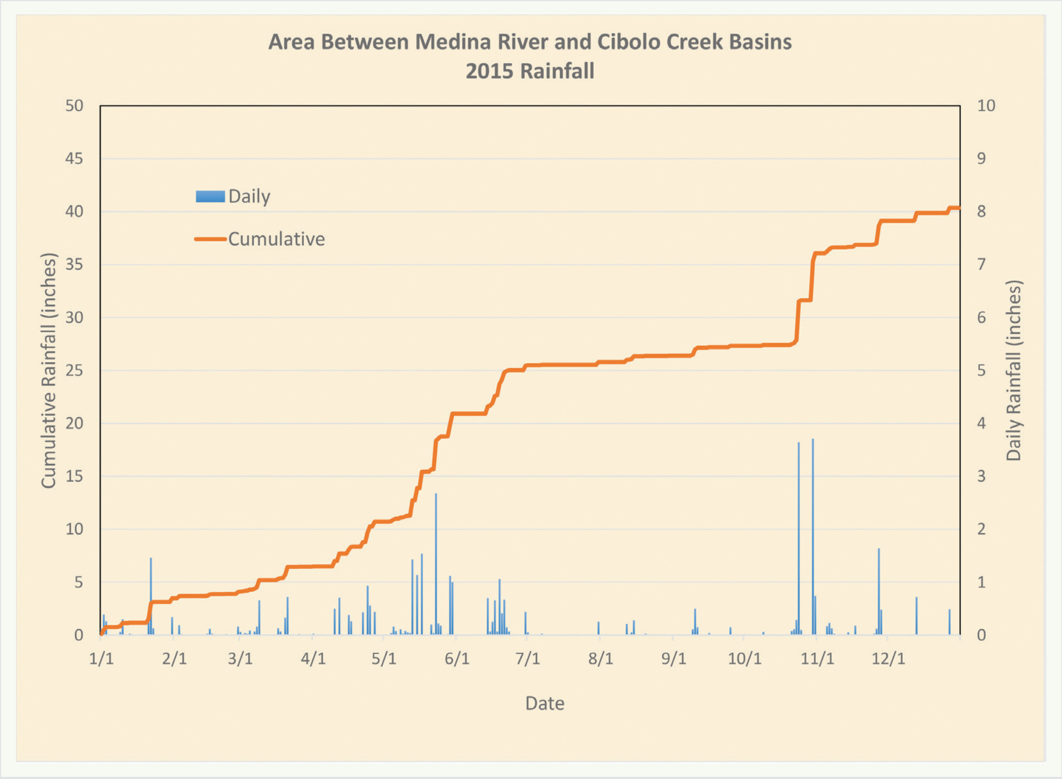

Fig. 8


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2015 Daily and Cumulative Rainfall for the Watershed Area of Cibolo Creek and Dry Comal Creek Basins

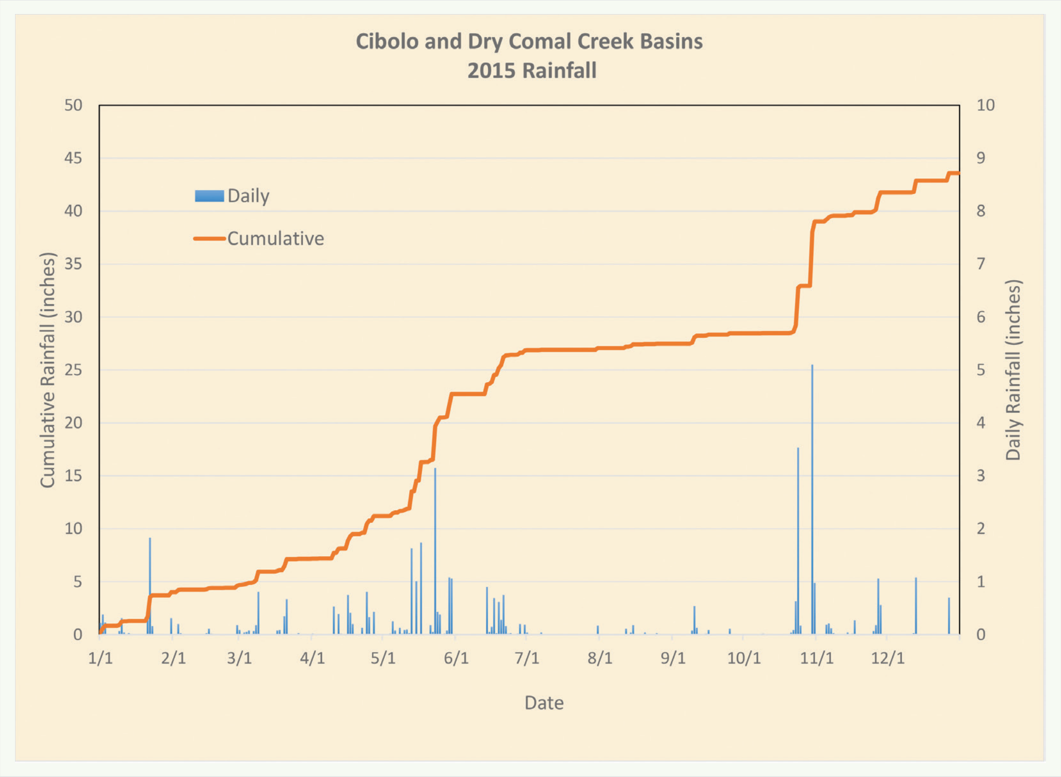


Fig. 9

2015 Daily and Cumulative Rainfall for the Watershed Area of Guadalupe River Basin

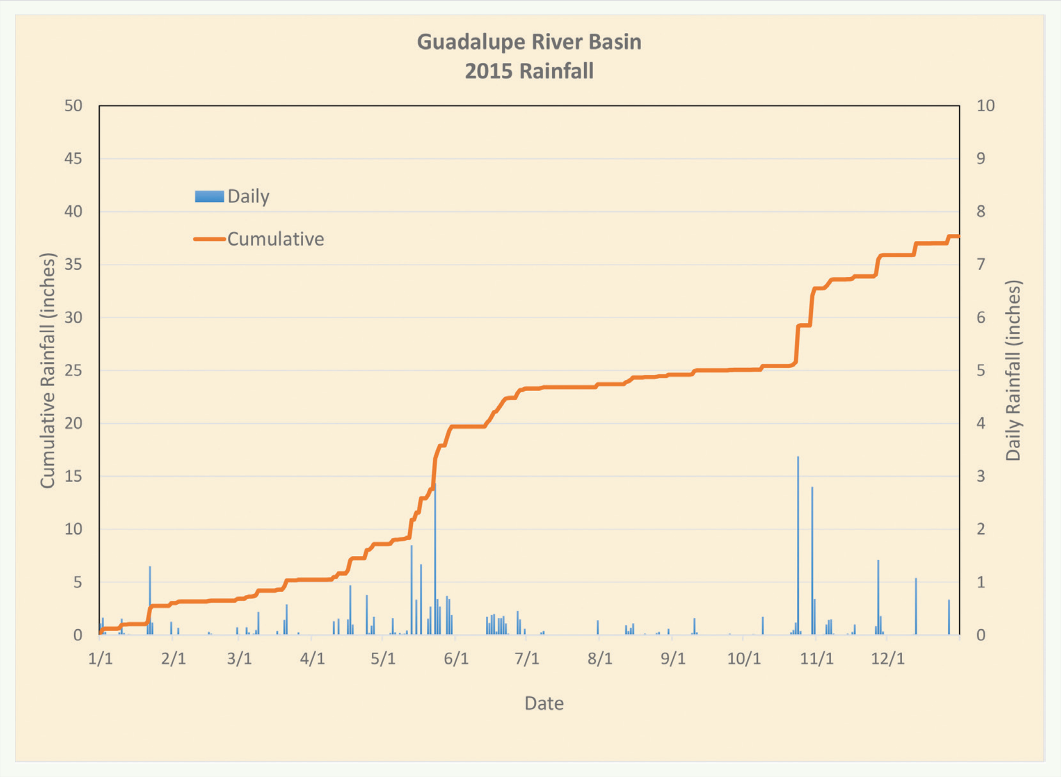


Fig. 10

2015 Daily and Cumulative Rainfall for the Watershed Area of Blanco River Basin

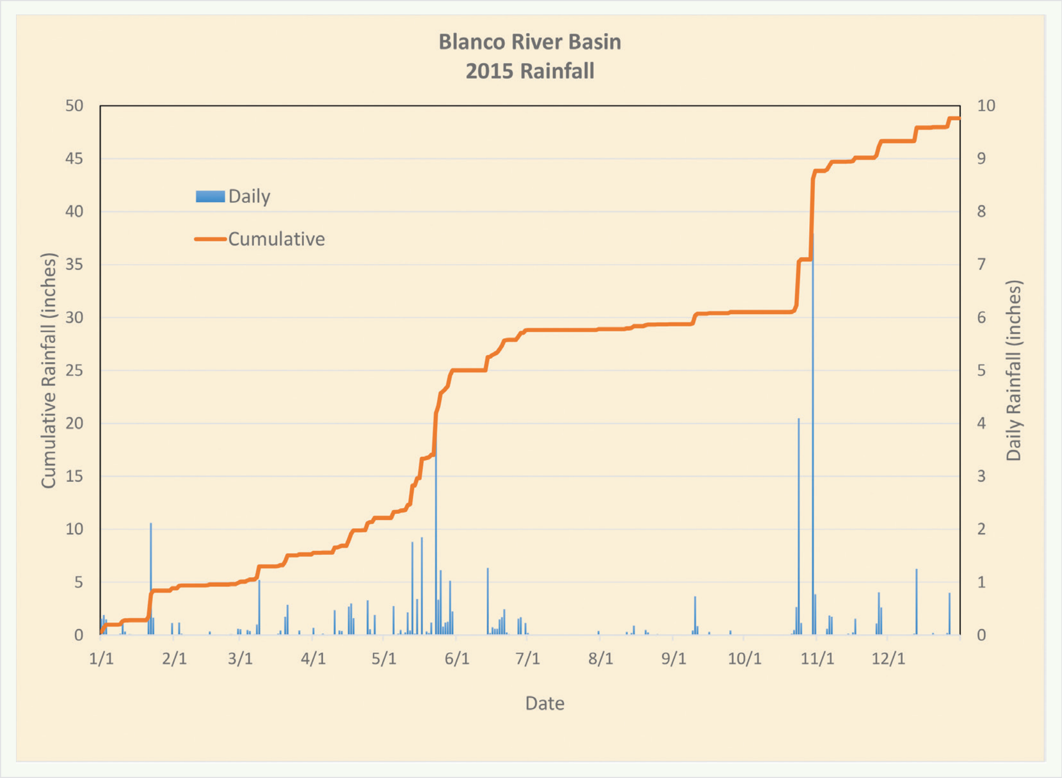


Fig. 11

Because the timeframe covered by EAA's calibrated NEXRAD rainfall data does not begin until year 2003, it is not yet suited for evaluating long term historical trends in annual rainfall. For this type of analysis, we rely on data at individual rain gauges that have been in place for many decades. Table 2 shows how the 2015 annual rainfall for several selected gauges across the region compares to the long-term average rainfall. It can be seen that above-average rainfall was observed at all of these locations in 2015.

2015 DEVIATION FROM MEAN RAINFALL VALUES				
GAUGE	COUNTY	LONG-TERM AVERAGE	2015 TOTAL	DEVIATION FROM AVERAGE
San Antonio Intl. Airport	Bexar	30.49	42.22	11.37
New Braunfels	Comal	32.88	43.45	10.57
San Marcos	Hays	34.08	52.29	18.21
Hondo*	Medina	28.62	32.90*	4.28*
Sabinal	Uvalde	24.02	41.62	17.60
Boerne	Kendall	34.14	50.09	15.95
Brackettville	Kinney	21.73	26.20	4.47

Table 2

* Incomplete data set, actual totals may be greater. (Rainfall amounts shown in inches)

Table 3 lists the annual rainfall totals for these gauges going back to 1934. These rainfall records indicate how variable rainfall can be at a particular location from year to year. For example, the lowest annual rainfall total observed at San Antonio Airport rain gauge was 13.7 inches in 1954, while the highest was 52.3 inches in 1973. Although these records show extended periods of above-average or below-average rainfall, there does not appear to be any significant trend of increasing or decreasing annual rainfall totals in the region over the long term.

The long-term records for these rain gauges and many other weather stations throughout the region can be obtained online from the National Centers for Environmental Information (formerly the National Climatic Data Center) at http://www.ncdc.noaa.gov/cdo-web/search. Data from the EAA's rain gauge network or calibrated NEXRAD database may be obtained from EAA upon request.

1934–2015 Annual Precipitation for Selected Rain Gauges in the Edwards Aquifer Region (in inches)

YEAR	BRACKETTVILLE	UVALDE	SABINAL	HONDO	SA	BOERNE	NB	SM
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	9.57a	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	33.74a	44.07	26.34	41.60	42.99	48.41
1942	21.01	19.01	11.37a	34.83	38.46	31.12	42.08	44.65
1943	23.39b	20.63	17.21	31.43	20.51	26.33	29.93	25.45
1944	24.76	32.76	27.62a	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	31.74b
1946	19.10	26.41	14.16a	29.65	45.17	45.62	61.60	52.24
1947	22.92b	22.67	---	18.98	17.32	21.89	27.52	27.53
1948	20.02a	18.31	---	28.82	23.64	23.77	19.88b	21.27a
1949	31.32	34.41	---	39.90	40.81	41.15	43.21	36.22
1950	17.70	18.27	15.28a	24.91	19.86	24.94	21.13	21.10
1951	14.71	16.07	15.63	24.05a	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	15.70a	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

Table 3

[Cont.]

1934–2015 Annual Precipitation for Selected Rain Gauges in the Edwards Aquifer Region (in inches)

YEAR	BRACKETTVILLE	UVALDE	SABINAL	HONDO	SA	BOERNE	NB	SM
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	29.88b	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	35.14b	47.82	52.28	50.93	51.66	47.91
1974	18.25	30.94	20.93b	36.41b	37.00	41.80	42.85	37.28a
1975	26.62	24.92	23.65	25.84a	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	36.35b	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	22.47b
1983	19.35	24.45a	23.33	20.92b	26.11	34.60	34.13	36.95
1984	16.24	15.33b	20.67	21.19a	25.95	26.97	20.90	8.26b
1985	18.93	5.76a	23.67	21.94	41.43	37.77	37.26	33.54
1986	27.44	29.86b	29.62b	36.01b	42.73	43.52	47.14	42.20
1987	39.45	36.39	38.36	40.09	37.96	39.86	37.33a	37.94
1988	12.08	15.20	13.52	9.81b	19.01	19.49	16.27b	21.50
1989	16.98	18.65	17.26	16.10	22.14	25.14	20.99	25.46
1990	38.24b	24.73	30.06	27.01	38.31	42.51	24.58a	35.14b
1991	23.11	21.77	31.12	34.55	42.76	48.22	56.55	51.07
1992	22.22	27.85a	37.73	45.34	46.49	64.17	38.84b	40.33b
1993	15.18	9.32c	13.20	16.60	32.00	24.02	19.54b	24.01b

Table 3

[Cont.]

1934–2015 Annual Precipitation for Selected Rain Gauges in the Edwards Aquifer Region (in inches)

YEAR	BRACKETTVILLE	UVALDE	SABINAL	HONDO	SA	BOERNE	NB	SM
1994	22.85a	39.61	29.32	22.38b	40.42	40.98	35.76a	40.85
1995	25.87	19.47	27.55	24.55	23.20	30.29	23.29	32.57
1996	20.32b	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	27.40b	20.66b	30.44a	42.10	45.74	52.98	58.51
1999	19.88	19.08	2.55b	16.94	16.63	18.67	21.07	19.38
2000	18.11b	23.84	22.87	32.49	35.86	46.30a	36.34b	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	25.19c	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	27.58b
2011	12.98	9.91	13.81	15.27	17.58	17.76	19.25	19.39b
2012	20.35a	13.97	18.70	25.96	39.30	29.78	35.49	34.26
2013	21.18a	22.75	22.87	19.48a	31.99	28.95	32.88	31.30
2014	18.92a	21.09	20.62	17.84a	28.20	29.00	23.17	23.84
2015	26.20 a	---	41.62	32.90 a	42.22	50.09	43.45	52.29
Y. OF RECORD	78	81	79	82	82	81	82	82
MEAN	21.76	23.06	24.02	28.62	30.49	34.14	32.88	34.08
MEDIAN	20.34	22.67	23.02	27.85	30.43	32.73	33.69	33.25

Data sources:

U.S. Department of Commerce; Uvalde data: Texas A&M AgriLIFE Extension Service.

a Partial record not included in long-term mean or median; missing one month.

b Partial record not included in long-term mean or median; missing more than one month.

c Change in gauge location from previous years.

--- No data available.

Mean and median values calculated using only years with full records.

Years with partial or missing records discarded from data set.

SA San Antonio

NB New Braunfels

SM San Marcos

GROUNDWATER DISCHARGE AND USAGE

Groundwater discharges from the Edwards Aquifer either 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 greatly benefits the recreational economies in New Braunfels and San Marcos, and both springs provide habitat for threatened and endangered animal and plant species. Figure 1 shows locations of the major springs in the Edwards Aquifer region. Wells drilled into the Edwards Aquifer throughout the region provide water for many diverse uses, including irrigation, municipal water supplies, industrial applications, and domestic/livestock consumption.

Estimates of total annual groundwater discharge from combined springflow and pumping for the Edwards Aquifer are provided in Table 1 for the period of record (1934–2015). 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 2015, the total groundwater discharged from the Edwards Aquifer from wells and springs is estimated at 729,645 acre-feet: 404,468 acre-feet as springflow and 325,177 acre-feet as pumping from wells.

The portion of discharge as springflow is estimated by measuring streamflow downstream of the springs and converting the streamflow measurements to spring discharge by subtracting any estimated contributions from surface runoff. Total annual spring discharge has varied from a low of 69,800 acre-feet in 1956 to a high of 802,800 acre-feet in 1992. Monthly springflow estimates for 2015 at each of the six major Edwards Aquifer springs are provided in Table 2.

In Figures 2 and 3, flows at Comal and San Marcos springs are shown as mean annual flows compared with the long-term historical mean flow for the available period of record. The 2015 mean annual flow was greater than the historical mean discharge at San Marcos springs and below the historical mean discharge at Comal Springs.

Discharge as well pumping can be classified as either reported or unreported discharge. 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. Unreported discharge refers to use that does not require a groundwater withdrawal permit from the EAA, such as domestic, livestock, or federal facility use. Unreported discharge is estimated based on numbers of wells and statistical estimates of per-well usage. In 2015, unreported discharge for domestic and livestock wells was estimated at 13,948 acre-feet, and non-reporting federal facility discharge was estimated at 5,330 acre-feet, for a total of 19,278 acre-feet of unreported discharge. Reported discharge totaled 305,899 acre-feet. The total of all reported and unreported pumping discharge is 325,177 acre-feet.

GROUNDWATER DISCHARGE AND USAGE

Table 3 provides a summary of well and spring discharge for 2015 based on type of use and county. The distribution of discharge from springflows and the different types of pumping for 2015 is shown graphically in Figure 4. Total annual discharge from pumping and springflow are compared in Figure 5 for the period of record from 1934–2015. The years when springflow exceeds pumping tend to be wet years when pumping demand is lowered by more frequent rainfall and higher aquifer levels produce increased springflows. Conversely, during dry years pumping tends to exceed springflow due to increased municipal and agricultural demand and lower aquifer levels.

Since 1997, however, the increase in pumping demand during dry years has been limited by the withdrawal permit system and critical period pumping reductions implemented under the Edwards Aquifer Authority Act. Table 4 provides a historical list of total annual discharge by type of use for the period 1955–2015.

Major Springs in the Southern Segment of the Balcones Fault Zone Edwards Aquifer

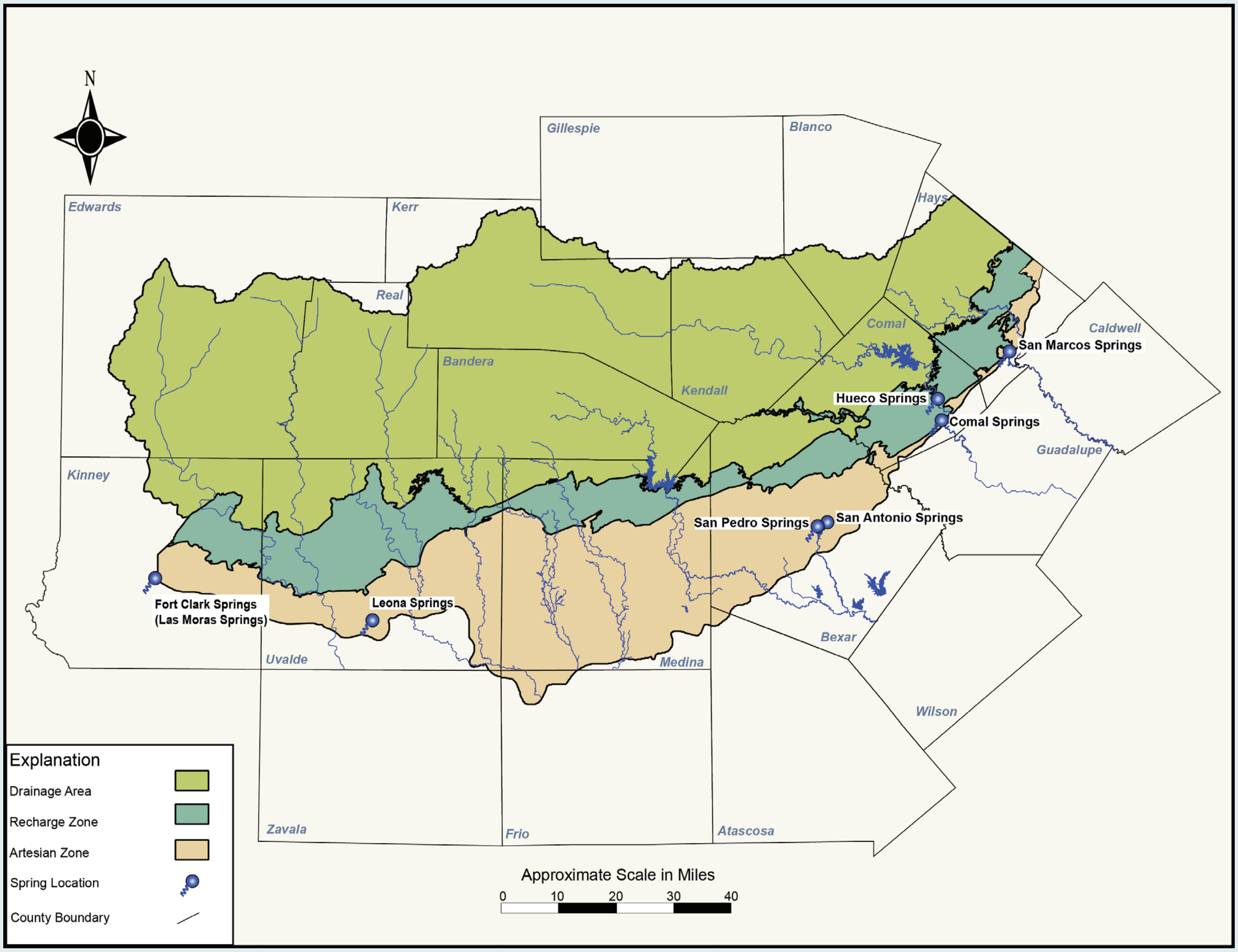


Figure 1

1934–2015 Annual Estimated Groundwater Discharge Data by County for the Edwards Aquifer (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

Table 1 [Cont.]

1934–2015 Annual Estimated Groundwater Discharge Data by County for the Edwards Aquifer (Measured in thousands of acre-feet)

Year	Uvalde[a]	Medina	Bexar[b]	Comal[c]	Hays	Total	Total Wells	Total Springs
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
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

Table 1

[Cont.]

1934–2015 Annual Estimated Groundwater Discharge Data by County for the Edwards Aquifer (Measured in thousands of acre-feet)

Year	Uvalde[a]	Medina	Bexar[b]	Comal[c]	Hays	Total	Total Wells	Total Springs
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	154.9	96.0	588.6	355.8	232.8
2014	41.5	43.1	230.5	114.5	97.9	527.5	332.2	195.4
2015	27.1	27.6	256.3	239.8	178.8	729.7	325.2	404.5
For period of record 1934–2015:								
Median	72.4	18.1	254.8	233.1	117.7	690.0	328.6	379.9
Mean	71.5	23.7	248.5	226.3	121.7	694.5	315.4	379.3
For period of record 2006–2015 (last ten years):								
Median	61.1	43.7	272.4	211.7	103.0	711.3	378.7	307.2
Mean	65.4	43.1	278.6	208.3	113.9	732.5	379.7	352.8

Table 1

Data source: Unpublished USGS and Edwards Aquifer Authority files (2015).

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.

Estimated Spring Discharge from the Edwards Aquifer, 2015 (measured in acre-feet)

January	0	0	0	8,950	2,560	7,700	19,210
February	0	0	0	10,340	2,970	8,660	21,970
March	0	0	0	11,960	2,850	10,140	24,950
April	0	2.6	0	11,820	3,670	10,440	25,933
May	0	48.0	0	15,220	6,460	12,790	34,518
June	44.5	246	183	19,260	6,130	20,250	46,114
July	135	183	43.0	20,560	5,140	19,560	45,621
August	144	3.8	0	16,500	4,380	17,330	38,358
September	187	0	0	12,840	2,920	14,310	30,257
October	345	3.1	0	12,880	3,180	12,660	29,068
November	378	114	0	17,600	5,910	19,350	43,352
December	470	188	0	18,940	5,500	20,020	45,118
Total	1,704	789	226	176,870	51,670	173,210	404,468
	1	2	3	4	5	6	7

Table 2

1. Leona Springs and Leona River Underflow 2. San Pedro Springs 3. San Antonio Springs 4. Comal Springs 5. Hueco Springs 6. San Marcos Springs 7. Total Monthly Discharge from Springs

Data source: USGS unpublished report (April 2016).

Totals might not equal sum of discharge values as a result of rounding.

Comprehensive Discharge Summary for Calendar Year 2015 (in acre-feet)

Reported Use (permitted wells) | Unreported Use

County	Irrigation	Municipal	Industrial	Domestic or Livestock*	Non-Reporting Facilities*	Total Well Discharge	Spring Discharge	Total Wells and Springs
Atascosa	983	0	0	0	0	983	0	983
Bexar	2,810	223,554	13,929	8,908	5,100	254,301	1,014	255,315
Comal	44	6,146	4,472	400	0	11,062	228,540	239,602
Guadalupe	0	4	173	0	0	177	0	177
Hays	33	3,096	1,408	876	230	5,643	173,210	178,843
Medina	18,808	5,906	1,770	1,131	0	27,615	0	27,615
Uvalde	19,477	3,152	134	2,633	0	25,396	1,704	27,096
Totals	42,154	241,859	21,887	13,948	5,330	325,177	404,468	729,645

* Federal facilities and domestic and livestock wells do not report annual use (non-reporting); quantities estimated.

Differences in totals may occur as a result of rounding.

Table 3

Mean Annual Discharge at Comal Springs

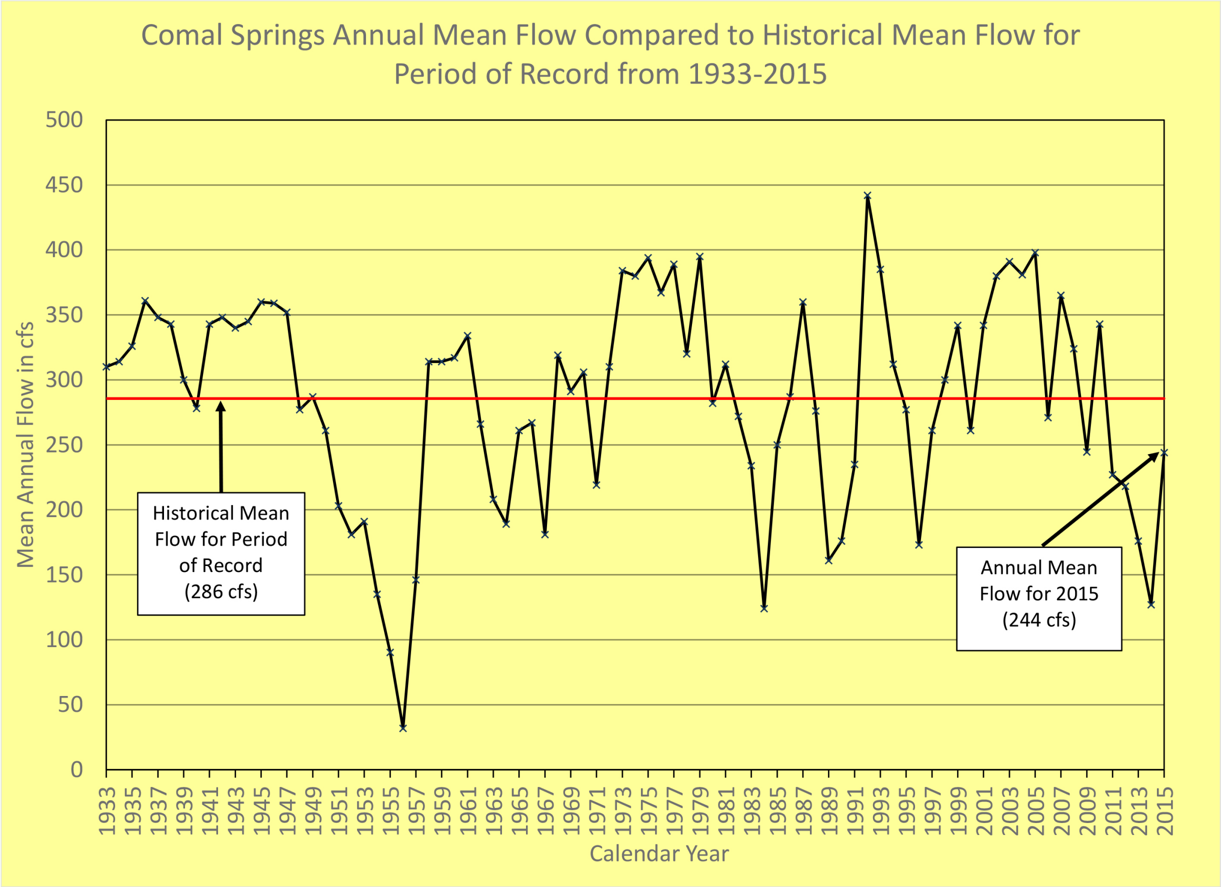


Figure 2

Mean Annual Discharge at Sam Marcos Springs

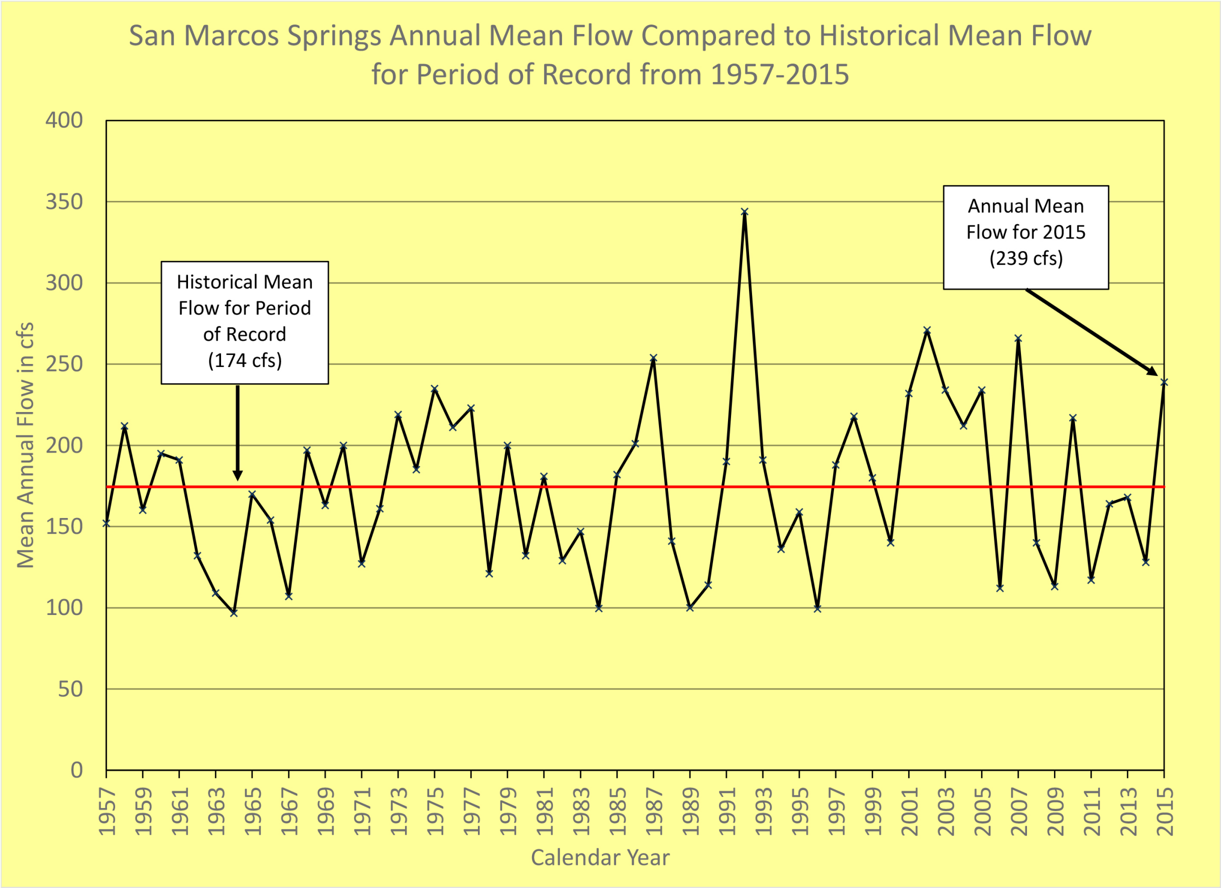


Figure 3

2015 Discharge by Type of Use

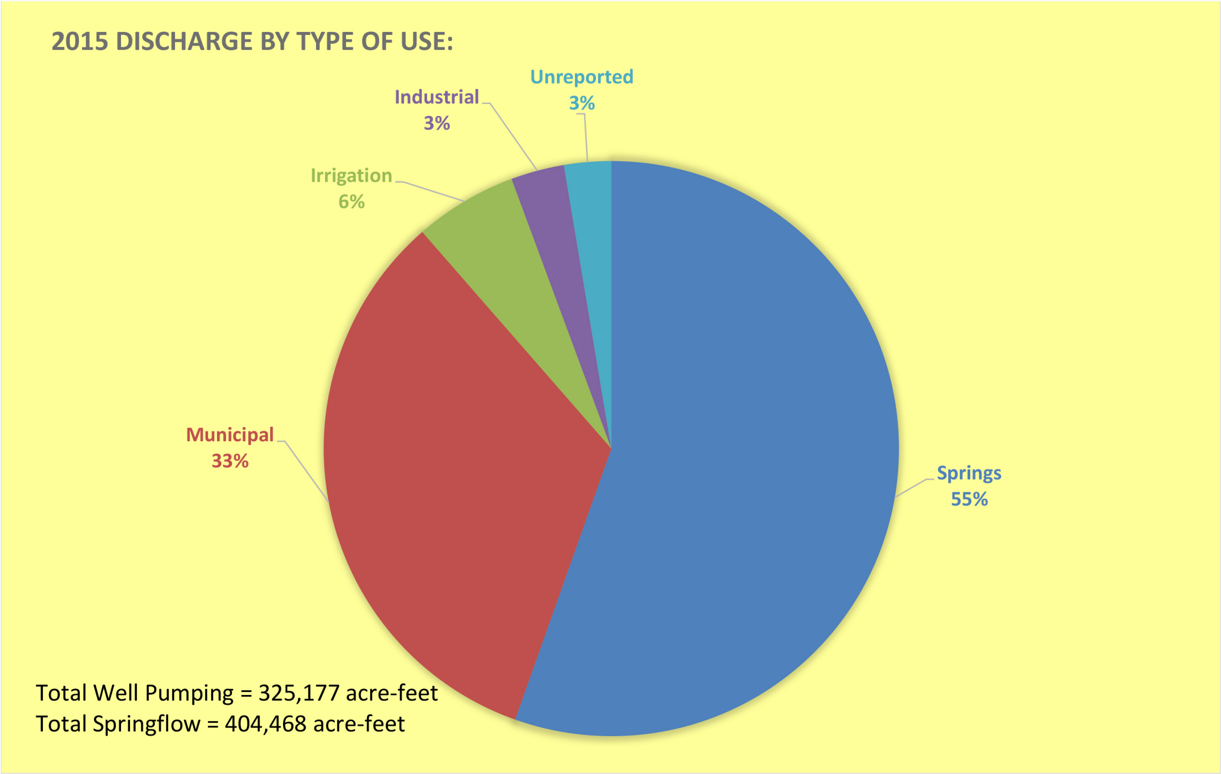


Figure 4

Groundwater Pumping Compared with Springflow

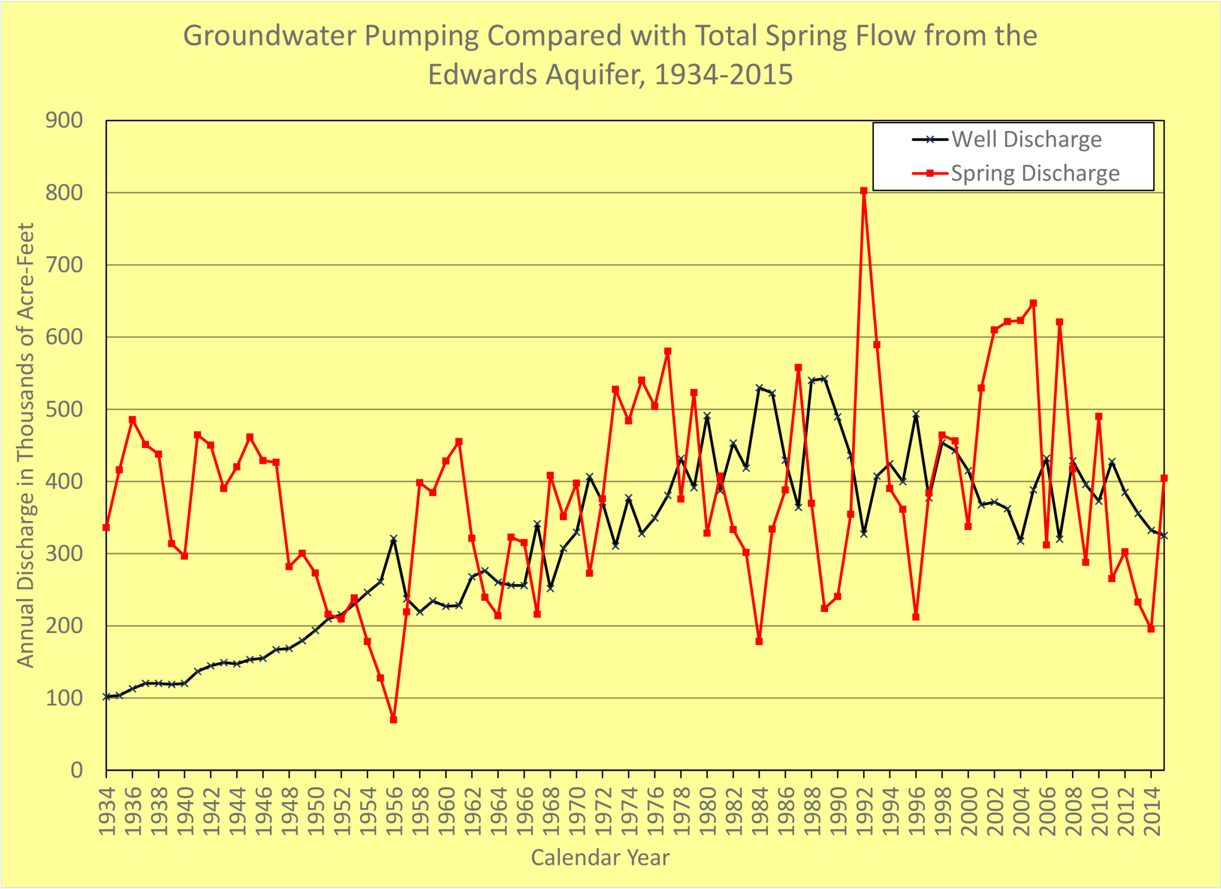


Figure 5

1955–2015 Annual Estimated Edwards Aquifer Groundwater Discharge by Use (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

Table 4 [Cont.]

1955–2015 Annual Estimated Edwards Aquifer Groundwater Discharge by Use
(Measured in thousands of acre-feet)

Year	Irrigation	Municipal	Domestic / Stock	Industrial / Commercial	Springs
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	41.7b	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
2014	75.3	220.1	13.9**	22.8	195.4
2015	42.2	247.2	13.9**	21.9	404.5

For period of record 1955–2015:					
Median	96.4	236.5	13.6**	22.8	375.8
Mean	104.2	214.2	13.4**	24.9	387.3
For period of record 2006–2015 (last ten years):					
Median	83.5	252.7	13.7	26.0	307.2
Mean	89.5	250.6	13.7	26.0	352.8

Table 4

Data source: USGS unpublished report and Edwards Aquifer Authority files (2015).

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

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

* = In 1995 USGS revised the method of calculating domestic/livestock pumpage, which significantly decreased the estimates 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.

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 surface recharge estimates for eight of the nine major drainage basins with streams that flow on to the Edwards Aquifer recharge zone (Figure 1). Recharge is estimated using a water-balance method that relies on precipitation and streamflow measurements across the region. Based on the USGS methodology, the Guadalupe River Basin does not appear to provide significant recharge to the Edwards Aquifer, so recharge is not estimated for that drainage basin.

Table 1 lists estimated annual recharge by drainage basin for the period of record from 1934 through 2015 on the basis of USGS calculations. Estimates of total annual recharge ranged from 43,700 acre-feet at the height of the drought of record in 1956 to 2,486,000 acre-feet in 1992, as shown in Figure 2. In 2015, total estimated surface recharge was 1,358,000 acre-feet, which is nearly double the mean annual recharge of 700,200 acre-feet. The median annual recharge for the period of record is 557,000 acre-feet. The median value represents the amount of annual recharge that has a 50-percent chance of being exceeded in any given year.

The pie chart in Figure 2 shows the distribution of annual recharge for the 13-year period from 2003 through 2015. It can be seen that the median was exceeded for six of the 13 years, or about half of the time. More than two thirds of the total recharge for this period was produced during three exceptionally wet years (2004, 2007, and 2015), illustrating the importance of these occasional wet years to the long-term average recharge to the aquifer. Conversely, a run of several consecutive exceptionally dry years, such as the years 2011 through 2014, can result in significant declines in aquifer water levels and the need to implement critical period water withdrawal reductions.

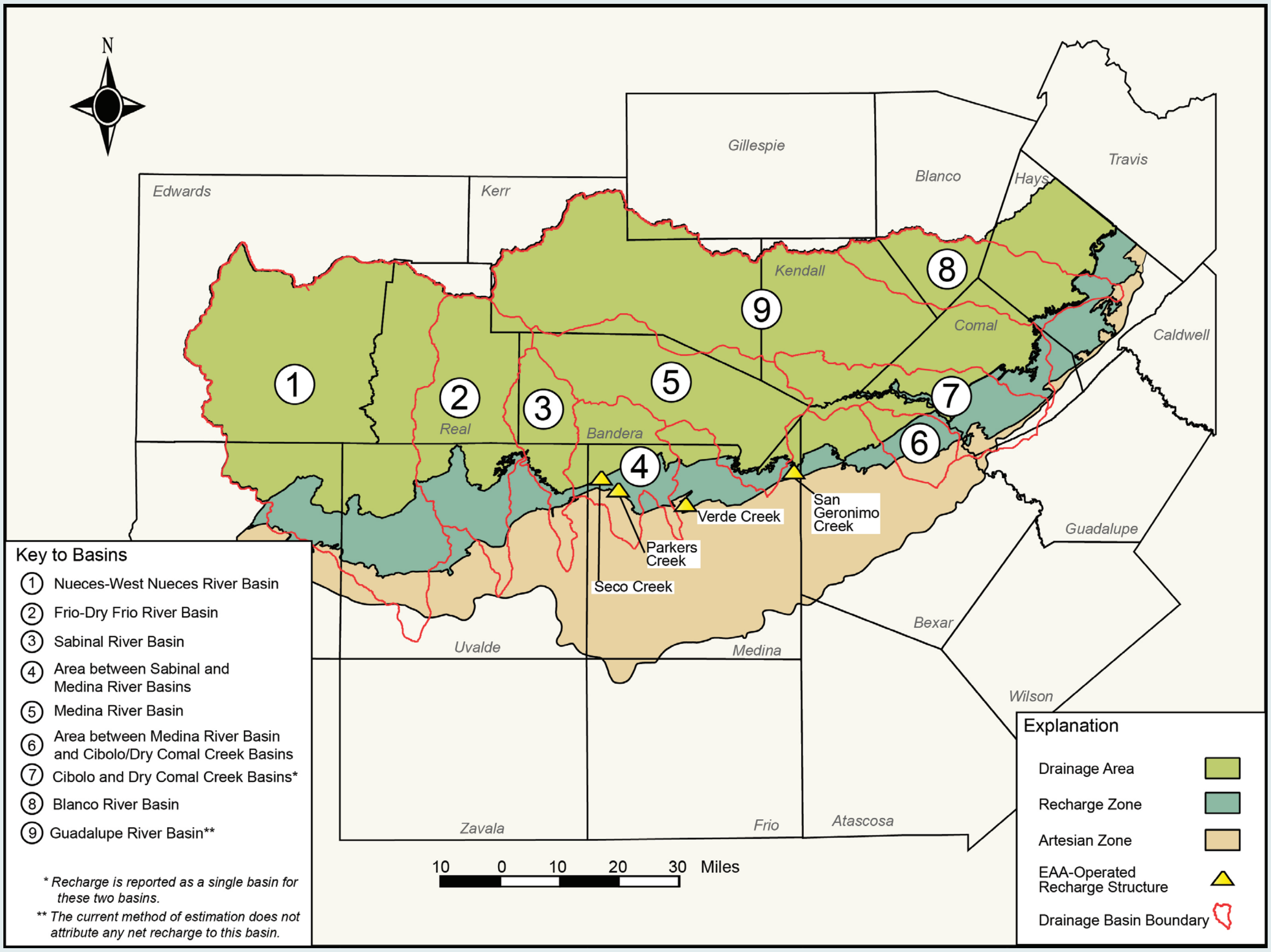
In an effort to enhance recharge, the EAA operates four recharge structures in Medina County on the Edwards Aquifer Recharge Zone (yellow triangles in Figure 1). The total amount of enhanced recharge for each site is estimated using data from stage recorders near these structures.

Enhanced recharge refers to the estimated amount of additional recharge attributable to these structures above the amount of recharge that would have occurred naturally in the absence of these structures. Table 2 shows the estimated annual enhanced recharge for each site since construction. The total enhanced recharge for these structures was 7,079 acre-feet in 2015.

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 2014. The approximate historical median annual enhanced recharge from the combined structures is 941 acre-feet; the historical mean annual enhanced recharge from the combined structures is 4,551 acre-feet. Enhanced recharge is generally a small fraction of total recharge and tends to be greater in wet years when natural recharge is also high.

Recharge resulting from interformational flow in adjacent aquifers such as the Trinity Aquifer is not estimated annually. Estimates associated with interformational flow are 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. The Edwards Aquifer Authority is presently conducting an Interformational Flow Study that may help to better quantify the amount of water that may inter the Edwards Aquifer from Trinity Aquifer formations to the north.

Fig. 1 Major Drainage Basins and Edwards Aquifer Authority-Operated Recharge Structures in the San Antonio Segment of the Balcones Fault Zone Edwards Aquifer



1934–2015 Estimated Annual Groundwater Recharge to the San Antonio Segment of the Balcones Fault Zone Edwards Aquifer by Drainage Basin (in thousands of acre-feet)

YEAR	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	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

Table 1 [Cont.]

BASIN 1. Nueces River/West Nueces River Basin **BASIN 2.** Frio River/Dry Frio River Basin **BASIN 3.** Sabinal River Basin **BASIN 4.** Area between Sabinal River and Medina River Basins **BASIN 5.** Medina RIver Basin **BASIN 6.** Area between Medina River and Cibolo Creek/Dry Comal Creek Basins **BASIN 7.** Cibolo Creek/Dry Comal Creek Basin **BASIN 8.** Blanco River Basin

1934–2015 Estimated Annual Groundwater Recharge to the San Antonio Segment of the Balcones Fault Zone Edwards Aquifer by Drainage Basin (in thousands of acre-feet)

YEAR	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	TOTAL
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
1974	91.1	135.7	36.1	115.3	96.2	68.1	76.9	39.1	2
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

Table 1 [Cont.]

BASIN 1. Nueces River/West Nueces River Basin **BASIN 2.** Frio River/Dry Frio River Basin **BASIN 3.** Sabinal River Basin **BASIN 4.** Area between Sabinal River and Medina River Basins **BASIN 5.** Medina RIver Basin **BASIN 6.** Area between Medina River and Cibolo Creek/Dry Comal Creek Basins **BASIN 7.** Cibolo Creek/Dry Comal Creek Basin **BASIN 8.** Blanco River Basin

1934–2015 Estimated Annual Groundwater Recharge to the San Antonio Segment of the Balcones Fault Zone Edwards Aquifer by Drainage Basin (in thousands of acre-feet)

YEAR	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	TOTAL
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

Table 1 [Cont.]

BASIN 1. Nueces River/West Nueces River Basin **BASIN 2.** Frio River/Dry Frio River Basin **BASIN 3.** Sabinal River Basin **BASIN 4.** Area between Sabinal River and Medina River Basins **BASIN 5.** Medina RIver Basin **BASIN 6.** Area between Medina River and Cibolo Creek/Dry Comal Creek Basins **BASIN 7.** Cibolo Creek/Dry Comal Creek Basin **BASIN 8.** Blanco River Basin

1934–2015 Estimated Annual Groundwater Recharge to the San Antonio Segment of the Balcones Fault Zone Edwards Aquifer by Drainage Basin (in thousands of acre-feet)

YEAR	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	TOTAL
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
2014	19.8	32.8	4.9	14.4	8.9	0.4	9.5	16.5	107.2
2015	343.8	281.9	42.2	218.4	54.6	131.6	177.3	108.3	1,358.1

Table 1

BASIN 1. Nueces River/West Nueces River Basin **BASIN 2.** Frio River/Dry Frio River Basin **BASIN 3.** Sabinal River Basin **BASIN 4.** Area between Sabinal River and Medina River Basins **BASIN 5.** Medina RIver Basin **BASIN 6.** Area between Medina River and Cibolo Creek/Dry Comal Creek Basins **BASIN 7.** Cibolo Creek/Dry Comal Creek Basin **BASIN 8.** Blanco River Basin

Recharge for the period of record 1934–2014:

Median	99.7	115.9	31.2	76.3	58.6	49.9	77.4	36.05	557.01
Mean	126.2	136.1	40.8	109.8	61.2	70.2	108.9	47.0	700.2

Recharge for the period of record 2006–2015 (last ten years):

Median	63.1	52.4	7.4	14.0	46.7	6.2	27.6	34.8	211.9
Mean	128.4	115.2	21.0	87.3	45.0	47.3	77.8	45.5	567.5

Data source: USGS unpublished report (April 2016).

1934–2015 Estimated Annual Recharge for the San Antonio Segment of the Balcones Fault Zone Edwards Aquifer

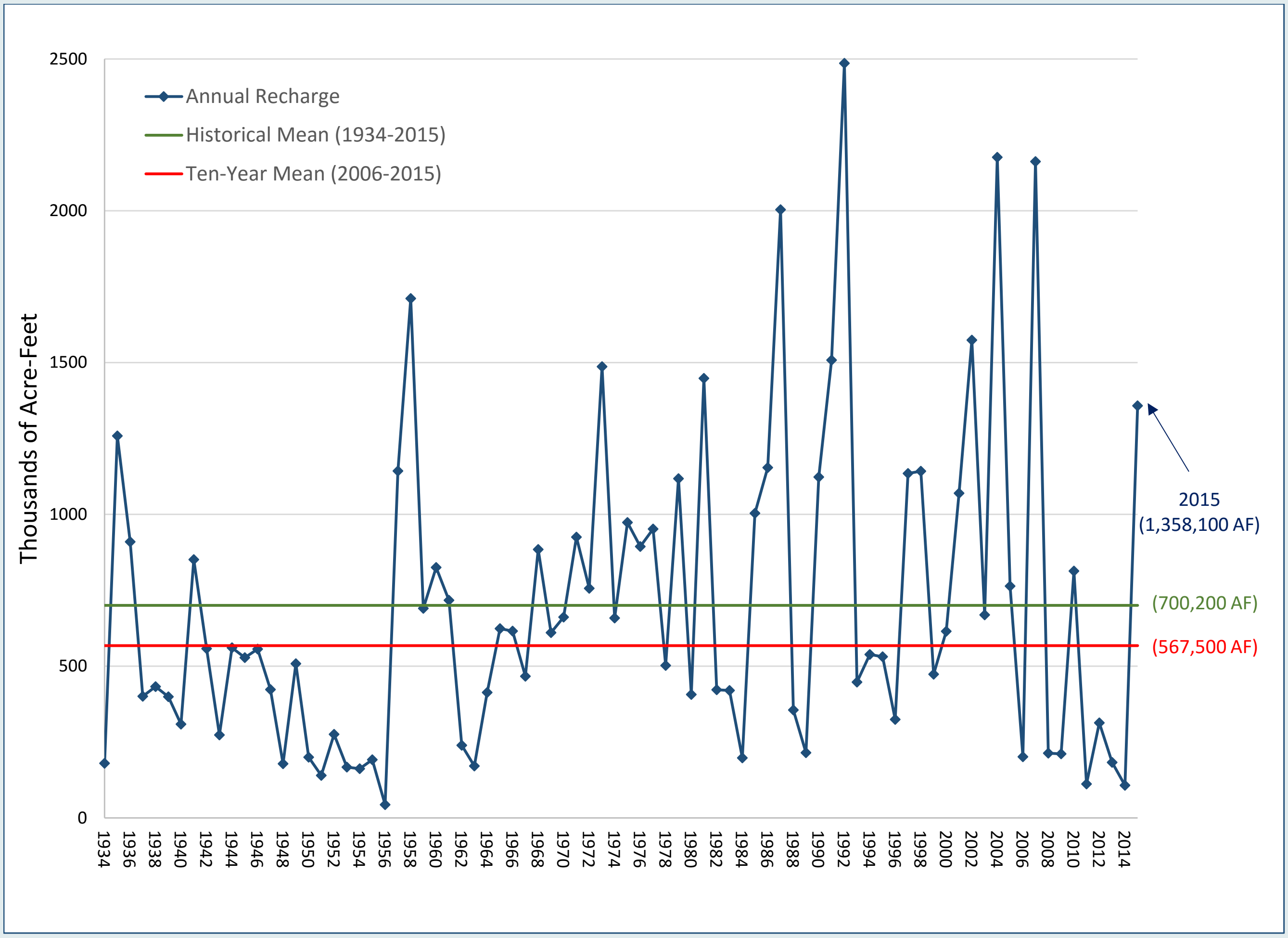


Figure 2

2003–2015 Estimated Annual Proportion of Total Recharge to the San Antonio Segment of the Balcones Fault Zone Edwards Aquifer

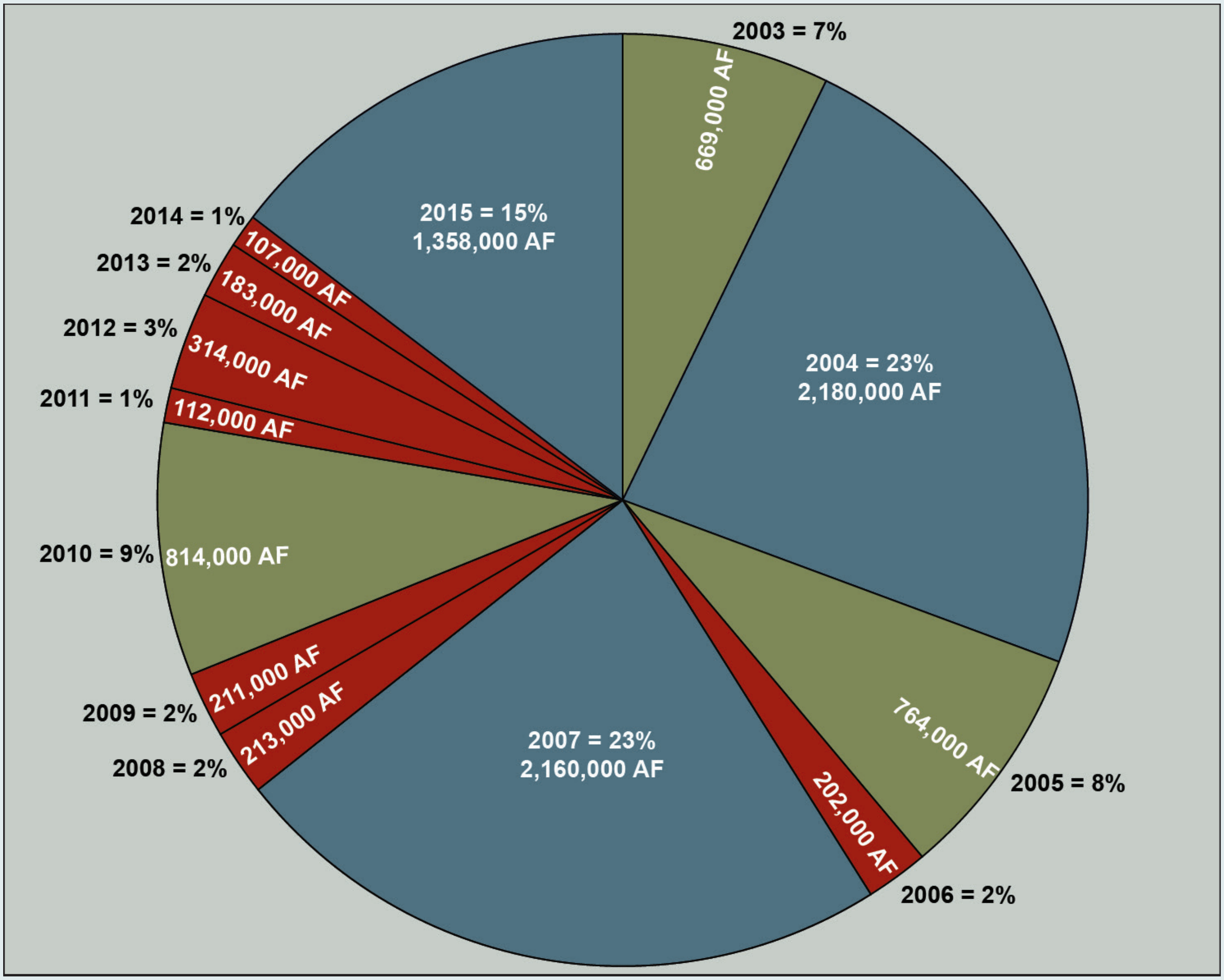


Figure 3

Estimated Annual Enhanced Recharge from Edwards Aquifer Authority-Operated Recharge Structures (Measured in acre-feet)

YEAR	DAM 1	DAM 2	DAM 3	DAM 4	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

Table 2 [Cont.]

DAM 1. Parker (April 1974) **DAM 2.** Verde (April 1978) **DAM 3.** San Geronimo (November 1979) **DAM 4.** Seco (October 1982)

Estimated Annual Enhanced Recharge from Edwards Aquifer Authority-Operated Recharge Structures (Measured in acre-feet)

YEAR	DAM 1	DAM 2	DAM 3	DAM 4	ANNUAL TOTAL
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
2014	759	38.0	0	319.4	1,116.4
2015	418.5	815.8	1,162.8	4,682.1	7,079.2
Total	310,040	25,812	37,078	104,289	202,014
Median	242	180	51	465	941
Mean	739	679	1,002	3,16	4,810

Table 2

DAM 1. Parker (April 1974) **DAM 2.** Verde (April 1978) **DAM 3.** San Geronimo (November 1979) **DAM 4.** Seco (October 1982)

Data source: Unpublished Edwards Aquifer Authority 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.

2015 WATER QUALITY SUMMARY

The purpose of EAA's water quality program is to monitor the quality of the water in the aquifer by sampling stream, wells, and springs across the region for a variety of parameters. Stream sample locations are located upstream of the recharge zone to monitor the water quality entering the aquifer. Well sample locations are located throughout the recharge and artesian zones to monitor the water quality within the aquifer. Spring samples monitor the water quality discharging from the aquifer. EAA's sampling program provides a representative "snapshot" of water quality conditions relative to the location, time, and date the sample was collected.

The Edwards Aquifer is a karst groundwater system that was formed by the dissolution of limestone rock by carbonic and sulfuric acids. Dissolution occurs when slightly acidic rainwater comes into contact with the limestone. Sulfuric acid has a deep aquifer source, and dissolution usually occurs along the saline/fresh water interface. These two processes significantly enhanced the permeability of the Edwards Aquifer. The aquifer is characterized by rapid recharge and groundwater velocities in the recharge zone, very productive wells in the artesian zone, and large springs (Comal and San Marcos Springs). The large interconnected pore spaces in the aquifer supports a unique ecology of bacteria, invertebrates, salamanders, and fish to thrive.

Water quality composition can change rapidly and be highly variable in time and location in the recharge zone as a result of stream infiltration, rainfall, and rapid groundwater velocities. However, water quality composition in the deep artesian zone can be very stable in comparison to the recharge zone because of the slower groundwater velocities and larger available water volume. In 2015, EAA staff collected water quality samples from 12 streams, 49 wells (some wells were sampled multiple times), and seven spring groups. Samples for PPCPs were collected at three wells, five spring groups, and eight streams. Grab samples of water collected at either wells or the springs are discrete samples that represent the water composition at a specific time and place. Routine water quality data collected from streams, wells, and springs can be viewed and downloaded from the EAA's Scientific Reports Document Library at: http:www.edwardsaquifer. org/scientific-research-and-reports/scientific-reports-document-library.

Overall, the Edwards Aquifer produces high quality water suitable for almost any purpose. Although most samples were non-detect for contaminants, some compounds of concern were detected at less than Texas Commission on Environmental Quality's MCLs.

SAMPLE-COLLECTION SUMMARY, CALENDAR YEAR 2015

Parameter Group	Number of Sample Locations	Number of Samples	Detections above MCL
Bacteria samples	44 wells	56	5
	5 spring groups	62	30
	12 stream sites	21	20
Metal samples	33 wells	68	3
	7 spring groups	84	1
	11 stream sites	23	0
Nitrate-Nitrite as Nitrogen	33 wells	68	0
	7 spring groups	84	0
	11 stream sites	23	0
Volatile Organic Compounds (VOCs)	46 wells	66	0
	5 spring groups	70	0
Semivolatile Organic Compounds (SVOCs)	44 wells	56	0
	5 spring groups	70	0
	8 stream sites	16	0
Pesticide and/or Herbicide Compounds	43 wells	55	0
	5 spring groups	70	0
	8 stream sites	16	0
Polychlorinated Bi-Phenyls (PCBs)	9 wells	9	0
	5 spring groups	70	0
	8 stream sites	16	0
Pharmaceuticals and Personal Care Products (PPCPs)	3 wells	3	No MCLs are established for this parameter group
	5 spring groups	20	
	8 stream sites	8	

MCL= Maximum Contaminant Level. For water quality samples, analytical results are compared with the primary standards based on concentrations published in Title 30 of the Texas Administrative Code, Chapter 290, Subchapter F http://www.sos.state.tx.us/tac/index.shtml. For compounds that do not have an established MCL, the protective concentration level is based on the Texas Risk Reduction Program, Tier 1, residential value, as referenced in Title 30, Texas Administrative Code, Chapter 350 https://www.tceq.texas.gov/remediation/trrp/trrppcls.html.

Stream samples were generally collected within the drainage area and recharge zone of the aquifer at USGS gauging stations. Surface streams recharge the Edwards Aquifer. No PCBs, SVOCs, herbicide and pesticide compounds were detected in surface water analyses.

In wells, the compounds detected with the highest frequency were VOCs, such as tetrachloroethene (PCE) and chloroform. PCE is a common organic solvent used in the dry-cleaning industry and as a degreaser. There are known former dry cleaning sites with PCE contamination in Bexar and Uvalde Counties. See caption on map for a more detailed explanation of PCE. Chloroform is a common byproduct associated with chlorination of water; and may entered the aquifer from septic tanks or lawn watering. None of the VOC detections exceeded their MCL. Well samples collected for herbicide and pesticide analyses resulted in two detections of 2, 4-D, and one detection each of silvex and tokuthion. All detections were below their MCLs. Iron was detected twice and strontium once above their MCLs but they are naturally occurring compounds.

Springs provide composite samples of the vast underground drainage network that makes up the aquifer. Spring samples analyzed for VOCs detected two compounds: (acetone), (a probably laboratory contaminate) and naphthalene. Naphthalene is naturally present in diesel fuel and probably originated from underground tank leaks. Both detections were below its MCL. SVOC compound di-n-butyl phthalate was detected twice and benzyl alcohol and phenol, were detected once below their MCLs. The sources for these materials are not known. No PCB, herbicide and pesticide compounds were detected in springs samples. One metal, iron, was detected above its MCL.

PPCP sampling performed in 2015 provided additional insight into the presence of these compounds in surface water, groundwater, or springflow. At the 31 sample sites tested for PPCPs in 2015, 24 compounds were detected as indicated on the map. All detections were at extremely low levels. The types of compounds detected were generally trace concentrations of antibiotics, estrogen compounds, and other medications. Currently, PPCP compounds detected in environmental samples do not have a regulatory limit.

Although the Edwards Aquifer produces high quality water for municipal and agricultural uses, there is the potential of contaminants entering the aquifer through the recharge zone. The EAA will continue to manage, enhance, and protect the Edwards Aquifer and its water quality.

The map on the right shows the water quality samples from 12 streams, 49 wells (some wells were sampled multiple times), and seven spring groups that EAA staff collected in 2015. Samples for PPCPs were collected at three wells, five spring groups, and eight streams. Most of the samples were obtained from the Recharge and Artesian Zones of the Edwards Aquifer. Most sample locations had no detection of organic compounds or PPCP compounds, and they are indicated by blue symbols. Most surface water and spring sample locations and a few well locations detected PPCP compounds, and they are indicated by dark red symbols. Some well locations detected organic compounds, and they are indicated by pink symbols.

BACTERIA SAMPLES AND PRIVATE WELL OWNERS

In 2015, the EAA collected 56 bacteria samples from 44 wells. Only five samples tested positive for bacteria, Escherichia coli (E. coli). The EAA collects bacteria samples from wells before 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 that are generally collected after chlorination equipment. Samples ranged in concentration from non-detectable to 20 MPN of colonies per 100 milliliters of water. E. coli bacteria analyses are used to indicate the possible presence of fecal matter in groundwater and surface water. Private well owners who have water tested positive for bacteria should have their water periodically tested and treatment may be necessary to provide safe water supply.

UVALDE TETRACHLOROETHENE PLUME

In 1979, a fire at an industrial dry cleaning operation on the east side of Uvalde, Texas, resulted in a release of tetrachloroethene (PCE) into the aquifer and subsequently created a groundwater plume that extends approximately two miles down gradient to the east. The PCE was first detected in a City of Uvalde water supply well (Edwards Aquifer well) in 1982, and it was removed from service. Groundwater monitoring is continuing in the area, particularly at sample location YP-69-51-114. This sample location has been sampled quarterly since August 2014 and routinely indicate low level detections of PCE.