



Status of Climate and Water Resources at Casa Grande Ruins National Monument

Water Year 2017

Natural Resource Report NPS/SODN/NRR—2018/1691



ON THE COVER

Interpretive area, Casa Grande Ruins National Monument. NPS photo.

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Executive Summary

Climate is a major driver of ecosystems. It helps shape ecosystem structure and function, particularly in arid and semi-arid ecosystems. Understanding changes in climate is central to assessing the condition of park biota and key cultural resources. This report summarizes climate conditions at Casa Grande Ruins National Monument (NM) for water year 2017 (October 2016–September 2017).

Air temperatures at Casa Grande Ruins NM were generally higher than normal for most of the year (up to +7.0°F), with the exception of slightly below-normal temperatures during the summer months (up to -1.5°F). There were substantially fewer extremely cold days than normal. Annual precipitation was only 73% of normal (6.70" vs. 9.18") in WY2017 when compared to normalized climate data for 1981–2010. Both the winter rainy season and summer monsoon started with near- or above-normal rainfall, which tapered off quickly. The normally dry spring months were especially dry in WY2017. There were no extreme precipitation events (>1") in WY2017, reflecting the overall drier-than-normal conditions.

Groundwater levels near Casa Grande Ruins NM in WY2017 declined 13.3 feet from WY2016, consistent with a general downward trend since 1995. Irrigation districts in the Eloy basin near the Central Arizona Project canal began receiving water in 1987. However, the San Carlos Irrigation District, adjacent to the park, is outside the Central Arizona Project service area, and groundwater levels have generally declined. Land subsidence at Casa Grande Ruins NM was 0–1 centimeter in most of the park, and up to two centimeters in some areas of the park from March 2016 to April 2017.

Acknowledgements

We thank the Arizona Department of Water Resources for monitoring wells near Casa Grande Ruins NM, and for making those data publicly available. Andy Hubbard (Sonoran Desert Network) contributed to this report. Climate data were collected from climateanalyzer.org.

1 Introduction

Climate is a major driver of ecosystems. It helps shape ecosystem structure and function, particularly in arid and semi-arid ecosystems. Understanding changes in climate is central to assessing the condition of park biota and key cultural resources. This document summarizes climate and groundwater conditions for water year (WY) 2017 (Octo-

ber 2016–September 2017) for Casa Grande Ruins National Monument, a small (191-ha) National Park Service unit in central Arizona. Detailed analyses of trends will follow in subsequent reports as the period of record warrants such assessments. For details on monitoring protocols, park setting and resources, and other management issues, please see <https://www.nps.gov/im/sodn/cagr.htm>.

2 Climate

2.1 Background and methods

Climate is the suite of characteristic meteorological conditions of the near-surface atmosphere at a given place (Strahler 2013), and is the primary driver of ecological processes on earth. A broader temporal scale (seasons to years) is what distinguishes climate from the instantaneous conditions reflected by the term, “weather.”

Climate mediates the fundamental properties of ecological systems, such as soil–water relationships, plant–soil interactions, net primary productivity, the cycling of nutrients and water, and the occurrence, extent, and intensity of disturbances—in short, the underpinnings of the natural resources that the National Park Service manages and protects.

Casa Grande Ruins National Monument (NM) has one of the longest-operating National Oceanic and Atmospheric Administration (NOAA) Cooperative Observer Program (COOP) weather stations in Arizona (Casa Grande Ruins NM, ID#3288778). This weather station, established in 1906, provides a reliable long-term dataset used for analyses in this report.

The monument also contains two recently established climate stations: a remote automated weather station (RAWS), installed in 2014; and a Regional Climate Reference Network station, installed in 2011 (Figure 2-1). Both are maintained and operated by the National Park Service Sonoran Desert Network. In combination with the excellent, long-term, NOAA COOP dataset, these stations provide a unique opportunity to study climate and weather patterns in the Sonoran Desert.

Data from all stations are accessible through www.climateanalyzer.org. The Sonoran Desert Network Climate Monitoring Protocol (Hubbard et al. in prep) includes details on methods and data handling.

An aridity index (UNEP 1992), based on long-term average annual precipitation relative to average annual potential evapotranspiration, can be a useful tool for contrasting the local climate of national parks (Figure 2-2). Used globally to classify climate zones, arid-



Figure 2-1. Weather stations at Casa Grande Ruins National Monument: A remote automated weather station, shown at left, and a high-precision regional climate reference network station, shown at right. A NOAA Cooperative Observer Program station is located near the Great House (seen in background).

ity index seeks to answer the question, “How dry is dry?” (Tsakiris and Vangelis 2005). Using the period of record (1906–present), the climate of Casa Grande Ruins NM is classified as “arid.”

2.2 Results and discussion

2.2.1 Departures from 30-year normals (1981–2010)

Data quality at the COOP station during WY2017 was fair, with missing values on 23 days. Precipitation may be underestimated, particularly for October and May, which were missing >10% of data. Annual precipitation at Casa Grande Ruins NM was only 73% of normal (6.73" vs. 9.18") as compared to the 1981–2010 normalized climate data.

2.2.1.1 Cool season (October–March)

Precipitation was below normal (69%, -1.68") for the fall and winter of WY2017. Rainfall in November through January was near normal. The winter rains tapered off early; rainfall for February and March was less than 39% and 35% of normal, respectively (Figure 2-3). Mean monthly maximum temperatures were warmer than normal (+2.2–7.0°F), except the mean monthly maximum temperature for January, which was -3.6°F below normal (Figure 2-4).

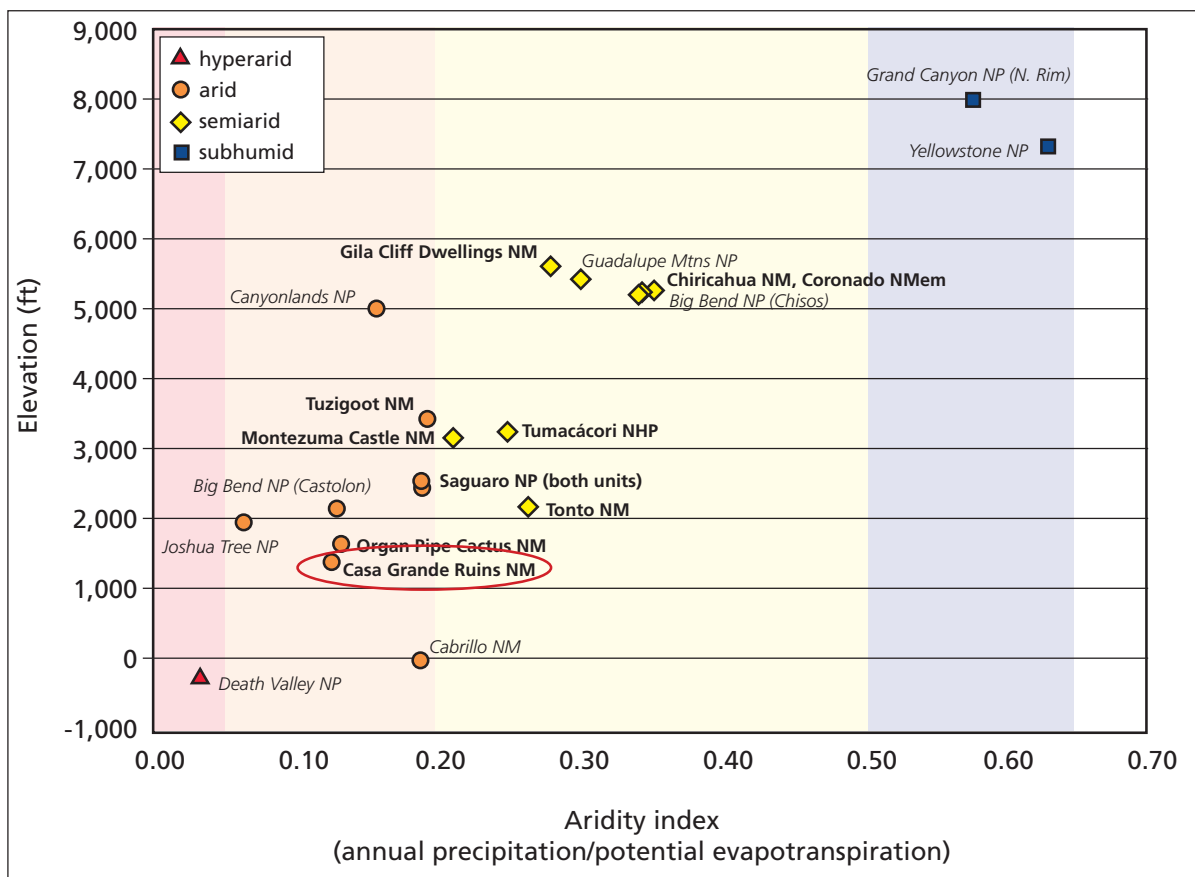


Figure 2-2. Aridity index vs. elevation of selected southwestern national parks, including Casa Grande Ruins National Monument. Figure from Hubbard and others (in prep).

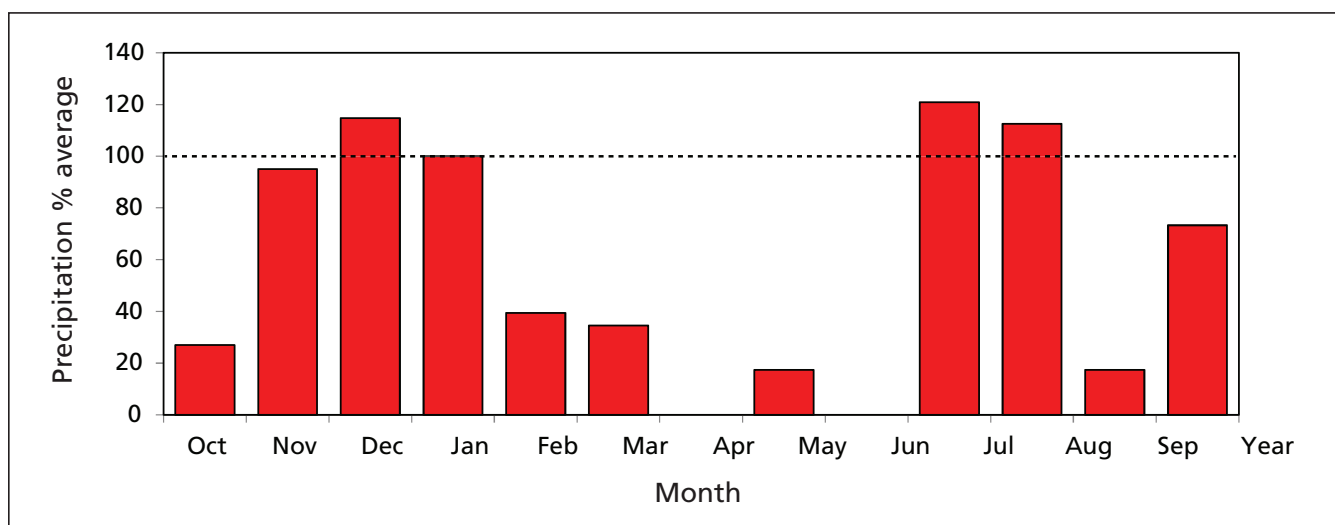


Figure 2-3. Departures from 30-year (1981–2010) normal precipitation, Casa Grande Ruins National Monument, WY2017. Daily precipitation data are missing for 22 days, with October and May missing >10% of daily data.

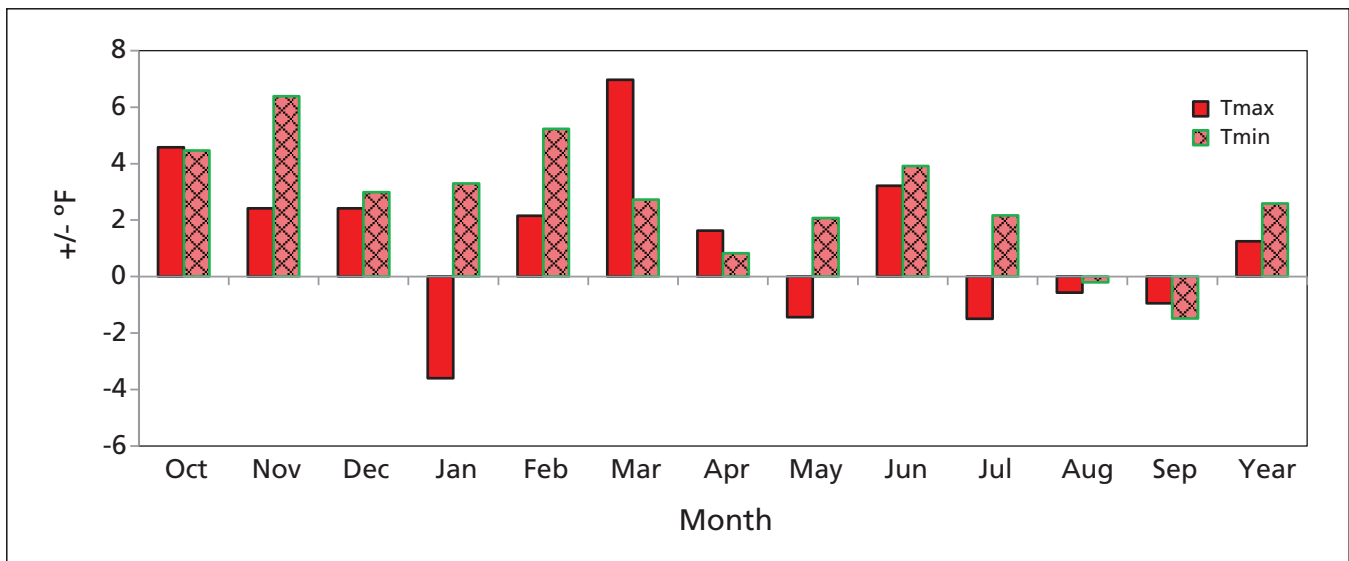


Figure 2-4. Departures from 30-year (1981–2010) normal minimum and maximum air temperature, Casa Grande Ruins National Monument, WY2017. Daily temperature data are missing for 22 days, with October and May missing >10% of daily data.

2.2.1.2 Warm season (April–September)

July and August had slightly above normal precipitation, but an extremely dry spring and September resulted in total rainfall for the warmer months being 80% of normal (-0.77") (Figures 2-3 and 2-5). Mean maximum and minimum monthly temperatures were generally warmer than normal during the spring months, while the summer months were slightly cooler than normal. The milder summer temperatures may have been caused by a monsoon-related weather system that affected southern Arizona.

2.2.2 Reconnaissance Drought Index

Reconnaissance drought index (RDI; Tsakiris and Vangelis 2005) is a measure of drought severity and extent relative to long-term climate, based on average precipitation to average potential evapotranspiration over shorter periods of time (seasons to years). RDI for Casa Grande Ruins NM reflects the extended regional drought since 2000 (Figure 2-6), with brief recoveries in WY2005, 2013, and 2015, followed by much more xeric condition, including WY2017. The five-year moving mean of total annual precipitation from 1981 to 2017 (Figure 2-7) suggests that Casa Grande Ruins experienced a brief water surplus in recent years, but below-average rainfall in WY2016 and WY2017 caused the five-year moving mean to fall below the mean for 1981–2017 (8.57" vs. 9.18").

2.2.3 Extreme weather events

Stochastic events, such as air-temperature extremes and unusually intense precipitation events, may be as important to understanding ecological patterns as long-term climate averages are. Although high air temperatures are a defining feature of warm deserts, extreme frost events also have important consequences for Sonoran Desert ecosystems. For example, sustained low air temperatures can damage or even kill long-lived keystone plants, such as columnar cacti (e.g., saguaro cactus) and native trees (e.g., velvet mesquite; Turner et al. 2003). Extreme precipitation events can also cause localized flooding and erosion events, spur or inhibit plant productivity and reproduction, and modify animal behavior. Localized erosion and exposure of critical archeological resources by extreme precipitation events is of particular importance at Casa Grande Ruins NM.

Extremely cold days (<30°F, 5th percentile of 1981–2010 data) occurred less frequently than normal (5 days vs. 16.8 ± 0.9 days) in WY2017, and were of a shorter duration (1.7 consecutive days vs. 2.6 ± 0.2 days).

There were no extreme precipitation events (>1") in WY2017, reflecting the overall drier-than-normal conditions. Casa Grande Ruins NM receives an average of 2.3 ± 0.6 days per year with precipitation of at least 1", based on 1981–2010 normalized climate data.

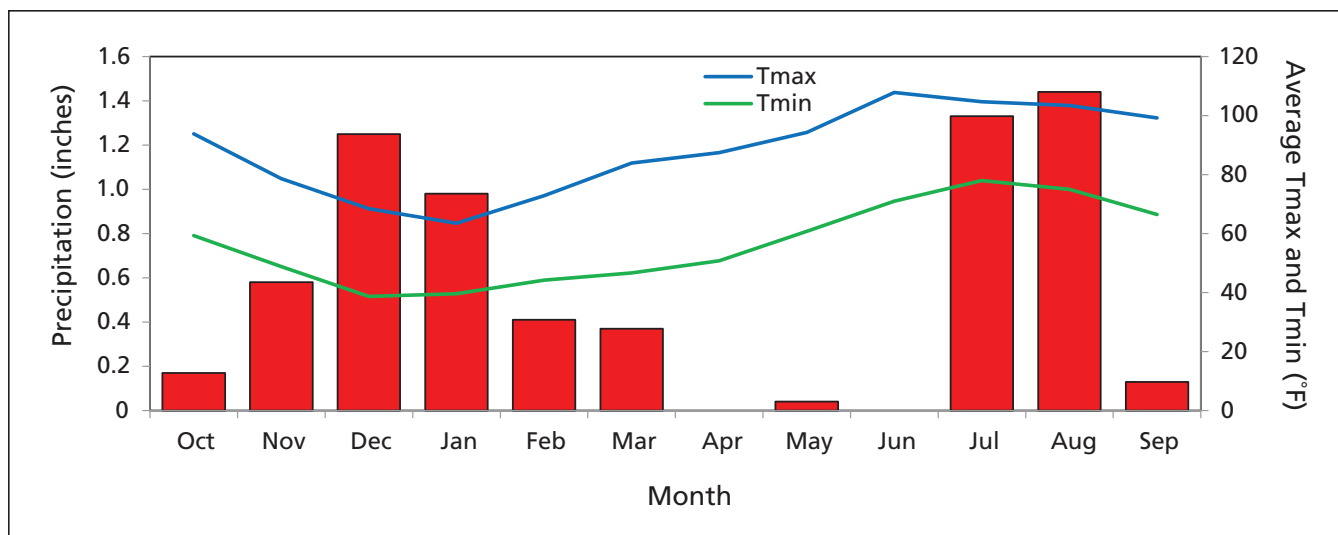


Figure 2-5. Climogram for Casa Grande Ruins National Monument, WY2017. COOP weather station precipitation data were used for all months except the October and May precipitation totals, which were taken from the RAWLS station.

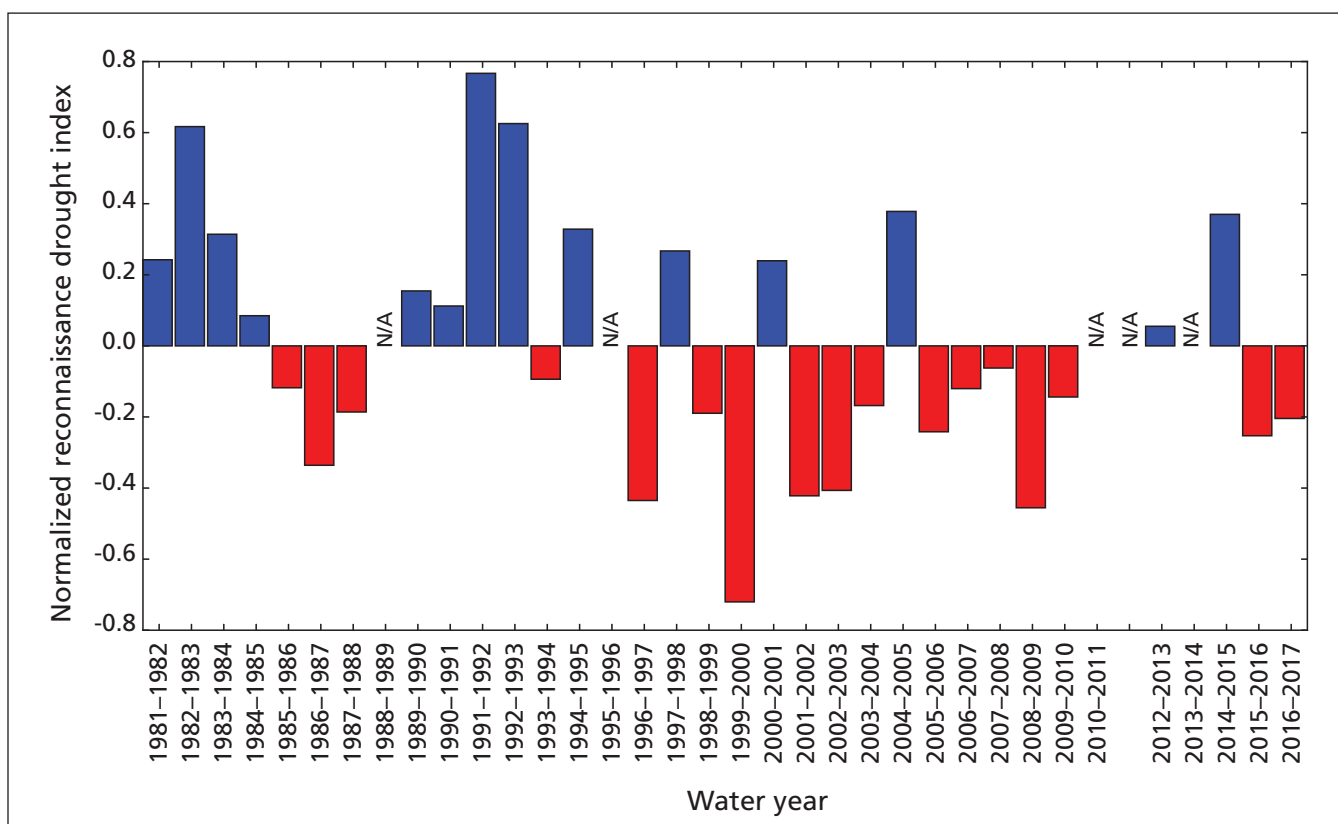


Figure 2-6. Reconnaissance Drought Index for Casa Grande Ruins National Monument, water years 1981–2017. "n/a" = insufficient data to generate reliable RDI estimates. Graphics generated by www.climateanalyzer.org.

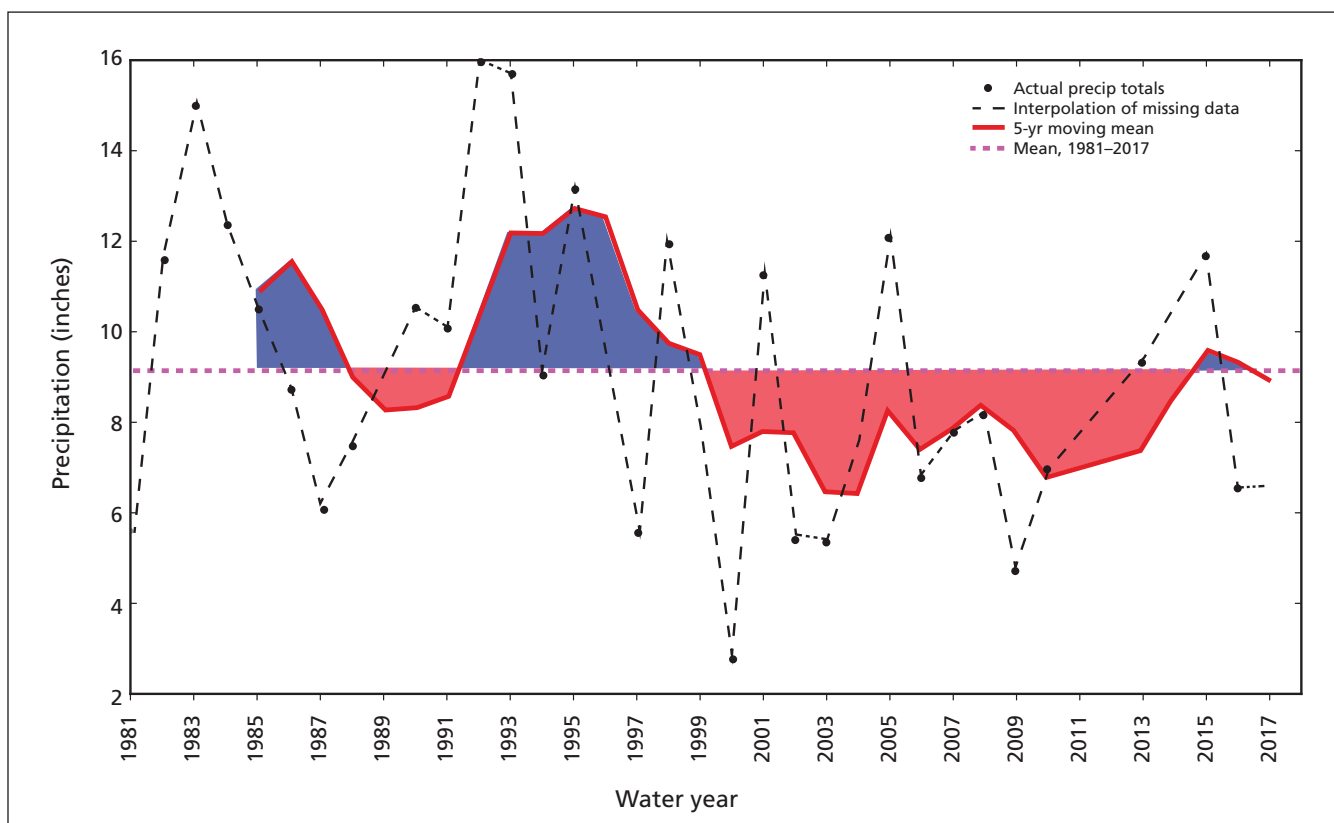


Figure 2-7. Five-year moving mean of annual precipitation, Casa Grande Ruins National Monument, 1981–2017. The moving mean (solid red line) is based on a timeseries with 16.2% (6 of 37) missing values, and includes the current year and previous four years. Missing years are linearly interpolated (dashed grey lines). Graphics generated by climateanalyzer.org

3 Groundwater

3.1 Background

Groundwater is one of the most critical natural resources of the American Southwest, providing drinking water, irrigating crops, and sustaining springs, rivers, and streams throughout the region. Groundwater is closely linked to long-term precipitation patterns and surface waters, as ephemeral flows sink below ground to reappear months, years, decades, or even centuries later as perennial and intermittent streams and springs. Groundwater also sustains trees and shrubs that are common throughout the region and is the primary source of water for almost all humans in the southwestern U.S. Groundwater therefore interacts either directly or indirectly with all key ecosystem features of the arid Sonoran Desert ecoregion.

Casa Grande Ruins NM is located in the northeast quadrant of the Pinal Active Management Area (AMA) and in the north-central section of the Eloy groundwater subbasin. The Eloy groundwater subbasin occupies a pair of hydrologically connected structural depressions formed by the relatively impermeable bedrock of the surrounding mountains and pre-Basin and Range sedimentary rocks (Hammett 1992). The bedrock depressions are filled with 800 to more than 1,000 feet of sediments, including sequences of coarse and fine-grained sediments in the area around the monument (Richard et al. 2007). Measurements in the early 20th century indicated that water-level elevations were similar for both shallow and deep wells around the subbasin (Hammett 1992). This indicates horizontal and vertical hydrologic connectivity within the basin. Under those conditions, significant differences in water-level elevations between wells are the result of localized pumping or recharge, which occurs through underflow into the basin; streambed infiltration from the Gila River during flood events; and, to a lesser extent, recharge from the surrounding mountains.

Since about 1900, groundwater conditions in the Eloy subbasin have been increasingly dominated by agricultural use. Between 2001 and 2005, 96% of all water pumped in the Pinal AMA went to agricultural uses (ADWR

2010). Since the early 20th century, the Eloy subbasin has been in groundwater deficit, with more water pumped from the aquifer than was naturally replenished. This has resulted in substantial changes to the natural flow regime, declining water levels, and land subsidence. The introduction of water from the Central Arizona Project in 1987 resulted in reduced groundwater pumping in irrigation districts near the canal (Corkhill 2012). As a result, mean water level across the Eloy subbasin did not change between 1996 and 2016 (ADWR 2017a). However, groundwater levels have generally declined in the San Carlos Irrigation district, which is adjacent to the park and outside the CAP service area (Corkhill 2012).

Long-term declines in groundwater levels throughout Arizona have resulted in areas of land subsidence (gradual collapse, fissuring or slumping) (ADWR 2017b). Subsidence occurs in areas where deep basins filled with alluvial sediments are dewatered, especially where compressible and plastic fine-grained materials are present. Land subsidence is not reversible. Casa Grande Ruins NM is located near the northern end of the Picacho–Eloy subsidence feature. In response to overdrafting and land subsidence, the Bureau of Land Management is currently studying the Eloy and Maricopa–Stanfield groundwater basins with the goal to better manage groundwater supplies.

3.2 Methods

Casa Grande Ruins NM does not have an accessible well within the park boundary. The State of Arizona Department of Water Resources Water monitors levels at two wells near the park, owned by the San Carlos Irrigation Project. These data are accessible through <http://gisweb.azwater.gov/water-resourcedata>. Well 621935, approximately 1.3 miles northwest of park headquarters, is 820 feet deep and measured annually. Well 621937, immediately west of the park boundary, is 1,110 feet deep and infrequently measured (Figure 3-1).

The former water-supply well for the park (Well 629148) was constructed in 1931. This 180-foot-deep well was used until 1952, when the park connected to the City of



Wells in and near Casa Grande Ruins National Monument

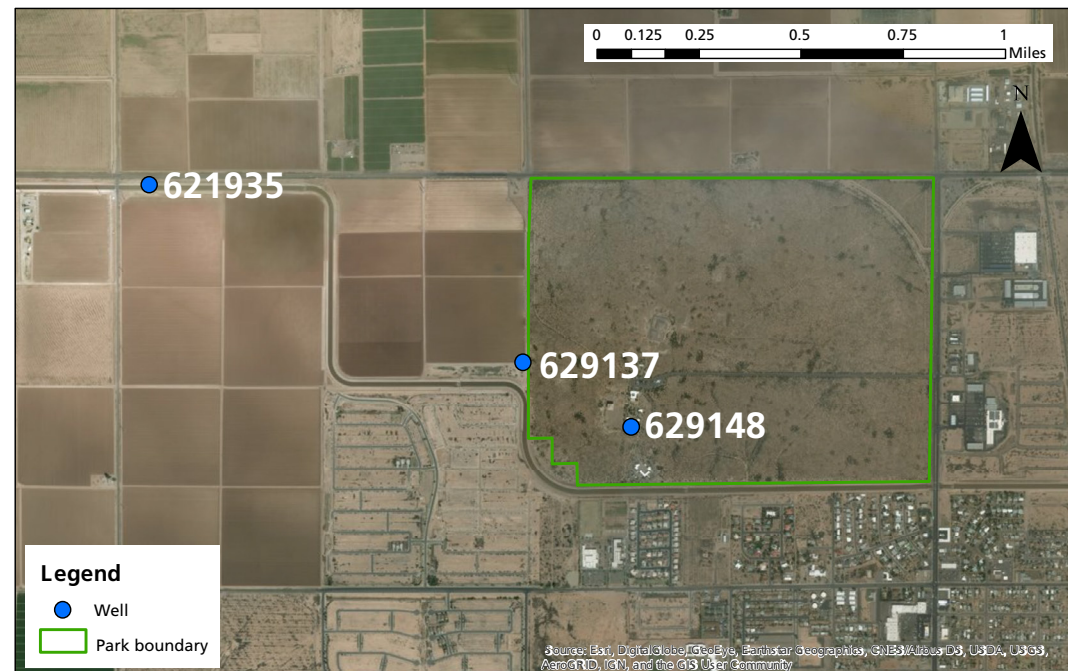


Figure 3-1. Wells near Casa Grande Ruins National Monument.

Coolidge water supply. The well was accessible until 1989, when the pump house was remodeled into a library (Clemensen 1992). Monitoring of the park's water-supply well (629148) prior to 1989 indicated that its water level was similar to that of Well 621937. Differences between water levels in these two wells and in well 621935 are attributed to groundwater pumping.

Detailed information on monitoring methods may be found in the SODN groundwater monitoring protocol (Filippone et al. 2014).

3.3 Results and discussion

Two water-level measurements were collected from Well 621935 in WY2017: 136.30 feet below ground surface (bgs) on 11/7/2016, and 136.70 feet bgs on 12/21/2016. These measurements represented a decrease of

13.3 feet from WY2016, and were consistent with a general downward trend since 1995 (Figure 3-2). Over the monitoring record, the water level has varied 102.2 feet, with a low of 171.40 feet bgs recorded in June 1986 and a high of 69.20 feet bgs in November 1995.

The historical water-level record documented in Figure 3-3 reflects substantial groundwater-level increases attributed to infiltration from the Gila River following the major regional flood years of 1983 and 1993, and, to a lesser extent, 2007. Groundwater levels in the Eloy subbasin decline between high flow events on the Gila River.

Land subsidence at Casa Grande Ruins NM between March 2016 and April 2017 was 0–1 centimeter in most of the park, and up to two centimeters in some areas of the park (Figure 3-4).

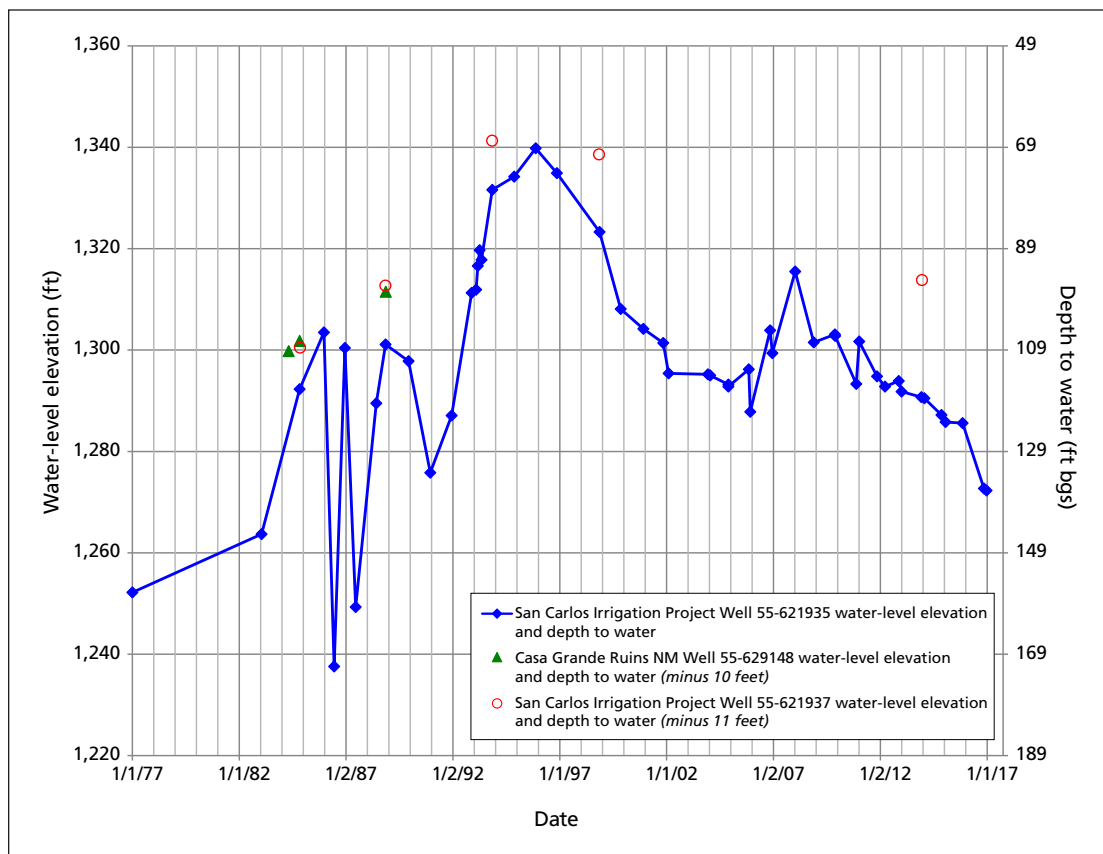


Figure 3-2. Water-level elevation and depth to water at and near Casa Grande Ruins National Monument, 1977–2017. Wellhead elevation for well 621935 is 1,409 feet. Wellhead elevation for well 629148 is 1,419 feet, so 10 feet should be added to the scale shown on the right y-axis to obtain the correct depth. Wellhead elevation for well 621937 is 1,420 feet, so 11 feet should be added to the scale shown on the right y-axis to obtain the correct depth.

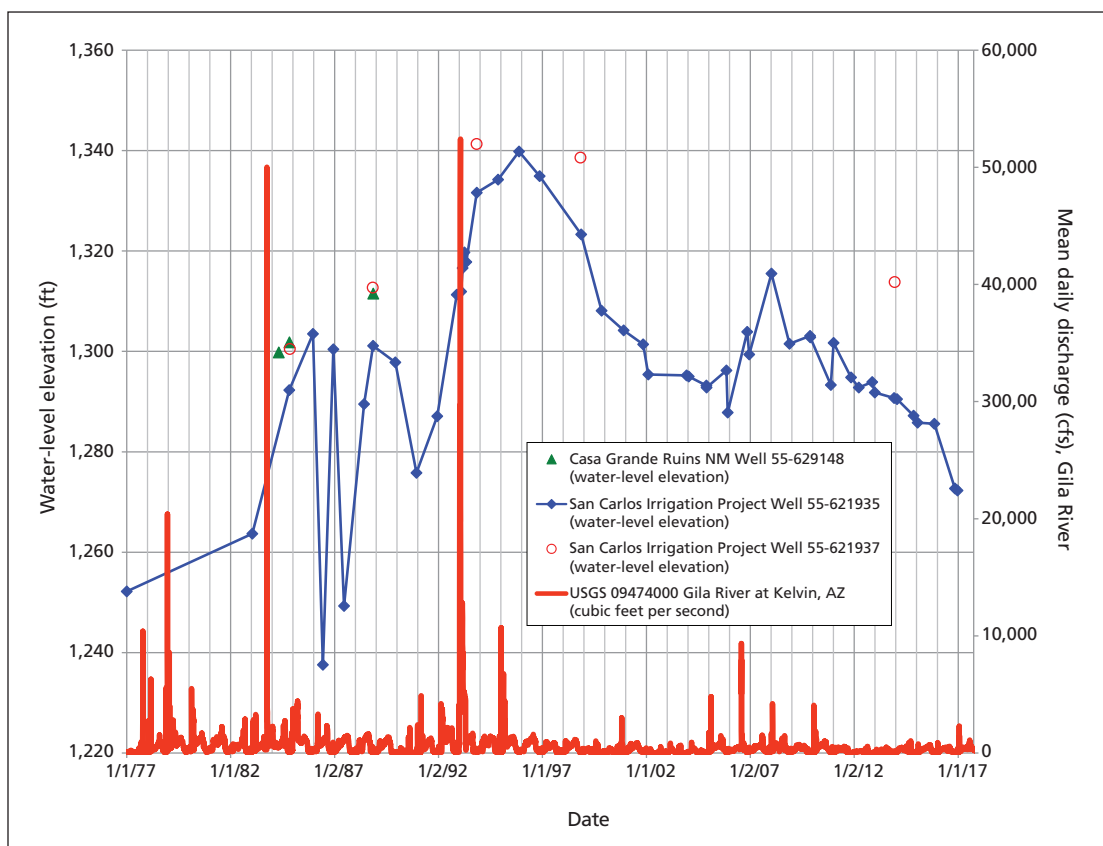


Figure 3-3. Gila River mean daily discharge at Kelvin, Arizona, and water-level elevation in and around Casa Grande Ruins National Monument, 1977–2017.

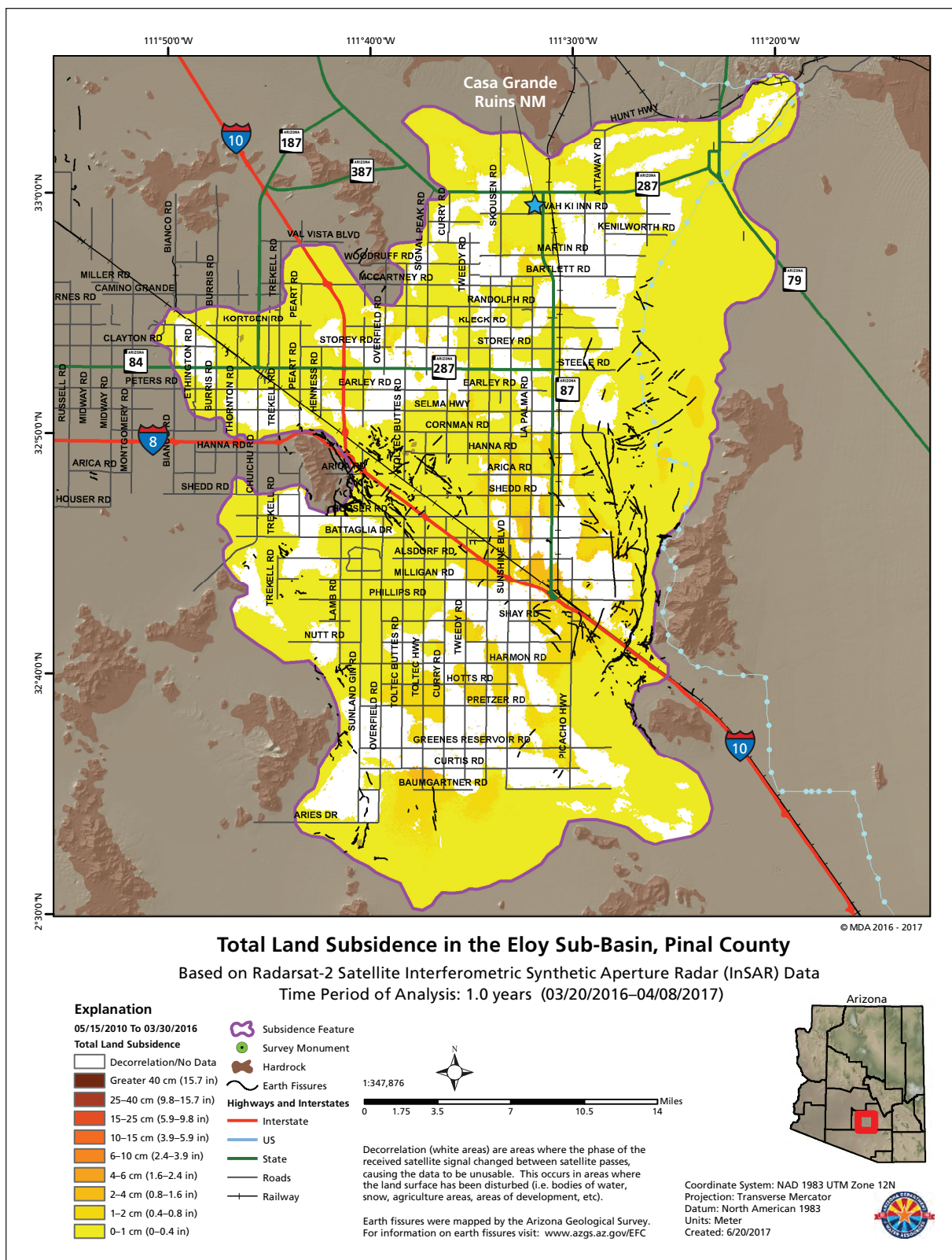


Figure 3-4. Land subsidence and earth fissures in the Eloy subbasin, 3/20/16–4/17/2017. Source: Arizona Department of Water Resources, eLibrary, https://new.azwater.gov/sites/default/files/PicachoArea03-2016to04-2017_8x11.pdf.

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