National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

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

Water Year 2016

Natural Resource Report NPS/SODN/NRR—2018/1629

ON THE COVER

Weather stations at Casa Grande Ruins National Monument. NPS photo.

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

Water Year 2016

Natural Resource Report NPS/SODN/NRR—2018/1629

Prepared by
Colleen Filippone
Sonoran Desert Network
National Park Service
12661 E. Broadway Blvd.
Tucson, AZ 85748

Kara Raymond
Southern Arizona Office
3636 N. Central Ave., Suite 410
Phoenix, AZ 85012

Editing and Design
Alice Wondrak Biel
Sonoran Desert Network
National Park Service
12661 E. Broadway Blvd.
Tucson, AZ 85748

May 2018

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

This report is available from the Sonoran Desert Network website, as well as at the Natural Resource Publications Management website. If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov.

Please cite this publication as:

Filippone, C., and K. Raymond. 2018. Status of climate and water resources at Casa Grande Ruins National Monument: Water year 2016. Natural Resource Report NPS/SODN/NRR—2018/1629. National Park Service, Fort Collins, Colorado.

NPS 303/144932, May 2018

Contents

Figures

Executive Summary

Climate and hydrology are major drivers of ecosystems. They dramatically shape ecosystem structure and function, particularly in arid and semi-arid ecosystems. Understanding changes in climate and groundwater is central to assessing the condition of park biota and key cultural resources. This report combines data collected on climate with an overview of groundwater resources at Casa Grande Ruins National Monument (NM) for water year 2016 (October 2015–September 2016).

Air temperatures were generally below normal (-1 to -4°F) from November through January, whereas minimum and especially maximum air temperatures soared in February and March relative to 1981–2010 normals. Minimum air temperatures were generally above normal throughout the warm season. Annual precipitation at Casa Grande Ruins NM was only 72% of normal (6.57" vs. 9.18") in WY2016 when compared to normalized climate data for 1981–2010. Very little precipitation fell during December, February, and March, which are typically among the monument's wettest months—yet in June, precipitation was about five times normal (0.25" vs 0.05"). There were no extreme precipitation events (>1") in WY2016, reflecting the overall drier-than-normal conditions.

Groundwater conditions have significant impacts on Casa Grande Ruins National Monument and the surrounding area. The monument is located in the north-central section of the Eloy groundwater subbasin. Since about 1900, groundwater conditions in the Eloy subbasin have been increasingly dominated by agricultural use. 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. Groundwater loss has the potential to affect the water supply as well as the stability of structures through land subsidence.

1 Introduction

Climate and hydrology are major drivers of ecosystems. They dramatically shape ecosystem structure and function, particularly in arid and semi-arid ecosystems. Understanding changes in climate and groundwater is central to assessing the condition of park biota and key cultural resources. This document summarizes climate and water resource conditions for water year (WY) 2016 (October 2015–September 2016) 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 information on other resources of management focus, please see https://www.nps.gov/im/sodn/cagr.htm.

2 Climate

2.1 Background

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

Figure 2-1. Three weather stations at Casa Grande Ruins National Monument: (1) A remote automated weather station, shown at left, (2) a high-precision regional climate reference network station, shown at right, and (3) the NOAA Cooperative Observer Program station, located near the Great House (seen in background).

2.2 Findings for WY2016

2.2.1 Departures from the 1981–2010 normals

Annual precipitation at Casa Grande Ruins NM was only 72% of normal (6.57" vs. 9.18") in WY2016 when compared to the 1981–2010 NOAA normalized climate data. Data quality during WY2016 was excellent, with missing values on only four days (11/26/15, 12/2/15, 12/25/15, and 3/18/16).

2.2.1.1 Cool season (October–March)

Precipitation was below normal (74%, -1.4") for the fall and winter of WY2016, although October and January were somewhat wetter than normal (Figure 2-3). Very little precipitation fell during December, February, and March, which are typically among the monument's wettest months. Air temperatures were generally below normal (-1 to -4°F) from November through January, whereas minimum and especially maximum air tem-

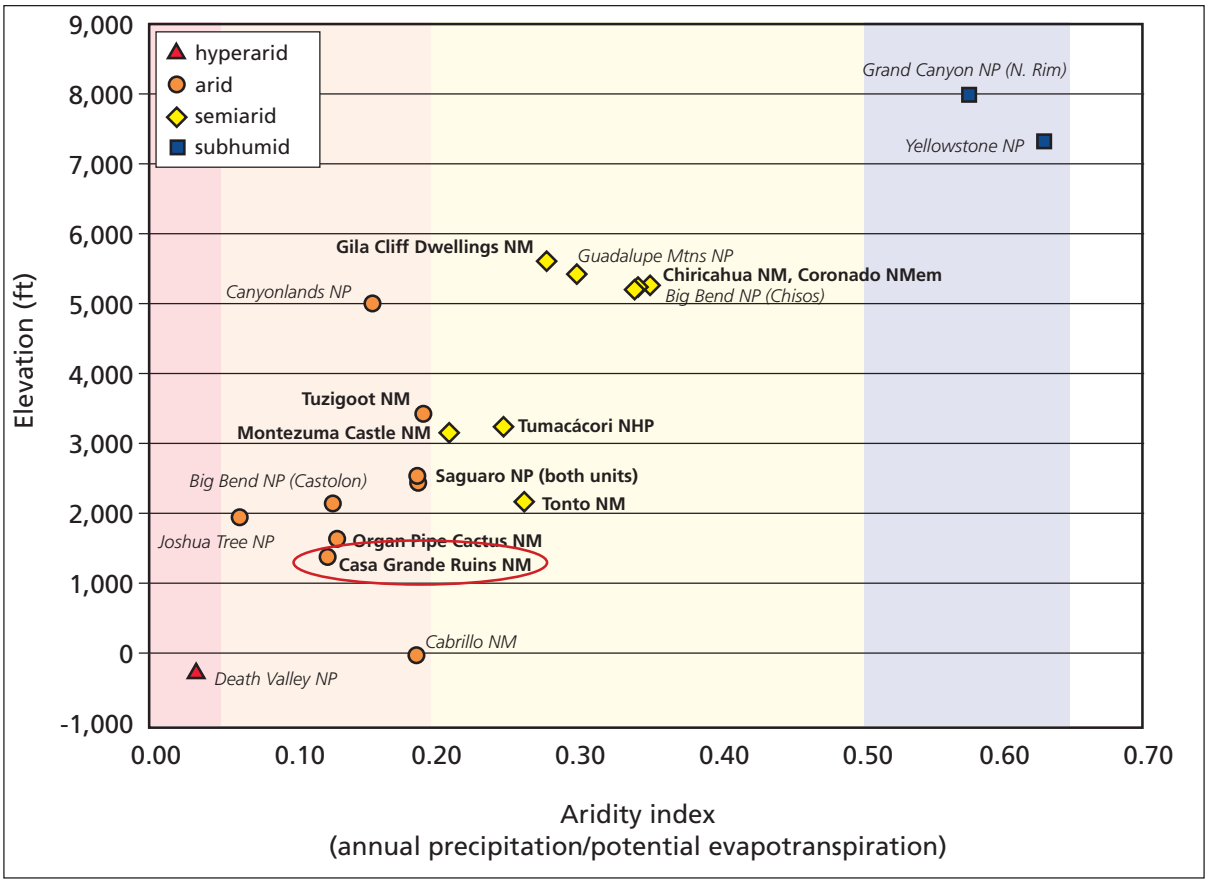


Figure 2-2. Aridity index vs. elevation of selected southwestern national parks, including Casa Grande Ruins National Monument. Figure from Hubbard and others (in prep).

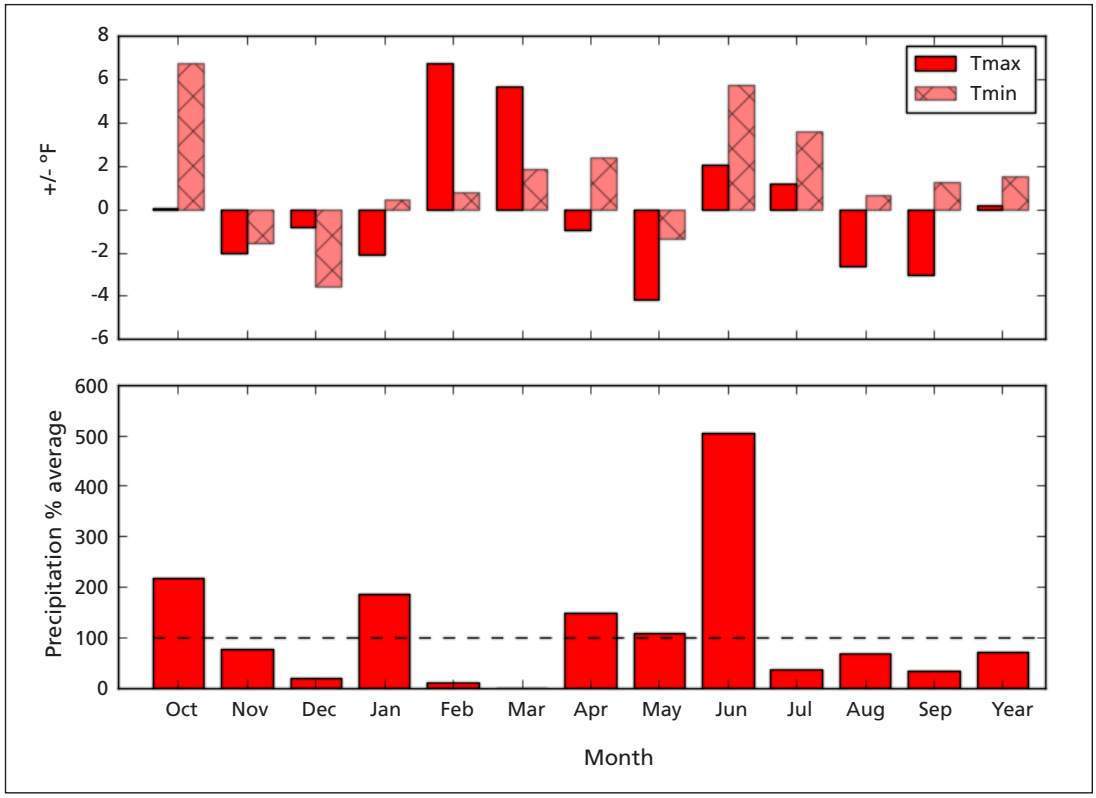


Figure 2-3. Departures from 30-year (1981–2010) normal minimum and maximum air temperature and precipitation, Casa Grande Ruins National Monument, WY2016. Graphics generated by climateanalyzer.org.

peratures soared in February and March relative to 1981–2010 normals (Figure 2-3).

2.2.1.2 Warm season (April–September)

Precipitation for spring and early summer of WY2016 was above normal—particularly during June, when monthly precipitation was about five times normal (0.25" vs 0.05"). Almost no rain falls in June during most years (Figure 2-4). In combination with below-normal rainfall in July–September, the overall warm-season precipitation total was greatly below (68%, -1.21") 1981–2010 normals. Minimum air temperatures at the monument were generally above normal throughout the warm season. Maximum air temperatures were above normal in early summer, followed by more mild maximum air temperatures throughout the rest of the monsoon season.

2.2.2 Reconnaissance Drought Index

Reconnaissance drought index (RDI; Tsakiris and Vengelis 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 2-5), with brief recoveries in WY2005, 2013, and 2015, followed by much more xeric conditions in WY2016. The five-year moving mean of total annual precipitation from 1981 to 2016 (Figure 2-6) suggests that recent wet years prior to WY2016 have brought a slight precipitation surplus. However, results may be skewed due to missing data.

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) were within the 1981–2010 normal range (16 days vs. 16.8 ± 0.9 days) in WY2016, and were of a normal duration (3.2 consecutive days vs. 2.6 ± 0.2 days).

There were no extreme precipitation events (>1") in WY2016, 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.

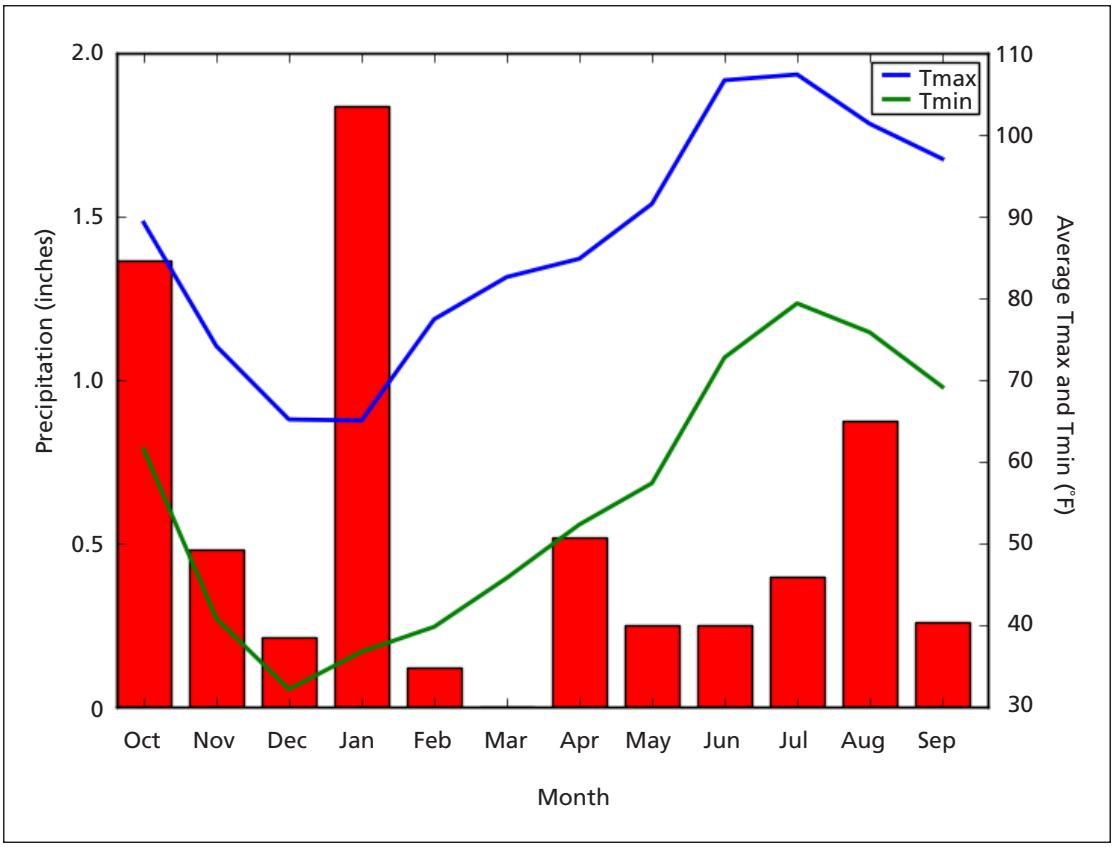


Figure 2-4. Climogram for Casa Grande Ruins National Monument, WY2016. Graphics generated by climateanalyzer.org.

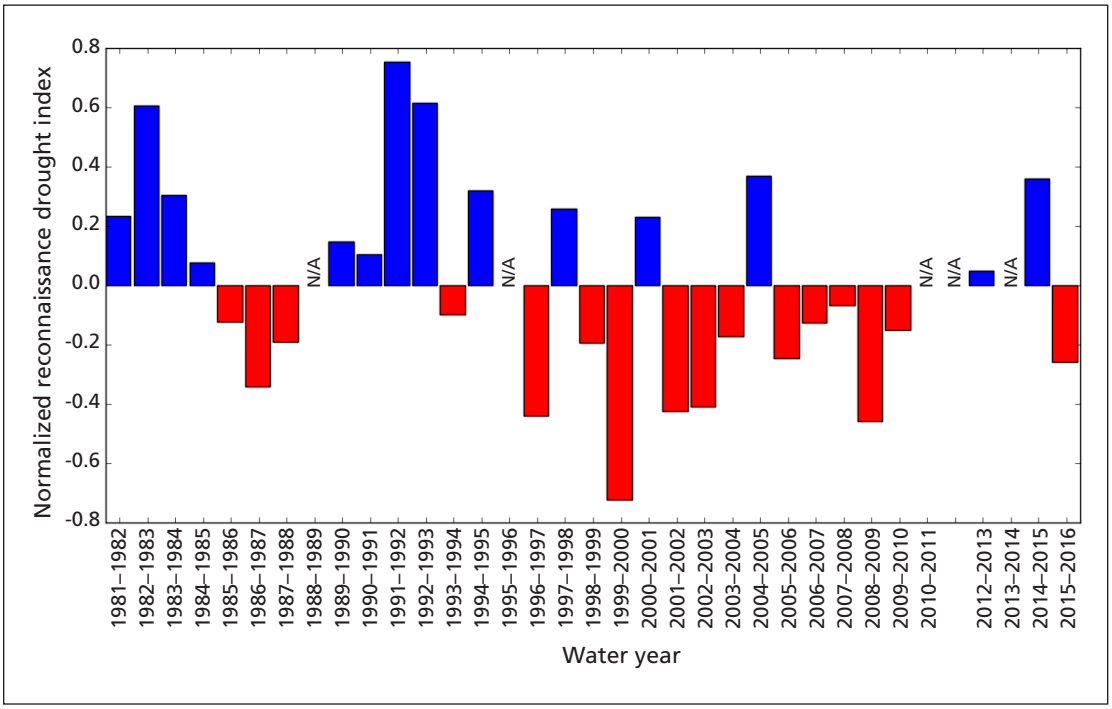


Figure 2-5. Reconnaissance drought index for Casa Grande Ruins National Monument, water years 1981–2016. "n/a" = insufficient data to generate reliable RDI estimates. Graphics generated by www.climateanalyzer.org.

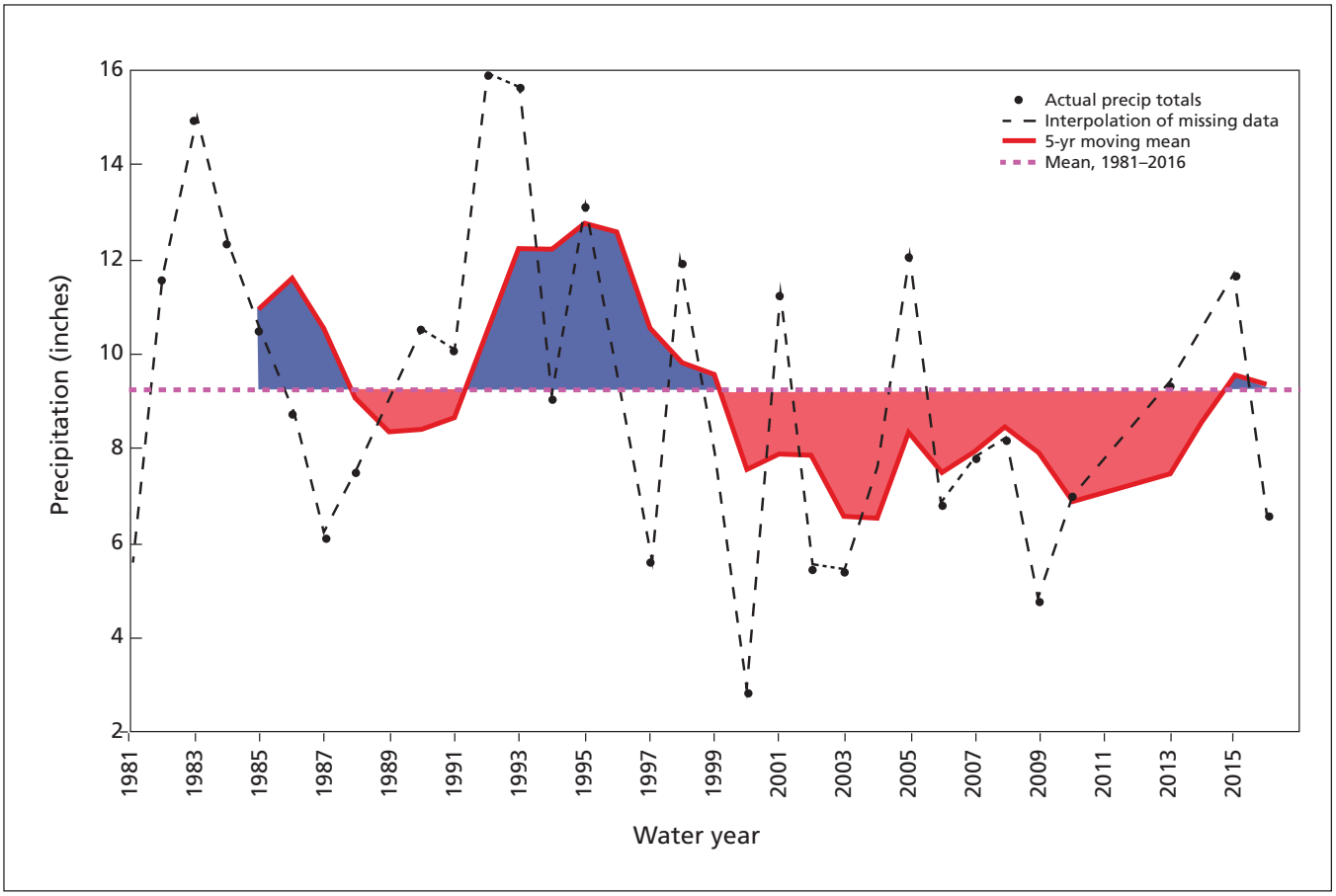


Figure 2-6. Five-year moving mean of annual precipitation, Casa Grande Ruins National Monument, 1981–2016. The moving mean (solid red line) is based on a timeseries with 14% (5 of 36) missing values, and includes the current year and previous four years. Missing years are linearly interpolated (dashed grey lines). Graphics generated by climateanalyzer.org.

Figure 2-7. Thunderstorm development during the summer monsoon, Casa Grande Ruins National Monument.

3 Groundwater

3.1 Background

Casa Grande Ruins National Monument is located in the northeast quadrant of the Pinal Active Management Area (AMA, Figure 3-1; figures start on page 11) and in the north-central section of the Eloy groundwater subbasin (Figure 3-2). 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. One-third of the county's land area is devoted to agricultural production, including livestock, cotton, livestock forage and feed of various types, grains, vegetables, and orchards (USDA 2014). The tens of thousands of acres of groundwater-dependent agricultural fields that surround the monument and the city of Coolidge also influence the environment and experience of park visitors. In a sense, the fields may be viewed as a modern-day reminder of the Hohokam peoples, who irrigated and farmed this same land more than 1,500 years ago.

The stated management goal of the Pinal AMA is to preserve existing agricultural interests as long as is feasible while allowing both development and preservation of future water supplies for non-irrigation uses (ADWR 2017a). 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 potable water supply for Casa Grande Ruins National Monument is delivered by the Arizona Water Company.

3.2 Groundwater levels in the Eloy subbasin

Water levels at selected wells in the monument area are monitored by the State of Arizona Department of Water Resources (ADWR). Figure 3-3 shows water-level elevations measured at three wells in and near the monument. Well 629148, located inside the monument boundary is 180 feet deep and believed to be a former water supply. Wells 621935 (820 feet deep) and 621937 (1,110 feet deep) are owned by the San Carlos Irrigation Project (SCIP). Figure 3-4 shows the locations of these wells. SCIP well 621935, an ADWR index well, is monitored annually by the state.

Figure 3-3 shows that water levels between the monument well and SCIP well 621937 are very similar, despite significant differences in the total depths of these wells. 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 (Figure 3-5). Groundwater levels in the Eloy subbasin decline between high flow events on the Gila River. Differences between the wells at and adjacent to the monument and the ADWR index well, located about 1.4 miles from park headquarters, are attributed to pumping at the index well.

Figure 3-6 maps water-level changes in the Eloy subbasin between the late 1980s/early 1990s and the mid/late 2000s (Corkhill 2012). The introduction of water from the Central Arizona Project (CAP, shown in Fig-

ure 3-1) in 1987 resulted in reduced groundwater pumping in irrigation districts near the canal, including the Hohokam and the Central Arizona Irrigation and Drainage districts (Corkhill 2012). This reduction had a significant influence on groundwater levels in the basin. Outside of CAP service areas, groundwater levels generally declined, such as in the San Carlos Irrigation and Drainage District, adjacent to the monument, and other non-irrigation-district agricultural areas (Corkhill 2012). The slow dissipation of a groundwater mound formed after flooding of the Gila River was a second factor in groundwater-level changes at wells located near the Gila River during this period.

3.3 Land subsidence

Long-term declines in groundwater levels throughout Arizona have resulted in areas of land subsidence (gradual collapse, fissuring or slumping), as shown in Figure 3-7 (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 (Figure 3-8). Figure 3-9 illustrates subsidence measured between 2010 and 2016, together with traces of known earth fissures in the subbasin (ADWR 2017b). Additional information about this subsidence feature and maps of measured subsidence in the area from 2004 through 2016 may be found at http://www.azwater.gov/AzDWR/Hydrology/Geophysics/PicachoEloySubsidence.htm. The Eloy subbasin has the dubious distinction of harboring the greatest number of earth fissures in the state, mostly clustered along the central eastern and central western parts of the subbasin (AGS 2016).

Online viewing of natural hazards around the state, including earth fissures, is available from the Arizona Geological Survey at http://data.azgs.az.gov/hazard-viewer/. Detailed geospatial data for creating customized earth fissure maps are available at http://repository.azgs.az.gov/uri_gin/azgs/dlio/997. In the area of Casa Grande Ruins NM, subsidence between 2010 and 2016 was relatively small (0–1 cm). Only a few minor earth fissures are known in the Coolidge area.

3.4 Discussion

In summary, groundwater conditions have significant impacts on Casa Grande Ruins National Monument and the surrounding area. In the monument and the city of Coolidge, groundwater is the potable water source. Groundwater loss has the potential to affect the water supply as well as the stability of structures through land subsidence.

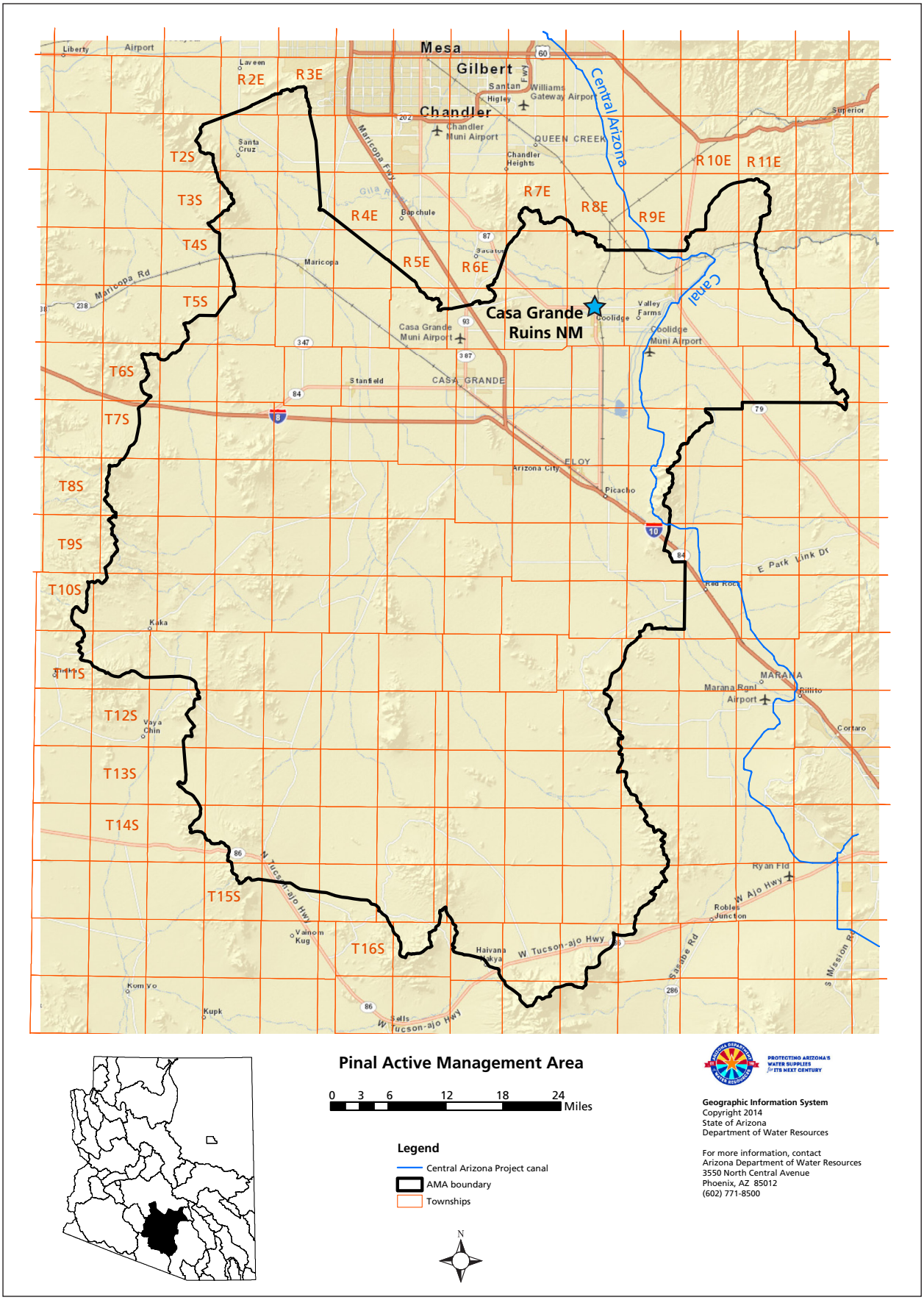


Figure 3-1. Map of Pinal Active Management Area (ADWR 2014).

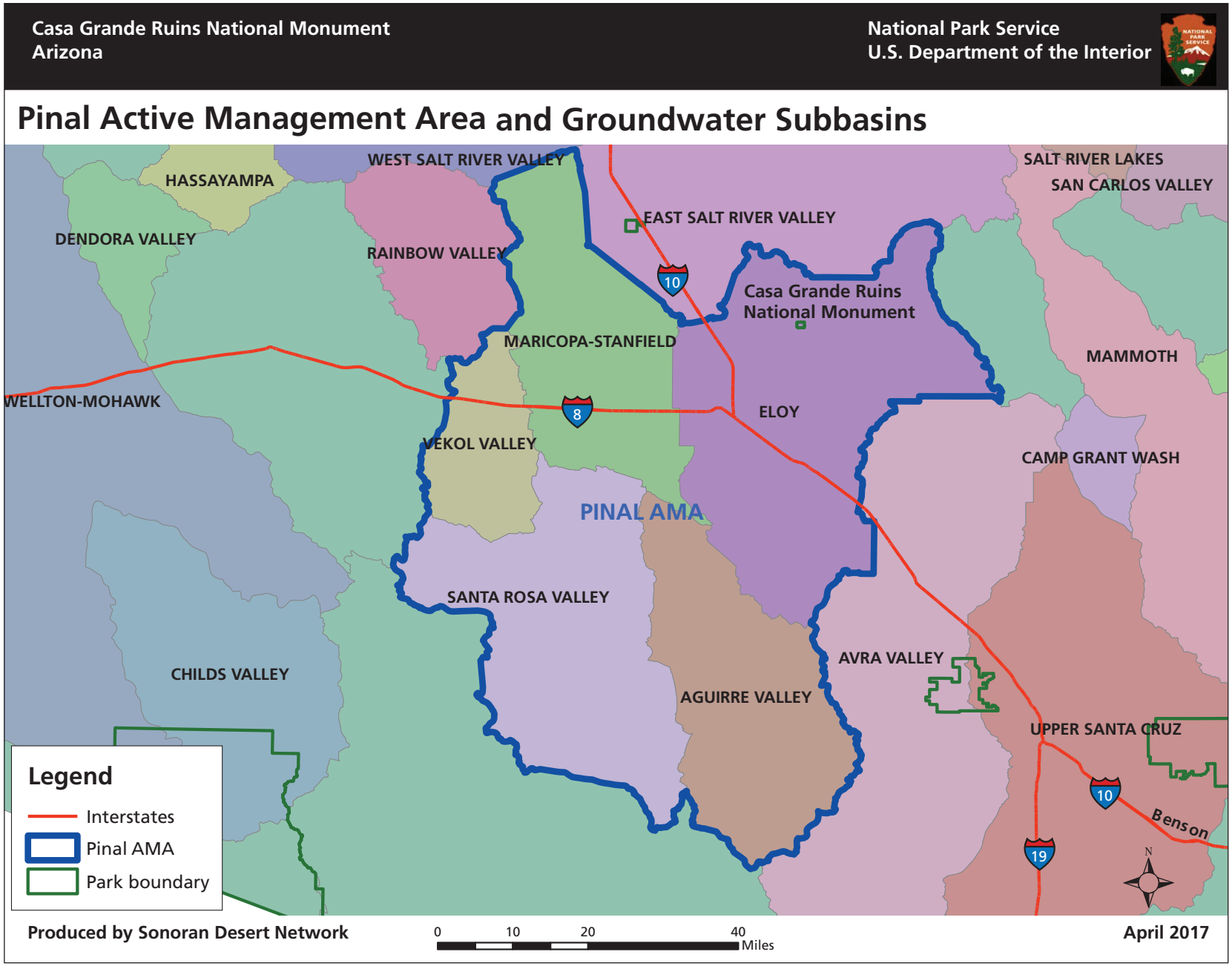


Figure 3-2. Active Management Areas and groundwater subbasins around Casa Grande Ruins National Monument.

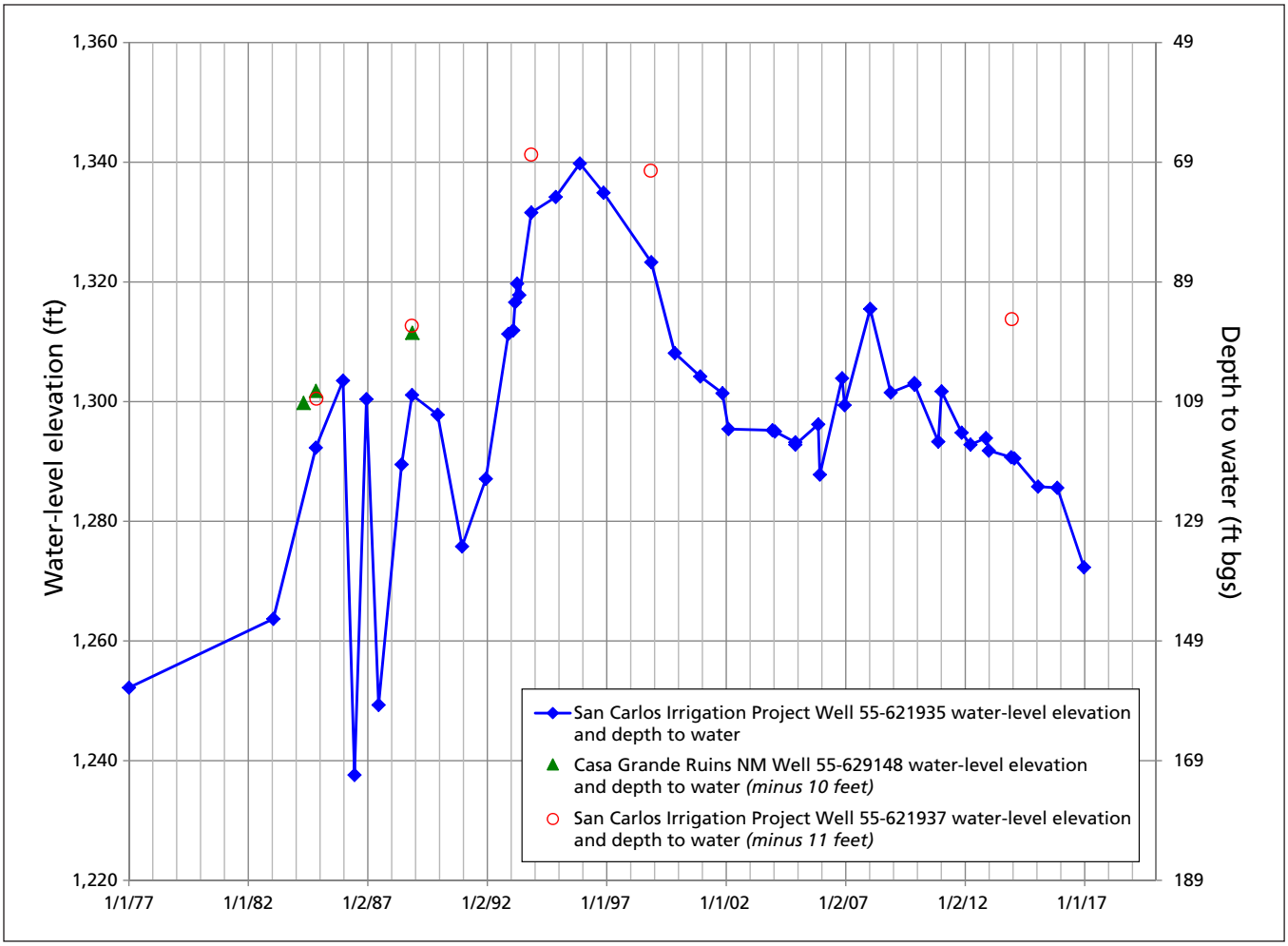


Figure 3-3. Water-level elevation and depth to water at and near Casa Grande Ruins National Monument. Wellhead elevation for well 621935 is 1,409 feet. Wellhead elevation for well 629148 is 1,419 feet, so 10 feet should be added to the scale shown on the right y-axis to obtain the correct depth. Wellhead elevation for well 629937 is 1,420 feet, so 11 feet should be added to the scale shown on the right y-axis to obtain the correct depth.

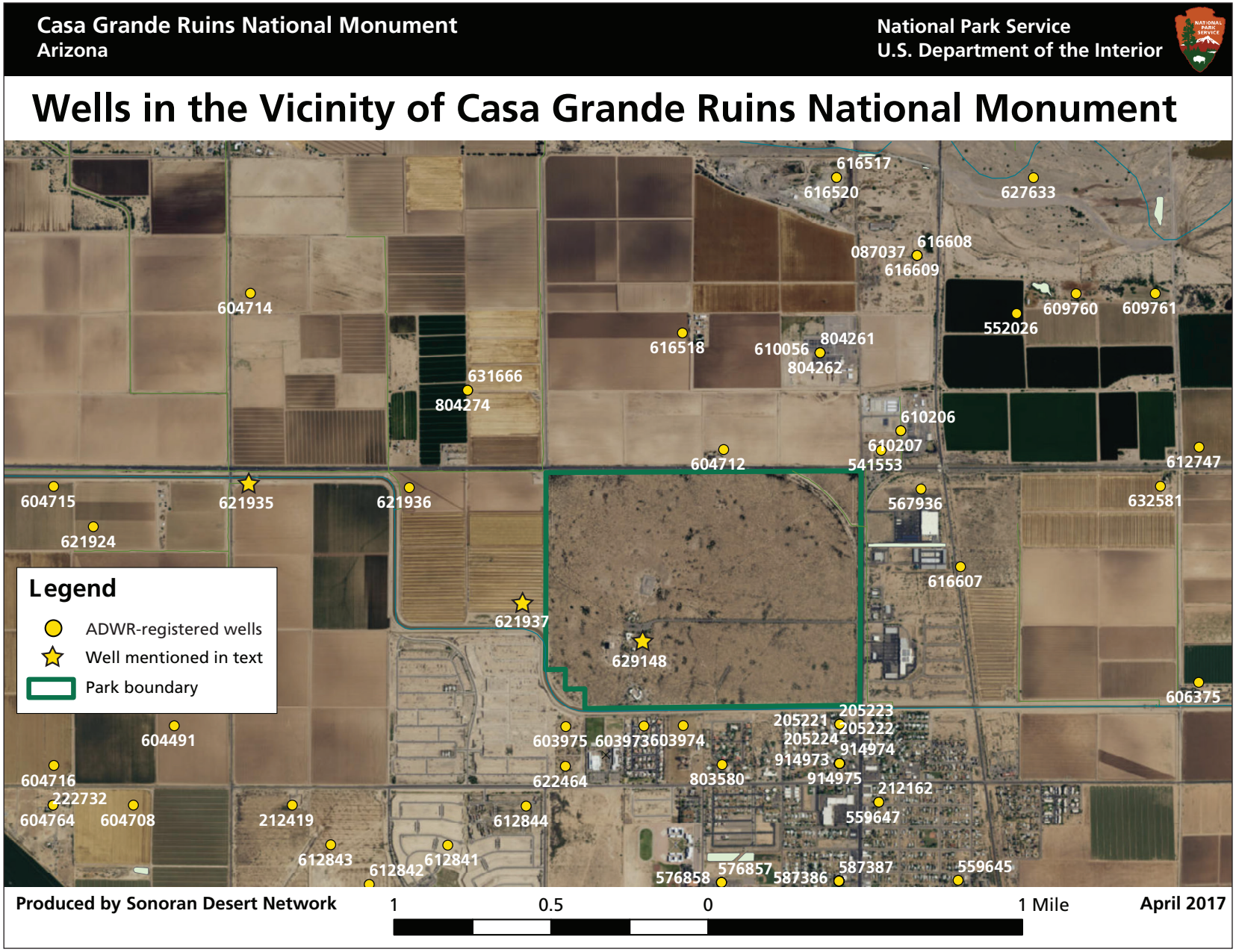


Figure 3-4. Location and state registry numbers for wells in the vicinity of Casa Grande Ruins National Monument.

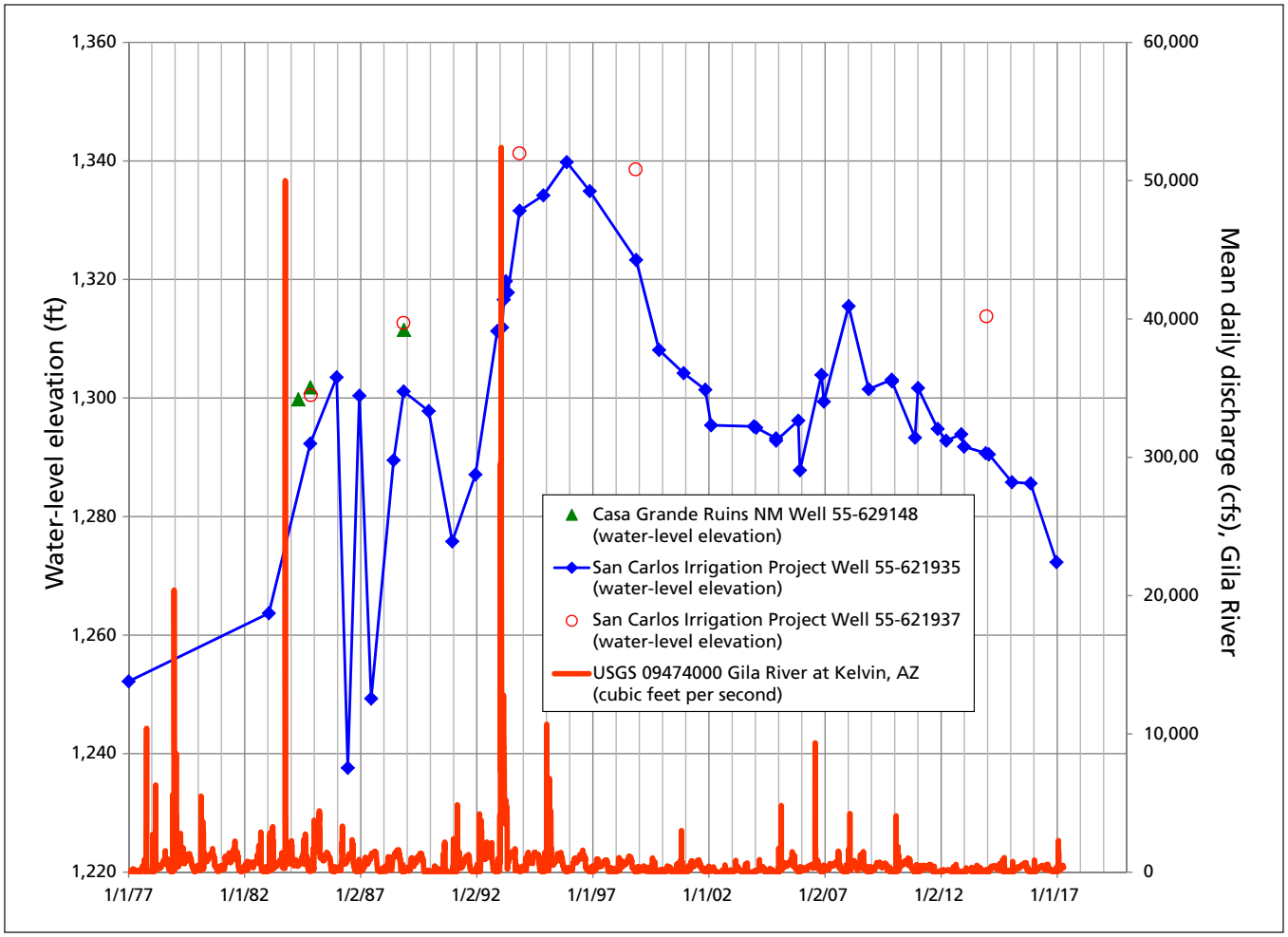


Figure 3-5. Gila River mean daily discharge at Kelvin, Arizona, and water-level elevation in and around Casa Grande Ruins National Monument, 1977–2016.

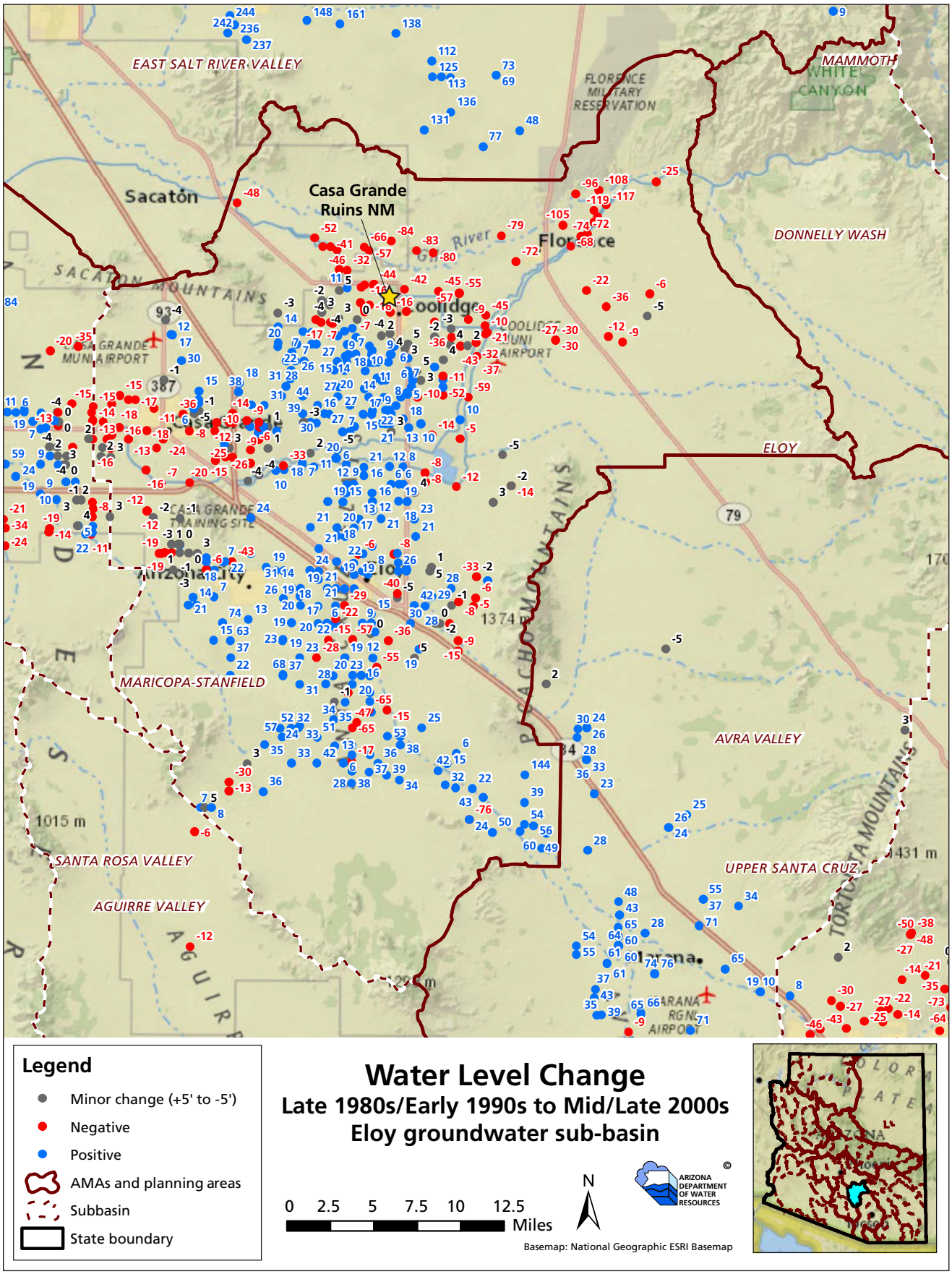


Figure 3-6. Water-level change in the Eloy groundwater subbasin (Corkhill 2012).

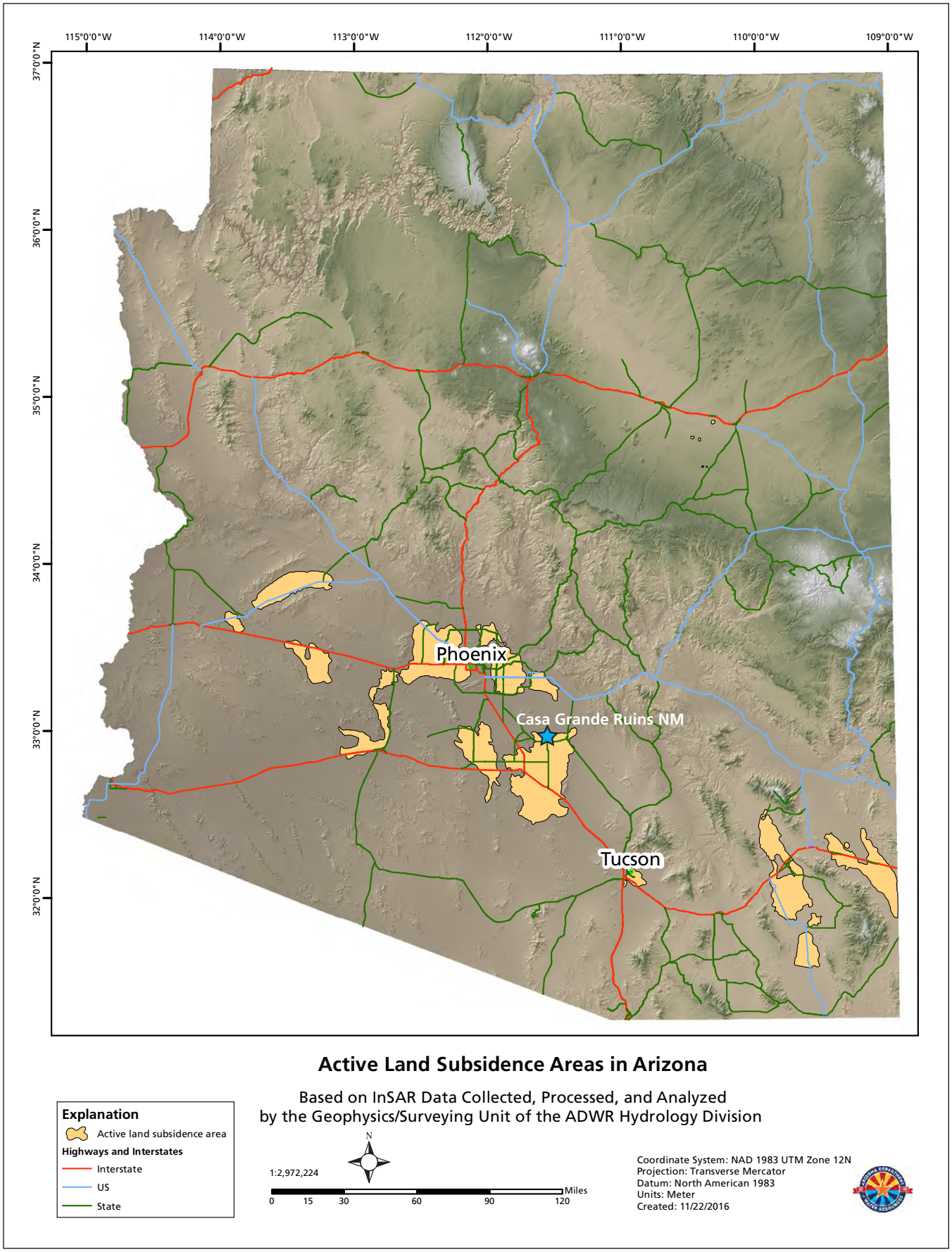


Figure 3-7. Areas experiencing active land subsidence in Arizona (ADWR 2017b).

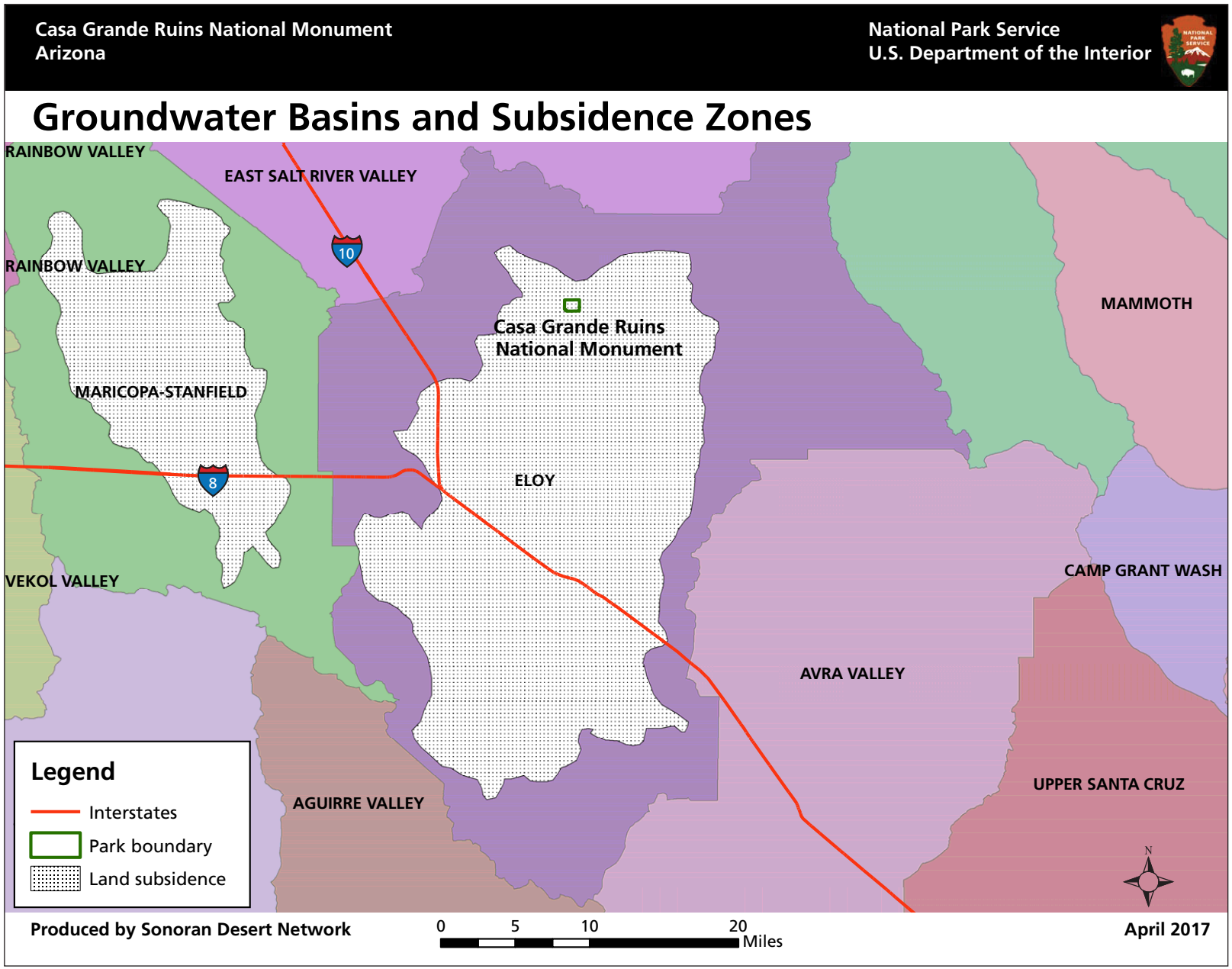
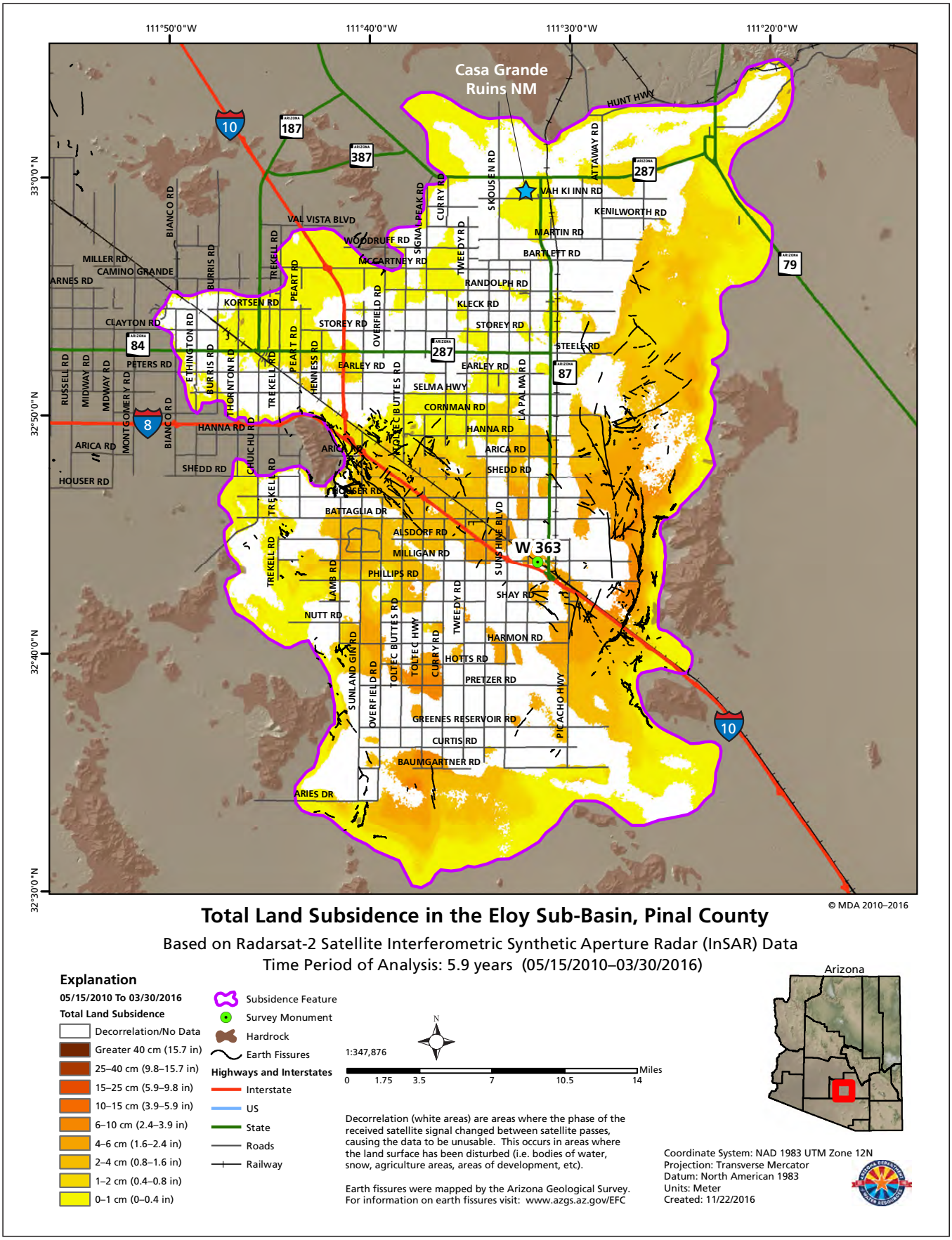


Figure 3-8. Groundwater subbasins and areas experiencing subsidence at and near Casa Grande Ruins National Monument.



Total Land Subsidence in the Eloy Sub-Basin, Pinal County

Based on Radarsat-2 Satellite Interferometric Synthetic Aperture Radar (InSAR) Data
Time Period of Analysis: 5.9 years (05/15/2010–03/30/2016)

Explanation

05/15/2010 To 03/30/2016

Total Land Subsidence

- Decorrelation/No Data
- Greater 40 cm (15.7 in)
- 25–40 cm (9.8–15.7 in)
- 15–25 cm (5.9–9.8 in)
- 10–15 cm (3.9–5.9 in)
- 6–10 cm (2.4–3.9 in)
- 4–6 cm (1.6–2.4 in)
- 2–4 cm (0.8–1.6 in)
- 1–2 cm (0.4–0.8 in)
- 0–1 cm (0–0.4 in)

- Subsidence Feature
- Survey Monument
- Hardrock
- Earth Fissures

Highways and Interstates

- Interstate
- US
- State
- Roads
- Railway

1:347,876

0 1.75 3.5 7 10.5 14 Miles

Decorrelation (white areas) are areas where the phase of the received satellite signal changed between satellite passes, causing the data to be unusable. This occurs in areas where the land surface has been disturbed (i.e. bodies of water, snow, agriculture areas, areas of development, etc).

Earth fissures were mapped by the Arizona Geological Survey. For information on earth fissures visit: www.azgs.az.gov/EFC

Arizona

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 11/22/2016

Figure 3-9. Land subsidence and earth fissures in the Eloy subbasin (ADWR 2017b).

4 Literature Cited

Arizona Department of Water Resources (ADWR). 2010. Arizona water atlas volume 8: Active Management Area planning area. 454 pp.

——. 2017a. Pinal AMA home page. Located at http://www.azwater.gov/AzDWR/Watermanagement/AMAs/PinalAMA/default.htm. Accessed April 10, 2017.

——. 2017b. Land subsidence monitoring report No. 3. January. 40 pp.

Arizona Geological Survey (AGS). 2016. Locations of mapped earth fissure traces in Arizona v. 01.31.16. Geospatial data and Google Earth-KMZ files downloaded from http://repository.azgs.az.gov/uri_gin/azgs/dlio/997. Accessed April 11, 2017.

Corkhill, F. 2012. Final report: Statewide hydrologic monitoring report (Late 1980s early/mid 1990s to mid/late 2000s). Arizona Department of Water Resources Hydrology Division, Phoenix, Arizona.

Hammett, B. A. 1992. Maps showing groundwater conditions in the Eloy and Maricopa-Stanfield sub-basins of the Pinal Active Management Area, Pinal, Pima, and Maricopa Counties, Arizona, 1989. Arizona Department of Water Resources, Hydrologic Map Series No. 23.

Hubbard, J. A., K. Raymond, E. Gwilliam, and M. Tercek. in prep. Climate monitoring protocol for the Sonoran, Chihuahuan, and Southern Plains national parks.

National Aeronautics and Space Administration (NASA). 2017. NASA, NOAA data show 2016 warmest year on record globally. https://www.nasa.gov/press-release/nasa-noaa-data-show-2016-warmest-year-on-record-globally. Accessed January 11, 2018.

Richard, S. M., T. C. Shipman, L. C. Greene, and R. C. Harris. 2007. Estimated depth to bedrock in Arizona. Arizona Geological Survey Digital Geologic Map Series DGM-52, Version 1.0.

Strahler, A.H. 2013. Introducing physical geography. 6th edition. Hoboken, N.J.: Wiley.

Tsakiris, G., and H. Vangelis. 2005. Establishing a drought index incorporating evapotranspiration. European Water 9/10:3–11.

Turner, R. M., R. H. Webb, J. E. Bowers, and J. R. Hastings. 2003. The changing mile revisited. Tucson: University of Arizona Press.

United Nations Environment Programme (UNEP). 1992. World atlas of desertification. London: Edward Arnold.

U.S. Department of Agriculture (USDA). 2014. 2012 Census of agriculture: Arizona state and county data. Volume 1, Geographic Area Series Part 3. AC-12-A-3. May. 425 pp.

NPS 303/144932, May 2018

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525

www.nature.nps.gov