# Table of Contents

## Acknowledgements

## Executive Summary

- Land Subsidence .......................................................................................................................... 6
- Earth Fissure Monitoring and Mapping ....................................................................................... 6
- ADWR Land Subsidence Monitoring Program .............................................................................. 7
- ADWR InSAR Program .................................................................................................................. 7
- ADWR InSAR Results ................................................................................................................... 8
- GNSS Surveying ........................................................................................................................... 8
  - Willcox Groundwater Basin Results ......................................................................................... 9
  - Bowie/San Simon Results ......................................................................................................... 10
  - Elfrida Results ......................................................................................................................... 11
- McMullen Valley Groundwater Basin Results ............................................................................ 11
- Harquahala Valley Groundwater Basin Results ....................................................................... 12
- Ranegas Results ......................................................................................................................... 13
- Hawk Rock Results ................................................................................................................... 13
- Northeast Phoenix/Scottsdale Results ....................................................................................... 13
- West Valley Results .................................................................................................................... 14
- Picacho-Eloy Results ................................................................................................................ 14
- Maricopa-Stanfield Results ....................................................................................................... 14
- Green Valley/Sahuarita Results ................................................................................................ 15

## Continually Operating Reference Station (CORS)

## Additional Critical Data for Monitoring Land Subsidence

## Future Land Subsidence Data Collection

## Selected References
List of Figures

Figure 1. All satellite frames used to collect InSAR data in Arizona ...................................................... 18
Figure 2. Arizona land subsidence features .......................................................................................... 19
Figure 3. West Valley land subsidence feature historical land subsidence ........................................... 20
Figure 4. West Valley land subsidence feature ..................................................................................... 21
Figure 5. Northeast Phoenix/Scottsdale land subsidence feature historical land subsidence .......... 22
Figure 6. Northeast Phoenix/Scottsdale land subsidence feature ........................................................ 23
Figure 7. Hawk Rock land subsidence feature historical land subsidence .......................................... 24
Figure 8. Hawk Rock land subsidence feature ..................................................................................... 25
Figure 9. Tucson land subsidence feature ............................................................................................ 26
Figure 10. Green Valley land subsidence feature .................................................................................. 27
Figure 11. Maricopa-Stanfield land subsidence feature historical land subsidence ............................... 28
Figure 12. Maricopa-Stanfield land subsidence feature ......................................................................... 29
Figure 13. Picacho-Eloy land subsidence feature historical land subsidence ....................................... 30
Figure 14. Picacho-Eloy land subsidence feature .................................................................................. 31
Figure 15. McMullen Valley land subsidence feature ........................................................................... 32
Figure 16. Harquahala Valley land subsidence feature ........................................................................... 33
Figure 17. Ranegras Valley land subsidence feature ............................................................................. 34
Figure 18. Fort Grant Rd land subsidence feature ................................................................................ 35
Figure 19. Kansas Settlement land subsidence feature ......................................................................... 36
Figure 20. Elfrida land subsidence feature ............................................................................................ 37
Figure 21. Bowie/San Simon land subsidence feature ......................................................................... 38
Figure 22. Holbrook Basin land subsidence feature ............................................................................ 39
Figure 23. Location Map of Usery Mountain Park and San Tan Mountain Park CORS ..................... 40
Figure 24. Groundwater wells used for monitoring groundwater elevation change in Arizona ........ 41
Figure 25. Current satellite frames used by ADWR to collect InSAR data in Arizona ........................... 42

List of Photos

Photo 1. Land Subsidence Diagram ........................................................................................................ 6
Photo 2. Arizona Geological Survey Earth Fissure Map ....................................................................... 6
Photo 3. InSAR Diagram .......................................................................................................................... 7
Photo 4. Willcox Basin Land Subsidence Photo, 1969 to 2018 ............................................................... 9
Photo 5. Exposed well casing in Willcox Basin ....................................................................................... 9
Photo 6. Earth fissure near Dragoon Rd .................................................................................................. 9
Photo 7. GNSS Surveying in Elfrida ........................................................................................................ 11
Photo 8. Earth fissure in the McMullen Valley ..................................................................................... 11
Photo 9. Rogers earth fissure ............................................................................................................... 12
Photo 10. GNSS surveying in Ranegas Plain Basin ............................................................................. 13
Photo 11. Earth fissure located at Baseline Rd and Meridian Rd in the Hawk Rock feature ............ 13
Photo 12. CAP Canal Pool 24 freeboard construction ........................................................................ 13
Photo 13. West Valley Land Subsidence Photo, 1957 to 1991 ............................................................... 14
Photo 14. Picacho-Eloy Land Subsidence Photo, 1952 to 2018 ......................................................... 14
Photo 15. Rosemont West Transducer, Green Valley .......................................................................... 15
Photo 16. San Tan Mountain Park bedrock CORS ............................................................................. 16

List of Graphs
Graph 1. GNSS Survey data for land subsidence along Dragoon Rd in Cochise County .............. 10
Graph 2. Groundwater Hydrograph of an ADWR Automated Transducer Site, Harquahala Valley .... 12
Graph 3. GNSS Survey and groundwater data for the Green Valley Land Subsidence Feature ....... 15

List of Tables
Table 1. 2018 GNSS Survey Results ................................................................................................... 43
Acknowledgements

This Land Subsidence Monitoring Report was completed with the help of many individuals who collected and/or contributed data, helped with data analysis, or provided editorial help and suggestions. Contributors include, but are not limited to Jeff Inwood, Teri Davis, Paul Ivanich, Brian Mihlfeith, Sally Lee, and Doug MacEachern of ADWR who offered editorial suggestions. Brian Mihlfeith, Jason Mitchell, Nick Valverde, Bryan Dixon, Chris Jones, Brian Conway, and Paul Ivanich of ADWR assisted with survey-grade GNSS data and transducer groundwater level data collection.

The help provided by these individuals and all those not listed is deeply appreciated.

This report would like to highlight the life of Herbert H. Schumann who passed away on October 16, 2017. Herb worked for the United States Geological Survey for 36 years and was one of the pioneers to study land subsidence and earth fissures in Arizona. Through his research, publications, and passion for studying land subsidence and earth fissures, Arizona continues to successfully monitor and mitigate land subsidence and earth fissures.
Executive Summary

In 1997, the Arizona Department of Water Resources (ADWR) created a land subsidence monitoring program. The program initially focused on monitoring land subsidence in the east valley of the Phoenix Metropolitan area, what is known as the Hawk Rock Area, using survey-grade Global Navigation Satellite System (GNSS) equipment. In 2002, ADWR was awarded a 3-year $1.3 million NASA grant to expand the land subsidence monitoring program to include Interferometric Synthetic Aperture Radar data (InSAR). Upon completion of the NASA grant in 2005, ADWR quickly migrated to a land subsidence program that primarily utilized InSAR data using GNSS surveying to support the program. With the InSAR data, ADWR has identified more than 26 individual land subsidence features in Arizona, collectively covering more than 3,400 square miles. In addition, the program now cooperates with 14 entities whose financial assistance allows ADWR to fund the InSAR data collection. ADWR provides land subsidence maps for download from ADWR’s website. As of February 2019, 460 land subsidence maps are available for download and are used daily by geologists, hydrologists, engineers, planners, surveyors, floodplain managers, GIS analysts, and water resources managers.
Land Subsidence

Land subsidence has been occurring across Arizona since the 1940s (Robinson and Peterson, 1962). Thousands of people live unaware of active land subsidence areas within Arizona. Most of the time, there is no clear and identifiable sign that land subsidence has occurred in an area. Areas in Maricopa and Pinal counties have subsided more than 18 feet since 1940.

Land subsidence in the basins of Arizona is generally due to compaction of the alluvium caused by lowering of the water table. As the water table declines, pores in the alluvium once held open by water pressure are no longer supported and collapse (Photo 1). Collapse and subsequent lowering in elevation of the land surface is defined as land subsidence. There are two types of land subsidence: elastic land subsidence, which is reversible; and inelastic land subsidence, which is irreversible. Elastic land subsidence occurs from seasonal groundwater declines and recoveries/recharge related to seasonal groundwater pumping and recharge from artificial and natural events, resulting in both seasonal land subsidence and uplift. Inelastic land subsidence occurs when groundwater levels continue to decline over time causing the pore pressure to decrease and a subsequent increase of stress in the subsurface. This results in the rearrangement and permanent compaction of the mineral grains in the subsurface, causing the overlying material to collapse. The permanent compaction from land subsidence also results in a loss of aquifer storage, decreasing the amount of groundwater that could be stored in the subsurface. If this subsidence occurs over areas of bedrock, differential subsidence can occur.

Differential subsidence is when adjacent areas subside at different rates. Bedrock will not compress like the surrounding alluvium, creating a subsurface platform. Differential subsidence occurs where shallow bedrock and deep bedrock are adjacent to each other, creating a zone of differential change in surface elevation. Because of these different amounts of subsidence, tension can build in the alluvium layer at this differential subsidence zone, forming an earth fissure.

Earth Fissure Monitoring and Mapping

Earth fissures are cracks at or near the earth’s surface that are the result of differential land subsidence. Earth fissures start out as small cracks and may not be visible on the surface. The earth fissures grow and widen from surface water flowing in the crack, eroding material from the sides. Earth fissures have caused millions of dollars in property and infrastructure damage, damaging pipelines, roads, canals, flood retention structures, bridges, building, and private property.

The Arizona Geological Survey (AZGS) is responsible for monitoring and mapping earth fissures throughout Arizona (https://azgs.arizona.edu/center-natural-hazards/earth-fissures-ground-subsidence). The AZGS provides earth fissure maps (Photo 2) for each earth fissure study area that are available for download through their website. The AZGS currently has 27 earth fissure study area maps and has mapped a total of 357 miles of earth fissures throughout Arizona. ADWR and AZGS work closely together to monitor earth fissures by using InSAR data to identify areas of differential land subsidence which may result in future earth fissuring.
ADWR Land Subsidence Monitoring Program

In 1997, the installation of numerous non-exempt wells (wells that pump more than 35 gallons per minute) was proposed in the Apache Junction and Luke Air Force Base areas, both areas noted for significant historic land subsidence and earth fissuring. ADWR management had concerns over the potential for the new wells to cause unreasonable increasing harm due to regional land subsidence, which led to a Directorate level decision to begin a land subsidence monitoring program. The Geophysics/Surveying Unit (GSU) of the Hydrology Division was created and started monitoring land subsidence by collecting survey-grade Global Navigation Satellite System (GNSS) data on survey monuments in the Hawk Rock land subsidence area located in east Mesa and Apache Junction. In 2002, ADWR was awarded a $1.3 million NASA grant to develop a land subsidence monitoring program over three years to process satellite-based synthetic aperture radar data using interferometry (InSAR). Upon completion of the NASA grant in 2005, ADWR permanently established a land subsidence program that primarily utilized InSAR data with GNSS surveying to support the program.

ADWR InSAR Program

Synthetic Aperture Radar (SAR) is a side-looking, active (produces its own illumination) radar-imaging system that transmits a pulsed microwave signal towards the earth and records both the amplitude and phase of the back-scattered signal that returns to the antenna. InSAR is a technique that utilizes interferometric processing that compares the amplitude and phase signals received during successive passes of the SAR platform over a specific geographic area at different times. InSAR techniques, using satellite-based SAR platform data, can be used to produce land-surface deformation products with centimeter (cm)-scale vertical resolution (Photo 3).

Changes in land elevation are detected through the change in phase of the radar signal. InSAR is used to detect surface displacement over otherwise undisturbed open land and deformation along active faults, on volcanoes, landslides, sinkholes, and other geologic features and hazards (Galloway and Hoffmann, 2007).

ADWR has developed an extensive library of more than 1,700 SAR scenes used to process InSAR data, covering an area greater than 150,000 square miles to confirm existing land subsidence areas and to investigate other areas of the state; at a cost of more than $1.7 million, predominantly purchased through grants and cooperators (Figure 1). ADWR has compiled a statewide dataset for the active land subsidence areas identified with InSAR data in Arizona. Most datasets cover time periods between 1992 to 2000, 2004 to 2010, 2006 to 2011, and 2010 to present depending on the satellite used. Using these data, ADWR has identified more than 26 individual land subsidence features in Arizona, collectively covering more than 3,400 square miles (Figure 2). ADWR provides land subsidence maps for download from ADWR’s website. As of February 2019, 460 land subsidence maps are available for download and are used daily by geologists, hydrologists, engineers, planners, surveyors, floodplain managers, GIS analysts, water resources managers, and other interested parties. The maps can be accessed at this link:

https://new.azwater.gov/hydrology/e-library

ADWR uses InSAR data not only for monitoring land subsidence, but also for the following: monitoring seasonal deformation (uplift and subsidence), and natural and artificial recharge events; as a tool for geological mapping and investigations; locating earth fissures; and identifying areas where conditions may exist for future earth fissure formation. In addition, InSAR data can be used for dam mitigation and land-subsidence modeling and monitoring floodplains.

ADWR cooperates with the following groups: Flood Control District of Maricopa County, Pinal County Flood Control District, Metropolitan Domestic Water Improvement District, Central Arizona Project,
ADWR currently collects InSAR data over more than 50,000 square miles throughout Arizona focusing on the active land subsidence areas. InSAR data are collected throughout the year with the majority of the data being collected during the fall and spring months to capture any seasonal deformation signals. ADWR uses primarily the Radarsat-2 satellite at this time to fulfill its InSAR data needs and also incorporates Sentinel-1 and ALOS-2 datasets. ADWR uses primarily conventional interferometry processing techniques but has the ability to process areas using the PS-InSAR technique. Interferograms and xyz files are freely available by request to other agencies, consultants, cooperators, and the public.

ADWR InSAR Results
ADWR initially focused the InSAR data collection efforts on the Phoenix and Tucson Active Management Areas (AMAs), where there were already identified and well-documented land subsidence features. Three land subsidence features in the Phoenix AMA known as the West Valley (Figures 3 and 4), Northeast Phoenix/Scottsdale (Figure 5 and 6), and the Hawk Rock (Figures 7 and 8) land subsidence features, and two land subsidence features in the Tucson AMA known as the Central Well-field and the Valencia (Figure 9) land subsidence features (both part of the Tucson land subsidence feature) were readily identified by ADWR using archived InSAR data from the 1900s and 2000s.

By cooperating with other federal, state, county, and local agencies and water companies, ADWR was able to greatly expand its data collection efforts to cover the entire State. The additional InSAR data provided ADWR the necessary resources to identify a dynamic land subsidence feature south of Tucson called the Green Valley (Figure 10) land subsidence feature that has seasonal uplift and land subsidence. InSAR data for the Pinal AMA confirmed two well-documented land subsidence areas known as the Maricopa-Stanfield (Figures 11 and 12) and the Picacho-Eloy (Figures 13 and 14) land subsidence features.

InSAR data for west-central Arizona helped ADWR identify three new land subsidence features in far western Maricopa and eastern La Paz Counties known as the McMullen Valley (Figure 15), Harquahala Valley, (Figure 16) and the Ranegras Valley (Figure 17) land subsidence features. ADWR also identified two more land subsidence features in southwestern Maricopa County known as the Buckeye and Gila Bend features.

InSAR data for southeastern Arizona helped ADWR identify four land subsidence features in Cochise County and Graham County. The Cochise County and Graham County features currently have the highest rate of land subsidence in the entire State, greater than 15 centimeters/year (5.9 inches/year) and are known as the Fort Grant Road (Figure 18), Kansas Settlement (Figure 19), Elfrida (Figure 20), and the Bowie/San Simon (Figure 21) land subsidence features. Over the last eight years, cumulative land subsidence of 0.74 meters (2.43 feet) has occurred in both the Fort Grant Road and Kansas Settlement land subsidence features.

InSAR data for the Holbrook Basin helped ADWR identify five land subsidence features in Navajo County. These features are known as the Holbrook Basin (Figure 22) land subsidence features and appear to be related to naturally occurring sinks and dissolution features. InSAR data also is being collected to establish a baseline for any existing land subsidence around the Petrified Forest National Park.

GNSS Surveying
ADWR collects survey-grade GNSS (Global Navigation Satellite System) data for validating (“ground-truthing”) the InSAR data and for continued surveying on existing survey monuments. The GNSS data also are used for land subsidence monitoring in the Hawk Rock Area in east Mesa and Apache Junction (Figure 5), the Sahuarita/Green Valley Area (Figure 7), the Eloy Area (Figure 9), the McMullen Valley Area (Figure 10), the Harquahala Valley Area (Figure 11), the Ranegras Area (Figure 12), the Willcox Groundwater Basin (Figures 13 and 14), the Elfrida Area (Figure 15), and the Bowie/San Simon Areas (Figure 16), the Chimney Canyon land subsidence feature in the Holbrook Basin (Figure 17), and the East Valley land subsidence feature (Figure 18).
Land subsidence rates within the Phoenix and Tucson AMAs have decreased between 25 percent and 90 percent when comparing the 1990s InSAR data and the recent 2018 InSAR data. This is a result of decreased groundwater pumping, groundwater recharge, and recovering groundwater levels in the AMAs.

**Willcox Groundwater Basin Results**

ADWR started collecting InSAR data over the Willcox Groundwater Basin in 2010 and has documented land subsidence of as much as 15 centimeters/year (5.9 inches) between 2017 and 2018. A comparison of InSAR data between the historical 1996 dataset and the recently acquired 2018 dataset document that land subsidence rates have tripled in some areas.

ADWR also collects survey-grade GNSS data throughout the Willcox Basin which includes two different locations near the center of two subsidence-bowls; one (Dragoon monument) located along Dragoon Road between US 191 and Cochise Stronghold Road about 16 miles southwest of Willcox within the Kansas Settlement land subsidence feature and another (BM850G monument) located near Old Fort Grant Road and Ranch House Road about 13 miles northwest of Willcox within the Fort Grant Road subsidence feature (Figure 18). Since 2011, ADWR has been measuring the Dragoon monument, which is a replacement for the V 261 monument that was originally established in 1945 by the National Geodetic Survey (NGS). Comparing recent (2019) ADWR GNSS data with the historical 1992 data, ADWR determined that a total of 1.56 meters (5.11 feet) of land subsidence has occurred at this location since 1992, and 0.72 meters (2.3 feet) of land subsidence has occurred between 2011 and 2019 (Graph 1).

During the summer of 2018, while searching for a location to install a survey monument near a subsidence bowl within the Fort Grant Road subsidence feature, ADWR recovered five old Arizona Department of Transportation (ADOT) survey monuments that were first leveled in 1969 (BM850G, BM850H, BM850J, BM850L, and BM850P). Comparing the 1969 elevations with the 2018 elevations, land subsidence of 9.6 feet (Photo 4) was measured at the BM850G survey monument (Table 1).

Earth fissures have been an ongoing problem in the Willcox Groundwater Basin and have impacted a natural gas pipeline, roads, a power plant, and power lines. The AZGS has mapped 44.5 miles of earth fissures in the basin. A protruding well casing (Photo 5) about 1.4 north of Dragoon Road on Cochise Stronghold Road, and numerous earth fissures located in the Willcox Groundwater Basin (Photo 6), further document the amount of historical land subsidence that has occurred in the immediate area. They also document the need to continue GNSS surveying for land subsidence in the basin.
**Bowie/San Simon Results**

InSAR data from 2018 have documented land subsidence of as much as 4.4 centimeters/year (1.7 inches) between 2017 and 2018 in the Bowie/San Simon Area within the San Simon Valley Groundwater Sub-basin. ADWR collects survey-grade GNSS data at two survey monuments, Portal and Z 330 (Photo 4) within the Bowie/San Simon subsidence feature. In 2018 ADWR collected survey-grade GNSS data at both survey monuments (Figure 21). Between the 2016 and 2018 measurements, Portal has subsided 4.8 centimeters (1.89 inches) and Z 330 has subsided 4.6 centimeters (1.81 inches). Comparing 2018 ADWR GNSS data with the historical NGS data for both monuments, Portal has subsided a total of 1.38 meters (4.51 feet) since 1993; and Z 330 has subsided a total of 1.01 meters (3.30 feet) since 1991 (Table 1).

Earth fissures have been occurring in the San Simon and Bowie area for many years and have crossed I-10 and a natural gas pipeline. The AZGS has mapped 19.9 miles of earth fissures in this area.
Elfrida Results

ADWR first discovered land subsidence in the Elfrida Area within the Douglas Irrigation Non-Expansion Area in 2008 using InSAR data. Before 2008, land subsidence had never been documented in the area. InSAR data from 2018 have documented land subsidence of as much as 8.1 centimeters/year (2.0 inches) between 2017 and 2018 in the Elfrida Area. ADWR collects survey-grade GNSS data at five survey monuments (Photo 7) within the Elfrida land subsidence feature (Figure 20). In 2018, ADWR surveyed the B 421 monument, and between 2016 and 2018, ADWR measured 15.1 centimeters (5.94 inches) of land subsidence. Comparing 2018 ADWR GNSS data with the historical 1991 data for B 421, a total of 1.04 meters (3.41 feet) of land subsidence has occurred since 1991. (Table 1). Earth fissures have also been identified by the AZGS, having mapped 1.3 miles of earth fissures in the area.

McMullen Valley Groundwater Basin Results

ADWR first delineated land subsidence in the McMullen Valley Groundwater Basin in 2008 using InSAR data. In 2010, the Town of Wenden, located in the McMullen Valley, was flooded for the second time in ten years by Centennial Wash. The Town of Wenden is located within a land subsidence bowl which has exacerbated the recent flooding events. ADWR has surveyed seven historical NGS monuments (A 480, H 25, L 25, S 479, T 479, X 479, and Y 479) that are used for on-going ground-truthing of the InSAR data and for land subsidence monitoring in the McMullen Valley (Figure 15).

Comparing recent ADWR GNSS survey data collected between 2013 and 2018 for monument X 479, there was 37.8 centimeters (1.24 feet) of land subsidence and between 1991 and 2018 there was 1.19 meters (3.89 feet) of land subsidence (Table 1).

In early 2019, the AZGS identified and mapped new earth fissures in the McMullen Valley southeast of the Town of Wenden (Photo 8). The AZGS has mapped a total of 2.1 miles in the McMullen Valley.
Harquahala Valley Groundwater Basin Results
ADWR last delineated land subsidence in the Harquahala Valley in 2008 with InSAR data. Land subsidence was first documented in the Harquahala Valley with the opening of the Rogers earth fissure (Photo 9) in September 1997 following a large rain event during Hurricane Nora. ADWR has been collecting survey-grade GNSS data on a survey monument, 4BR1, within the Harquahala Valley since 2014 (Figure 16). Between 2014 and 2018, GNSS data showed 1.8 cm (0.71 in) of land subsidence. Comparing 2018 ADWR GNSS data with the historical 2000 data for 4BR1, a total of 8.3 centimeters (3.27 inches) of land subsidence has occurred since 2000. ADWR will continue to survey the 4BR1 survey monument for monitoring land subsidence in the Harquahala Valley. The Rogers earth fissure (Photo 6) continues to be active, extending at the eastern end.

Groundwater levels have been declining at a steady rate of about 11 feet per year (Graph 2) at an ADWR Automated Transducer site since 2008 (Figure 16). If the current trend continues, the groundwater level will drop below the historical low in about 4 years, exceeding the pre-consolidation stress level. This may result in a dramatic increase of land subsidence rates in the Harquahala Valley.

Graph 2 – Groundwater Hydrograph of an ADWR Automated Transducer Site in the Harquahala Valley
Ranegras Plain Groundwater Basin Results
ADWR first discovered land subsidence in the Ranegras Plain Groundwater Basin in 2008 using InSAR data. Before 2008, land subsidence had never been documented in the basin. In 2016, ADWR began collecting survey grade GNSS data at two survey monuments, H 478 (Photo 10) and Bonita, within the Ranegras area (Figure 17). Between the 2016 and 2018 measurements, Bonita has subsided 3.5 cm (1.38 inches) and H 478 has subsided 2.9 centimeters (1.14 inches). Comparing 2018 ADWR GNSS data with the historical 1993 data for H 478, a total of 14.5 centimeters (5.71 inches) of land subsidence has occurred since 1993 (Table 1). ADWR will continue to survey both survey monuments for land subsidence. A comparison of InSAR data between the historical 1992 - 1997 dataset and the recently acquired 2018 dataset, show that land subsidence rates have tripled in some areas.

Hawk Rock Results
The Hawk Rock land subsidence feature located in the Phoenix AMA has been experiencing land subsidence for more than 40 years. Historical leveling and surveying had documented land subsidence of more than five feet (Figure 7) between 1948 and 1980 (Carpenter, 1987).

ADWR has conducted repeat GNSS surveys in the Hawk Rock Area since 1997. During the fall of 2018, a GNSS survey campaign was completed on the monuments in the Hawk Rock Area. Between the 1999 and 2018 surveys, land subsidence as high as 0.45 m (1.45 feet) had been measured (Figure 8) at US 60 and Ironwood Road. The US 60 highway has been significantly impacted by land subsidence.

The monument, SGC 17, located at US 60 and Meridian Road, has subsided 1.56 meters (5.04 feet) since it was first measured in 1973. Earth fissures have been a problem in the area for several decades, damaging roads, flood control structures, and private property. The AZGS has mapped 10.17 miles of earth fissures (Photo 11 and Figure 11) in the Hawk Rock feature.

Northeast Phoenix/Scottsdale Results
The Northeast Phoenix/Scottsdale land subsidence feature located in the Phoenix AMA has been experiencing land subsidence for more than 50 years. Historical leveling and surveying had documented land subsidence of more than three feet (Figure 5) between 1962 and 1982 (Pewe and Larson, 1982).

Due to the land subsidence, the Central Arizona Project spent millions of dollars to add more freeboard to the CAP canal in the Pool 24 area (Photo 12). An earth fissure also is located in the Pool 24 area near Cactus Road and Frank Lloyd Wright Boulevard (Figure 6) and parallels the CAP canal.
West Valley Results

The West Valley land subsidence feature located in the Phoenix AMA has been experiencing land subsidence for more than 60 years. Historical leveling and surveying had documented land subsidence of more than 18 feet (Figure 3) between 1957 and 1992 (Schumann & O’Day, 1995).

The Dysart Drain flood control structure was constructed to channel rain runoff away from Luke Air Force Base (Luke AFB). Due to the large amount of land subsidence (Photo 13), the engineered-design slopes for the Dysart Drain reversed, causing Luke AFB to flood in 1993 which resulted in millions of dollars in damage to Luke AFB.

Earth fissures have been a problem in the West Valley feature for more than 20 years and have impacted private property, roads, flood-control structures, and utilities. The AZGS has mapped 14.57 miles of earth fissures in the West Valley feature (Figure 4).

Picacho-Eloy Results

The Picacho-Eloy land subsidence feature located in the Pinal AMA has been greatly affected by land subsidence. Historical leveling and surveying had documented land subsidence of more than 15 feet by 1985 (Schumann, H.H., & Genualdi, R.B., 1986). Using historical leveling between 1949 and 1977 (Laney, et al, 1978) and benchmark elevations from the 1922, 1924, 1947 and 1992 USGS topographic maps, historical land subsidence to the nearest foot is estimated (Figure 13) and varies from 1 foot to 16 feet in the Picacho-Eloy land subsidence feature.

In 2018, ADWR collected GNSS data at six survey monuments (Figure 14). The 2018 surveyed elevations were compared to the historical NGS elevations from 1993. Land subsidence varied from 3.4 centimeters (0.11 feet) to 23 centimeters (0.74 feet) (Table 1). Combining the recent surveying results with previous published NGS and USGS repeat leveling results, land subsidence of 16 feet has occurred at the L 304 survey monument since 1952 (Photo 14).

The Picacho-Eloy land subsidence feature has had earth fissures since the 1950s (Carpenter, 1999). The AZGS has mapped 222 miles of earth fissures in the area. Land subsidence and earth fissures have affected the Santa Cruz floodplain and many types of infrastructure in the area (roads, pipelines, canals and railroads).

Maricopa-Stanfield Results

The Maricopa-Stanfield land subsidence feature is another area in the Pinal AMA that has been greatly affected by land subsidence. Historical leveling had documented land subsidence of almost 12 feet by 1977 (Laney, et al, 1978). Using historical leveling between 1949 and 1977 (Laney, et al, 1978) and benchmark elevations from the 1922, 1924, 1947 and 1992 USGS topographic maps, historical land subsidence to the nearest foot is estimated (Figure 11) and varies from 1 foot to almost 12 feet in the Maricopa-Stanfield land subsidence feature.

The Maricopa-Stanfield land subsidence feature has 23 miles of earth fissures (Figure 12) that have been mapped by the AZGS. Land subsidence and earth fissures have affected the Santa Cruz floodplain and many types of infrastructure in the area (roads, pipelines, and canals).
**Green Valley/Sahuarita Results**

Comparison of recent GNSS surveying data with ADWR groundwater elevation data (Photo 15) from the Sahuarita/Green Valley Area has shown a striking correlation. Seasonal groundwater pumping demands have caused both seasonal groundwater declines and subsequent recoveries of approximately 110 feet between February and May (period of decline) and November and February (period of recovery). The groundwater level changes have resulted in both seasonal land subsidence and uplift that reflect the groundwater changes (Graph 3).

ADWR collected GNSS surveying data at 4 monuments in the Sahuarita/Green Valley area to document historical subsidence and to incorporate the monuments into the GNSS network for future subsidence monitoring (Figure 10). Comparing the historical 1991 NGS data with the 2018 ADWR GNSS results, there was subsidence as great as 9 centimeters (3.54 inches) between 1991 and 2018 (Table 1).

---

**Graph 3 – GNSS Survey and transducer groundwater data for the Green Valley Land Subsidence Feature**
Continuous Operating Reference Station
Over the past ten years, ADWR has played an important role in site-selection and installation of several GNSS Continuous Operating Reference Station (CORS) sites in Arizona. Many of the CORS sites are operated by ADOT and all the data are managed by the National Geodetic Survey. There are more than twenty CORS sites located throughout Arizona that provide precise GNSS data that are then used for both real-time and post-processed surveying projects. For those projects that require accurate and precise elevations, it is crucial that the survey control is stable and not subsiding. As a result, ADWR has provided guidance to ADOT and other entities for locating stable sites away from land subsidence areas.

ADWR has worked with ADOT, Central Arizona Project, Maricopa County Department of Transportation, and Maricopa County Parks to install two new stable CORS sites that are located on bedrock in Eastern Maricopa County at Usery Mountain and San Tan Mountain Regional Parks (Photo 16). These sites will provide stable vertical control around the Hawk Rock land subsidence feature (Figure 23).

Additional Critical Data for Monitoring Land Subsidence
Land subsidence maps and InSAR data are important tools for monitoring and understanding land subsidence in an area. There are several other critical datasets which should be examined when studying land subsidence, including groundwater level data and pumping data which are freely accessible through ADWR’s website. ADWR provides statewide groundwater level data for more than 44,340 wells through its website (majority are ADWR-collected), of which 1,783 are Index Wells (wells that are measured at least annually, if not quarterly or bi-annually) and 129 are automated groundwater monitoring sites (80 of which are equipped with telemetry and provide near real-time groundwater elevation measurements) (Figure 24). All groundwater level data can be downloaded, and the user has the ability to display hydrographs for both the manual and automated (if equipped) groundwater measurements. Available well construction, well logs, and other well-related information can be obtained from ADWR’s website. The well logs help provide insight into the subsurface geology and are used to better understand land subsidence in an area. Historical groundwater pumping data from 1984 to the present also are available for online viewing or download.

Future Land Subsidence Data Collection
ADWR’s GNSS-surveying program plays a vital role in supporting the statewide InSAR land subsidence monitoring program. Additionally, the GNSS surveying also is used for ongoing aquifer storage change monitoring conducted by ADWR and the United States Geological Survey (USGS) in several groundwater basins in southcentral Arizona. Routine survey data will continue to be collected in existing areas, and other subsidence areas will be examined to determine if additional surveying locations should be added for enhanced monitoring using GNSS surveying techniques.

ADWR continues to provide land subsidence products for its own hydrologic studies and for cooperators, consultants, other government and private entities, and the public. At the same time, ADWR is continually searching for additional InSAR cooperators, educating groups about the InSAR data and how the data can be used to meet their monitoring needs, and further enhancing the InSAR program through investments in software and hardware upgrades.

ADWR will continue to collect InSAR data around the State at the existing data collection frequency and spatial distribution of more than 50,000 square miles (Figure 25). If needed, ADWR will begin to collect InSAR data in areas where increasing groundwater demands and declining groundwater levels may be occurring or starting to occur. ADWR also will continue to update land subsidence maps on an annual basis, making the maps available on ADWR’s website.
Selected References


Figure 1 - All Satellite Frames Used to Collect InSAR Data in Arizona
InSAR Data is Collected, Processed, and Analyzed
by the Geophysics/Surveying Unit of the ADWR Hydrology Division

Explanation
Cities
Radarsat-2
ALOS-1
Radarsat-1
Envisat
ERS-1 & 2

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/26/2019
Figure 2 - Active Land Subsidence Areas in Arizona Based on InSAR Data

InSAR Data is Collected, Processed, and Analyzed by the Geophysics/Surveying Unit of the ADWR Hydrology Division

Explanation
- Active Land Subsidence Area

Highways and Interstates
- Interstate
- US
- State

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/26/2019
Figure 3 - Historical Land Subsidence in Feet in Western Metropolitan Phoenix

Time Period of Analysis: 35 Years 1957 To 1992

Explanation
- Historical Subsidence (in feet)
- Subsidence Feature (Based On InSAR)
- Hardrock
- CAP Canal
- Earth Fissures

Highways and Interstates
- Interstate
- US
- State
- Roads
- Railway

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, agricultural 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

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/27/2019
Figure 4 - Total Land Subsidence in Western Metropolitan Phoenix
Based on Radarsat-2 Satellite Interferometric Synthetic Aperture Radar (InSAR) Data

Subsidence Feature
- Hardrock

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)

Earth Fissures
- CAP Canal

Highways and Interstates
- Interstate
- US
- State
- Roads
- Railway

Explanation
05/08/2010 To 03/27/2018

Total Land Subsidence
- Decorrelation/No Data

Time Period of Analysis: 7.9 Years 05/08/2010 To 03/27/2018

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

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/26/2019
Figure 5 - Historical Land Subsidence in Feet in Northeast Phoenix and Scottsdale Areas
Time Period of Analysis: 20 Years 1962 To 1982

Explanation
- Historical Subsidence (In Feet)
- Subsidence Feature (Based on InSAR)
- Hardrock
- CAP Canal
- Earth Fissures

Highways and Interstates
- Interstate
- US
- State
- Roads

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

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/27/2019
Figure 6 - Total Land Subsidence in Northeast Phoenix and Scottsdale Areas

Based on Radarsat-2 Satellite Interferometric Synthetic Aperture Radar (InSAR) Data

Time Period of Analysis: 7.9 Years 05/08/2010 To 03/27/2018

Explanation
05/08/2010 To 03/27/2018

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
- Hardrock
- CAP Canal
- Earth Fissures

Highways and Interstates
- Interstate
- US
- State
- Roads

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

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/26/2019
Figure 7 - Historical Land Subsidence in Feet in the Hawk Rock Area of East Mesa and Apache Junction
Based on Carpenter, M.C. 1987, USGS Water Resources Investigation Report 86-7071 and ADWR GNSS Surveying


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

Time Period of Analysis: 8.0 Years 05/15/2010 To 04/03/2018

Figures 8 - Total Land Subsidence in the Hawk Rock Area of East Mesa and Apache Junction Based on Radarsat-2 Satellite Interferometric Synthetic Aperture Radar (InSAR) Data
Figure 9 - Total Land Subsidence in the Tucson Metropolitan Area
Based on Radarsat-2 Satellite Interferometric Synthetic Aperture Radar (InSAR) Data

Time Period of Analysis: 8.0 Years  05/15/2010 To 04/03/2018

Explanation
05/15/2010 To 04/03/2018
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
- Hardrock
- Highways and Interstates
  - Interstate
  - US
  - State
  - Roads
  - Railway

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.).

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/26/2019
Figure 10 - Total Land Subsidence in the Sahuarita and Green Valley Areas, Pima County Based on Radarsat-2 Satellite Interferometric Synthetic Aperture Radar (InSAR) Data

Time Period of Analysis: 1.2 Years 02/06/2015 To 04/19/2016

Explanation
02/06/2015 To 04/19/2016 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
Hardrock
GNSS Monument
Groundwater Level Transducer
CAP Canal
Highways and Interstates
Interstate
US
State
Roads
Railway

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).

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/27/2019

© MDA 2015 - 2016
Figure 11 - Historical Land Subsidence in Feet in the Maricopa-Stanfield Sub-Basin, Pinal County
Based on 1922, 1924, 1947, and 1992 USGS Topographic Map Benchmark Elevations

Explanation
- Historical Subsidence (In Feet)
- Topo Map Benchmark (In Feet)
- Subsidence Feature (Based on 2018 InSAR)
- Hardrock
- Earth Fissures

Highways and Interstates
- Interstate
- US
- State
- Roads
- Railway

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

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 3/7/2019
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

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/26/2019
Figure 13 - Historical Land Subsidence in Feet in the Eloy Sub-Basin, Pinal County
Based on 1922, 1924, 1947, and 1992 USGS Topographic Map Benchmark Elevations

Explanation
- Historical Subsidence (In Feet)
- Topo Map Benchmark (In Feet)
- Earth Fissures
- Subsidence Feature (Based on 2018 InSAR)
- Hardrock

Highways and Interstates
- Interstate
- US
- State
- Roads
- Railway

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

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 3/7/2019
Figure 14 - 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: 7.9 Years 05/15/2010 To 03/10/2018

Subsidence Feature
- Hardrock
- GNSS Monument
- Earth Fissures

Highways and Interstates
- Interstate
- US
- State
- Roads
- Railway

Explanation
05/15/2010 To 03/10/2018
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)

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

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/26/2019
Figure 15 - Total Land Subsidence in the McMullen Valley, Maricopa and La Paz Counties Based on Radarsat-2 Satellite Interferometric Synthetic Aperture Radar (InSAR) Data

Time Period of Analysis:  7.9 Years:  05/01/2010 To 03/20/2018

Explanation
05/01/2010 To 03/20/2018
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
Hardrock
GNSS Monument
Earth Fissures

Highways and Interstates
Interstate
US
State
Roads
Railway

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

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/26/2019
Figure 16 - Total Land Subsidence in the Harquahala Valley, Maricopa County
Based on Radarsat-2 Satellite Interferometric Synthetic Aperture Radar (InSAR) Data

Time Period of Analysis: 7.9 Years: 05/01/2010 To 03/20/2018

Explanation
05/01/2010 To 03/20/2018
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
- Hardrock
- ADWR Transducer
- GNSS Monument
- CAP Canal
- Earth Fissures

Highways and Interstates
- Interstate
- US
- State
- Roads

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

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/27/2019
Figure 17 - Total Land Subsidence in the Ranegas Plain, La Paz County Based on Radarsat-2 Satellite Interferometric Synthetic Aperture Radar (InSAR) Data

Time Period of Analysis: 7.9 Years: 05/01/2010 To 03/20/2018

Explanation

05/01/2010 To 03/20/2018
Total Land Subsidence

- **Subsidence Feature**
  - Hardrock
  - GNSS Monument
  - CAP Canal

- **Highways and Interstates**
  - Interstate
  - US
  - State
  - Roads

- **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)

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).

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/26/2019

Land Subsidence Monitoring Report No. 4
Figure 18 - Total Land Subsidence in the Fort Grant Rd and Willcox Areas, Cochise County
Based on Radarsat-2 Satellite Interferometric Synthetic Aperture Radar (InSAR) Data

Time Period of Analysis: 8.0 Years 05/05/2010 To 05/11/2018

Explanation
05/05/2010 To 05/11/2018
Total Land Subsidence
Decoration/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
Hardrock
GNSS Monument
Earth Fissures

Highways and Interstates
Interstate
State
Roads
Railway

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

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/26/2019
Figure 19 - Total Land Subsidence in the Willcox and Kansas Settlement Areas, Cochise County
Based on Radarsat-2 Satellite Interferometric Synthetic Aperture Radar (InSAR) Data

Time Period of Analysis: 8.0 Years 05/05/2010 To 05/11/2018

Transformations
Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/26/2019

Explanation
05/05/2010 To 05/11/2018
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
Hardrock
GNSS Monument
Earth Fissures

Highways and Interstates
Interstate
US
State
Roads
Railway

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
Figure 20 - Total Land Subsidence in the Elfrida Area, Cochise County
Based on Radarsat-2 Satellite Interferometric Synthetic Aperture Radar (InSAR) Data

Time Period of Analysis: 8.0 Years 05/05/2010 To 05/11/2018

Explanation
05/05/2010 To 04/03/2016
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
- Hardrock
- GNSS Monument
- Earth Fissures

Highways and Interstates
- Interstate
- US
- State
- Roads
- Railway

-0.172 subsidence in meters

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

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/26/2019
Figure 21 - Total Land Subsidence in the Bowie and San Simon Areas, Cochise County
Based on Radarsat-2 Satellite Interferometric Synthetic Aperture Radar (InSAR) Data

Time Period of Analysis: 8.0 Years 05/05/2010 To 05/11/2018

Explanation
05/05/2010 To 05/11/2018
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
- Hardrock
- GNSS Monument
- Earth Fissures

Highways and Interstates
- Interstate
- US
- State
- Roads
- Railway

Subsidence Feature
- -0.172 subsidence in meters

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

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/26/2019

for information on earth fissures visit: www.azgs.az.gov/EFC
Figure 22 - Total Land Subsidence in the Holbrook Basin, Navajo County
Based on Radarsat-2 Satellite Interferometric Synthetic Aperture Radar (InSAR) Data

Time Period of Analysis: 5.5 Years 09/22/2012 To 04/24/2018

Explanation
09/22/2012 To 04/24/2018
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
Hardrock
Cities/Towns

Highways and Interstates
- Interstate
- US
- State
- Roads
- Railway

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).

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/26/2019
Earth fissures were mapped by the Arizona Geological Survey. For information on earth fissures visit: www.azgs.az.gov/EFC

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

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/27/2019

Figure 23 - Bedrock CORS Sites
Figure 24 - Groundwater Wells Used to Monitor Annual Changes in Groundwater Levels
Groundwater Data is Collected by the Basic Data and Transducer Units of the ADWR Hydrology Division

Explanation
- Automated Wells (129)
- Index Wells (2,783)
- All GWSI Wells (44,340)

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/26/2019
Figure 25 - Current Radarsat-2 Satellite Frames Used to Collect InSAR Data in Arizona
InSAR Data is Collected, Processed, and Analyzed by the Geophysics/Surveying Unit of the ADWR Hydrology Division

Explanation

- InSAR Frames
- Active Land Subsidence Area

Highways and Interstates:
- Interstate
- US
- State

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 2/26/2019
<table>
<thead>
<tr>
<th>Station</th>
<th>Latitude(NAD83)</th>
<th>Longitude(NAD83)</th>
<th>Basin</th>
<th>Project Area</th>
<th>Subsidence(m)</th>
<th>Subsidence(ft)</th>
<th>Survey Dates</th>
<th>NGS Datasheet</th>
</tr>
</thead>
<tbody>
<tr>
<td>T 420</td>
<td>31 50 23.75450</td>
<td>109 41 43.12509</td>
<td>Douglas INA</td>
<td>Elfrida</td>
<td>-0.06</td>
<td>-0.20</td>
<td>1991 - 2018</td>
<td><a href="https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=CF0214">https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=CF0214</a></td>
</tr>
<tr>
<td>Weber</td>
<td>31 38 30.98324</td>
<td>109 38 48.98058</td>
<td>Douglas INA</td>
<td>Elfrida</td>
<td>-0.03</td>
<td>-0.10</td>
<td>2008 - 2014</td>
<td><a href="https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DN3643">https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DN3643</a></td>
</tr>
<tr>
<td>Whitewater</td>
<td>31 43 46.80253</td>
<td>109 38 07.03861</td>
<td>Douglas INA</td>
<td>Elfrida</td>
<td>-0.21</td>
<td>-0.68</td>
<td>2008 - 2014</td>
<td><a href="https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DN3644">https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DN3644</a></td>
</tr>
<tr>
<td>L 361</td>
<td>33 08 44.81597</td>
<td>112 40 37.28767</td>
<td>Gila Bend</td>
<td>Gila Bend</td>
<td>-0.05</td>
<td>-0.17</td>
<td>1991 - 2018</td>
<td><a href="https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DV0811">https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DV0811</a></td>
</tr>
<tr>
<td>M 361</td>
<td>33 09 35.92754</td>
<td>112 40 55.52644</td>
<td>Gila Bend</td>
<td>Gila Bend</td>
<td>-1.11</td>
<td>-3.66</td>
<td>1991 - 2018</td>
<td><a href="https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DV0810">https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DV0810</a></td>
</tr>
<tr>
<td>4BR1</td>
<td>33 25 16.10854</td>
<td>113 10 16.54929</td>
<td>Harquahala Valley</td>
<td>Harquahala Valley</td>
<td>-0.08</td>
<td>-0.27</td>
<td>2001 - 2018</td>
<td><a href="https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=AJ3564">https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=AJ3564</a></td>
</tr>
<tr>
<td>A 480</td>
<td>33 53 51.19015</td>
<td>113 32 39.00082</td>
<td>McMullen Valley</td>
<td>McMullen Valley</td>
<td>-0.53</td>
<td>-1.73</td>
<td>1991 - 2018</td>
<td><a href="https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DV1482">https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DV1482</a></td>
</tr>
<tr>
<td>H 25</td>
<td>33 54 44.30988</td>
<td>113 18 17.80642</td>
<td>McMullen Valley</td>
<td>McMullen Valley</td>
<td>-0.75</td>
<td>-2.48</td>
<td>1991 - 2018</td>
<td><a href="https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DV0997">https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DV0997</a></td>
</tr>
<tr>
<td>S 479</td>
<td>33 47 53.88969</td>
<td>113 35 03.23905</td>
<td>McMullen Valley</td>
<td>McMullen Valley</td>
<td>-0.37</td>
<td>-1.22</td>
<td>1991 - 2018</td>
<td><a href="https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DV1474">https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DV1474</a></td>
</tr>
<tr>
<td>T 479</td>
<td>33 48 28.14726</td>
<td>113 34 00.97863</td>
<td>McMullen Valley</td>
<td>McMullen Valley</td>
<td>-0.42</td>
<td>-1.37</td>
<td>1991 - 2018</td>
<td><a href="https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DV1475">https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DV1475</a></td>
</tr>
<tr>
<td>X 479</td>
<td>33 50 29.04923</td>
<td>113 32 40.76314</td>
<td>McMullen Valley</td>
<td>McMullen Valley</td>
<td>-1.19</td>
<td>-3.89</td>
<td>1991 - 2018</td>
<td><a href="https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DV1479">https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DV1479</a></td>
</tr>
<tr>
<td>Y 479</td>
<td>33 51 20.48242</td>
<td>113 32 38.29354</td>
<td>McMullen Valley</td>
<td>McMullen Valley</td>
<td>-0.60</td>
<td>-1.96</td>
<td>1991 - 2018</td>
<td><a href="https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DV1480">https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DV1480</a></td>
</tr>
<tr>
<td>1543</td>
<td>33 24 55.60014</td>
<td>111 37 35.90945</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.03</td>
<td>-0.10</td>
<td>1997 - 2018</td>
<td></td>
</tr>
<tr>
<td>1580</td>
<td>33 24 55.53256</td>
<td>111 36 41.45066</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.17</td>
<td>-0.56</td>
<td>1997 - 2018</td>
<td></td>
</tr>
<tr>
<td>1608</td>
<td>33 24 55.52019</td>
<td>111 35 42.60969</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.11</td>
<td>-0.35</td>
<td>1997 - 2018</td>
<td></td>
</tr>
<tr>
<td>001</td>
<td>33 22 46.53940</td>
<td>111 34 51.05492</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.16</td>
<td>-0.50</td>
<td>2001 - 2018</td>
<td><a href="https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=AJ3653">https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=AJ3653</a></td>
</tr>
<tr>
<td>018</td>
<td>33 25 18.77057</td>
<td>111 37 59.87779</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.02</td>
<td>-0.08</td>
<td>2001 - 2018</td>
<td><a href="https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=AJ3672">https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=AJ3672</a></td>
</tr>
<tr>
<td>207</td>
<td>33 20 09.15246</td>
<td>111 38 22.83490</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.02</td>
<td>-0.07</td>
<td>2007 - 2018</td>
<td><a href="https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=AJ3652">https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=AJ3652</a></td>
</tr>
<tr>
<td>007</td>
<td>33 21 42.67361</td>
<td>111 33 06.35600</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.14</td>
<td>-0.46</td>
<td>1997 - 2018</td>
<td></td>
</tr>
<tr>
<td>012</td>
<td>33 22 14.86981</td>
<td>111 33 40.26423</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.27</td>
<td>-0.88</td>
<td>1997 - 2018</td>
<td></td>
</tr>
<tr>
<td>021</td>
<td>33 20 09.06873</td>
<td>111 32 02.51126</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.04</td>
<td>-0.14</td>
<td>1997 - 2015</td>
<td></td>
</tr>
<tr>
<td>027</td>
<td>33 21 00.96902</td>
<td>111 32 36.62151</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.04</td>
<td>-0.11</td>
<td>1997 - 2018</td>
<td></td>
</tr>
<tr>
<td>020</td>
<td>33 19 18.56759</td>
<td>111 32 45.92408</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.06</td>
<td>-0.21</td>
<td>1997 - 2018</td>
<td></td>
</tr>
<tr>
<td>011</td>
<td>33 21 26.49100</td>
<td>111 38 08.30771</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.07</td>
<td>-0.22</td>
<td>1997 - 2018</td>
<td></td>
</tr>
<tr>
<td>017</td>
<td>33 23 09.74938</td>
<td>111 34 55.96332</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-1.56</td>
<td>-5.04</td>
<td>1973 - 2018</td>
<td><a href="https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DU1323">https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DU1323</a></td>
</tr>
<tr>
<td>015</td>
<td>33 22 23.02079</td>
<td>111 34 42.32485</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.29</td>
<td>-0.95</td>
<td>1978 - 2018</td>
<td></td>
</tr>
<tr>
<td>013</td>
<td>33 22 23.30040</td>
<td>111 34 40.58109</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.27</td>
<td>-0.87</td>
<td>1978 - 2018</td>
<td></td>
</tr>
<tr>
<td>014</td>
<td>33 23 15.51454</td>
<td>111 36 56.54030</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.25</td>
<td>-0.80</td>
<td>1997 - 2018</td>
<td></td>
</tr>
<tr>
<td>016</td>
<td>33 23 15.85809</td>
<td>111 37 57.07782</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.37</td>
<td>-1.20</td>
<td>1997 - 2018</td>
<td></td>
</tr>
<tr>
<td>Station</td>
<td>Latitude(NAD83)</td>
<td>Longitude(NAD83)</td>
<td>Basin</td>
<td>Project Area</td>
<td>Subsidence(m)</td>
<td>Subsidence(ft)</td>
<td>Survey Dates</td>
<td>NGS Datasaheet</td>
</tr>
<tr>
<td>---------</td>
<td>----------------</td>
<td>------------------</td>
<td>-------</td>
<td>--------------</td>
<td>---------------</td>
<td>----------------</td>
<td>--------------</td>
<td>----------------</td>
</tr>
<tr>
<td>SUIR</td>
<td>33 23 15.47119</td>
<td>111 33 49.33746</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.45</td>
<td>-1.45</td>
<td>1997 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>SUSI</td>
<td>33 23 15.49322</td>
<td>111 35 53.91983</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.30</td>
<td>-0.97</td>
<td>1997 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>WUCE</td>
<td>33 22 42.55546</td>
<td>111 31 44.66164</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.03</td>
<td>-0.09</td>
<td>1997 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>WUCN</td>
<td>33 23 09.91893</td>
<td>111 32 15.34943</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.06</td>
<td>-0.19</td>
<td>1997 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>WUCS</td>
<td>33 22 08.14325</td>
<td>111 32 14.72193</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.12</td>
<td>-0.37</td>
<td>1997 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>WUCW</td>
<td>33 22 42.60832</td>
<td>111 32 55.87601</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.26</td>
<td>-0.85</td>
<td>1997 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>Y 473</td>
<td>33 22 21.91575</td>
<td>111 34 50.84473</td>
<td>Phoenix AMA</td>
<td>Hawk Rock</td>
<td>-0.50</td>
<td>-1.60</td>
<td>1991 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>L 304</td>
<td>32 42 20.89535</td>
<td>111 33 03.21021</td>
<td>Pinal AMA</td>
<td>Picacho-Eloy</td>
<td>-0.20</td>
<td>-0.64</td>
<td>1993 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>M 516</td>
<td>32 42 19.44573</td>
<td>111 37 12.78035</td>
<td>Pinal AMA</td>
<td>Picacho-Eloy</td>
<td>-0.14</td>
<td>-0.45</td>
<td>1993 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>N 304</td>
<td>32 40 33.66302</td>
<td>111 33 04.31618</td>
<td>Pinal AMA</td>
<td>Picacho-Eloy</td>
<td>-0.18</td>
<td>-0.58</td>
<td>1993 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>U 516</td>
<td>32 49 17.99573</td>
<td>111 30 55.91368</td>
<td>Pinal AMA</td>
<td>Picacho-Eloy</td>
<td>-0.12</td>
<td>-0.39</td>
<td>1993 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>V 516</td>
<td>32 52 45.94397</td>
<td>111 30 33.28734</td>
<td>Pinal AMA</td>
<td>Picacho-Eloy</td>
<td>-0.03</td>
<td>-0.11</td>
<td>1993 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>W 363</td>
<td>32 43 59.29971</td>
<td>111 31 29.95277</td>
<td>Pinal AMA</td>
<td>Picacho-Eloy</td>
<td>-0.23</td>
<td>-0.74</td>
<td>1993 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>Bonita</td>
<td>33 40 28.30577</td>
<td>113 46 02.55408</td>
<td>Ranegras Plain</td>
<td>Ranegras Plain</td>
<td>-0.03</td>
<td>-0.11</td>
<td>2019 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>H 478</td>
<td>33 42 58.24319</td>
<td>113 46 53.64748</td>
<td>Ranegras Plain</td>
<td>Ranegras Plain</td>
<td>-0.14</td>
<td>-0.48</td>
<td>1993 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>Portal</td>
<td>32 13 00.91824</td>
<td>109 10 34.79637</td>
<td>San Simon</td>
<td>Bowie-San Simon</td>
<td>-1.38</td>
<td>-4.51</td>
<td>1993 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>A 334</td>
<td>31 53 52.51060</td>
<td>110 57 46.05321</td>
<td>Tucson AMA</td>
<td>Green Valley</td>
<td>-0.08</td>
<td>-0.26</td>
<td>1991 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>R 75</td>
<td>31 54 43.76117</td>
<td>110 57 36.59715</td>
<td>Tucson AMA</td>
<td>Green Valley</td>
<td>-0.08</td>
<td>-0.25</td>
<td>1991 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>S 75</td>
<td>31 53 03.41698</td>
<td>110 58 07.97391</td>
<td>Tucson AMA</td>
<td>Green Valley</td>
<td>-0.01</td>
<td>-0.04</td>
<td>1991 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>Z 333</td>
<td>31 55 35.24159</td>
<td>110 57 32.49263</td>
<td>Tucson AMA</td>
<td>Green Valley</td>
<td>-0.09</td>
<td>-0.28</td>
<td>1991 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>BM850H</td>
<td>32 24 47.18189</td>
<td>109 57 38.76082</td>
<td>Willcox</td>
<td>Fort Grant Rd</td>
<td>-2.31</td>
<td>-7.58</td>
<td>1969 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>BM850L</td>
<td>32 26 30.76792</td>
<td>109 58 40.20909</td>
<td>Willcox</td>
<td>Fort Grant Rd</td>
<td>-1.42</td>
<td>-4.65</td>
<td>1969 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>BM850P</td>
<td>32 29 07.56049</td>
<td>109 58 42.55988</td>
<td>Willcox</td>
<td>Fort Grant Rd</td>
<td>-1.24</td>
<td>-4.08</td>
<td>1969 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>Apple</td>
<td>32 26 30.16141</td>
<td>109 55 40.04731</td>
<td>Willcox</td>
<td>Fort Grant Rd</td>
<td>-0.31</td>
<td>-1.03</td>
<td>2014 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>Ash Creek</td>
<td>32 32 14.41904</td>
<td>109 58 24.88593</td>
<td>Willcox</td>
<td>Fort Grant Rd</td>
<td>-0.01</td>
<td>-0.02</td>
<td>2014 - 2016</td>
<td>[link]</td>
</tr>
<tr>
<td>Ellis</td>
<td>32 20 24.96289</td>
<td>109 56 37.63941</td>
<td>Willcox</td>
<td>Fort Grant Rd</td>
<td>-0.17</td>
<td>-0.57</td>
<td>2005 - 2016</td>
<td>[link]</td>
</tr>
<tr>
<td>Fresh</td>
<td>32 28 15.03028</td>
<td>109 55 40.28499</td>
<td>Willcox</td>
<td>Fort Grant Rd</td>
<td>-0.23</td>
<td>-0.75</td>
<td>2014 - 2018</td>
<td>[link]</td>
</tr>
<tr>
<td>Station</td>
<td>Latitude(NAD83)</td>
<td>Longitude(NAD83)</td>
<td>Basin</td>
<td>Project Area</td>
<td>Subsidence(m)</td>
<td>Subsidence(ft)</td>
<td>Survey Dates</td>
<td>NGS Datasheet</td>
</tr>
<tr>
<td>---------</td>
<td>----------------</td>
<td>-----------------</td>
<td>-----------</td>
<td>------------------</td>
<td>---------------</td>
<td>----------------</td>
<td>--------------</td>
<td>---------------</td>
</tr>
<tr>
<td>L 358</td>
<td>32 17 04.01806</td>
<td>109 49 29.62692</td>
<td>Willcox</td>
<td>Fort Grant Rd</td>
<td>-0.42</td>
<td>-1.39</td>
<td>1992 - 2016</td>
<td><a href="https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=CY0486">https://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=CY0486</a></td>
</tr>
<tr>
<td>Nickels</td>
<td>32 19 55.63377</td>
<td>109 52 33.43652</td>
<td>Willcox</td>
<td>Fort Grant Rd</td>
<td>-0.02</td>
<td>-0.08</td>
<td>2008 - 2016</td>
<td><a href="https://geodesy.noaa.gov/OPUS/getDatasheet.jsp?PID=BBDS58">https://geodesy.noaa.gov/OPUS/getDatasheet.jsp?PID=BBDS58</a></td>
</tr>
<tr>
<td>Ranch</td>
<td>32 23 55.29910</td>
<td>109 55 37.87453</td>
<td>Willcox</td>
<td>Fort Grant Rd</td>
<td>-0.29</td>
<td>-0.96</td>
<td>2008 - 2016</td>
<td><a href="https://www.ngs.noaa.gov/OPUS/getDatasheet.jsp?PID=BBDS58">https://www.ngs.noaa.gov/OPUS/getDatasheet.jsp?PID=BBDS58</a></td>
</tr>
<tr>
<td>Willcox CA</td>
<td>32 14 56.24697</td>
<td>109 50 07.68447</td>
<td>Willcox</td>
<td>Fort Grant Rd</td>
<td>-0.05</td>
<td>-0.17</td>
<td>2006 - 2016</td>
<td><a href="https://www.ngs.noaa.gov/OPUS/getDatasheet.jsp?PID=BBGD42">https://www.ngs.noaa.gov/OPUS/getDatasheet.jsp?PID=BBGD42</a></td>
</tr>
<tr>
<td>Arabian</td>
<td>32 00 02.43363</td>
<td>109 51 51.34926</td>
<td>Willcox</td>
<td>Kansas Settlement</td>
<td>-0.09</td>
<td>-0.28</td>
<td>1991 - 2018</td>
<td><a href="https://www.geodesy.noaa.gov/OPUS/getDatasheet.jsp?PID=BBFS25">https://www.geodesy.noaa.gov/OPUS/getDatasheet.jsp?PID=BBFS25</a></td>
</tr>
<tr>
<td>Bell Ranch</td>
<td>32 02 09.98024</td>
<td>109 41 42.85163</td>
<td>Willcox</td>
<td>Kansas Settlement</td>
<td>-0.11</td>
<td>-0.37</td>
<td>2008 - 2016</td>
<td><a href="https://www.geodesy.noaa.gov/OPUS/getDatasheet.jsp?PID=BBGD42">https://www.geodesy.noaa.gov/OPUS/getDatasheet.jsp?PID=BBGD42</a></td>
</tr>
<tr>
<td>C 325</td>
<td>32 08 44.51532</td>
<td>109 54 10.67515</td>
<td>Willcox</td>
<td>Kansas Settlement</td>
<td>-0.09</td>
<td>-0.30</td>
<td>1991 - 2018</td>
<td><a href="https://www.geodesy.noaa.gov/cgi-bin/ds_mark.prl?PidBox=CY0374">https://www.geodesy.noaa.gov/cgi-bin/ds_mark.prl?PidBox=CY0374</a></td>
</tr>
<tr>
<td>C 420</td>
<td>32 04 01.40020</td>
<td>109 53 41.17879</td>
<td>Willcox</td>
<td>Kansas Settlement</td>
<td>-1.51</td>
<td>-4.94</td>
<td>1991 - 2018</td>
<td><a href="https://www.geodesy.noaa.gov/cgi-bin/ds_mark.prl?PidBox=CY0596">https://www.geodesy.noaa.gov/cgi-bin/ds_mark.prl?PidBox=CY0596</a></td>
</tr>
<tr>
<td>Domann</td>
<td>32 02 09.87011</td>
<td>109 47 48.92831</td>
<td>Willcox</td>
<td>Kansas Settlement</td>
<td>-0.45</td>
<td>-1.47</td>
<td>2005 - 2019</td>
<td><a href="https://www.geodesy.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DH5769">https://www.geodesy.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DH5769</a></td>
</tr>
<tr>
<td>Ike</td>
<td>32 09 57.7293</td>
<td>109 45 23.21838</td>
<td>Willcox</td>
<td>Kansas Settlement</td>
<td>-0.39</td>
<td>-1.28</td>
<td>2012 - 2016</td>
<td><a href="https://www.geodesy.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DH5772">https://www.geodesy.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DH5772</a></td>
</tr>
<tr>
<td>Kansas</td>
<td>32 04 49.93624</td>
<td>109 45 28.57135</td>
<td>Willcox</td>
<td>Kansas Settlement</td>
<td>-0.46</td>
<td>-1.50</td>
<td>2008 - 2016</td>
<td><a href="https://www.geodesy.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DH5773">https://www.geodesy.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DH5773</a></td>
</tr>
<tr>
<td>Playa</td>
<td>32 08 42.06334</td>
<td>109 45 15.46192</td>
<td>Willcox</td>
<td>Kansas Settlement</td>
<td>-1.20</td>
<td>-3.93</td>
<td>1993 - 2016</td>
<td><a href="https://www.geodesy.noaa.gov/cgi-bin/ds_mark.prl?PidBox=CY1136">https://www.geodesy.noaa.gov/cgi-bin/ds_mark.prl?PidBox=CY1136</a></td>
</tr>
<tr>
<td>Q 431</td>
<td>31 55 15.72635</td>
<td>109 49 17.45800</td>
<td>Willcox</td>
<td>Kansas Settlement</td>
<td>-0.01</td>
<td>-0.03</td>
<td>1991 - 2018</td>
<td><a href="https://www.geodesy.noaa.gov/cgi-bin/ds_mark.prl?PidBox=CF0201">https://www.geodesy.noaa.gov/cgi-bin/ds_mark.prl?PidBox=CF0201</a></td>
</tr>
<tr>
<td>Soles</td>
<td>31 59 33.65400</td>
<td>109 44 43.73813</td>
<td>Willcox</td>
<td>Kansas Settlement</td>
<td>-0.41</td>
<td>-1.35</td>
<td>2005 - 2016</td>
<td><a href="https://www.geodesy.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DH5782">https://www.geodesy.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DH5782</a></td>
</tr>
<tr>
<td>Turkey</td>
<td>31 54 19.39427</td>
<td>109 38 38.96737</td>
<td>Willcox</td>
<td>Kansas Settlement</td>
<td>-0.07</td>
<td>-0.24</td>
<td>2008 - 2016</td>
<td><a href="https://www.geodesy.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DH5785">https://www.geodesy.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DH5785</a></td>
</tr>
</tbody>
</table>

*Table 1 – 2019 GNSS Survey Result*