Global Positioning System Surveying and Interferometric Synthetic Aperture Radar to Assess Land Subsidence in Coachella Valley, California

Proposal # 2021-11

Cooperator: Coachella Valley Water District

Authors: Michelle Sneed and Justin Brandt

BACKGROUND/INTRODUCTION

The study area is located in the 50-mi long northwest-trending Coachella Valley, an arid desert basin in southeastern California, which extends from the San Gorgonio Pass to the Salton Sea (fig. 1). The valley covers about 440 mi^2 (California Department of Water Resources, 1964) and includes the cities and communities of Palm Springs, Palm Desert, Indio, and Coachella. The valley is bordered by the San Jacinto and Santa Rosa Mountains on the west, the San Bernardino and the Little San Bernardino Mountains on the north, the Cottonwood Mountains and the Mecca Hills on the east, and the Salton Sea on the south (fig. 1). The Coachella Valley is drained primarily by the Whitewater River, which flows into the Whitewater Stormwater Channel and Coachella Valley Stormwater Channel and eventually flows into the Salton Sea (fig. 1). Land-surface elevations vary from more than 10,000 ft above sea level in the San Bernardino and San Jacinto Mountains to more than 230 ft below sea level at the Salton Sea.

Groundwater has been a major source of water supply for the Coachella Valley since the 1920s. Pumping of groundwater resulted in groundwater-level declines as large as 50 feet (ft) by the late 1940s (Brandt and Sneed, 2020). The Coachella Valley Water District (CVWD) has the responsibility for effectively managing the water supply for a large part of the Coachella Valley. The management strategy involves reducing groundwater overdraft and related land subsidence while maintaining a reliable water supply to meet the growing demands of both agricultural and urban water users (Coachella Valley Water District, 2012). Because of concerns that groundwater-

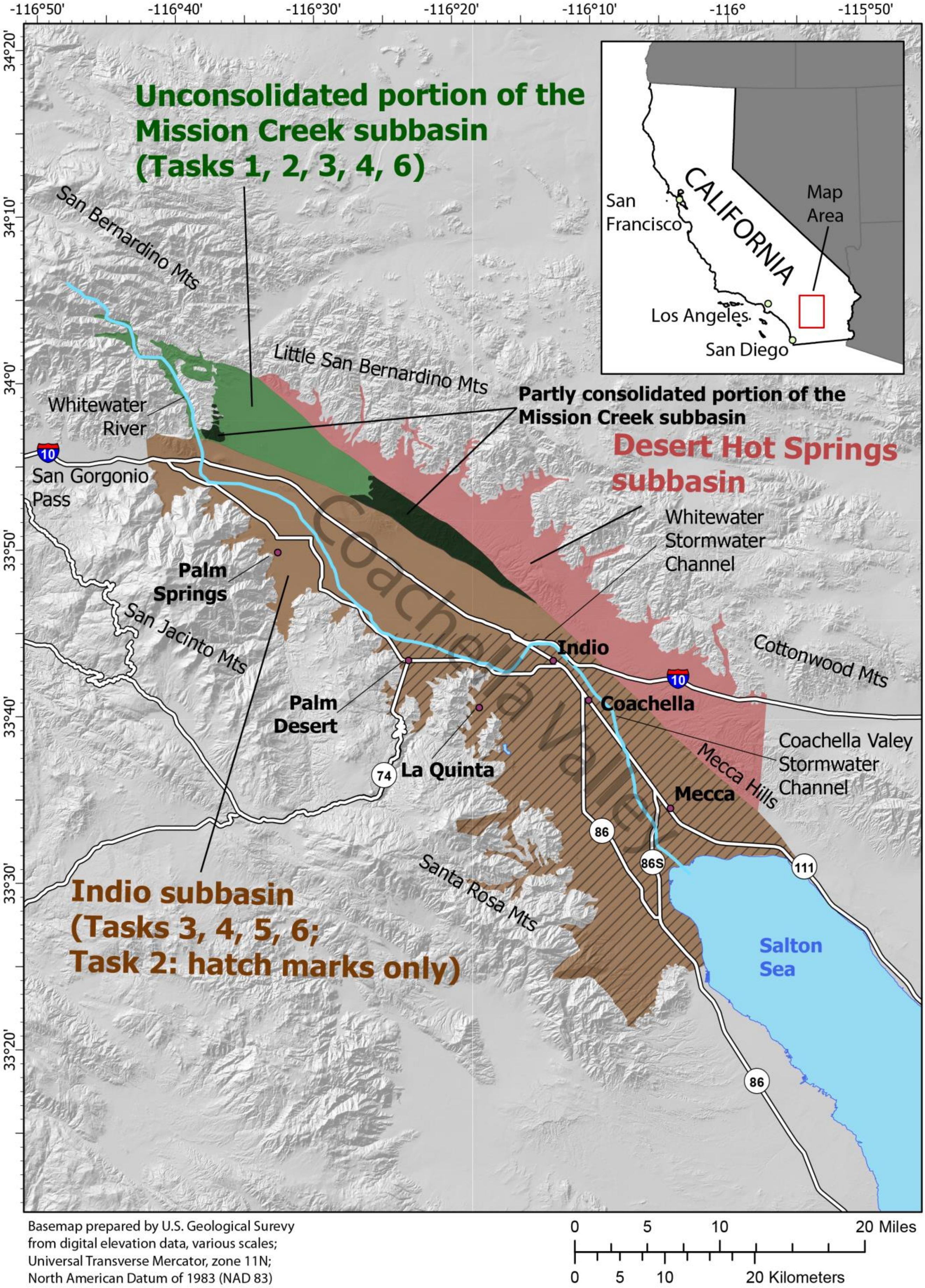

Figure 1. Map showing subbasins, cities, and major roads of the Coachella Valley, California. Subbasins are from the Department of Water Resources (2018), and coverage of partly consolidated areas of Mission Creek subbasin is from Rick Rees, Mission Creek Alternative Plan Update Team (personal communication, March 16, 2021).

level declines could cause land subsidence, the CVWD and the U.S. Geological Survey (USGS) have cooperatively investigated subsidence in the Coachella Valley since 1996. Results of these investigations indicate as much as about 2 ft of subsidence occurred along the southwestern margin of the Coachella Valley between 1995 and 2017.

The Coachella Valley groundwater basin has three subbasins (California Department of Water Resources, 2018): Indio subbasin, which is by far the largest and most developed; Mission Creek subbasin, which is northeast of the Indio subbasin; and Desert Hot Springs subbasin, which is northeast of the Mission Creek subbasin (fig. 1). The groundwater basin consists of unconsolidated to partly consolidated Holocene to Pleistocene alluvial and lacustrine deposits that are more than 2,400 ft thick in parts of the basin (Department of Water Resources, 1964). These deposits consist of an assemblage of gravel, sand, silt, and clay, and tend to be finer grained (contain more silt and clay) in the eastern part of the valley than in the western part because of the greater depositional distance from mountain source rocks, and transition into the lacustrine deposition from ancient Lake Cahuilla.

In the eastern part of the Indio subbasin, the aquifer system consists of an upper aquifer, a confining layer, and a lower aquifer. The thickness of the upper aquifer ranges from about 150 to 300 ft and consists of unconsolidated and partly consolidated silty sands and gravels with interbeds of silt and clay and is separated from the lower aquifer by a confining layer of silt and clay that is 100 to 200 ft thick. The lower aquifer is the most productive source of groundwater in the eastern Coachella Valley; it consists of unconsolidated and partly consolidated silty sands and gravels with interbeds of silt and clay. Available data indicate that the lower aquifer is at least 500 ft thick and may be as much as 2,000 ft thick (California Department of Water Resources, 1964, 1979). In the western part of the Indio subbasin and the Mission Creek subbasin, the confining layer is absent such that the aquifer system is not subdivided and is considered a single aquifer throughout its thickness (California Department of Water Resources, 1964, 1979). The Desert Hot Springs subbasin is not described here because it is not included in this proposed study.

PROBLEM

Declining groundwater levels can contribute to or induce land subsidence in aquifer systems that consist of a substantial fraction of unconsolidated fine-grained deposits (silts and clays;

Galloway and others, 1999). Results of the cooperative investigations indicated that the geology and groundwater-level declines in parts of the Indio subbasin resulted in aquifer-system compaction and subsequent land subsidence that damaged infrastructure (Sneed and others, 2001; 2002; 2014; Sneed and Brandt, 2007; 2020). Results of the investigations also indicated that as water-resource management actions that reduced reliance on the groundwater resource were implemented, groundwater levels increased, and land subsidence rates decreased. Global Positioning System (GPS) survey and Interferometric Synthetic Aperture Radar (InSAR) results indicate that subsidence rates in parts of the Indio subbasin generally had increased from 2000 to mid-2009 compared to earlier periods (Sneed and other, 2014). In mid-2009, in the eastern part of the Indio subbasin which began to be replenished by a managed aquifer recharge facility through spreading ponds, cessation of subsidence began to be observed (Sneed and others, 2014). By 2017, subsidence throughout the eastern part of the Indio subbasin had slowed or stopped (Sneed and Brandt, 2020). InSAR results indicate that the western part of the Indio subbasin uplifted small amounts during 2014–17 (this part of the subbasin was not assessed for subsidence prior to this period). The relation between geology, groundwater levels, and land-surface-elevation changes in the Mission Creek subbasin have not been previously studied and is of concern to CVWD, so is included in this proposal. The relation between geology, groundwater levels, and land-surface-elevation changes in the Desert Hot Springs subbasin is not of concern to CVWD because there is limited pumping in this subbasin and it is not a medium or high priority basin under Sustainable Groundwater Management Act regulations (Zoe Rodriguez del Rey, CVWD, written communication, May 11, 2021). Therefore, study of the Desert Hot Springs subbasin is excluded from this proposal. Continued monitoring of land subsidence in the Indio subbasin is needed to determine the effects of different water-resource scenarios in supply and demand, climate variability, and management actions on future land subsidence, such as projected increases in water demand, changes in land use, complex water transfers, water conservation, managed aquifer recharge, and source substitution. Initial assessment of subsidence and development of a subsidence monitoring plan for the Mission Creek subbasin is needed to begin understanding land subsidence there.

OBJECTIVES and SCOPE

This study will include the Indio and Mission Creek subbasins in the Coachella Valley. For the Indio subbasin, the objectives of this study are to (1) detect and quantify land subsidence using GPS methods (2015–22) and InSAR methods (2017–23), (2) evaluate the relation between changes in land-surface elevation and groundwater levels at selected sites during 2015–23, and (3) provide technical assistance to CVWD and their contractors in the development of subsidence simulation capabilities for an existing numerical groundwater flow model.

For the Mission Creek subbasin, the objectives of this study are to: (1) assess land-surface elevations during 2015–21 using available InSAR or other survey data, (2) develop a subsidence monitoring plan, (3) detect and quantify land subsidence as stipulated in the previously developed monitoring plan, and (4) evaluate the relation between changes in land-surface elevation and groundwater levels at selected sites as stipulated in the previously developed monitoring plan.

RELEVANCE and BENEFITS

In some areas of the Indio subbasin within the Coachella Valley, groundwater levels have recently been relatively stable or have risen after decades of persistent declines, and subsidence was slowed or arrested. These changes were related to water-resource management actions documented in previous USGS subsidence studies. The benefits of this study are to continue to improve our understanding about the relation between groundwater levels and land-surface-elevation changes during 2015–23 in the Indio subbasin. This study facilitates the continued examination of the rare case study of longer-term groundwater-level increase and subsidence cessation in the Indio subbasin and the initial subsidence assessment in the Mission Creek subbasin. This information can be used to effectively manage the water resources and related land subsidence and develop a greater understanding of subsidence and the geology of the Coachella Valley. This is of scientific and societal interest at this time as California has implemented the Sustainable Groundwater Management Act (SGMA), which stipulates management of land subsidence (State of California Water Code Section 10721). The study will address two USGS goals (Evenson and others, 2013): “Provide society the information it needs regarding the amount and quality of water in all components of the water cycle at high temporal and spatial resolution through the advancement of hydrologic monitoring networks and techniques,” and “Deliver timely hydrologic data, analyses, and decision-support tools seamlessly across the Nation to support water-resource decisions.”

APPROACH

The study will consist of six tasks:

1. Analyze available hydrogeologic and geodetic data for the unconsolidated part of the Mission Creek subbasin to:
   a. assess land-surface elevation conditions for 2015 through 2021, and
   b. develop a subsidence monitoring plan, which may include the installation of survey monuments;
2. Conduct and analyze the results of high-precision GPS surveys in 2022 to:
   a. determine the extent and magnitude of the changes in ellipsoid height between 2015 and 2022 at selected geodetic monuments in the Indio subbasin, and
   b. establish ellipsoid height at selected geodetic monuments for the unconsolidated part of the Mission Creek subbasin if stipulated in the monitoring plan developed in Task 1b;
3. Analyze California Department of Water Resources (DWR)-provided InSAR results to compute changes in land-surface elevation in the:
   a. Indio subbasin during 2017–23, and
   b. unconsolidated part of the Mission Creek subbasin if stipulated in the monitoring plan developed in Task 1b

      If InSAR results provided by DWR are determined to be insufficient for any reason as Task 3 is carried out, the CVWD and USGS may amend this agreement to obtain the InSAR results elsewhere;
4. Analyze relation between changes in groundwater levels and land-surface elevation changes near selected geodetic monuments and other sites of interest to CVWD in the:
   a. Indio subbasin during 2015–23, and
   b. unconsolidated part of the Mission Creek subbasin if stipulated in the monitoring plan developed in Task 1b;
5. Provide technical assistance to CVWD and their contractors to add subsidence simulation capabilities to an existing numerical groundwater flow model of the Indio subbasin; and
6. Document results of groundwater-level and land-surface-elevation changes between 2015 and 2023 in the Indio subbasin; and the results of the assessment, monitoring plan, and any data collection and analysis in the unconsolidated part of the Mission Creek subbasin in a USGS interpretive report

or journal article.

Analyze available hydrogeologic and geodetic data for the unconsolidated part of the Mission Creek subbasin (Task 1)

The USGS will analyze available hydrogeologic and geodetic data for the unconsolidated part of the Mission Creek subbasin to (a) assess land-surface elevation conditions in the Mission Creek subbasin for 2015 through 2021, and (b) develop a subsidence monitoring plan for the Mission Creek subbasin based on the results from (a). The assessment will involve review of existing land-subsidence information for the Mission Creek subbasin including 1) available InSAR interferograms provided by the USGS, the DWR, and others, 2) publicly available continuous GPS measurements from the University Navstar Consortium, Scripps Orbit and Permanent Array Center, and the Nevada Geodetic Laboratory at University of Nevada Reno, 3) available lithologic and geophysical logs from the DWR, the CVWD, and others, and 4) available groundwater-level data from the DWR, the CVWD, and others.

If the assessment indicates that subsidence has not been documented or determined, and the geologic conditions are not conducive to subsidence, the study may indicate that monitoring of subsidence in the subbasin could be accomplished by examining periodic InSAR results before embarking on more costly measures. Furthermore, this proposal assumes that suitable InSAR results will be available from the DWR; however, if suitable InSAR results are not available from the DWR, the USGS and the CVWD may amend this agreement, which may include the USGS processing InSAR data to produce suitable results in-house, or another mutually agreed upon option.

If the assessment indicates that subsidence has occurred and/or the geologic conditions are conducive to subsidence, the USGS will invoke a 2-pronged approach: 1) develop a subsidence monitoring plan, which may include the design and installation of a monument network for the GPS survey described in Task 2b, and 2) conduct a detailed analysis of land-surface elevation and groundwater-level changes during 2017–23 (Tasks 3b and 4b). The USGS will use the results of the assessment (such as areas of subsidence, locations of clay deposits, and substantial groundwater-level declines) to identify key locations for monuments. The monument network likely will consist of 6 or 7 monuments in the unconsolidated part of the Mission Creek subbasin, which is about a 35-

square-mile area. The monument network likely will be a combination of existing and newly constructed monuments. Existing monuments of interest will be identified by the USGS and initially be inspected by the CVWD survey crew by winter of 2021–22 for condition and suitability for GPS surveys. The USGS will inspect the monuments before the network design is finalized. For budget purposes, this study assumes that three existing monuments will be used, and three monuments will be constructed. Depending on site conditions, these monuments will be constructed similar to other deep-seated or surficial monuments previously built in cooperation with CVWD. Based on current knowledge, an environmental evaluation under the National Environmental Protection Act (NEPA) will not be required prior to monument installation because monuments (survey marks) are included as a Categorical Exclusion (CE) according to Department of Interior 43 CFR Part 46.210 and USGS DM Part 516 Chapter 9 (https://www.doi.gov/sites/doi.gov/files/uploads/doi_and_bureau_categorical_exclusions.pdf, accessed: May 12, 2021). If this interpretation is changed, the CVWD will be responsible for the NEPA requirements. CVWD will own the monuments. The new monument construction will occur by late spring 2022 to avoid the stifling heat of Coachella Valley summers for the labor-intensive installation, and to allow ample time for the monuments to set before the GPS survey (Task 2b).

Conduct and analyze the results of high-precision GPS surveys in 2022 (Task 2)

The USGS will conduct high-precision GPS Surveys in 2022 of the (a) existing subsidence monitoring network in the Indio subbasin to determine the extent and magnitude of the changes in ellipsoid heights between 2015 and 2022 (Sneed and others, 2001; 2002; 2014; Sneed and Brandt, 2007; 2020), and (b) newly established subsidence monitoring network in the unconsolidated part of the Mission Creek subbasin to establish ellipsoid heights, if stipulated in the monitoring plan developed in Task 1b. The two surveys will not be linked (will not share common monuments) due to the large distance between the networks. In winter or early spring 2022, field visits by the CVWD survey crew will be made to determine the suitability of the Indio subbasin geodetic monuments for use in the GPS Survey (monuments are often damaged or destroyed). Monument replacements will be selected or constructed as necessary soon after to avoid the stifling heat of Coachella Valley summers for the labor-intensive installation, and to allow ample time for the monuments to set before the GPS survey. In the weeks leading up to the surveys, the Indio and the Mission Creek subbasin monuments will be visited by the CVWD survey crew to inspect and mark/flag the monuments for efficiency of locating the monuments during the surveys. Changes in ellipsoid heights at the 24 geodetic monuments that were surveyed in 2015 in the Indio subbasin will be determined for the period 2015 to 2022 (dependent on suitability in 2022). Ellipsoid heights (relative to the GPS satellite reference frame) measured at geodetic monuments in 2015 will be compared with the ellipsoid heights measured in the 2022 GPS survey; these results will be put into context with the results from previous surveys. For the newly established network in the Mission Creek subbasin, ellipsoid heights will be determined at the monuments in 2022 which can be used for comparison with ellipsoid heights determined from future GPS surveys. Additionally, the horizontal components of the GPS data will be analyzed, which may elucidate vertical change between the monuments. If the horizontal motion of a monument is inconsistent with the northwest movement of the Pacific plate with respect to the North American plate, then the horizontal motion can be attributed to another mechanism such as nearby subsidence (Bawden and others, 2001). The GPS data will reside redundantly on regularly backed-up servers and made publicly available via a ScienceBase data release near the end of the project.

Analyze California Department of Water Resources (DWR)-provided InSAR results to compute changes in land-surface elevation during 2017–23 (Task 3)

The USGS will analyze DWR-provided InSAR results to compute changes in land-surface elevation in the (a) Indio subbasin during 2017–23, and (b) unconsolidated part of the Mission Creek subbasin, if stipulated in the monitoring plan developed in Task 1b. InSAR is a satellite-based remote sensing technique that can detect centimeter level ground-surface deformation over hundreds of square miles at a spatial resolution (pixel size) of 295 feet or better (Galloway and others, 2000). Synthetic Aperture Radar (SAR) imagery is produced by reflecting radar signals off a target area and measuring the two-way travel time back to the satellite. InSAR uses two or more SAR scenes of the same area taken at different times and “interferes” (differences) them, resulting in maps called interferograms that show relative ground-elevation change (range change) between the two times.

Selected InSAR results available for 2017–23 from the DWR will be obtained (California

Department of Water Resources, 2021) and used to create time series of land-surface elevations to temporally extend the subsidence history of the Indio subbasin (Sneed and others, 2001; 2002; 2014; Sneed and Brandt, 2007; 2020), and to establish a subsidence history of the unconsolidated part of the Mission Creek subbasin (if stipulated in Task 1b). The European Space Agency's (ESA) Sentinel-1 satellite constellation (2 operational satellites and 2 more planned satellites) has thus far been the source of DWR-provided InSAR datasets and also were used for the bulk of the most recent USGS subsidence analyses in the Coachella Valley (Sneed and Brandt, 2020). The Sentinel-1 satellite constellation is expected to remain viable based on the constellation redundancy and follow-on plan to replace satellites at end of life (European Space Agency, 2021). We expect to obtain the interferograms for 2017 through 2023 from the DWR at no cost (Benjamin Brezing, California Department of Water Resources, personal communication, May 11, 2021). If suitable interferograms are not available from the DWR for 2017–23, the USGS and the CVWD may consider amending our agreement to either obtain interferograms from other providers or process the data in-house using established methods.

Analyze relation between changes in groundwater levels and land-surface elevation changes near selected geodetic monuments and other sites of interest to CVWD (Task 4)

The USGS will analyze the relation between changes in groundwater levels and land-surface elevation near selected geodetic monuments and other sites of interest to CVWD in the (a) Indio subbasin, and (b) unconsolidated part of the Mission Creek subbasin, if stipulated in the monitoring plan developed in Task 1b. Selected available groundwater-level data for the Indio and Mission Creek subbasins for 2015–23 will be obtained from CVWD, the DWR, and other agencies to analyze the relation between changes in groundwater levels (stress) and changes in land-surface elevation (strain) at selected sites during this period. Groundwater-level hydrographs will be compared with land-surface-elevation changes to discern the timing (concurrent or residual) as well as the nature (recoverable or permanent) of measured land-surface elevation changes. The results of the analysis for the Indio subbasin will be put into context of results from previous assessments (Sneed and others, 2001; 2002; 2014; Sneed and Brandt, 2007; 2020). This will be the initial such analysis for the Mission Creek subbasin (dependent on the results from Task 1).

Provide technical assistance to CVWD and their contractors to add subsidence simulation capabilities to an existing numerical groundwater flow model of the Indio subbasin (Task 5)

The USGS will provide assistance and guidance in developing and implementing subsidence simulation capabilities in an existing MODFLOW-2005 model (Tyley, 1974; Swain, 1978; Reichard and Meadows, 1992; Fogg and others, 2000), pending CVWD evaluation of the need and value of such capabilities. For example, the subsidence simulation package that is compatible with MODFLOW-2005 is SUB (Hoffmann and others, 2003) and the capabilities of that code and experiences in other USGS models in constructing this package will be used as a guide. The USGS will provide technical assistance regarding construction of the subsidence-related components of the model that may include the geologic model, instantaneous and delayed compaction, parameter bounds (preconsolidation head, vertical hydraulic conductivity, elastic and inelastic storage), and subsidence observations. Reviewing and/or implementing the model itself and its simulation results are beyond the scope of this study.

Document results of groundwater-level and land-surface-elevation changes between 2015 and 2023 in the Indio subbasin; and the results of the assessment, monitoring plan, and any data collection and analysis in the unconsolidated part of the Mission Creek subbasin (Task 6)

The USGS will document the results of Tasks 1-4 in a USGS interpretive report or journal article, with reference to the reports that documented land-surface deformation results for 1996–2015 (GPS) and 1993–2017 (InSAR). The report will be published by June 30, 2025. The GPS data and results will be released through ScienceBase prior to publication of the report. If the InSAR data and results are provided by USGS, the data will be released through Sciencebase prior to the publication of the report. Additionally, written project updates will be provided upon request at intervals no more frequently than quarterly.

QUALITY ASSURANCE/QUALITY CONTROL

The quality assurance and quality control procedures this project will use to guide GPS and InSAR data-collection, processing, and review activities are based on the methods and procedures described in Sneed and others (2001; 2002; 2014) and Sneed and Brandt (2007; 2020). In short, static GPS methods follow National Geodetic Survey guidelines detailed in Zilkowski and others (1997) and learned through experience and National Geodetic Survey courses. InSAR results will be quantitatively compared to continuous GPS results for GPS stations geographically included in the InSAR coverage area and properly operating at the time of InSAR data acquisitions.

LABORATORY EVALUATION PLAN

n/a

PRODUCTS

The products that will be produced for this project include a USGS interpretive report or journal article and a USGS Data Release (Task 6).

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TIMELINE

The study will cover a period of 4 years (July 1, 2021–June 30, 2025). The timeline for the major elements of this study are shown in table 1:

Table 1: Timeline for proposed project

Task	Task Description	FY21				FY22				FY23				FY24				FY25			
		Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep
1	Assess land subsidence conditions, and develop monitoring plan for Mission Creek subbasin				X	X	X	X													
2	GPS Surveys in Indio and Mission Creek subbasins								X	X	X	X									
3	Analyze DWR-provided InSAR Results for Indio and Mission Creek subbasins												X	X	X	X					
4	Analyze Relation between changes in groundwater levels and land surface elevation at selected sites in the Indio and Mission Creek subbasins												X	X	X	X					
5	Provide technical assistance to CVWD and their contractors to add subsidence simulation capabilities to existing MODFLOW-2005 model												X	X	X	X					
6	Document results of Tasks 1-4																X	X	X	X	

PERSONNEL

The study will require a GS-14 hydrologist to supervise the program (Claudia Faunt), a GS-12 hydrologist (Michelle Sneed) and a GS-9 geophysicist (Justin Brandt) to execute the GPS surveys, process and interpret InSAR images, conduct analyses, provide technical support, and prepare the reports. In addition, several hydrologists/technicians will be needed for the GPS survey. The tasks will be conducted by project staff from San Diego and Sacramento. CVWD personnel (survey crew) will inspect and mark monuments in the Indio and Mission Creek subbasins as detailed in Tasks 1 and 2.

BUDGET SUMMARY

The total cost for the 4-year study is estimated to be $582,458. Subject to availability of Federal matching funds, the USGS will provide $98,220 for salaries, travel, and other miscellaneous project expenses. The CVWD would be responsible for providing $484,237 to complete the study. Costs for major study tasks are presented below (table 2). If the land subsidence assessment from Task 1a indicates that subsidence has not been documented or determined, and the geologic conditions are not conducive to subsidence, Tasks 2b, 3b, and 4b will not be performed, which would reduce the total cost of the project by about $133,000. Additionally, this budget assumes that 3 monuments will be built as part of Task 1b. If 6 monuments need to be built, the total cost for this task would increase by approximately $13,000. Costs for InSAR data are not included in this proposal, as we expect to have no-cost access to available InSAR data from the DWR (Benjamin Brezing, California Department of Water Resources, personal communication, May 11, 2021). Please be advised that costs are preliminary for the second, third, and fourth years of the study, as funding structures have not been developed for FFY2022-FFY2025.

Table 2: July 2021-June 2025 Budget

Task	Task Description	Agency	Year 1 July 1, 2021-June 30, 2022	Year 2 July 1, 2022-June 30, 2023	Year 3 July 1, 2023-June 30, 2024	Year 4 July 1, 2024-June 30, 2025	Task total (by agency)	Task total (combined)
1a	Assess subsidence in Mission Creek subbasin	CVWD	$25,322	$0	$0	$0	$25,322	$31,653
		USGS	$6,331	$0	$0	$0	$6,331	
1b	Develop monitoring plan for Mission Creek subbasin	CVWD	$32,198	$0	$0	$0	$32,198	$39,253
		USGS	$7,055	$0	$0	$0	$7,055	
2a	GPS Survey of 24 monuments in Indio subbasin to compute ellipsoid-height changes for 2015-22	CVWD	$0	$145,252	$24,178	$0	$169,430	$199,290
		USGS	$0	$23,816	$6,044	$0	$29,860	
2b	GPS Survey of 6-7 monuments in Mission Creek subbasin to establish elipsoid heights if stipulated in Task 1b	CVWD	$0	$89,519	$16,119	$0	$105,638	$122,700
		USGS	$0	$13,032	$4,030	$0	$17,062	
3a	Analyze DWR-provided InSAR Results for 2017-23 for the Indio subbasin	CVWD	$0	$0	$25,915	$0	$25,915	$32,394
		USGS	$0	$0	$6,479	$0	$6,479	
3b	Analyze DWR-provided InSAR Results for 2017-23 for the Mission Creek subbasin if stipulated in Task 1b	CVWD	$0	$0	$4,319	$0	$4,319	$5,399
		USGS	$0	$0	$1,080	$0	$1,080	
4a	Analyze relation between changes in groundwater levels and subsidence at selected sites in the Indio subbasin for 2015-23	CVWD	$0	$0	$37,282	$0	$37,282	$46,602
		USGS	$0	$0	$9,320	$0	$9,320	
4b	Analyze relation between changes in groundwater levels and subsidence at selected sites in the Mission Creek subbasin if stipulated in Task 1b	CVWD	$0	$0	$4,319	$0	$4,319	$5,399
		USGS	$0	$0	$1,080	$0	$1,080	
5	Provide technical assistance to CVWD and their contractors to add subsidence simulation capabilities to existing MODFLOW-2005 model	CVWD	$0	$0	$21,492	$0	$21,492	$26,865
		USGS	$0	$0	$5,373	$0	$5,373	
6	Document results of Tasks 1-4	CVWD	$0	$0	$0	$58,322	$58,322	$72,903
		USGS	$0	$0	$0	$14,581	$14,581	
Total by Year (CVWD)		CVWD	$57,520	$234,771	$133,624	$58,322	$484,237	
Total by Year (USGS)		USGS	$13,386	$36,848	$33,406	$14,581	$98,221	
GRAND TOTAL BY YEAR (CVWD + USGS)		CVWD + USGS	$70,906	$271,619	$167,030	$72,903	$582,458	
AGREEMENT TOTAL (CVWD + USGS)		CVWD + USGS	$582,458					