2019/20 Annual Report of the Ground-Level Monitoring Committee

FINAL REPORT
NOVEMBER 2020

Prepared for:
Ground-Level Monitoring Committee

Prepared by:

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Acronyms, Abbreviations, and Initialisms

af	Acre-ft
Ayala Park	Rubin S. Ayala Park
CCX	Chino Creek Extensometer Facility
DHX	Daniels Horizontal Extensometer
EDM	Electronic distance measurement
ft	Feet
ft-btoc	Feet below top of casing
GLMC	Ground-Level Monitoring Committee
GLMP	Ground-Level Monitoring Program
IMP	Management Zone 1 Interim Monitoring Program
InSAR	Interferometric synthetic aperture radar
MVWD	Monte Vista Water District
MZ-1	Chino Basin Optimum Basin Management Plan Management Zone 1
MZ-1 Plan	Management Zone 1 Subsidence Management Plan
OBMP	Optimum Basin Management Plan
PX	Pomona Extensometer Facility
SAR	Synthetic Aperture Radar
Subsidence Management Plan	2015 Chino Basin Subsidence Management Plan
USGS	United States Geological Survey
Watermaster	Chino Basin Watermaster
WEI	Wildermuth Environmental, Inc.
Work Plan	Work Plan to Develop a Subsidence Management Plan for the Northwest MZ-1

Section 1 – Introduction

This section describes background information on the history of land subsidence and ground fissuring in the Chino Basin, information on the formation of the Ground Level Monitoring Committee and its responsibilities, and a description of the development and implementation of the Management Zone 1 Subsidence Management Plan and the 2015 Chino Basin Subsidence Management Plan.

1.1 Background

In general, land subsidence is the sinking or settlement of the Earth's surface due to the rearrangement of subsurface materials. In the United States, over 17,000 square miles in 45 states have experienced land subsidence (United States Geologic Survey [USGS], 1999). In many instances, land subsidence is accompanied by adverse impacts at the ground surface, such as sinkholes, earth fissures, encroachment of adjacent water bodies, modified drainage patterns, and others. In populated regions, these subsidence-related impacts can result in severe damage to man-made infrastructure and costly remediation measures. Over 80 percent of the documented cases of land subsidence in the United States have been caused by groundwater extractions from the underlying aquifer-system (USGS, 1999).

For purposes of clarification in this document, subsidence refers to the inelastic deformation (i.e. sinking) of the land surface. The term inelastic typically refers to the permanent, non-recoverable deformation of the land surface or the aquifer-system. The term elastic typically refers to fully reversible deformation of the land surface or the aquifer-system. A glossary of terms and definitions discussed in this report as well as other terms related to basic hydrogeology and land subsidence is included in Section 5.

1.1.1 Subsidence and Fissuring in the Chino Basin

One of the earliest indications of land subsidence in the Chino Basin was the appearance of ground fissures within the City of Chino. These fissures appeared as early as 1973, but an accelerated occurrence of ground fissuring ensued after 1991 and resulted in damage to existing infrastructure. Figures 1-1 and 1-2 show the locations of these fissures. Scientific studies of the area have attributed the fissuring phenomenon to differential land subsidence caused by pumping of the underlying aquifer-system and the consequent drainage and compaction of aquitard sediments (Fife et al., 1976; Kleinfelder, 1993, 1996; Geomatrix, 1994; GEOSCIENCE, 2002).

1.1.2 The Optimum Basin Management Program

In 1999, the *Optimum Basin Management Program Phase I Report* (OBMP) identified the pumping-induced decline of hydraulic heads and subsequent aquifer-system compaction as the most likely cause of the land subsidence and ground fissuring observed in the Chino Basin OBMP Management Zone 1 (MZ-1; Wildermuth Environmental Inc. [WEI], 1999). Program Element 4 of the OBMP Implementation Plan, *Develop and Implement a Comprehensive Groundwater Management Plan for Management Zone 1*, called for the development and implementation of an interim management plan for MZ-1 that would:

1. minimize subsidence and fissuring in the short-term;
2. collect the information necessary to understand the extent, rate, and mechanisms of subsidence and fissuring; and
3. abate future subsidence and fissuring or reduce it to tolerable levels.

The OBMP called for an aquifer-system and land subsidence investigation in the southwestern region of MZ-1 to support the development of a management plan for MZ-1 (items 2 and 3 above). This investigation was titled the *MZ-1 Interim Monitoring Program* (IMP; WEI, 2003) and is described below.

The OBMP Phase I Report also identified that land subsidence was occurring in other parts of the basin besides in the City of Chino. Program Element 1 of the OBMP Implementation Plan, *Develop and Implement a Comprehensive Monitoring Program*, called for the initial collection of basin-wide data to characterize land subsidence, including ground-level surveys and remote-sensing (specifically, interferometric synthetic aperture radar or InSAR), and for the development of an ongoing monitoring program based on the analysis of the collected data.

1.1.3 Interim Management Plan and the MZ-1 Summary Report

From 2001 to 2005, the Chino Basin Watermaster (Watermaster) developed, coordinated, and conducted the IMP under the guidance of the MZ-1 Technical Committee. The MZ-1 Technical Committee was comprised of representatives from all major MZ-1 producers and their technical consultants, including the Agricultural Pool; the Cities of Chino, Chino Hills, Ontario, Pomona, and Upland; the Monte Vista Water District (MVWD); the Golden State Water Company; and the California Institution for Men.

The IMP consisted of three main monitoring elements for use in analyzing subsidence: ground-level surveys, InSAR, and aquifer-system monitoring. The ground-level surveys and InSAR analyses were used to characterize vertical ground motion. Aquifer-system monitoring of hydraulic and mechanical changes within the aquifer-system was used to characterize the causes of aquifer-system deformation.

The monitoring program was implemented in two phases: the Reconnaissance Phase and the Comprehensive Phase. The Reconnaissance Phase consisted of constructing 11 piezometers screened at various depths at Rubin S. Ayala Park (Ayala Park) in the City of Chino and installing pressure transducer data loggers in nearby pumping and monitoring wells to measure hydraulic head. Following installation of the monitoring network, several months of aquifer-system monitoring and testing were conducted. Testing included aquifer-system stress tests conducted at pumping wells in the area.

The Comprehensive Phase consisted of constructing a dual-borehole pipe extensometer at Ayala Park (Ayala Park Extensometer), near the area of historical fissuring. Following installation of the Ayala Park Extensometer, two aquifer-system stress tests were conducted, followed by passive aquifer-system monitoring.

During implementation of the IMP, Watermaster's Engineer (WEI) made the data available to the MZ-1 Technical Committee and prepared quarterly progress reports for the MZ-1 Technical

Committee, the Watermaster Pools and Board, and the Court.[1] The progress reports contained data and analyses from the IMP and summarized the MZ-1 Technical Committee meetings.

The main conclusions derived from the IMP were:

- Groundwater pumping from the deep and confined aquifer-system in the southwestern region of MZ-1 causes the greatest stress to the aquifer-system. In other words, pumping of the deep aquifer-system causes a hydraulic head decline that is much greater in magnitude and lateral extent than the hydraulic head decline caused by pumping of the shallow aquifer-system.
- Hydraulic head decline due to pumping from the deep aquifer-system can cause inelastic compaction of the aquifer-system sediments, which results in land subsidence. The initiation of inelastic compaction within the aquifer-system was identified during the investigation when hydraulic heads in the deep aquifer-system at the Ayala Park PA-7 piezometer fell below a depth of about 250 feet (ft).
- The state of aquifer-system deformation in southern MZ-1 was essentially elastic during the Reconnaissance Phase of the IMP. Very little inelastic compaction was occurring in this area, which contrasted with the recent past when about 2.2 ft of land subsidence occurred from about 1987 to 1995 and resulted in ground fissuring. Figure 1-1 shows the land surface deformation that was measured in the western Chino Basin and the wells that pumped during that period.
- During the development of the IMP, a previously unknown barrier to groundwater flow was identified, shown in Figures 1-1 and 1-2. The barrier was named the "Riley Barrier" after Francis S. Riley, a retired USGS geologist who first detected the barrier during the IMP. This barrier is located within the deep aquifer-system and is aligned with the historical zone of ground fissuring. Pumping from the deep aquifer-system was limited to the area west of the barrier, and the resulting hydraulic head decline did not propagate eastward across the barrier. Thus, compaction occurred within the deep aquifer-system on the west side of the barrier but not on the east side, which caused concentrated differential subsidence across the barrier and created the potential for ground fissuring.
- The InSAR and ground-level surveys indicated that subsidence in Central MZ-1 had occurred in the past and was continuing to occur. InSAR also suggested that the groundwater barrier (Riley Barrier) extends northward into Central MZ-1, as shown in Figure 1-1. These observations suggested that the conditions that very likely caused ground fissuring near Ayala Park in the 1990s were also present in Central MZ-1. However, there was not enough historical hydraulic head data in this area to confirm this relationship. The IMP recommended that, if subsidence continued or increased in Central MZ-1, the mechanisms causing the land subsidence should be studied in more detail.

The IMP provided enough information for Watermaster to develop Guidance Criteria for the Parties that pump from the southwestern region of MZ-1, that if followed, would minimize the potential for subsidence and fissuring in the investigation area. The methods, results, and

[1] San Bernardino County Superior Court, which retains continuing jurisdiction over the Chino Basin Judgment.

conclusions of the IMP, including the Guidance Criteria, were described in detail in the *MZ-1 Summary Report* (WEI, 2006).

The Guidance Criteria were:

1. The Managed Wells subject to the Guidance Criteria. Table 1-1 shows the list of Managed Wells with screens completed into the deep aquifer-system that are subject to the Guidance Criteria.
2. The spatial extent of the Managed Area. Figures 1-1 and 1-2 show the boundary of the Managed Area where the Guidance Criteria apply. Within the boundaries of the Managed Area, both existing (Table 1-1) and newly constructed wells are subject to being classified as Managed Wells. This area was delineated based on the observed and/or predicted effects of pumping on hydraulic heads and aquifer-system deformation. The Managed Well designations were based on the effects measured at the Ayala Park Extensometer during the IMP or well construction and borehole lithology.
3. A piezometric Guidance Level. The Guidance Level is a specified depth to water, as measured in feet below the top of the casing (ft-btoc) at the Ayala Park PA-7 piezometer. The initial Guidance Level was established as 245 ft-btoc. It was defined as the threshold hydraulic head level at the onset of inelastic compaction of the aquifer-system as recorded by the extensometer minus five feet. The five-foot reduction was meant to be a safety factor to ensure that inelastic compaction does not occur. The Guidance Level can be updated by Watermaster based on the periodic review of monitoring data.
4. Criteria for recommending pumping curtailment. If the hydraulic head level in PA-7 falls below the Guidance Level, Watermaster recommends that the MZ-1 Parties curtail their pumping from designated Managed Wells as required.
5. Real-time monitoring/reporting of head levels in PA-7. Watermaster was to provide the MZ-1 Parties with real-time hydraulic head level data from PA-7.
6. Reporting of pumping operations at Managed Wells. The MZ-1 Parties were requested to maintain and provide Watermaster with accurate records of operations at the Managed Wells, including pumping rates and on-off dates and times. The MZ-1 Parties were requested to promptly notify Watermaster of all operational changes made to maintain the hydraulic head level in PA-7 above the Guidance Level.
7. Request for ongoing monitoring at other monitoring wells. Watermaster recommended that the MZ-1 Parties allow it to continue to monitor hydraulic head levels at the Managed Wells.
8. Process for adapting the Guidance Criteria. Watermaster and Watermaster's Engineer were to evaluate the data collected as part of the MZ-1 Monitoring Program (now called the Ground-Level Monitoring Program or GLMP) after each fiscal year and determine if modifications, additions, and/or deletions to the Guidance Criteria were necessary. Changes to the Guidance Criteria could include additions or deletions to the list of Managed Wells, re-delineation of the Managed Area, raising or lowering of the Guidance Level, or additions and/or deletions to

the Guidance Criteria, including the need to have periods of hydraulic head level recovery.

9. Acknowledgement of uncertainty. Watermaster cautioned that some subsidence and fissuring could occur in the future, even if the Guidance Criteria were followed. Watermaster made no warranties that faithful adherence to the Guidance Criteria would eliminate subsidence or fissuring.

1.1.4 MZ-1 Subsidence Management Plan

The Guidance Criteria formed the basis for the *MZ-1 Subsidence Management Plan* (MZ-1 Plan; WEI, 2007), which was developed by the MZ-1 Technical Committee and approved by the Watermaster Board in October 2007. In November 2007, the Court approved the MZ-1 Plan and ordered its implementation.

To minimize the potential for future subsidence and fissuring in the Managed Area, the MZ-1 Plan codified the Guidance Level and recommended that the MZ-1 Parties manage their groundwater pumping such that the hydraulic head level in PA-7 remains above the Guidance Level.

The MZ-1 Plan called for ongoing monitoring, data analysis, annual reporting, and adjustments to the MZ-1 Plan, as warranted by the data. Implementation of the MZ-1 Plan began in 2008. The MZ-1 Plan called for the continued scope and frequency of monitoring implemented during the IMP within the Managed Area and expanded monitoring of the aquifer-system and land subsidence in other areas of the Chino Basin where the IMP indicated concern for future subsidence and ground fissuring. Figure 1-1 shows the location of these so-called Areas of Subsidence Concern: Central MZ-1, Northwest MZ-1, Northeast Area, and Southeast Area. The expanded monitoring efforts outside the Managed Area are consistent with the requirements of the OBMP Program Element 1 and its implementation plan contained in the Peace Agreement.[2]

Potential future efforts listed in the MZ-1 Plan included: 1) more intensive monitoring of horizontal strain across the zone of historical ground fissuring to assist in developing management strategies related to fissuring, 2) injection feasibility studies within the Managed Area, 3) additional pumping tests to refine the Guidance Criteria, 4) computer-simulation modeling of groundwater flow and subsidence, and 5) the development of alternative pumping plans for the MZ-1 Parties affected by the MZ-1 Plan. The MZ-1 Technical Committee (now called the Ground-Level Monitoring Committee or GLMC) discusses these potential future efforts, and if deemed prudent and necessary, they are recommended to Watermaster for implementation in future fiscal years.

1.1.5 2015 Chino Basin Subsidence Management Plan

The MZ-1 Plan stated that if data from existing monitoring efforts in the Areas of Subsidence Concern indicate the potential for adverse impacts due to subsidence, Watermaster would revise it to avoid those adverse impacts. The 2014 Annual Report of the GLMC recommended that the MZ-1 Plan be updated to better describe Watermaster's land subsidence efforts and obligations, including areas outside of MZ-1. As such, the update included a name change to

[2] http://www.cbwm.org/rep_legal.htm.

the 2015 Chino Basin Subsidence Management Plan (Subsidence Management Plan; WEI 2015a) and a recommendation to develop a subsidence management plan for Northwest MZ-1.

Watermaster had been monitoring vertical ground motion in Northwest MZ-1 via InSAR during the development of the MZ-1 Plan. Land subsidence in Northwest MZ-1 was first identified as a concern in 2006 in the MZ-1 Summary Report and again in 2007 in the MZ-1 Plan. Of particular concern, the subsidence across the San Jose Fault in Northwest MZ-1 has occurred in a pattern of concentrated differential subsidence—the same pattern of differential subsidence that occurred in the Managed Area during the time of ground fissuring. Ground fissuring is the main subsidence-related threat to infrastructure. The issue of differential subsidence, and the potential for ground fissuring in Northwest MZ-1, has been discussed at prior GLMC meetings, and the subsidence has been documented and described as a concern in Watermaster's State of the Basin Reports, the annual reports of the GLMC, and in the *Initial Hydrologic Conceptual Model and Monitoring and Testing Program for the Northwest MZ-1 Area* (WEI, 2017). Watermaster increased monitoring efforts in Northwest MZ-1 beginning in FY 2012/13 to include ground elevation surveys and electronic distance measurements (EDM) to monitor ground motion and the potential for fissuring.

In 2015, Watermaster's Engineer developed the *Work Plan to Develop a Subsidence Management Plan for the Northwest MZ-1 Area* (Work Plan; WEI 2015b). The Work Plan is characterized as an ongoing Watermaster effort and includes a description of a multi-year scope-of-work, a cost estimate, and an implementation schedule. The Work Plan was included in the Subsidence Management Plan as Appendix B. Implementation of the Work Plan began in July 2015.

The updated Subsidence Management Plan also addressed the need for hydraulic head "recovery periods" in the Managed Area by recommending that all deep aquifer-system pumping cease for a continuous six-month period between October 1 and March 31 of each year within the Managed Area. And, the Subsidence Management Plan recommends that every fifth year, all deep aquifer-system pumping cease for a continuous period until the hydraulic head at PA-7 reaches "full recovery" of 90 ft-btoc. These periodic cessations of pumping are intended to allow for sufficient hydraulic head recovery at PA-7 to recognize inelastic compaction, if any, at the Ayala Park Extensometer.

1.1.6 Annual Report of the Ground-Level Monitoring Committee

Pursuant to the Subsidence Management Plan, Watermaster will produce an annual report, containing the results of ongoing monitoring efforts, interpretations of the data, and recommended adjustments to the Subsidence Management Plan, if any. This annual report of the GLMC includes the results and interpretations for the data collected between March 2019 through March 2020 as well as recommendations for Watermaster's GLMP for FY 2020/21.

1.2 Report Organization

This report is organized into the following six sections:

Section 1 – Introduction. This section provides background information on the history of land subsidence and ground fissuring in Chino Basin, information on the formation of the GLMC and its responsibilities, and a description of the development and implementation of the Subsidence Management Plan, which calls for annual reporting.

Section 2 – Ground-Level Monitoring Program. This section describes the monitoring and testing activities performed by Watermaster for its GLMP between March 2019 and March 2020.

Section 3 – Results and Interpretations. This section discusses and interprets the monitoring data collected between March 2019 and March 2020, including basin stresses (groundwater pumping and recharge) and responses (changes in hydraulic heads, aquifer-system deformation, and ground motion).

Section 4 – Conclusions and Recommendations. This section summarizes the main conclusions derived from the monitoring program between March 2019 and March 2020 and describes recommended activities for the GLMP for FY 2020/21.

Section 5 – Glossary. This section is a glossary of the terms and definitions utilized within this report and in discussions at GLMC meetings.

Section 6 – References. This section lists the publications and reports cited in this report.

Table 1-1

Managed Wells Screened in the Deep Aquifer and Subject to the Guidance Criteria*

Well Name	CBWM ID	Owner	2017 Status	Well Screen Interval(s) *ft-bgs*
CIM-11A**	3602461	California Institution for Men	Active	174-187; 240-283; 405-465
C-7	3600461	City of Chino	Abandoned	180-780
C-15	600670	City of Chino	Inactive	270-400; 626-820
CH-1B	600487	City of Chino Hills	Inactive	440-470; 490-610; 720-900; 940-1,180
CH-7C	600687	City of Chino Hills	Abandoned	550-950
CH-7D	600498	City of Chino Hills	Destroyed	320-400; 410-450; 490-810; 850-930
CH-15B	600488	City of Chino Hills	Inactive	360-440; 480-900
CH-16	600489	City of Chino Hills	Inactive	430-940
CH-17	600499	City of Chino Hills	Active	300-460; 500-680
CH-19	600500	City of Chino Hills	Abandoned	300-460; 460-760; 800-1,000

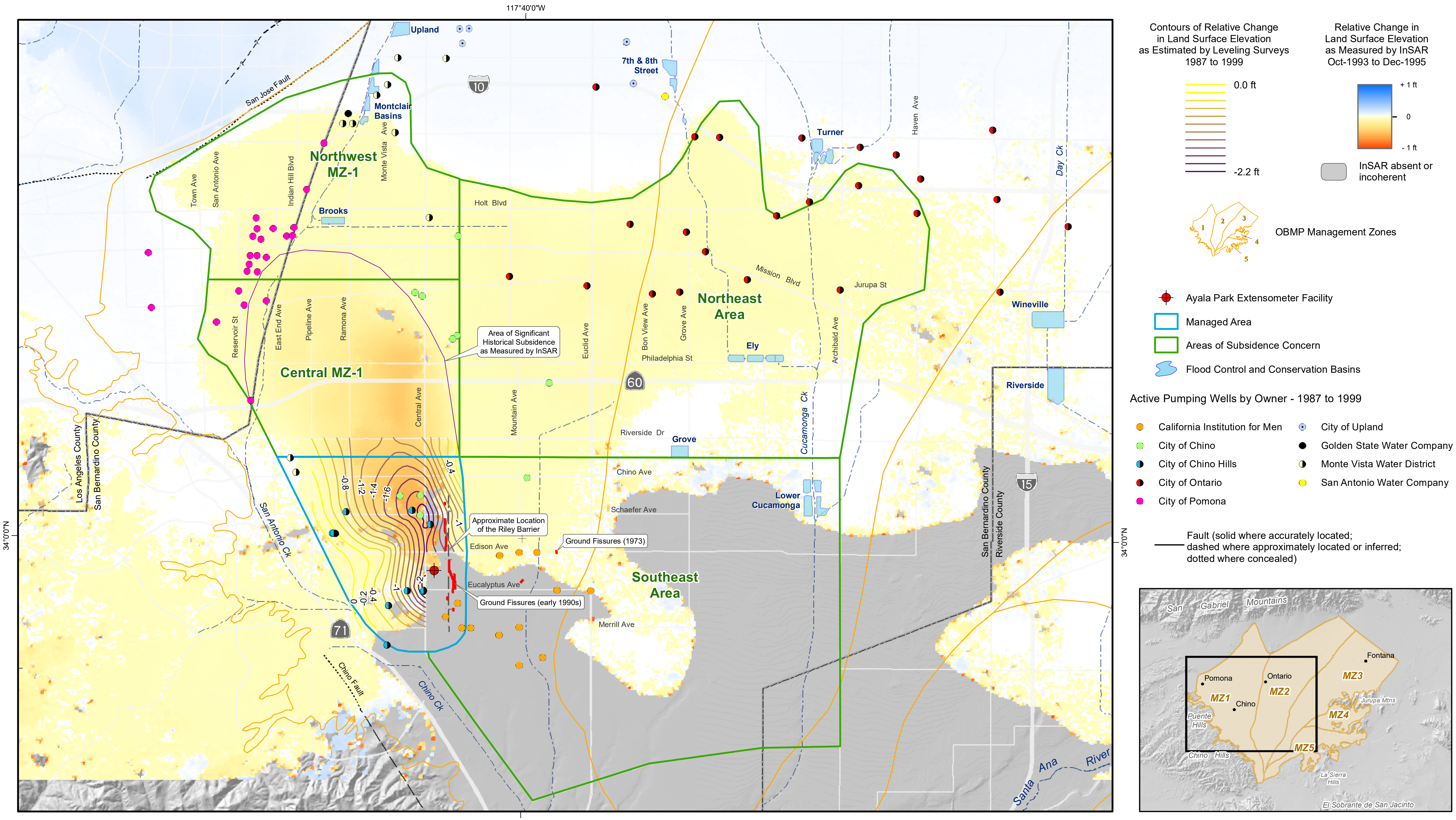
*The MZ-1 Subsidence Management Plan identified the Managed Wells that are subject to the Guidance Criteria for the Managed Area that, if followed, would minimize the potential for subsidence and fissuring.

**The original casing was perforated from 135-148, 174-187, 240-283, 405-465, 484-512, and 518-540 ft-bgs. This casing collapsed below 471 ft-bgs in 2011. A liner was installed to 470 ft-bgs with a screen interval from 155 to 470 ft-bgs.

Active = Well is currently being used for water supply

Inactive = Well can pump groundwater with little or no modifications

Abandoned = Unable to pump the well without major modifications



WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: RT
Date Saved: 7/9/2020
Document Name: Figure_1-1_2019_20

0 1 2 3 Miles
0 1 2 3 Kilometers

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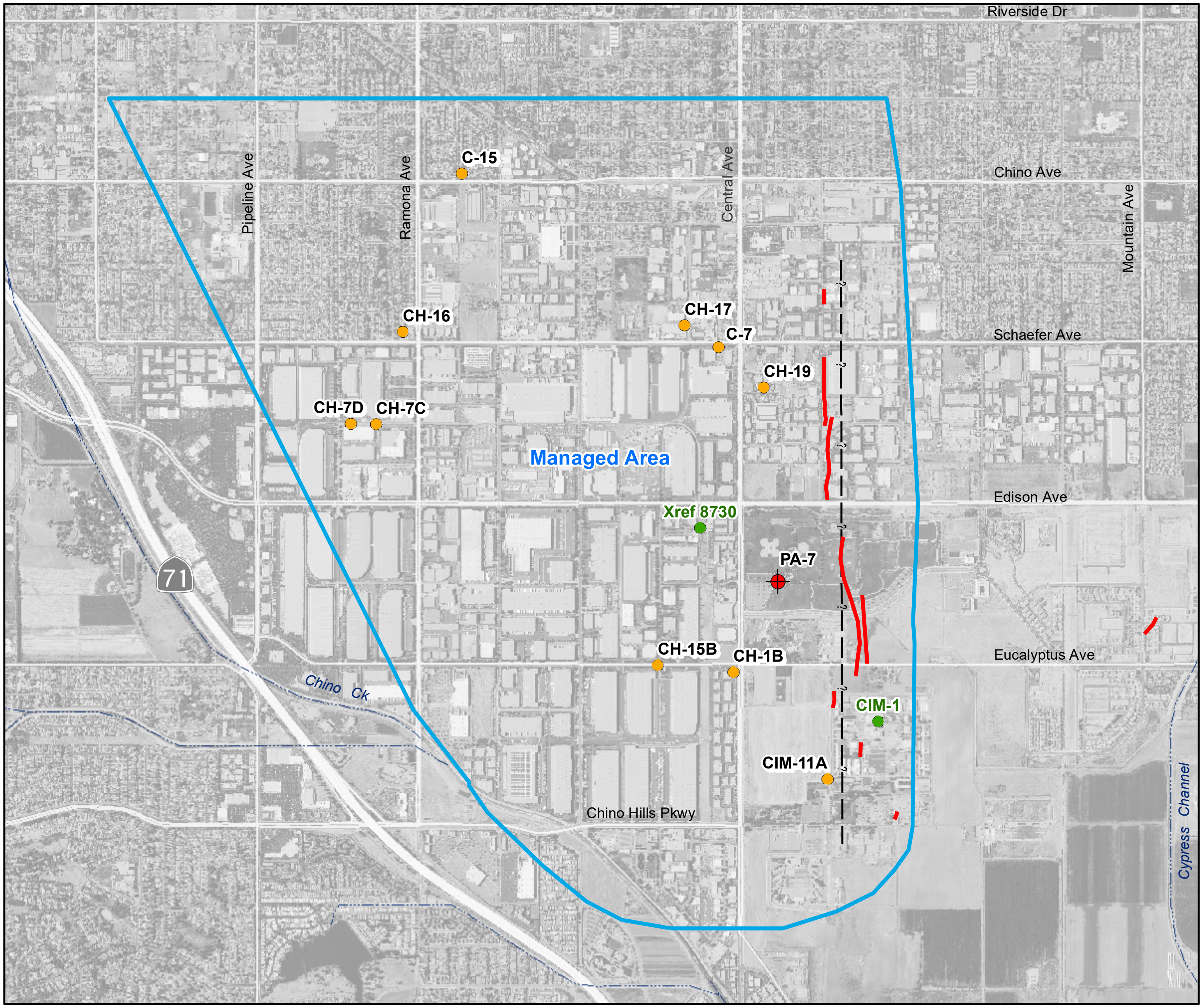
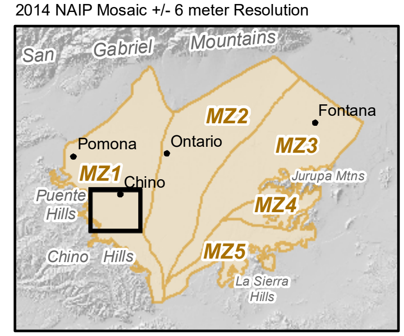
Historical Land Surface Deformation in Management Zone 1
1987-1999

Figure 1-1



Managed Area
Ayala Park Extensometer Facility
Managed Well
Other Production Well
Ground Fissures
Groundwater Barrier (Riley Barrier) approximate location

2014 NAIP Mosaic +/- 6 meter Resolution



WEI
Wildermuth Environmental, Inc.

Author: RT
Date Saved: 7/9/2020
Document Name: Figure_1-2_2019_20

0 0.5 1 Miles
0 0.5 1 Kilometers

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MZ-1 Managed Area and the Managed Wells

Figure 1-2

Section 2 – Ground-Level Monitoring Program

This section describes the activities performed by Watermaster for the GLMP between March 2019 and March 2020.

Figure 2-1 shows the groundwater pumping and recharge facilities in the western Chino Basin that impart pumping and recharge stresses to the aquifer-system. Figure 2-2 shows the locations of the monitoring facilities in Watermaster's ground-level monitoring network, including wells equipped with pressure-transducer data loggers that measure hydraulic heads, extensometers that measure vertical aquifer-system deformation, and benchmark monuments that are used to perform ground elevation and EDM surveys to measure vertical and horizontal deformation of the ground surface.

2.1 Ground-Level Monitoring Program

Watermaster conducts its GLMP in the Managed Area and other Areas of Subsidence Concern pursuant to the Subsidence Management Plan and the recommendations of the GLMC. The GLMP activities performed between March 2019 and July 2020 are described below.

2.1.1 Setup and Maintenance of the Monitoring Facilities Network

- Performed routine maintenance at the Ayala Park, Chino Creek, and Pomona Extensometer Facilities.

Specific to the Pomona Extensometer Facility (PX), the following activities were performed:

- The cable extensometer's mechanical components were fabricated and installed in May 2020.
- All devices used to monitor piezometric (pressure transducers) and aquifer-system deformation (linear potentiometers and vibrating wireline transducers) and data loggers were installed between June and September 2020.
- Dead-band testing at each cable extensometer was conducted on July 1, 2020. Dead-band testing was conducted to quantify the frictional properties of an extensometer, characterize its overall performance, develop confidence in the reliability of the record, and to refine the ideal counter-weight amount (Riley, 1986).

2.1.2 Monitoring Activities

Changes in hydraulic heads are caused by the stresses of groundwater pumping and recharge. Changes in hydraulic heads are the mechanism behind aquifer-system deformation, which in turn causes vertical and horizontal ground motion. Because of these cause-and-effect relationships, Watermaster monitors groundwater pumping, recharge, hydraulic heads, aquifer-system deformation, and vertical and horizontal ground motion across the western portion of the Chino Basin. The following sub-sections (2.1.2.1 through 2.1.2.4) describe Watermaster's monitoring activities between March 2019 and March 2020, as called for by the Subsidence Management Plan and in accordance with the recommendations of the GLMC.

2.1.2.1 Monitoring of Pumping, Recharge, and Piezometric Levels

Watermaster collects and compiles groundwater pumping data on a quarterly basis from well owners in the Managed Area and Areas of Subsidence Concern. The well locations that pumped groundwater between March 2019 and March 2020 are shown in Figure 2-1.

Watermaster collects data from the Inland Empire Utilities Agency on the volumes of imported water, stormwater, and recycled water that are artificially recharged at spreading basins, and the volumes of recycled water for direct use within the Chino Basin.

Hydraulic heads were measured and recorded once every 15 minutes using pressure transducer data loggers maintained by Watermaster at approximately 102 wells across the Managed Area and Areas of Subsidence Concern. Figure 2-2 shows the locations of these wells. Also, Watermaster staff and well owners typically measure hydraulic heads at other wells in western Chino Basin monthly.

2.1.2.2 Monitoring Vertical Aquifer-System Deformation

Watermaster measured and recorded the vertical component of aquifer-system deformation at the Ayala Park and the Chino Creek Extensometer Facilities once every 15 minutes.

2.1.2.3 Monitoring Vertical Ground Motion

Watermaster monitored vertical ground motion via ground-level surveys using InSAR and traditional leveling techniques.

For InSAR, Watermaster retained Neva Ridge Technologies, Inc. (now General Atomics) to acquire and post-process land-surface displacement data from the TerraSAR-X satellite operated by the German Aerospace Center. The width of the TerraSAR-X data frame covers the western half of the Chino Basin only.[3] Seven synthetic aperture radar (SAR) scenes were collected between March 2019 and March 2020. The scenes were used to create ten interferograms[4] to estimate short- and long-term vertical ground motion[5] over the following periods:

[3] All historical InSAR data that were collected and analyzed by Watermaster from 1993 to 2010 indicate that very little vertical ground motion occurred in the eastern half of the Chino Basin. In 2012, the GLMC decided to acquire and analyze InSAR only in the western portion of the Chino Basin as a cost-saving strategy.

[4] Two or more SAR scenes are used to generate grids of surface deformation (interferograms) over a given period. Typically, surfaces within a pixel will move up or down together as would be expected in recovery/subsidence scenarios. However, surfaces within the area of a pixel can move randomly and cause decorrelation in the radar signal. Examples of random motion within a pixel area are vegetation growing, urbanization, erosion of the ground surface, harvesting crops, plowing fields, and others. The magnitude of this decorrelation in the signal is measured mathematically and called incoherence. Based on the magnitude of decorrelation in an area, pixels will be rejected as “incoherent.”

[5] Several factors can influence the accuracy of ground motion results as estimated by InSAR, such as satellite orbital uncertainties and atmospheric interference. On average, accuracy of ground motion results as estimated by InSAR are +/- 0.02 ft.

2019/20 Interferograms	Long-Term Interferograms
March 2019 to April 2019	March 2011 to March 2020
March 2019 to May 2019	March 2019 to February 2020
March 2019 to July 2019	March 2019 to March 2020
April 2019 to May 2019	
May 2019 to July 2019	
July 2019 to February 2020	
February 2020 to March 2020	

According to General Atomics (Sean Yarborough, personal communication, September 3, 2020), this year's InSAR results were generated using a new processing method which allowed for estimates of vertical ground motion in areas that were previously incoherent. These areas included portions of the Southeast Area and the southeastern portions of the Northeast Area.

A brief description of the new processing technique and the impact the processing technique had on estimates of vertical ground motion across the western Chino Basin between 2011 and 2020 has been provided by General Atomics and is summarized below:

1. Tight filters[6] were applied to portions of the interferograms with higher overall coherence to preserve the shape and depth of smaller ground motion signals. Broad filters were used to retain and enhance ground motion trends in less coherent interferograms.

2. Intermittent coherence within agricultural and/or wildland (or open space) areas often result in a widespread loss of ground motion estimates, despite visible trends. Intermittently coherent points were interpolated in each interferogram.

The primary areas where the filters were applied (see No. 1 above) were agriculture and/or open-space areas in portions of the Southeast Area and the southeastern portions of the Northeast Area. The trade-off with using tight or broad filter sizes is that tight filters preserve the fine spatial detail of the ground motion in an area but creates noise in low coherence areas; and, broad filters preserve overall ground motion trends but obscure the fine spatial details in the shape and displacement of the ground motion. Prior processing methods heavily favored one or the other approach. This year's InSAR delivery is an evolution, selecting an appropriate filter based on the coherence of specific agricultural and/or open-space areas in each frame.

The intermittent coherence described in No. 2 above appeared in certain areas in western Chino Basin with coherent points that had a clear spatial trend and a small handful of randomly incoherent points. With previous processing methods, once a point becomes incoherent and if no further spatial processing is performed, ground motion estimates at that location are lost moving forward in time, even if the point becomes coherent in the next interferogram and remains coherent indefinitely thereafter. A region with widespread intermittent coherence becomes completely masked over time as each point experiences a brief period of incoherence,

[6] Filters are used to smooth the ground motion measurements by reducing the standard deviation of the pixels in a given area. Filters can differ in overall size (areal extent), smoothing shape (flat, triangle, Gaussian, etc.) and strength (enforcement).

even if its neighbors continue showing a clear trend. With the new processing techniques, these neighboring points are used to interpolate across intermittently incoherent points in order to preserve the overall ground motion estimate through time.

For the ground level surveys, Watermaster retained Guida Surveying, Inc. to conduct traditional leveling surveys at selected benchmark monuments in the western part of the Chino Basin. The table below shows the number of benchmark monuments that were surveyed within each ground-level survey area. The locations of the ground-level survey areas are shown in Figure 2-2.

Ground-Level Survey Area	Date of Most Recent Survey	Number of Benchmarks Surveyed
Managed Area*	January 2018	22
Central Area*	January 2018	14
Northwest Area	April 2020	26
San Jose Fault Zone Area	April 2020	10
Southeast Area*	January 2018	77
Northeast Area	April 2020	68

* The entire benchmark monument survey network for the ground-level survey area was not surveyed in 2020 based on the GLMC scope and budget recommendations for FY 2019/20.

2.1.2.4 Monitoring of Horizontal Ground Motion

Watermaster measures horizontal ground motion between benchmarks across areas that are susceptible to ground fissuring via EDMs. The EDMs were performed between the benchmarks located within the San Jose Fault Zone Area (Figure 2-2). The number of benchmark surveyed are shown in the table below.

Ground-Level Survey Area	Date of Most Recent Survey	Number of Benchmarks Surveyed
Fissure Zone Area*	February 2018	66
San Jose Fault Zone Area	April 2020	10

*EDMs across the Fissure Zone Area were not conducted in 2019 based on GLMC scope and budget recommendations for FY 2019/20.

2.2 Land-Subsidence Investigations

Watermaster performs land subsidence investigations pursuant to the Subsidence Management Plan, the recommendations of the GLMC for the GLMP, and the annually approved Watermaster budget. Investigations can include aquifer-stress tests (e.g. pumping and injection) and the simultaneous monitoring of hydraulic heads, aquifer-system deformation, and deformation of the ground surface. The goals of these investigations are to refine the Guidance Criteria and assist in the development of subsidence management plans to minimize or abate land subsidence and maximize the prudent extraction of groundwater.

This section describes the land subsidence investigations conducted between March 2019 and March 2020 that are called for by the Subsidence Management Plan.

2.2.1 Long-Term Pumping Test in the Managed Area

The GLMC developed the Long-Term Pumping Test in the Managed Area in response to the directives in the Subsidence Management Plan. The goal of the Long-Term Pumping Test is to develop a strategy for the prudent extraction of groundwater from the Managed Area. In this case, "prudent" is defined as extracting the maximum volume of groundwater possible without causing damage to the ground surface or the area's infrastructure. The test was specifically designed to answer:

1. Is the Guidance Level for the Managed Area, as currently defined, appropriate? If not, how should the Guidance Level be updated?
2. Does the Riley Barrier separate the Managed Area from the Southeast Area within the deep aquifer-system? If not, should the eastern boundary of the Managed Area be revised?
3. How does the recoverable and inelastic aquifer-system deformation that occurs in the Managed Area affect the horizontal strain across the historical zone of ground fissuring and its northward extension into the heavily urbanized portions of the City of Chino?
4. Is aquifer injection a viable tool for mitigating the decline of hydraulic heads and preventing inelastic compaction in the deep aquifer-system?
5. Is there an "acceptable" rate of subsidence in the Managed Area? If so, what is the "acceptable" rate?

Figure 1-2 shows the locations of the wells to be included in the Long-Term Pumping Test. The GLMC envisioned the following scope and sequence for the Long-Term Pumping Test:

1. Conduct a controlled pumping test of the deep aquifer-system in the Managed Area at wells CH-17 and CH-15B. This test should cause the hydraulic head at PA-7 to fall below the Guidance Level and may cause a small amount of subsidence.[7] The test will be closely monitored at the Ayala Park Extensometer Facility and will be stopped at the first indication of inelastic compaction. Hydraulic heads recorded at 15-minute intervals at PA-7 will be updated every three hours on Watermaster's website. When the hydraulic heads decline to within 20 ft of the Guidance Level, data from the Ayala Park Extensometer Facility will be downloaded and used to prepare a stress-strain diagram. The stress-strain diagram will be distributed promptly to the GLMC by e-mail. Watermaster staff and the Watermaster Engineer will remain in close telephonic contact with staff at the City of Chino, the City of Chino Hills, and the California Institution for Men to review and interpret the stress-strain diagram, to plan for the preparation of the next stress-strain diagram, or to decide to stop the test when appropriate.
2. Stop the pumping test and allow for the partial recovery of hydraulic heads.

[7] The aquifer-system stress testing in 2004-05 resulted in about 0.01 feet of non-recoverable compaction and associated land subsidence (WEI, 2006). The Long-Term Pumping Test may cause a similar small amount of subsidence. This small amount of subsidence is far less (three orders of magnitude) than the >2 ft of subsidence that occurred from 1987 to 1995 when ground fissures opened in the City of Chino and is much less (one order of magnitude) than the +/- 0.1 ft of elastic vertical ground motion that occurs seasonally in this area.

3. Conduct two cycles of injection at CH-16 to see how injection accelerates the recovery of the regional hydraulic heads that were lowered by pumping at CH-17 and CH-15B.[8] After the injection tests, allow for full recovery of hydraulic heads at PA-7 to pre-test conditions.

4. Conduct ground-level surveys, InSAR monitoring, and EDM surveys to measure vertical and horizontal ground motion across the Managed Area before, during, and after the test. Collect piezometric and aquifer-system deformation data at the Ayala Park Extensometer Facility once every 15 minutes throughout the test.

5. Check the stress-strain diagrams from the Ayala Park Extensometer Facility for inelastic compaction of the aquifer-system in the Managed Area. Analyze ground-level survey, InSAR, and EDM data for inelastic horizontal and vertical ground deformation within the Managed Area.

As of July 2020, the City of Chino Hills (M. Wiley, personal communication, July 9, 2020) reported the Long-Term Pumping test will not be completed in FY 2020/21 due to mechanical issues at CH-15B and 1,2,3-trichloropropane (TCP) and per- and polyfluoroalkyl substances (PFAS) contamination in CH-15B and CH-17. Injection at CH-16 will also likely not occur in FY 2020/21.

2.2.2 Analysis of EDM Measurements Across the Fissure Zone and San Jose Fault Zone

The Subsidence Management Plan calls for the Watermaster to monitor horizontal ground motion across areas that are susceptible to ground fissuring. Historically, this monitoring has occurred via EDMs and with the Daniels Horizontal Extensometer (DHX). The DHX was decommissioned and removed in 2015 because the site was developed. The GLMC annually recommends the scope and frequency of EDM surveys. The 2016 Annual Report of the GLMC included an in-depth review of horizontal strain that had occurred over time and measured from EDM data across the Fissure Zone to assess if the EDM data can be used in-lieu of the horizontal extensometer data collected at the DHX. Based on the review of EDM data between closely spaced benchmarks in the Fissure Zone Area, the EDM method appears to be a suitable monitoring technique to detect the occurrence of tensile strain within shallow soils and the potential threat of ground fissuring. Additionally, the 2016 Annual Report recommended that if permanent subsidence is absent in the Managed Area, the GLMC should consider performing EDM surveys across the Fissure Zone at a frequency greater than annual and performing EDM surveys in coordination with the Long-Term Pumping Test in the Managed Area. In 2020, the EDM survey across the Fissure Zone in the Managed Area was not conducted based on the GLMC scope and budget recommendations for FY 2019/20.

[8] The City of Chino Hills is conducting an injection feasibility study at CH-16 as part of the Long-Term Pumping Test. The study will help determine if aquifer injection is a viable tool to manage subsidence within the Managed Area while maximizing the use of existing infrastructure (i.e. wells). The study includes the conversion CH-16 to an aquifer storage and recovery well and pilot testing well. Watermaster assisted the City of Chino Hills in applying for and acquiring a Local Groundwater Assistance grant from the DWR to partially fund the study. Watermaster also assisted with a cost-share contribution of $368,000 to execute the study. As of the end of 2016, Chino Hills completed modifications to well CH-16 to convert it to an ASR well and completed connections to a potable water supply pipeline.

Like the benchmark network in the Fissure Zone in the Managed Area, a series of closely spaced benchmarks were installed across the San Jose Fault Zone in Northwest MZ-1. These benchmarks were installed along San Bernardino and San Antonio Avenues to measure horizontal strain across the fault zone. EDM surveys have been performed in this area each year since 2014.

2.2.3 Subsidence Management Plan for Northwest MZ-1

In 2015, the GLMC developed the final Work Plan to develop a subsidence-management plan for Northwest MZ-1, which describes a multi-year effort with cost estimates to execute the Work Plan. The Work Plan was included in the Subsidence Management Plan as Appendix B.[9] The background and objectives of the Work Plan are described in Section 1.1.5. Watermaster began implementation of the Work Plan in July 2015. The following describes the Work Plan tasks and current status of each task:

Task 1 Describe Initial Hydrogeologic Conceptual Model and Monitoring and Testing Program – A final report was submitted to the GLMC and Watermaster in December 2017 that summarized the current state of knowledge of the hydrogeology of Northwest MZ-1, the data gaps needed to be filled to fully describe the occurrence and mechanisms of aquifer-system deformation and the pre-consolidation stress, and a strategy to fill the data gaps.

Task 2 Implement the Initial Monitoring and Testing Program – Watermaster's Engineer worked with the Watermaster, the MVWD, the City of Pomona, and SCADA Integrations, Inc. to identify and equip a set of wells with supervisory control and data acquisition monitoring capabilities and/or pressure transducers. Through several field visits and technical meetings with the well owners, a protocol was developed to install monitoring equipment and collect pumping and piezometric data. For the City of Pomona, nine wells were equipped with pressure transducers. For MVWD, seven wells were equipped with pressure transducers, two wells with sonar units, and two wells with air-line units. Hydraulic heads are recorded once every 15 minutes. Nine of the 11 MVWD wells were connected to the MVWD's existing SCADA system. The hydraulic head data from these wells are currently being collected and analyzed as part of the Northwest MZ-1 monitoring and testing program for FY 2020/21.

Task 3 Develop and Evaluate the Baseline Management Alternative and Task 4 Develop and Evaluate the Initial Subsidence-Management Alternative – A final technical memorandum was submitted to the GLMC and Watermaster in December 2017 that described the construction, calibration, and use of a numerical one-dimensional aquifer-system compaction model in Northwest MZ-1, an area that has experienced gradual and persistent subsidence for decades (WEI, 2017b). The objective of this memo was to explore the future occurrence of subsidence in Northwest MZ-1 under various basin-operation scenarios of groundwater pumping and artificial recharge and to identify potential subsidence mitigation strategies.

Task 5 Design and Install the Pomona Extensometer Facility – Watermaster completed construction of two dual-nested piezometers located in Montvue Park, Pomona, CA in August 2019. Each PX piezometer was equipped with pressure transducer dataloggers and cable

[9] http://www.cbwm.org/rep_engineering.htm

extensometers in June and July 2020. PX is anticipated to be fully tested and operational by fall 2020.

Task 6 Design and Conduct Aquifer-System Stress Tests (if necessary) – The objective of this task is to perform controlled aquifer-system stress tests at pumping wells in Northwest MZ-1 and to monitor the depth-specific hydraulic head and aquifer-system deformation response at PX. This information, along with hydraulic head data collected as part of Task 2 will be used to help identify the subsidence mechanisms and the pre-consolidation stress(es) in Northwest MZ-1. The testing program will have a duration of one year and will start once the PX monitoring equipment (i.e. pressure transducers and cable extensometers) are installed, functional, and tested.

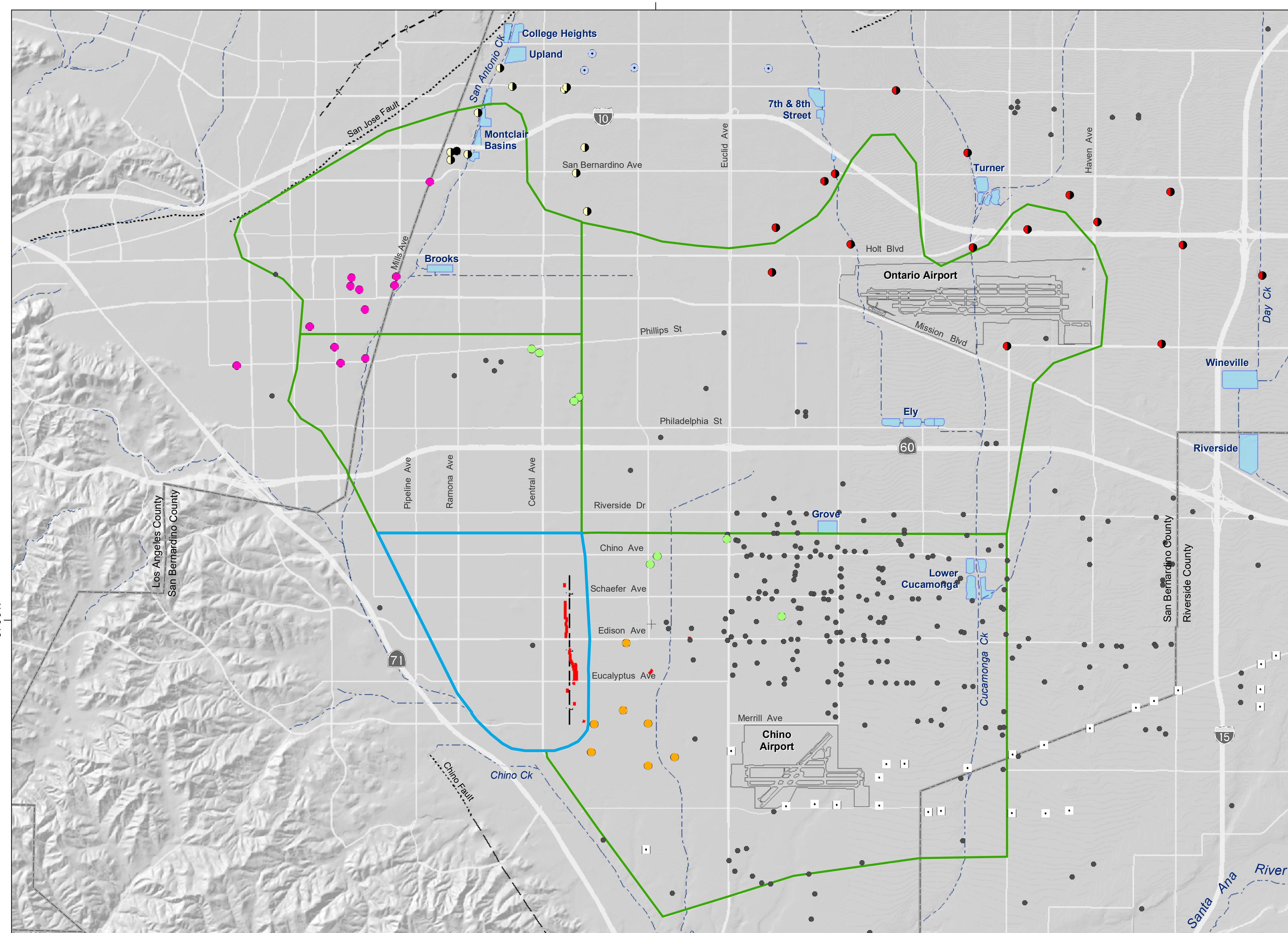
Task 7 Update the Hydrogeologic Conceptual Model – The objective of this task is to update the hydrogeologic conceptual model of Northwest MZ-1 based on an improved understanding from monitoring at PX and in Northwest MZ-1. The numerical one-dimensional aquifer-system compaction constructed in Tasks 3 and 4 will be updated and calibrated to represent the aquifer-system at PX. The model will be used to refine the hydraulic and mechanical property estimates of the aquifer-system and the pre-consolidation stress. This task will be completed in FY 2020/21.

Task 8 Update the Chino Basin Groundwater Model – The objective of this task is to update Watermaster's groundwater modeling tools to support the development and evaluation of subsequent subsidence-management alternatives. The layering and aquifer properties in the Watermaster's current groundwater model have been updated as part of the 2020 Chino Basin Safe Yield Recalculation. The 2020 groundwater model will be updated to include a subsidence package so it can be used to simulate subsidence across Northwest MZ-1 and the western Chino Basin under future basin management activities. New information and understanding derived in Task 7 will be used to update the 2020 groundwater model. This task is estimated be completed in FY 2020/21.

Task 9 Refine and Evaluate Subsidence-Management Alternatives – The objective of this task is to develop up to three additional subsidence-management alternatives that will minimize or abate the ongoing subsidence in Northwest MZ-1. Using new information on the subsidence mechanisms and the pre-consolidation stress and the results of the Initial Subsidence-Management Alternative, a new method to increase and hold hydraulic heads at the estimated pre-consolidation stress will be described and called Subsidence-Management Alternative 2 (SMA-2).

The assumptions of SMA-2, including the groundwater pumping and replenishment plans of the Chino Basin parties, will be described and agreed upon by the GLMC. The updated Chino Basin groundwater model will be used to characterize the basin response to the SMA-2, its ability to raise and hold hydraulic heads above the pre-consolidation stress, and its ability to minimize or abate the ongoing subsidence in Northwest MZ-1. Up to two additional subsidence-management alternatives will be developed and evaluated in the same fashion as SMA-2. This task is estimated to be completed in FY 2020/21 but is contingent on the successful completion of Tasks 8 and 9.

Task 10 Update the Chino Basin Subsidence Management Plan – The objective of this task is to incorporate the preferred subsidence-management alternative for Northwest MZ-1 into the Chino Basin Subsidence Management Plan. An implementation plan will be prepared as part of this effort. The implementation plan will require review and approval by the GLMC and the Watermaster Pools, Advisory Committee, and Board. Watermaster will apprise the Court of revisions to the plan as part of its OBMP implementation status reporting. The Updated Chino Basin Subsidence Management Plan is anticipated to be completed by the end of FY 2021/22.

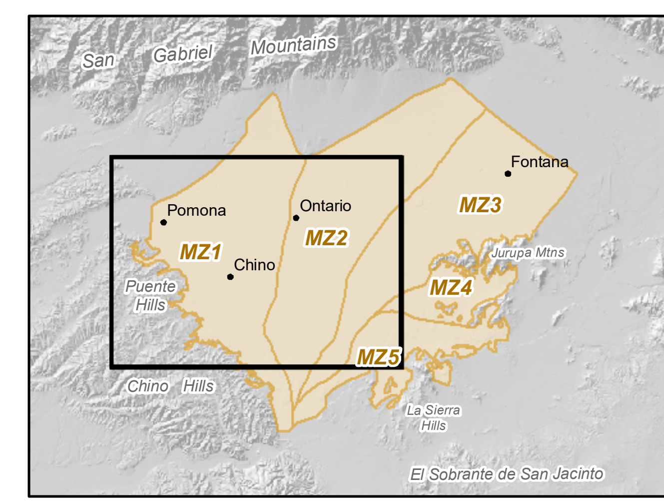


Active Groundwater Pumping Wells
April 1, 2019 to March 31, 2020

- Private
- California Institution for Men
- Chino Basin Desalter Authority
- City of Chino
- City of Chino Hills *
- City of Ontario
- City of Pomona
- City of Upland
- Golden State Water Company
- Monte Vista Water District

*Zero groundwater pumping reported to Watermaster between April 1, 2019 and March 31, 2020.

- Managed Area
- Areas of Subsidence Concern
- Flood Control and Conservation Basins
- Ground Fissures
- Approximate Location of the Riley Barrier
- Fault (solid where accurately located; dashed where approximately located or inferred; dotted where concealed)



WEI
Wildermuth Environmental, Inc.

Author: RT
Date: 9/10/2020
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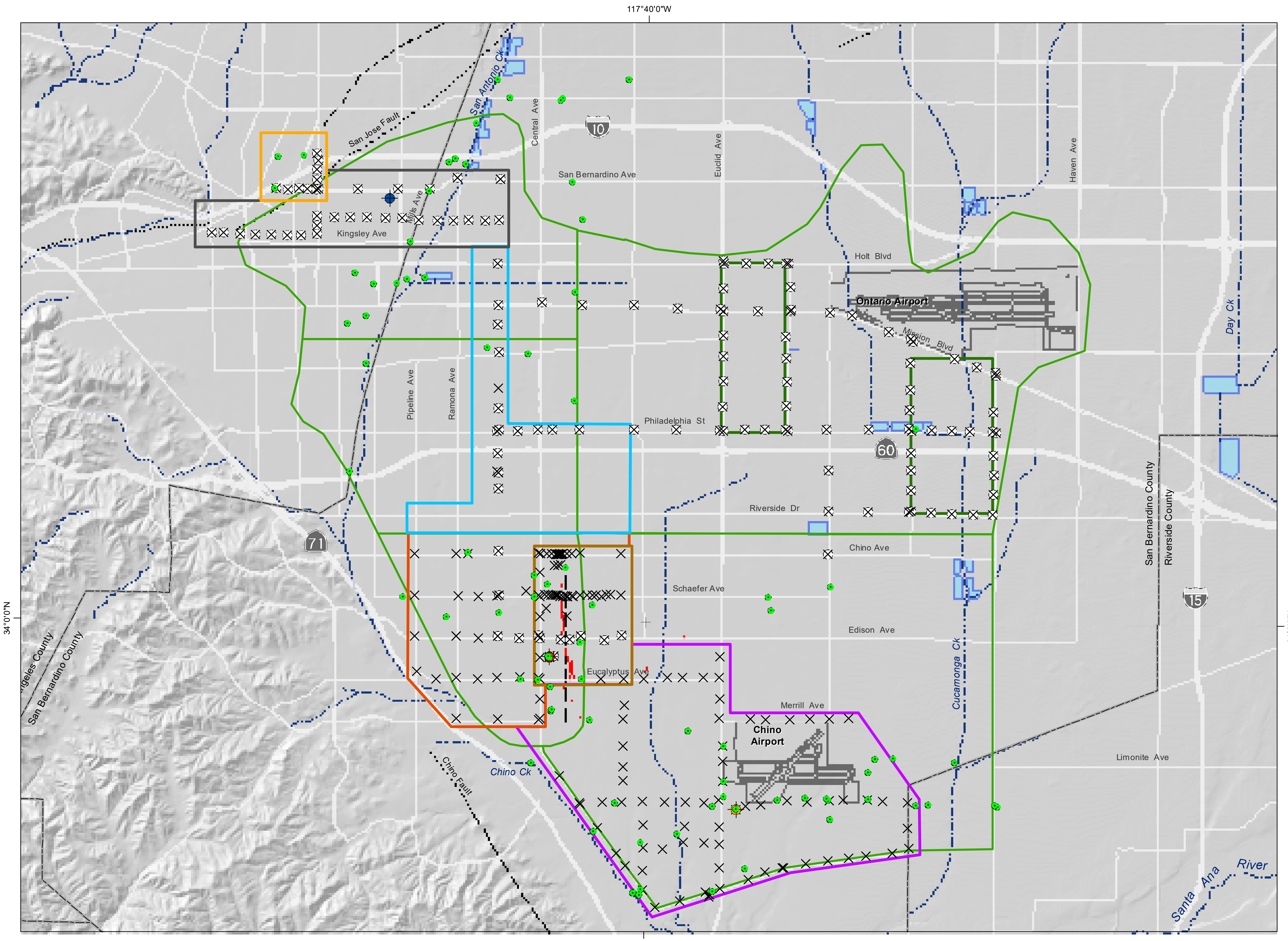
Ground-Level Monitoring Committee
2019/20 Annual Report

Pumping and Recharge Facilities
Western Chino Basin: 2019/20

Figure 2-1



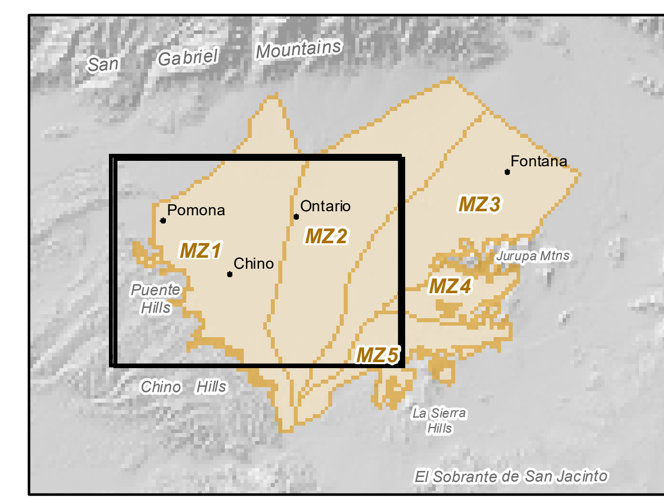
Ground-Level Monitoring Network Facilities

- Ayala Park Extensometer
- Chino Creek Extensometer
- Pomona Extensometer
- Well Equipped with Pressure Transducer or Automated Data Logger (2019/20)
- Ground-Level Survey Benchmark
- Ground-Level Survey Benchmark (Measured in April 2020)

Ground-Level Survey Areas

- Managed Area
- Fissure Zone Area
- Central Area
- Northwest Area
- San Jose Fault Zone Area
- Northeast Area
- Southeast Area

- Areas of Subsidence Concern
- Flood Control and Conservation Basins
- Ground Fissures
- Approximate Location of the Riley Barrier
- Fault (solid where accurately located; dashed where approximately located or inferred; dotted where concealed)



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Ground-Level Monitoring Committee
2019/20 Annual Report

Ground-Level Monitoring Network
Western Chino Basin

Figure 2-2

Section 3 – Results and Interpretations

This section describes the results and interpretations derived from the GLMP for the Managed Area and Areas of Subsidence Concern in the Chino Basin for the March 2019 and March 2020 reporting period. Figures 3-1a and 3-1b display vertical ground motion as measured by InSAR across the western portion of the Chino Basin between the periods of March 2011 and March 2020 and between March 2019 and March 2020, respectively. The maps also show the locations and magnitude of pumping and artificial recharge—the stresses to the aquifer system that can cause ground motion. The data shown in these and subsequent figures are described and interpreted in this section.

3.1 Managed Area

The Managed Area is the primary focus of the Subsidence Management Plan. The discussion below describes the results and interpretations of the monitoring program in the Managed Area and, where appropriate, relative to the Guidance Criteria in the Subsidence Management Plan.

3.1.1 History of Stress and Strain in the Aquifer-System

Figure 3-2 illustrates the long-term history of groundwater pumping, hydraulic heads, and vertical ground motion in the Managed Area. Also shown is the volume of the direct use of recycled water in the Managed Area, which is an alternative water supply that can result in decreased groundwater pumping from the area. Recycled water is often used for irrigation purposes and can contribute to groundwater recharge as well. General observations and interpretations from this chart are:

- Pumping from the shallow aquifer-system between the 1930s and about 1977 caused hydraulic heads to decline by about 150 ft. From 1978 to 1990, hydraulic heads recovered by about 50 ft.

- Pumping from the confined, deep aquifer-system during the 1990s caused the hydraulic heads to a decline, coinciding with high rates of land subsidence. About 2.5 ft of subsidence occurred from 1987 to 1999, and ground fissures opened within the City of Chino in the early 1990s.

- Since the early 2000s, groundwater pumping decreased, hydraulic heads in the deep aquifer-system recovered, and the rate of land subsidence declined significantly across the Managed Area.

- The direct use of recycled water, which began in 1997, may have contributed to observed increases in hydraulic heads in the Managed Area.

- Since 2005, hydraulic heads at PA-7 have not declined below the Guidance Level, and very little inelastic compaction was recorded in the Managed Area. These observations demonstrate the effectiveness of the Subsidence Management Plan in the management of land subsidence in the Managed Area.

3.1.2 Recent Stress and Strain in the Aquifer-System

This section discusses the last nine years of groundwater pumping, changes in hydraulic heads, and vertical ground motion in the Managed Area under the Subsidence Management Plan.

3.1.2.1 Groundwater Pumping and Hydraulic Heads

Table 3-1 summarizes groundwater pumping by well within the Managed Area for fiscal year 2012 through March 2020. A total of about 23 acre-feet (af) of groundwater pumping occurred in the Managed Area from July 1, 2019 to March 31, 2020 —95 percent of the groundwater pumping was from wells screened in the shallow aquifer-system. Groundwater pumping in the Managed Area has declined from about 5,680 af in fiscal year 2012 to almost negligible volumes in 2018 and 2019.

Figure 3-3 displays the hydraulic stresses and mechanical strains that have occurred within the shallow and deep aquifer-systems in the Managed Area over the period January 2011 through March 2020. The figure includes three time-series charts: quarterly groundwater pumping (hydraulic stress to the aquifer systems); the resultant head changes (hydraulic responses to pumping); and aquifer-system deformation as measured at the Ayala Park Extensometers (mechanical strain that occurred within the aquifer-system sediments in response to the head changes). The following are observations and interpretations with regard to pumping and head changes:

- Historically, there has been a general seasonal pattern of pumping in the Managed Area – increased pumping during the spring to fall and decreased pumping during the winter.
- Hydraulic heads respond differently to the pumping stresses in the shallow and deep aquifer-systems. Pumping from the deep confined aquifer-system causes a hydraulic head decline that is much greater in magnitude than the hydraulic head decline caused by pumping from the shallow aquifer-system despite that more groundwater pumping occurs from the shallow aquifer-system.
- The hydraulic head at PA-7 (deep aquifer-system) has fluctuated from a low of approximately 190 ft-btoc in August 2013 to a high of about 63 ft-btoc in March 2020 and has not declined below the Guidance Level of 245 ft-btoc.
- The recovery of the hydraulic head in the deep aquifer-system to above 90 ft-btoc in February 2019 represented "full recovery" of hydraulic head at PA-7 as defined in the Subsidence Management Plan, and the hydraulic head at PA-7 has remained above 90 ft-btoc.
- Since the first instance of full recovery in 2012, the hydraulic head at PA-7 recovered to 90 ft-btoc or greater in 2016, 2018 and 2019, which complies with the recommendation in the Subsidence Management Plan for full recovery within the deep aquifer-system at least once every five years.[10]

[10] Page 2-2 in the Subsidence Management Plan, Section 2.1.1.3—Recovery Periods: "Every fifth year, Watermaster recommends that all deep aquifer-system pumping cease for a continuous period until water-level recovery reaches 90 ft-btoc at PA-7. The cessation of pumping is intended to allow for sufficient water level

- As a result of almost zero pumping from the shallow and deep aquifer-systems, hydraulic heads at PA-10 and PA-7 have increased to their highest levels since implementation of the GLMP in 2003: about 56 ft-btoc in PA-10 and about 63 ft-btoc in PA-7.

Figure 3-3 also shows that between April 2019 and January 2020 there were short episodes of head decline observed in the deep aquifer-system at PA-7. These short episodes of hydraulic head decline are not supported by Watermaster's pumping records for the Managed Area.

3.1.2.2 Aquifer-System Deformation

Figure 3-3 also includes a time-series chart of vertical deformation of the aquifer-system as measured at the Ayala Park Extensometers for the period January 2011 through March 2020. The following are observations and interpretations regarding aquifer-system deformation in response to the pumping and head changes:

- There has been seasonal compression and expansion of the aquifer-system in response to the seasonal decline and recovery of hydraulic heads, which indicates that the vertical deformation of the aquifer-system was mainly elastic during this period.

- However, between April 6, 2011 and June 27, 2016 (dates of full recovery at PA-7 to 90 ft-btoc), the Ayala Park Deep Extensometer recorded about 0.029 ft of aquifer-system compression, which indicates that this compression is permanent compaction that occurred within the depth interval of 30-1,400 ft-bgs.[11]

- From June 27, 2016 to February 1, 2019 (dates of full recovery at PA-7), the Deep Extensometer recorded an extended cycle of aquifer-system compression and expansion in response to the extended decline and recovery cycle of hydraulic heads at PA-7. By February 1, 2019, the Deep Extensometer recorded a slight amount of expansion from June 27, 2016, indicating that the vertical deformation of the deep aquifer-system was mainly elastic during this period.

- Since February 2019, the Deep Extensometer has continued to record purely elastic aquifer-system deformation – a total of about 0.041 ft of aquifer-system expansion was recorded at the Deep Extensometer between February 1, 2019 and March 31, 2020.

Figure 3-4 is a stress-strain diagram of hydraulic heads measured at PA-7 (stress) versus vertical deformation of the aquifer-system sediments as measured at the Deep Extensometer (strain). This diagram provides additional information on the nature of the aquifer-system deformation (i.e. elastic versus inelastic deformation). The hysteresis loops on this figure represent cycles of hydraulic head decline-recovery and the resultant compression-expansion of the aquifer-system sediments. The diagram can be interpreted to understand the timing and magnitude of the occurrence of compaction within the depth interval of the aquifer-system that is penetrated by the Deep Extensometer. Hydraulic head decline is shown as increasing from bottom to top on

recovery at PA-7 to recognize inelastic compaction, if any, at the Ayala Park Extensometer and at other locations where groundwater-level and ground-level data are being collected."

[11] The analysis of full recovery and inelastic compaction at Ayala Park was included in the 2016 Annual Report (WEI, 2016).

the y-axis, and aquifer-system compression is shown as increasing from left to right on the x-axis. The following are observations and interpretations regarding aquifer-system deformation in response to the head changes:

- From May 2006 to May 2018, the hysteresis loops progressively shifted to the right on this chart, indicating that about 0.065 ft of inelastic compaction occurred during this time-period. However, the rate of inelastic compaction appeared to gradually decline over this 12-year period.

- From May 2018 to April 2020, the hydraulic heads at PA-7 fluctuated but remain higher than 120 ft-btoc and gradually increased to their highest levels since 2003. During this period, the hysteresis loops started to overlap one another and then shifted to the left, indicating that the vertical deformation of the aquifer-system was mainly elastic expansion of the aquifer-system sediments.

3.1.2.3 Vertical Ground Motion

Vertical ground motion is measured across the Managed Area via InSAR, traditional ground-level surveys, and the Deep Extensometer. For FY 2019/20, the benchmark monument network in the Managed Area was not surveyed per the GLMC's scope and budget recommendations. Figures 3-5a and 3-5b illustrate vertical ground motion[12] as estimated by InSAR for the period from March 2011 to March 2020 and from March 2019 to March 2020, respectively.

Where coherent, the InSAR estimates shown in Figure 3-5a indicate the occurrence of zero to about -0.08 ft of vertical ground motion across the Managed Area from 2011 to 2020. The greatest downward ground motion occurred in the northern and central portions of the Managed Area. The principal areas of InSAR incoherence in the Managed Area are located south of Schaefer Avenue.

The InSAR estimates shown in Figure 3-5b indicate very little vertical ground motion occurred across the Managed Area from March 2019 to March 2020. The vertical ground motion observed in the Managed Area was mainly downward east of the Riley Barrier and in the northern portion of the Managed Area. Upward vertical ground motion was observed mainly across the central portion of the Managed Area between Schafer and Eucalyptus Avenues. The InSAR estimates of ground motion are consistent with the Deep Extensometer record at Ayala Park from March 2019 to March 2020. Over this one-year period, the Deep Extensometer recorded about 0.02 ft of aquifer-system expansion compared to about 0.01 ft of upward ground motion estimated by InSAR at the Deep Extensometer location. The upward ground motion across most of the Managed Area during this period is likely due to two main factors:

1. Hydraulic heads in the shallow and deep aquifer-systems continue to experience an extended period of recovery since December 2017. Hydraulic heads in both the shallow and deep aquifer-systems are at historical highs since monitoring began for the GLMP.

[12] Upward vertical ground motion is indicated by positive values; downward vertical ground motion is indicated by negative values.

2. Permanent compaction of the aquifer-system is no longer occurring in the Managed Area. Aquifer-system deformation recorded at the Ayala Park Extensometer has shown mainly expansion of the aquifer-system since June 2016.

As described above, Figure 3-5a shows that maximum downward ground motion during 2011-2020 occurred in the northern portions of the Managed Area. The InSAR estimates of vertical ground motion are coherent in this area. City of Chino Well 15 (C-15) is located in this area, is screened across both the shallow and deep aquifers, and has been equipped with a pressure transducer data logger that measures and records hydraulic heads once every 15 minutes. These data provide information on the nature of the aquifer-system deformation that occurred in this area (i.e. elastic versus inelastic deformation). Figure 3-6 is a time-series chart that compares the hydraulic heads at C-15 to vertical ground motion as measured by InSAR at the same location between 2005 and 2020. The main observations from this chart are:

1. The InSAR record at C-15 is measuring seasonal elastic vertical ground motion that is caused by seasonal fluctuations in hydraulic head and the resultant seasonal elastic deformation in the aquifer-system(s). The seasonal fluctuations of hydraulic head at C-15 are coincident with the seasonal fluctuations of vertical ground motion measured by InSAR at the same location.
2. InSAR indicates a long-term trend of downward vertical ground motion at C-15 from 2007 to 2017. However, hydraulic heads at C-15 during this same time-period increased, indicating that about 0.188 ft of subsidence was caused by inelastic compaction of the aquifer-system. The inelastic compaction that occurred during this period of increasing hydraulic heads most likely represents the delayed drainage and compaction of aquitards due to historical head declines.
3. Since 2017, the long-term subsidence trend appears to have stopped, indicating that inelastic compaction of the aquitards has also stopped. This observation is supported by the Ayala Park Deep Extensometer record, which indicates mostly elastic deformation of the aquifer-system since 2016 (see Figure 3-4). The recent cessation of subsidence observed at C-15 is likely a result of increasing hydraulic heads in the aquifers, which has led to equilibration with hydraulic heads in the aquitards and the cessation of aquitard drainage and compaction. These monitoring data may be providing information on hydraulic head "thresholds" that could be used as management criteria to protect against the future occurrence of land subsidence. At C-15, when groundwater elevations remain above 580 ft-amsl, InSAR indicates no permanent land subsidence. Therefore, 580 ft-amsl is the current estimate of the pre-consolidation stress threshold at C-15.

3.2 Southeast Area

Vertical ground motion is measured across the Southeast Area via InSAR, traditional ground-level surveys, and the Chino Creek Extensometer Facility (CCX). The InSAR results are generally incoherent across much of this area because the overlying agricultural land uses are not hard, consistent reflectors of radar waves. Where InSAR results are incoherent, the history of subsidence is best characterized by ground-level surveys and the CCX.

Figure 3-7 is a time-series chart that displays and describes the history of groundwater pumping, the direct reuse of recycled water, hydraulic heads, and vertical ground motion in the Southeast

Area from 1930 to 2020. Figure 3-8 is a map that illustrates vertical ground motion as estimated by InSAR across the Southeast Area during 2019-20. The main observations and interpretations from these figures are:

- From the 1940s to about 1968, hydraulic heads declined by up to about 75 ft. There is a data gap from about 1968 to 1988; however, it is likely that hydraulic heads continued to decline from 1968 to 1978, as was the case in most portions of the Chino Basin during this period. In the western portion of the Southeast Area, hydraulic heads remained relatively stable from 1988 to 2010 and then gradually increased by about 10 to 25 ft from 2010 to 2020 (see wells CH-18A, C-13, CCPA-1, and CCPA-2). In the eastern portion of the Southeast Area, hydraulic heads have been gradually declining by about 5 to 12 ft between 2005 and March 2020 (see wells HCMP-1/1 and HCMP-1/2).

- In general, the occurrence of subsidence has been relatively minor between March 2019 and March 2020 – between about -0.01 and -0.03 ft across most of the Southeast Area, with some areas showing upward vertical ground motion. Hydraulic heads remained relatively stable or increased across most of the area during this period, which indicates that the downward ground motion is, at least in part, permanent subsidence due to delayed aquitard drainage in response to the historical declines in hydraulic heads that occurred from the 1940s to about 1978.

Figure 3-9 displays the time series of hydraulic and vertical aquifer-system deformation recorded at the CCX, which began collecting data in July 2012. Groundwater pumping began at the Chino Creek Well Field in 2014, but appears to have had little, if any, effect on hydraulic heads or aquifer-system deformation at the CCX through March 2020. In general, hydraulic heads at the CCX vary seasonally and have gradually increased since 2012, and a small amount of expansion of the aquifer-system has been measured by the CCX extensometers. This observation is consistent with the ground-levels surveys at BM 157/71 near the CCX (through 2018).

3.3 Central MZ-1

Vertical ground motion is measured across Central MZ-1 via InSAR and traditional ground-level surveys. Figures 3-1a and 3-1b illustrate vertical ground motion as estimated by InSAR across Central MZ-1 for 2011-2020 and 2019-2020, respectively. The InSAR results are generally coherent across this area because the overlying land uses are urban and serve as hard, consistent reflectors of radar waves. Ground-level surveys are performed periodically along the eastern portion of the area. Figure 3-10 is a time-series chart that displays and describes the long-term history of pumping, recharge, hydraulic heads, and vertical ground motion in Central MZ-1. The following observations and interpretations are derived from these figures:

- Hydraulic head data are absent in the southern portion of Central MZ-1. In the northern portion of Central MZ-1, hydraulic heads declined by about 200 ft from 1930 to about 1978. From 1978 to 1986, hydraulic heads increased by about 80 ft and remained relatively stable or have slightly increased from 1986 to 2020. Recent hydraulic heads (1986 to 2020) in the northern portion of Central MZ-1 are about 120 ft lower than the hydraulic heads in the 1930s.

- About 1.9 ft of subsidence occurred near Walnut and Monte Vista Avenue from 1988 to 2000, as measured by ground-level surveys at BM 125/49 (about 0.16 ft/yr). Since 2000, the rate of subsidence has slowed significantly—about 0.35 ft of subsidence occurred at a gradually declining rate from 2000 to 2018 (about 0.019 ft/yr). This time history and magnitude of vertical ground motion along the eastern side of Central MZ-1 is like the time history and magnitude of vertical ground motion in the Managed Area, which suggests a relationship to the causes of land subsidence in the Managed Area; however, there is not enough historical hydraulic head data in this area to confirm this relationship.

- Figure 3-1a shows that the areas that experienced the greatest magnitude of subsidence from March 2011 to March 2020 are located in the western portion of Central MZ-1, where up to about -0.18 ft of vertical ground motion has occurred (about -0.02 ft/yr). Hydraulic heads remained relatively stable in this area from 2011 to 2020, which indicates that the downward vertical ground motion is, at least in part, permanent subsidence due to delayed aquitard drainage in response to the historical declines in hydraulic heads that occurred from 1930 to 1978.

- The ground motion measured by InSAR in Figure 3-1a also shows that the groundwater barrier (Riley Barrier) may extend from the Managed Area northward into Central MZ-1 to at least Phillips Street. This observation is evidenced by a steep subsidence gradient located just east of Central Avenue.

- Figure 3-1b shows that between March 2019 and 2020, most of Central MZ-1 experienced a minor amount of downward vertical ground motion – between about -0.01 to -0.03 ft, with some areas in the western and southern portions of Central MZ-1 experiencing some upward vertical ground motion.

3.4 Northwest MZ-1

3.4.1 Vertical Ground Motion

Vertical ground motion is measured across Northwest MZ-1 via InSAR and ground-level surveys. The InSAR results are generally coherent across this area because the overlying land uses are urban and serve as hard, consistent reflectors of radar waves. Ground-level surveys have been performed annually in the early spring across the area to complement and check the InSAR estimates of vertical ground motion.

Figure 3-1a illustrates vertical ground motion as estimated by InSAR across Northwest MZ-1 during 2011-2020. Figure 3-11 is a time-series chart that displays and describes the long-term history of pumping, recharge, hydraulic heads, and vertical ground motion in Northwest MZ-1. Figures 3-12a and 3-12b are maps of the most recent data and illustrate vertical ground motion as estimated by InSAR and ground-level surveys across Northwest MZ-1 from January 2014 to March 2020 and from March 2019 to March 2020, respectively. The following observations and interpretations are derived from these figures:

- From about 1930 to 1978, hydraulic heads in Northwest MZ-1 declined by about 200 ft. From 1978 to 1985, hydraulic heads increased by about 100 ft. From 1985 to 2020 hydraulic heads fluctuated but remained relatively stable. Since 2018, hydraulic heads have shown a slight recovery trend but are at least 100 ft lower than hydraulic heads in the 1930s.

- A maximum of about 1.27 ft of subsidence occurred in this area from 1992 through March 2020—an average rate of about 0.05 ft/yr—while hydraulic heads remained relatively stable. The persistent subsidence that occurred from 1992 to 2020 cannot be entirely explained by the concurrent changes in hydraulic heads. A plausible explanation for this subsidence is that thick, slow-draining aquitards are permanently compacting in response to the historical declines in hydraulic heads that occurred between 1930 and 1978.

- From March 2011 to March 2020, the InSAR results indicate a maximum of about -0.29 ft of vertical ground motion occurred in Northwest MZ-1 near the intersection of Indian Hill Boulevard and San Bernardino Avenue (see Point C on the inset map on Figure 3-11). From 2014 to 2020, the rate vertical ground motion slowed to about -0.03 ft/yr at this location.

- Figure 3-12a shows that the ground-level survey results from 2014-2020 indicate a similar spatial pattern of downward ground motion as estimated by InSAR but with slightly different magnitudes. Both methods indicate the maximum downward ground motion from December 2013 to March 2020 occurred near the intersection of Indian Hill Boulevard and San Bernardino Avenue. There is a minor difference in the magnitudes of vertical ground motion between InSAR and ground-level survey results, but these differences are most likely related to the different timing of the ground-level surveys and the SAR acquisition and/or relative errors associated with each monitoring technique.

- Figure 3-12b shows that most of Northwest MZ-1 experienced downward vertical ground motion from March 2019 and March 2020. The downward vertical ground motion measured by InSAR is consistent with the observation that groundwater pumping increased and groundwater levels declined slightly during this period (see Figure 3-11). The ground-level survey results from 2019-2020 shown on Figure 3-12b indicate a different spatial pattern of ground motion compared to the ground motion estimated by InSAR. Overall, the ground-level surveys recorded upward ground motion between April 2019 and April 2020.

The ground-level survey results from 2019-2020 shown on Figure 3-12b indicate a different direction of ground motion compared to the ground motion estimated by InSAR – the ground-level survey results recorded upward ground motion between April 2019 and April 2020. Although the ground motion direction and absolute displacement measured by the ground-level surveys is different than the ground motion direction and displacement measured by InSAR, the relative displacement between adjacent benchmarks generally corroborate the spatial pattern of ground motion measured by InSAR across Northwest MZ-1 between 2019 and 2020.

The discrepancy between ground motion measured by InSAR and ground-level surveys over the 2019-2020 period may be related to the relative errors associated with each monitoring technique. The general accuracy associated with both monitoring techniques is about +/- 0.02 ft. However, for ground-level surveys, the farther away the surveyed benchmarks are from the starting benchmark (i.e. the Ayala Park Extensometer), the larger the potential error and uncertainty in the absolute position of the benchmark (Jim Elliot, personal communication, September 4, 2020). The future Pomona Extensometer Facility is planned to be used as the starting benchmark for future ground-level surveys in Northwest MZ-1, which should increase the accuracy of future ground-level surveys.

As described above, Figure 3-1a shows that maximum downward ground motion during 2011-2020 occurred near the intersection of Indian Hill Boulevard and San Bernardino Avenue in Northwest MZ-1. City of Pomona Well 30 (P-30) is located just south of this area. P-30 is a non-pumping well, is screened across the shallow aquifer and upper portion of the deep aquifer and has been equipped with a pressure transducer that measures and records hydraulic heads once every 15 minutes since September 2006. These data can provide information on the nature of the aquifer-system deformation that occurred in this area (i.e. elastic versus inelastic deformation). Figure 3-13 is a time-series chart that compares the hydraulic heads at P-30 to vertical ground motion as estimated by InSAR between 2005 and 2020. The main observations from this chart are:

- The InSAR record at P-30 is measuring seasonal elastic vertical ground motion that is caused by seasonal fluctuations in hydraulic head and the resultant seasonal elastic deformation in the aquifer-system(s). The seasonal fluctuations of hydraulic head at P-30 are coincident with the seasonal fluctuations of vertical ground motion measured by InSAR, but the long-term trend of subsidence remains persistent between 2005 and 2020 despite periods of hydraulic head recovery.

- InSAR indicates a long-term trend of downward vertical ground motion at P-30 from 2005 to 2017. However, hydraulic heads at P-30 during this same time-period increased, indicating that at least about 0.7 ft of subsidence was caused by inelastic compaction of the aquifer-system. The inelastic compaction that occurred during this period of increasing hydraulic heads most likely represents the delayed drainage and compaction of aquitards due to historical head declines.

- Between 2018 and 2020, the long-term subsidence trend appeared to have slowed down, indicating that inelastic compaction of the aquitards had also slowed down. The recent slowing of subsidence observed at P-30 was likely a result of increasing hydraulic heads in the aquifers, which had led to equilibration with hydraulic heads in the aquitards and the slowing of aquitard drainage and compaction.

- From March 2019 to March 2020, the hydraulic head at P-30 experienced a cycle of head decline and recovery. Since March 2019, the hydraulic head at P-30 declined by almost 20 ft through November 2019 but recovered by about 18 ft through the end of March 2020. The head decline and recovery at P-30 is also contemporaneous with the downward and upward vertical ground motion measured by InSAR at P-30 during this same time period. These observations suggest that in Northwest MZ-1: (i) changes in hydraulic heads, which are controlled by the pumping and recharge stresses in the area, have at least some control on the pattern and rate of subsidence and (ii) these monitoring data may be providing information on hydraulic head "thresholds" that could be used as management criteria to protect against the future occurrence of land subsidence.

3.4.2 Horizontal Ground Motion

Figure 3-1a shows a steep gradient of subsidence across the San Jose Fault in Northwest MZ-1—the same pattern of "differential subsidence" that occurred in the Managed Area during the time of ground fissuring. Differential subsidence can cause an accumulation of horizontal strain in the shallow sediments and the potential for ground fissuring.[13]

To identify potential areas of accumulation of tensile horizontal strain in the shallow soils in this area, annual EDM surveys between closely spaced benchmark monuments that cross the San Jose Fault have been performed annually since December 2013. Figure 3-14 displays the time series of east/west-oriented and north/south-oriented strain between the pairs of closely spaced benchmarks (see the inset map on Figure 3-14) between 2013 and 2020. For reference, the top left chart on Figure 3-14 shows the downward vertical ground motion in Northwest MZ-1 as estimated by InSAR at Point C on Figure 3-11. The horizontal strain between most pairs of benchmarks appears to behave elastically – alternating between compressive and tensile deformation between EDM surveys.

3.4.3 Pomona Extensometer Facility

In July 2019, the PX piezometers were equipped with pressure transducer data loggers set to record hydraulic heads once every 15 minutes. Figures 3-15, 3-16, and 3-17 are time-series charts showing the available hydraulic head data at each PX piezometer for the time-period between July 2019 and March 2020. Also shown on the time-series charts are hydraulic heads at a nearby pumping wells: MVWD-28 and City of Pomona well 27 (P-27). Both wells are the closest pumping wells to PX and are screened across the shallow and deep aquifer-systems.

The key observations from Figures 3-15, 3-16, and 3-17 are:

- Since July 2019, the hydraulic heads at the PX piezometers have generally increased, with shorter-term head fluctuations (monthly and daily). The hydraulic head changes at the PX piezometers are most likely in response to nearby pumping. Hydraulic heads at PX1-2 and PX2-3 show a greater response to nearby pumping than PX1-1 and PX2-4. This observation is exemplified with the synchronous head response at PX1-2 and PX2-3 to daily pumping cycles at MVWD-28 (Figures 3-15 and 3-16). When MVWD-28 turns on or off, there is an immediate drawdown or recovery response at both PX1-2 and PX2-3. A similar head response to pumping at MVWD-28 is also observed at P-27.

- Figures 3-15 and 3-16 also shows that between December 2019 and January 2020, heads at PX1-1 and PX2-4 did not respond to the daily pumping cycles at MVWD-28. These observations suggest: 1) the PX1-1 piezometer screen interval (440 to 470 ft-bgs) is completed near the water table and that the heads are not noticeably influenced by pumping from the deeper portions of the aquifer-system; and 2) the PX2-4 piezometer screen interval (1,235 to 1,275 ft-bgs) may be located below the deepest portion of the aquifer-system in Northwest MZ-1.

- P-27 is the closest pumping well to PX, but its pumping signal at PX is difficult to distinguish from the pumping and recovery signals generated at MVWD-28. Figure 3-

[13] Ground fissuring is the main subsidence-related threat to overlying infrastructure. Watermaster, consistent with the recommendation of the GLMC, has determined that the Subsidence Management Plan needs to be updated to include a *Subsidence Management Plan for the Northwest MZ-1* with the long-term objective to minimize or abate the occurrence of the differential land subsidence. Development of this subsidence management plan is an ongoing, multi-year effort of the Watermaster.

17 shows a brief period of time between December 31, 2019 and January 6, 2020 when both pumping wells P-27 and MVWD-28 turned off and on. The main observations from this chart are: 1) during the period when both pumping wells were off, the hydraulic head at PX1-2 recovered to levels slightly higher than previous levels when MVWD-28 was not pumping and P-27 was pumping; 2) when pumping at P-27 resumed on January 5, 2020, and MVWD-28 remained off, there was a slight drawdown response observed at both PX1-2 and MVWD-28; and 3) when pumping at MVWD-28 resumed on January 6, 2020, there was a drawdown response at both PX1-2 and P-27.

The important takeaways from the hydraulic head data measured at the PX piezometers and the hydraulic head data measured as part of the Northwest MZ-1 monitoring program, thus far, are:

- PX1-1 is screened near the water table and heads do not appear to respond to nearby pumping.
- PX1-2 is screened in the shallow aquifer-system but responds to nearby pumping from both the shallow and deep aquifer-system (e.g. P-27 and MVWD-28).
- PX2-3 is screened in the deep aquifer-system, heads at PX2-3 are about 60 ft lower than heads at PX1-2, and heads at PX2-3 respond only to pumping from the deep aquifer-system.
- PX2-4 does not respond to pumping from the deep aquifer-system and is most likely screened across weathered sedimentary bedrock.

The hydraulic head data shown in Figures 3-15, 3-16, and 3-17 provide initial information on the depth-specific aquifer-system(s) response to seasonal and/or pumping induced hydraulic head change at PX. This information, coupled with the PX depth-specific extensometer data,[14] will be used to establish the relationship between depth-specific head change in the aquifer-system (stress) and depth-specific aquifer-system deformation (strain) in Northwest MZ-1.

3.5 Northeast Area

Vertical ground motion is measured across the Northeast Area via InSAR and ground-level surveys. In December 2017, a new network of benchmarks were installed across the Northeast Area (see Figure 2-2) and surveyed for initial elevations in January 2018. The entire Northeast Area benchmark network was surveyed in April 2019 and April 2020.

Figures 3-1a and 3-1b illustrate vertical ground motion, as measured by InSAR, across the Northeast Area from March 2011 to March 2020 and from March 2019 to March 2020, respectively. Figure 3-18 is a time-series chart that displays and describes the long-term history of pumping, recharge, hydraulic, and vertical ground motion in the Northeast Area. Figure 3-19 illustrates vertical ground motion as estimated by InSAR and ground-level surveys across the Northeast Area from March 2019 to April 2020. The following observations and interpretations are derived from these figures:

[14] The PX extensometer is anticipated to be collecting accurate aquifer-system deformation data by fall 2020.

- From about 1930 to 1978, hydraulic heads in the Northeast Area declined by about 125 ft. From 1978 to about 1985, hydraulic heads increased by about 25 ft. From 1985 to 2020 hydraulic heads fluctuated but generally remained relatively stable or show a recovery trend since 2011. For example, City of Ontario well O-34 has increased about 20 ft since 2011. However, hydraulic heads across the Northeast Area are about 100 ft lower than the hydraulic heads in the 1930s.

- About one foot of subsidence occurred in the Northeast Area near the intersection of Euclid Avenue and Phillips Street (see Point D on the inset map on Figure 3-18) from 1992 to 2020. From 1992 to 2011, the subsidence occurred at a gradual and persistent rate of about 0.04 ft/yr. From 2011 to 2020, the subsidence rate declined to about 0.02 ft/yr. Hydraulic heads have remained relatively stable or increased in this area from 1992-2020, which indicates that the downward vertical ground motion is, at least in part, permanent subsidence due to delayed aquitard drainage in response to the historical declines in hydraulic heads that occurred from 1930 to 1978. The recent decline in the rate of subsidence may be due to recent decreases in pumping, increases in recharge, and increases in hydraulic heads.

- The InSAR estimates in Figures 3-1a also indicate that downward ground motion has occurred in a concentrated area between Vineyard Avenue and Archibald Avenue south of the Ontario International Airport, where a maximum of about -0.21 ft of vertical ground motion occurred from March 2011 to March 2020. Between 2019 and 2020, the same area experienced about -0.07 ft of vertical ground motion. The western edge of this subsiding area exhibits a steep subsidence gradient, or "differential subsidence." Differential subsidence is thought to have led to episodes of ground fissuring in the Managed Area during the early 1990s. The causes of the downward ground motion in the Northeast Area is not known at this time, but a probable mechanism may be aquifer-system compaction. The differential subsidence shown in Figure 3-1a is a feature now more visible in the current InSAR long-term map for the time-period between 2011 and 2020 compared to previous long-term InSAR maps (see the 2018/19 Annual Report of the GLMC). One reason this feature is now more visible is the result of better and new processing and interpolation techniques used by General Atomics in the post-processing the SAR data and preparation of interferograms (see Section 2.1.2.3).

- Figure 3-19 shows that the majority of the Northeast Area experienced downward motion between March 2019 and March 2020. In the eastern portion of the Northeast Area – specifically in the area between Vineyard Avenue and Archibald Avenue south of the Ontario International Airport, both methods indicate minor downward ground motion, but with slightly different magnitudes. These differences are minor and most likely related to the different timing of the ground-level surveys and the SAR acquisition and/or relative errors associated with each monitoring technique.

- In the western portion of the Northeast Area, the ground-level survey results from 2019-2020 shown on Figure 3-19 indicate a different direction of ground motion compared to the ground motion estimated by InSAR – the ground-level survey results recorded upward ground motion between April 2019 and April 2020. Similar to the ground-level survey results for Northwest MZ-1, the discrepancy between ground motion measured by InSAR and ground-level surveys may be related to the relative errors associated with each monitoring technique. As stated in Section 3.4.1, the farther away the surveyed benchmarks are from the starting benchmark (i.e. the Ayala Park Extensometer), the larger the potential error and uncertainty in the absolute position of the benchmark.

3.6 Seismicity

Tectonic displacement of the land surface on either side of geologic faults can be horizontal, vertical, or a combination of both. During a large earthquake, the land surface can deform suddenly (Weischet, 1963; Myers and Hamilton, 1964; Plafker, 1965). Aseismic creep is a process where smaller, more frequent earthquakes cause the land surface to deform more gradually (Harris, 2017). Figure 3-20 displays the location and magnitude of earthquake epicenters relative to vertical ground motion from March 2011 to March 2020.

Tectonic movement along the San Jose Fault Zone, including aseismic creep, is a plausible mechanism for the differential land subsidence that has occurred in Northwest MZ-1. While the earthquake epicenters shown on Figure 3-20 do not show a spatial relationship to the differential subsidence in Northwest MZ-1, without direct measurement of aquifer-system deformation, as will be provided by PX, tectonic deformation cannot be ruled-out as a mechanism for the observed subsidence in Northwest MZ-1.

Between March 2011 and March 2020, several earthquake epicenters, varying in magnitude (local magnitude) from zero to four, occurred south of the Ontario International Airport. Figure 3-20 shows that the seismicity observed along the eastern edge of the Northeast Area extends northeast towards the San Jacinto Fault. The observed seismicity may reflect deep-seated convergence between the Perris Block that underlies the Chino Basin and the San Gabriel Mountains south of the Cucamonga Fault Zone (Morton and Yerkes, 1974; Morton et al., 1982; Morton and Matti, 1987).

Currently, there is not enough data and information to determine whether tectonic movement, aquifer-system deformation, or both are the mechanisms of the observed subsidence in the eastern portion of the Northeast Area. Additional monitoring and investigation are necessary to assist in this determination.

Table 3-1
Groundwater Pumping in the Managed Area for Fiscal Year 2012 Through 2020
acre-ft

Well Name	Aquifer Layer	Fiscal Year								Fiscal Year 2020				
		2012	2013	2014	2015	2016	2017	2018	2019	Qtr 1	Qtr 2	Qtr 3	Qtr 4*	By Layer
C-4	Shallow	524	0	0	0	0	0	0	0	0	0	0	-	22.1
C-6		1049	594	0	0	0	0	0	0	0	0	0	-	
CH-1A		1137	909	738	861	649	637	369	0	0	0	0	-	
CH-7A		530	380	170	286	156	66	0	0	0	0	0	-	
CH-7B		712	264	200	616	261	232	350	0	0	0	0	-	
CIM-1		724	1,109	1,127	878	911	908	586	0	0	0	0	-	
XRef 8730**		3	5	5	4	3	35	29	29	7.4	7.4	7.4	-	
	Sub-Totals	*4,679*	*3,260*	*2,240*	*2,644*	*1,980*	*1,879*	*1,334*	*29*	*7.4*	*7.4*	*7.4*	-	
CH-17	Deep***	758	1,444	937	1,142	567	624	571	0	0	0	0	-	1.1
CH-15B		0	28	105	0	0	0	0	0	0	0	0	-	
CIM-11A		243	239	195	92	94	222	0	0	0	0	1.1	-	
	Sub-Totals	*1,001*	*1,711*	*1,237*	*1,234*	*662*	*846*	*571*	*0*	*0*	*0*	*1*	-	
	Totals	**5,680**	**4,971**	**3,477**	**3,878**	**2,642**	**2,725**	**1,905**	**29**	**7.4**	**7.4**	**8.5**	**-**	

"C" = City of Chino

"CH" = City of Chino Hills

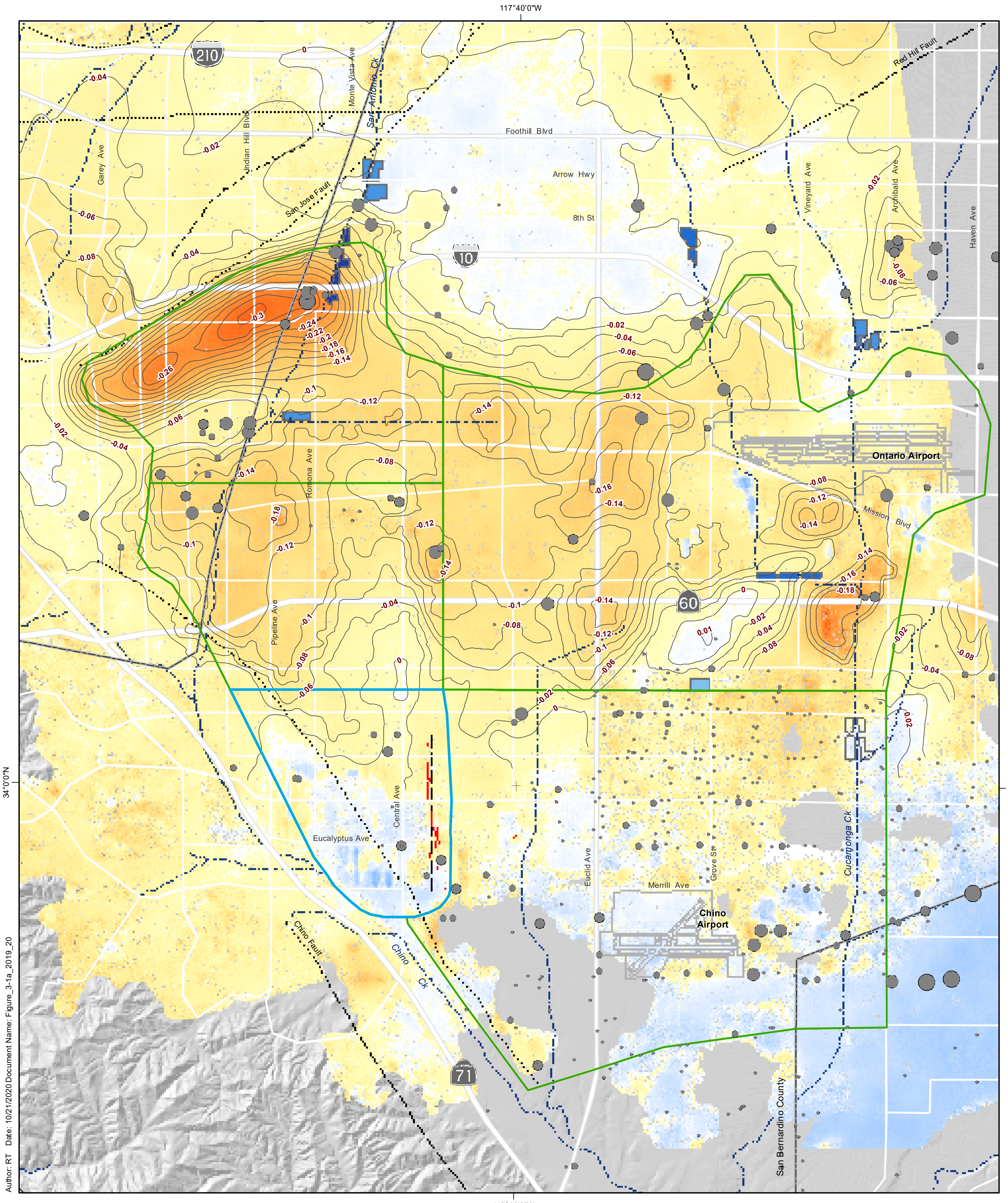
"CIM" = California Institution for Men

"XRef" = Private

*Data only available through March 2020.

**Well screen interval is unknown but assumed to be shallow based on typical well construction for other private wells in the vicinity.

***These wells have screen intervals that extend into the shallow-aquifer system, so a portion of the production comes from the shallow aquifer-system.



Relative Change in Land Surface Elevation as Estimated by InSAR (March 2011 to March 2020)

+ 0.25 ft

0 ft

- 0.25 ft

InSAR absent or incoherent

Average Annual Groundwater Pumping April 1, 2011 to March 31, 2020 (afy)

0 - 100

100 - 500

500 - 1,000

1,000 - 2,000

>2,000

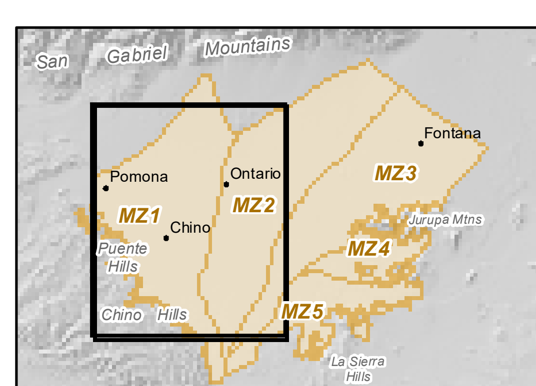
Average Annual Basin Recharge April 1, 2011 to March 31, 2020 (afy)

0

<1,000

1,000 - 2,500

2,500 - 5,000



Managed Area

Areas of Subsidence Concern

Historical Ground Fissures

Approximate Location of the Riley Barrier

Fault (solid where accurately located; dashed where approximately located or inferred; dotted where concealed)

0 1 2 Miles

0 1 2 Kilometers

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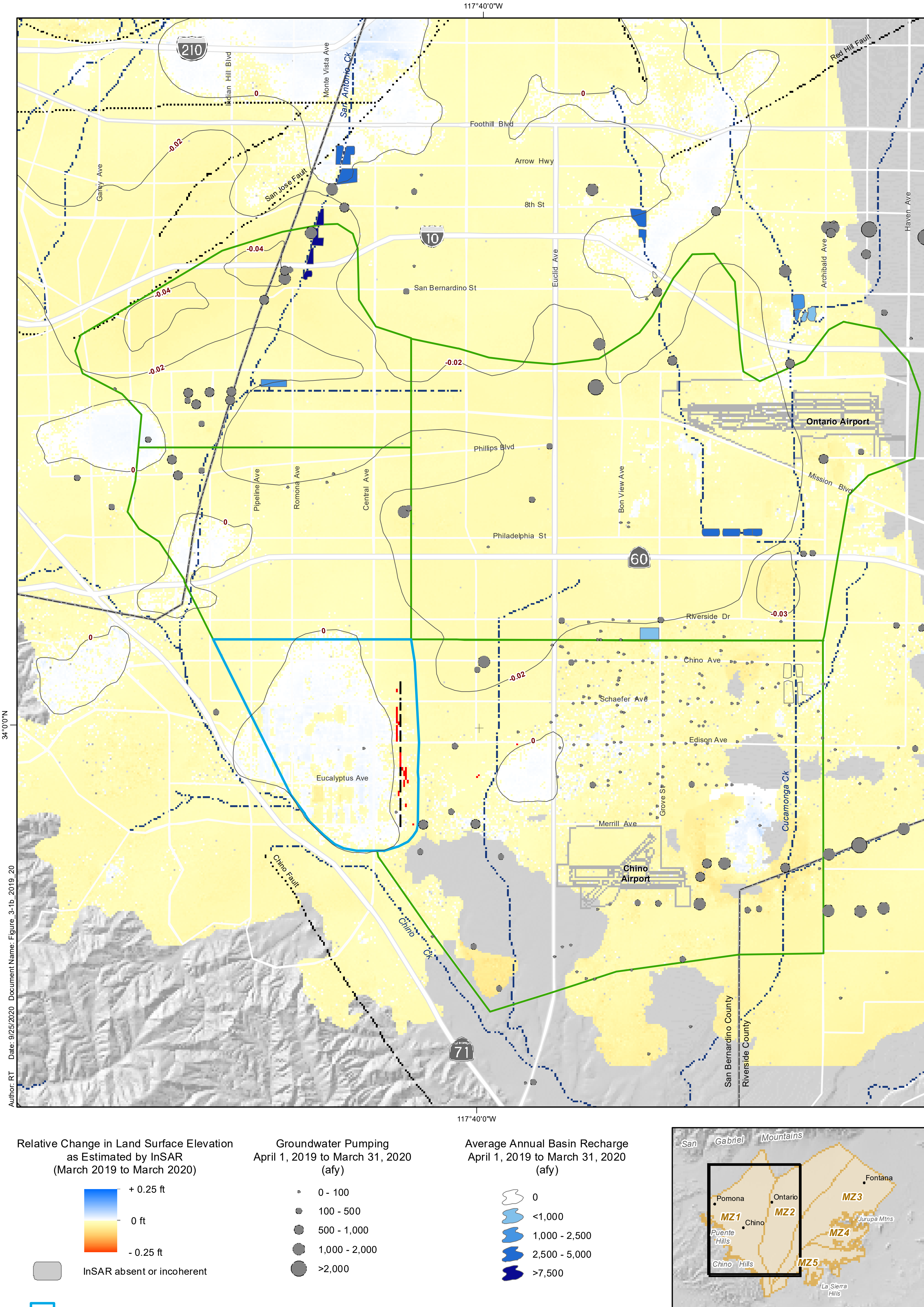
Vertical Ground Motion across the Western Chino Basin
2011-2020

Figure 3-1a



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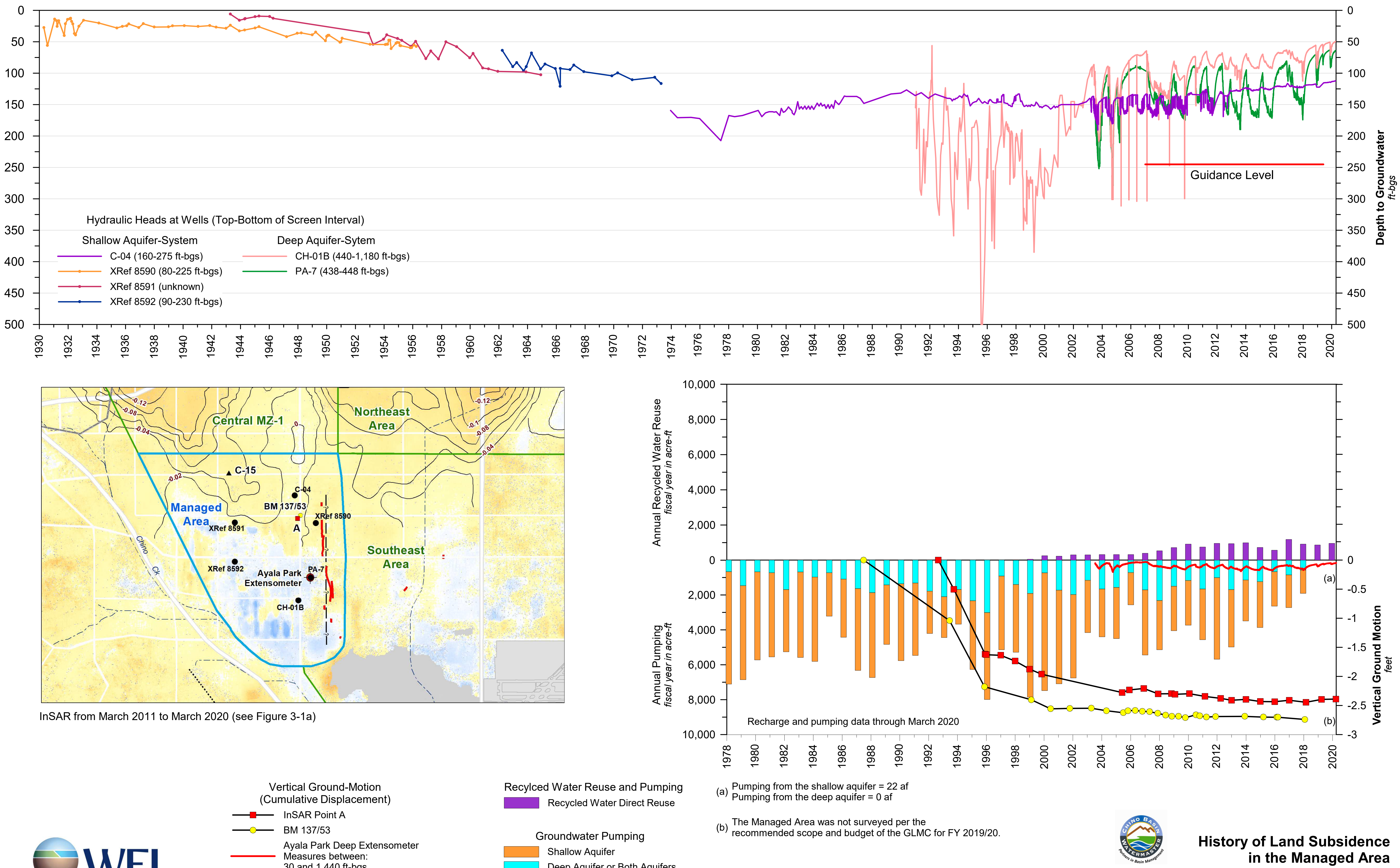
Vertical Ground Motion across the Western Chino Basin
2019/20

Figure 3-1b



History of Land Subsidence in the Managed Area

Figure 3-2

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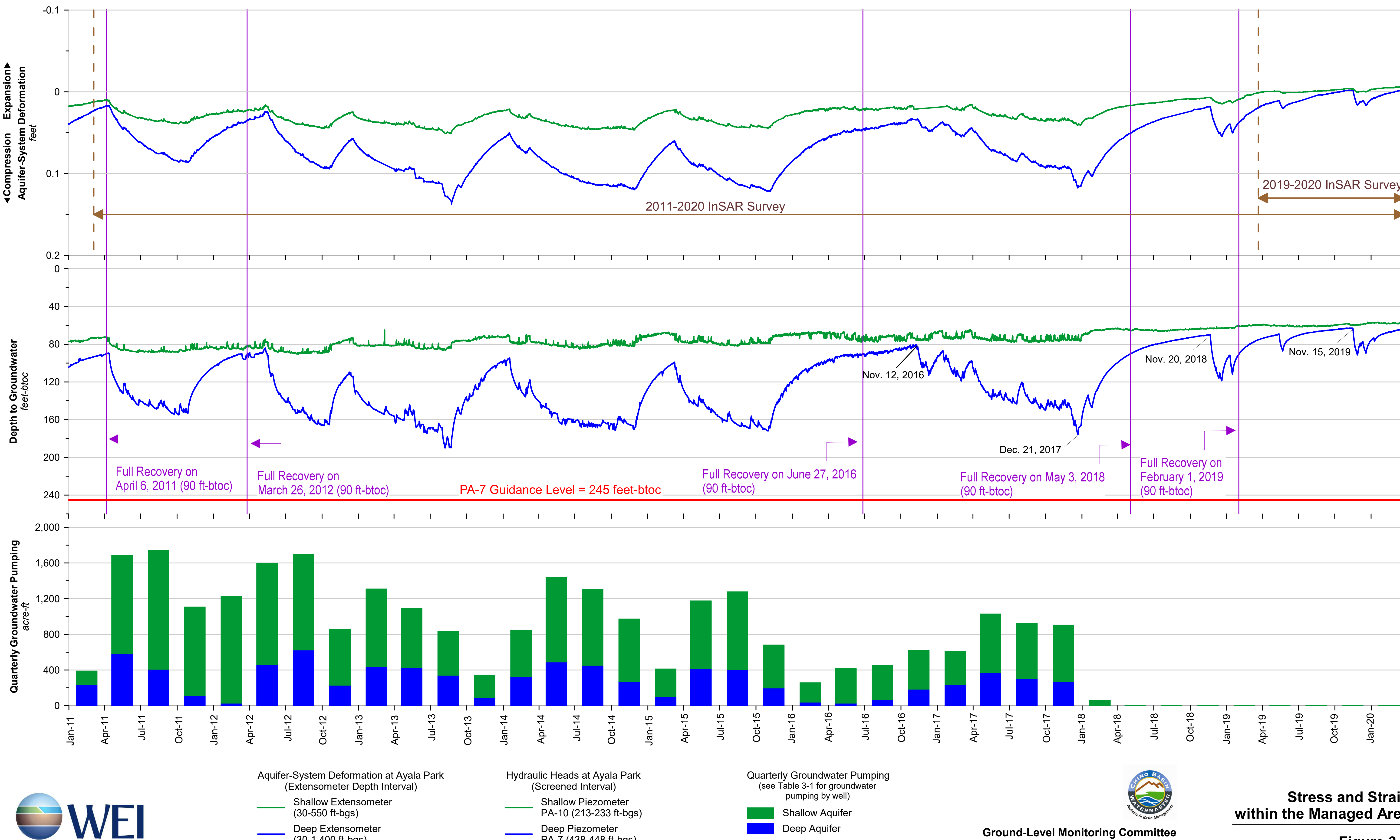

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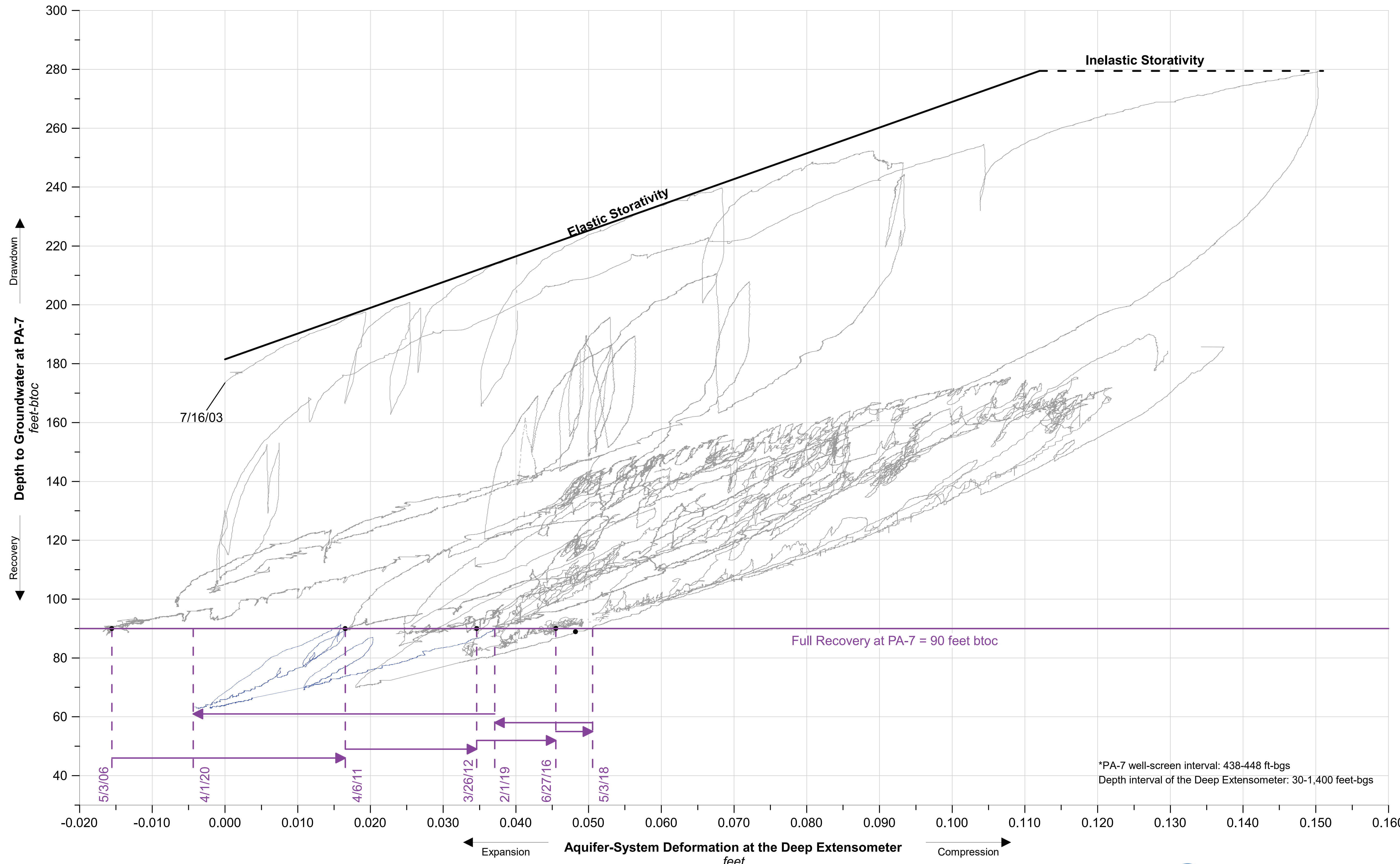
Stress and Strain within the Managed Area

Figure 3-3



Stress - Strain Hysteresis Loops of Drawdown and Recovery Cycles

Drawdown and recovery between July 16, 2003 and January 31, 2019

Drawdown and recovery between April 1, 2019 and April 1, 2020

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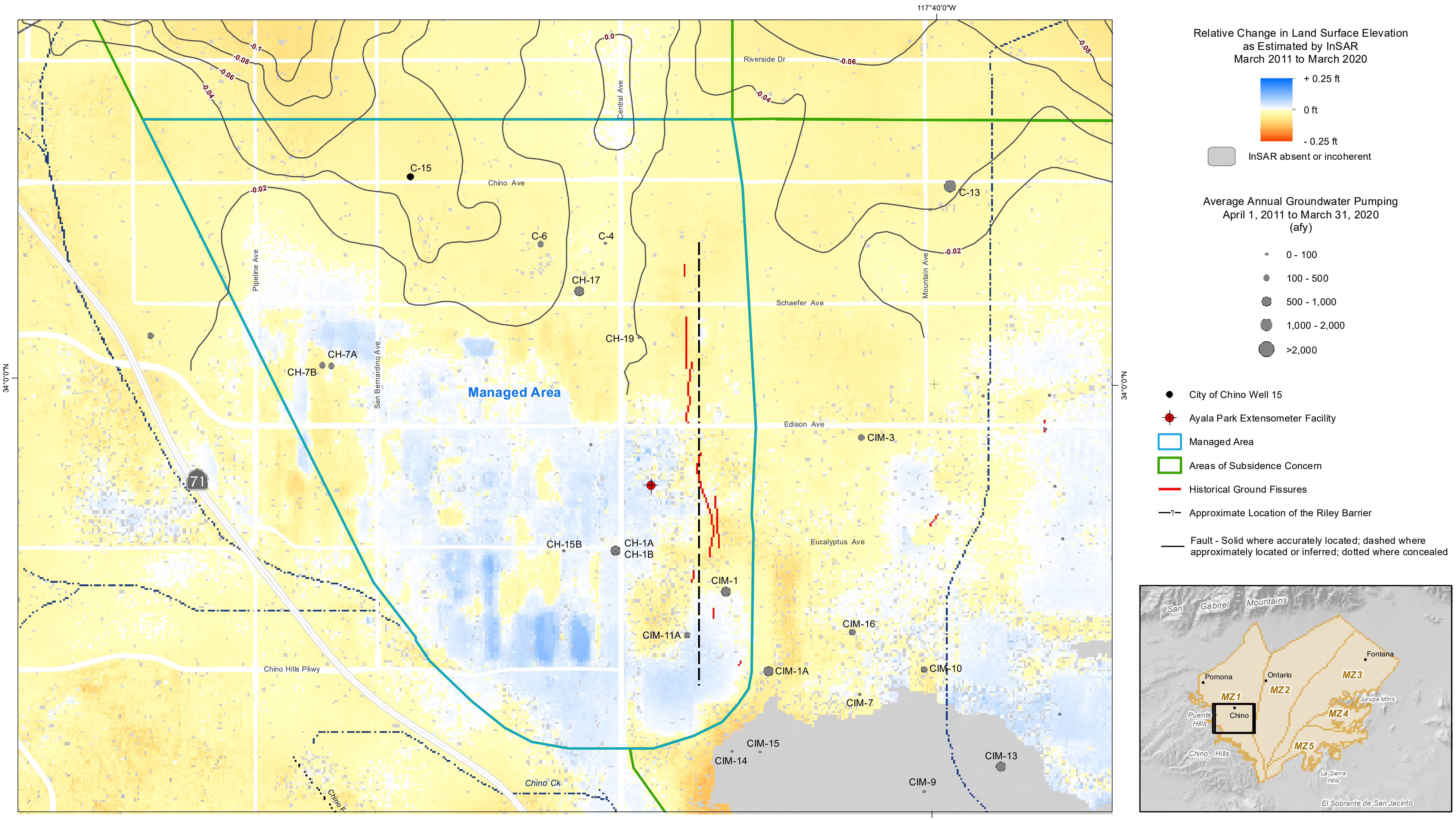
Stress-Strain Diagram
Ayala Park Extensometer

Figure 3-4



0 0.5 1 Miles

0 0.5 1 Kilometers

Author: RT
Date: 10/21/2020
Document Name: Figure_3-5a_2019_20_Managedgroundmotion_TS

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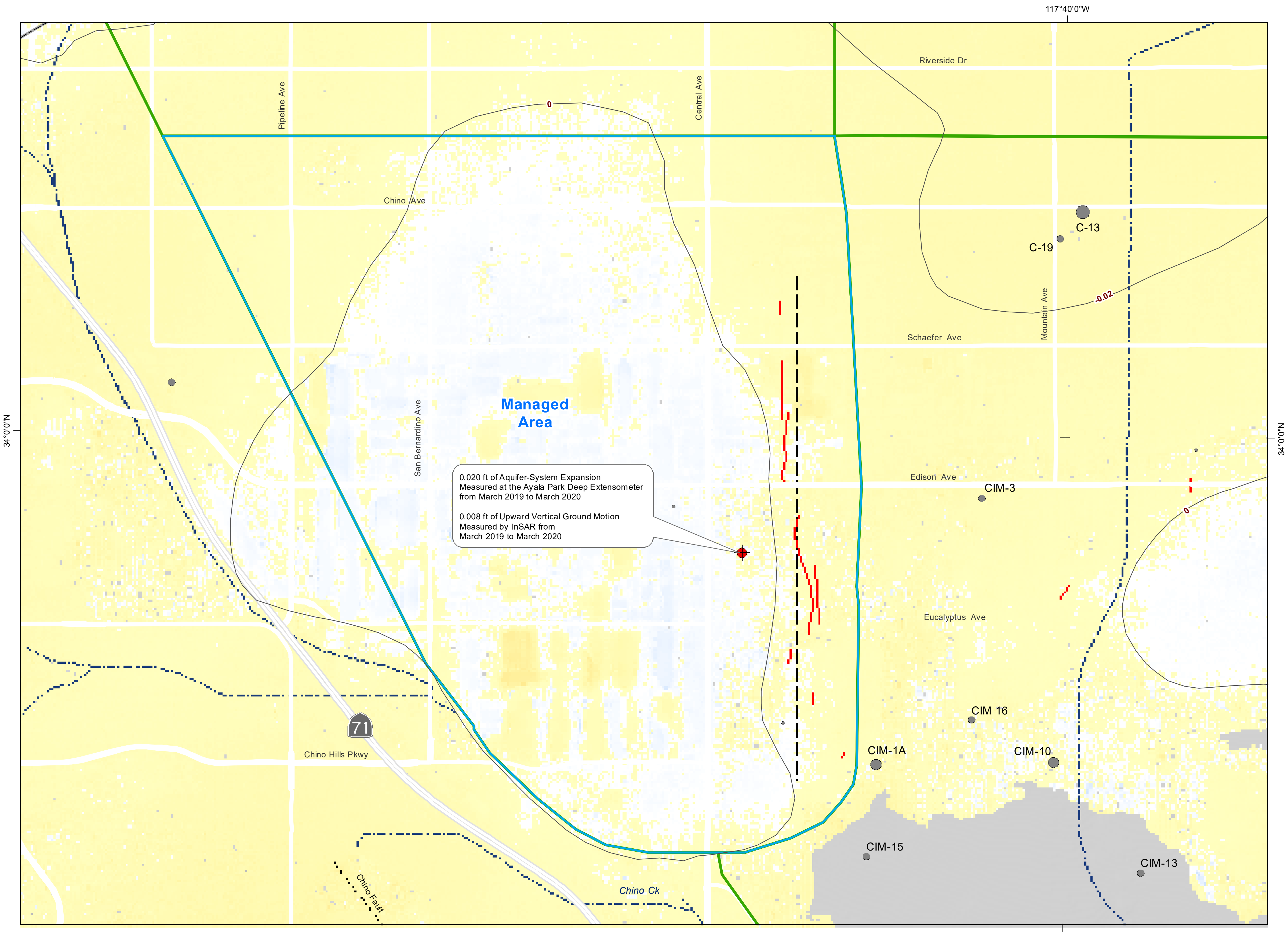
Vertical Ground Motion across the Managed Area
2011-2020

Figure 3-5a



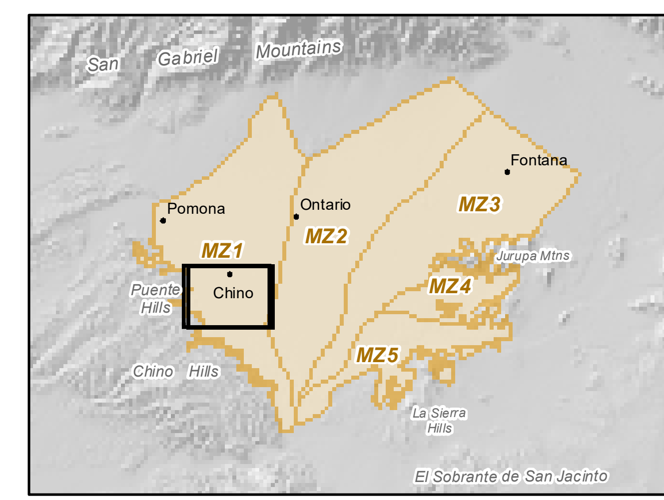
Relative Change in Land Surface Elevation as Estimated by InSAR
March 2019 to March 2020

+ 0.25 ft
0 ft
- 0.25 ft
InSAR absent or incoherent

Groundwater Pumping
April 1, 2019 to March 31, 2020
(afy)

0 - 100
100 - 500
500 - 1,000
1,000 - 2,000

Ayala Park Extensometer Facility
Managed Area
Areas of Subsidence Concern
Historical Ground Fissures
Approximate Location of the Riley Barrier
Fault - Solid where accurately located; dashed where approximately located or inferred; dotted where concealed



WEI
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Author: RT
Date: 10/21/2020
Document Name: Figure_3-5b_2019_20_Managedgroundmotion_TS

0 0.5 1 Miles
0 0.5 1 Kilometers

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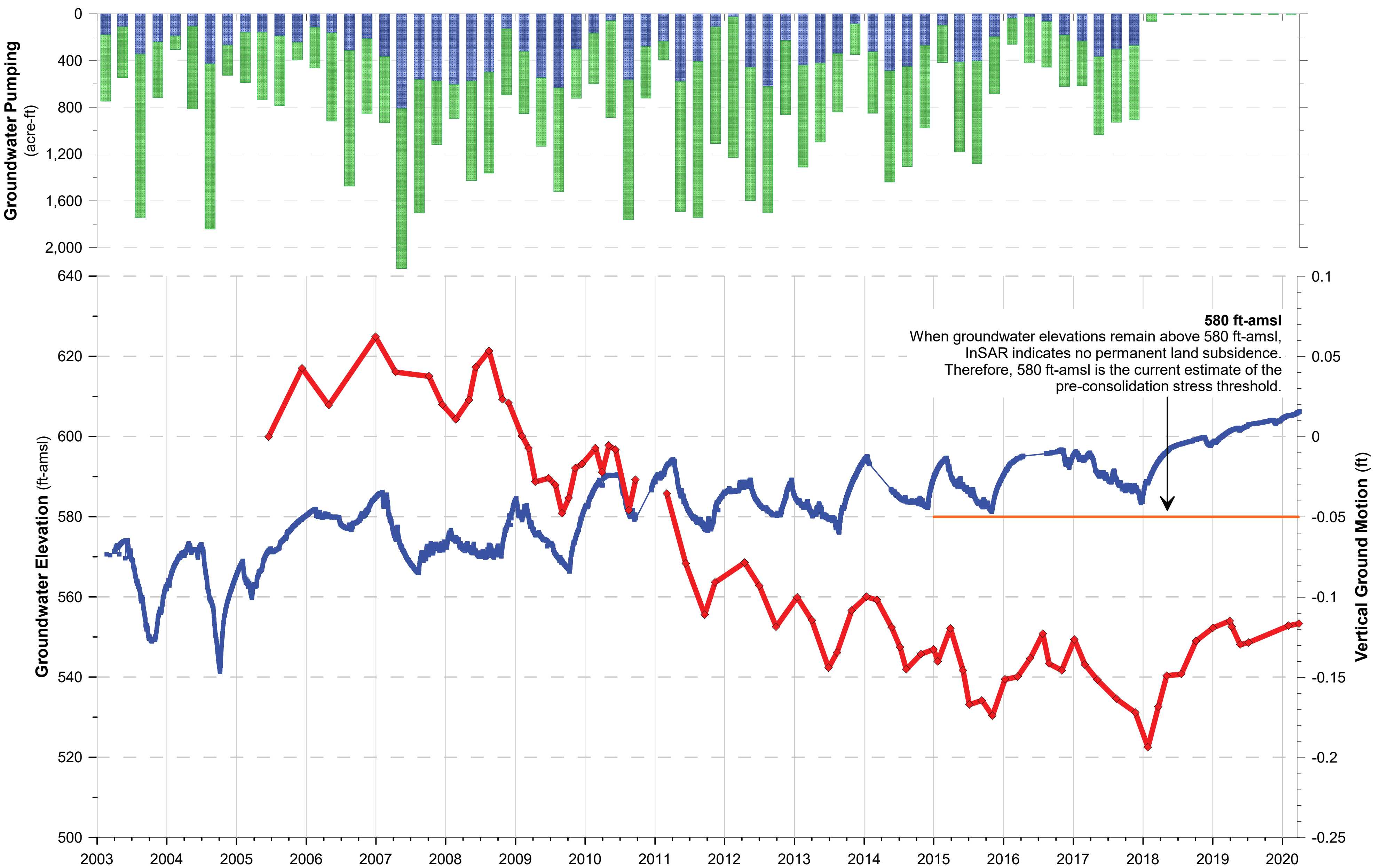
Vertical Ground Motion across the Managed Area
2019/20

Figure 3-5b



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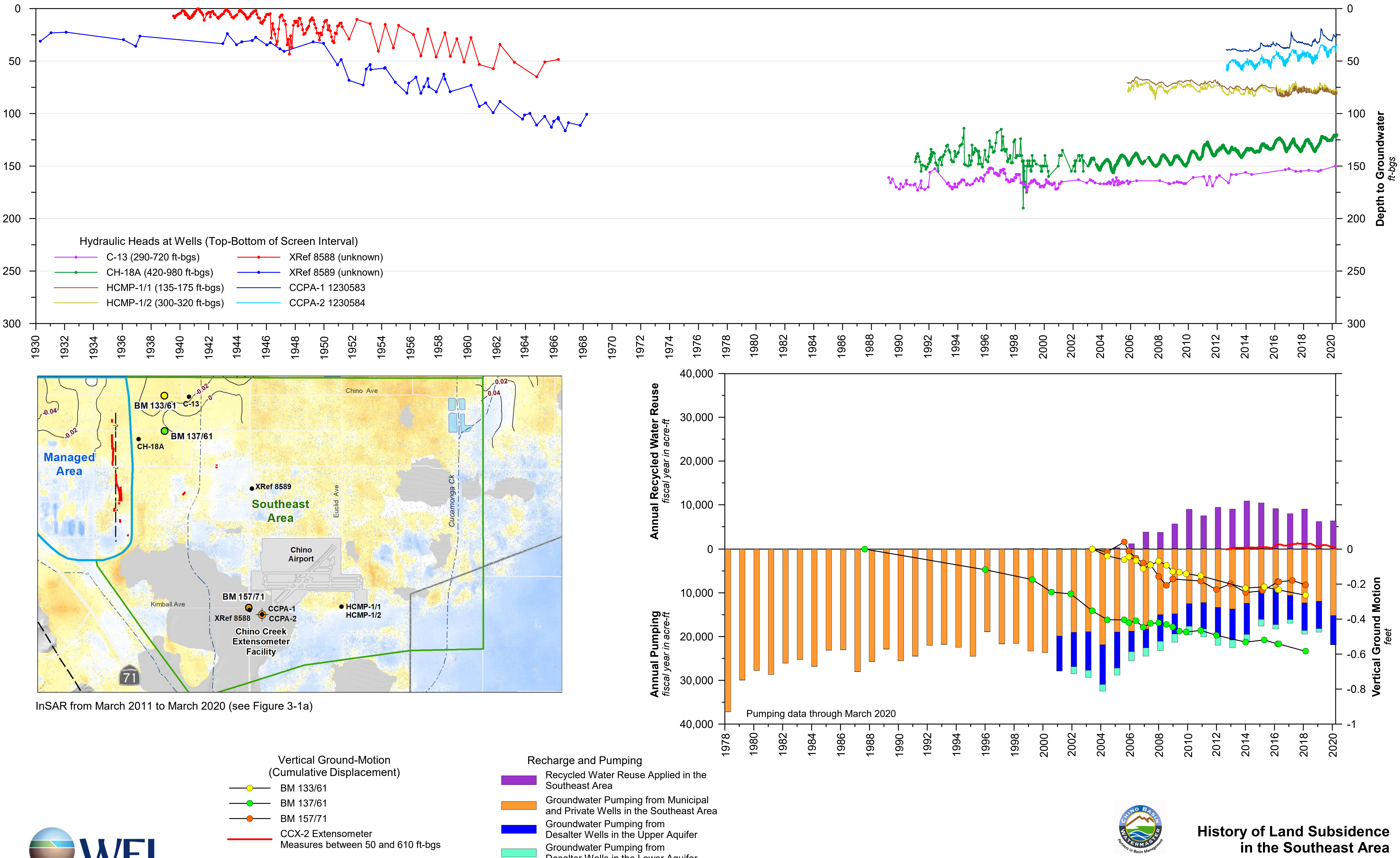
Hydraulic Heads at C-15 Versus Groundwater Pumping and Vertical Ground Motion

Figure 3-6



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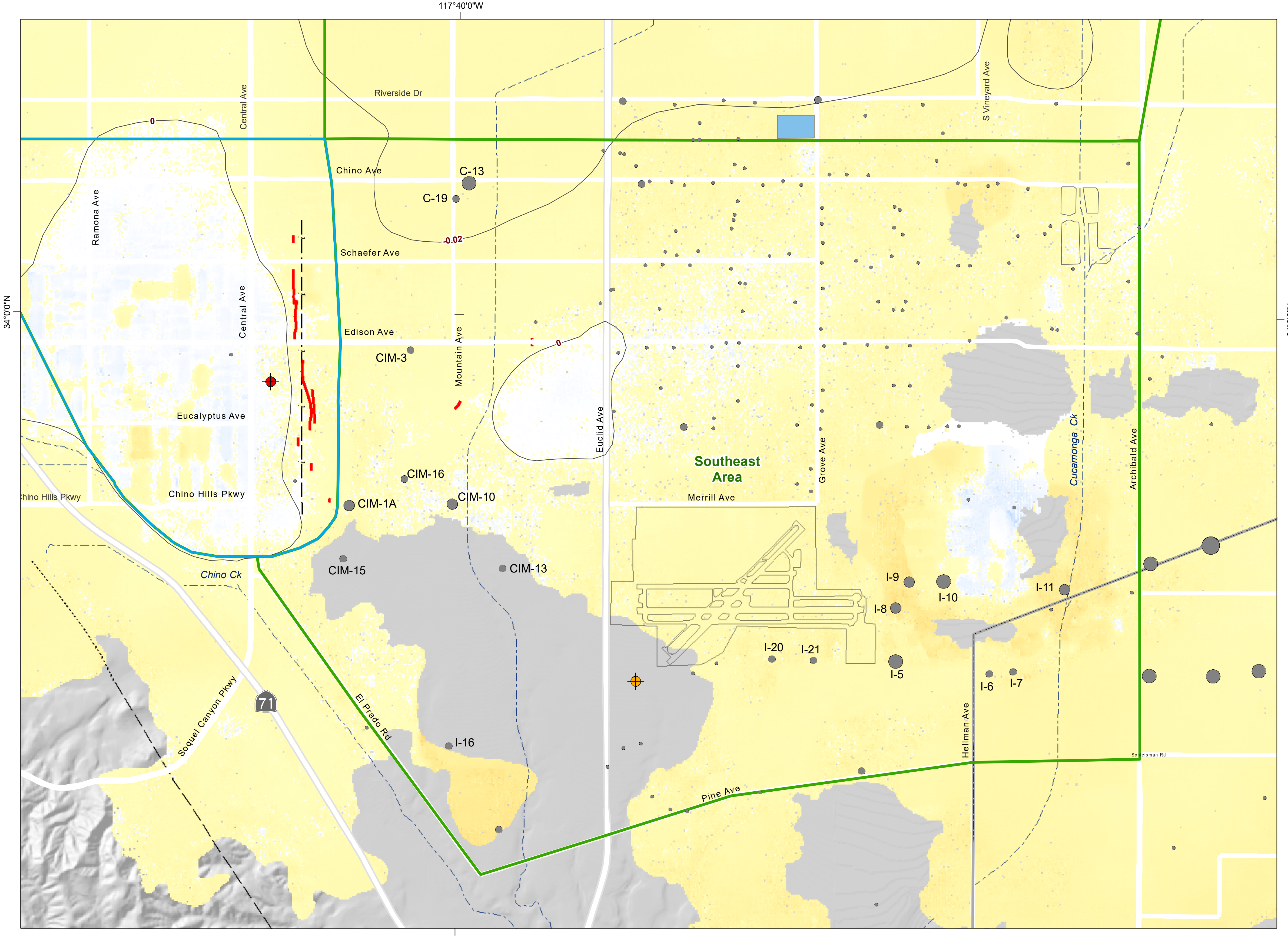
History of Land Subsidence in the Southeast Area

Figure 3-7



Relative Change in Land Surface Elevation as Estimated by InSAR March 2019 to March 2020

- + 0.25 ft
- 0 ft
- - 0.25 ft
- InSAR absent or incoherent

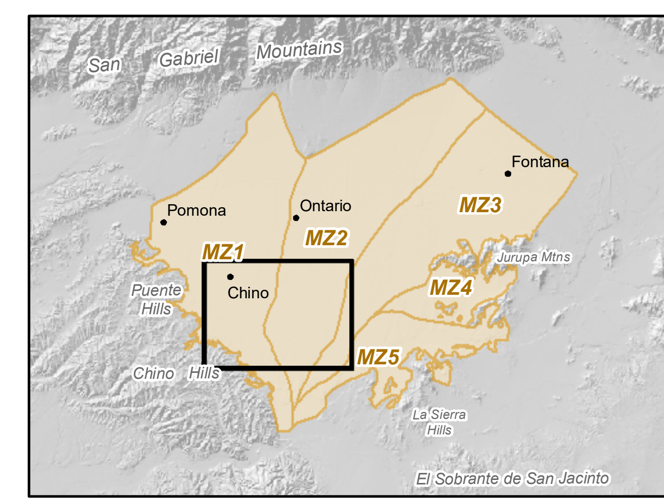
Groundwater Pumping April 1, 2019 to March 31, 2020 (afy)

- 0 - 100
- 100 - 500
- 500 - 1,000
- 1,000 - 2,000

Average Annual Basin Recharge April 1, 2019 to March 31, 2020 (afy)

- 0
- <1,000

- Chino Creek Extensometer Facility
- Ayala Park Extensometer Facility
- Managed Area
- Areas of Subsidence Concern
- Ground Fissures
- Approximate Location of the Riley Barrier
- Fault - Solid where accurately located; dashed where approximately located or inferred; dotted where concealed.



WILDERMUTH ENVIRONMENTAL, INC.

Author: RT
Date: 9/14/2020
Document Name: Figure_3-8_2019_20_SEgroundmotion

0 0.5 1 Miles

0 0.5 1 Kilometers

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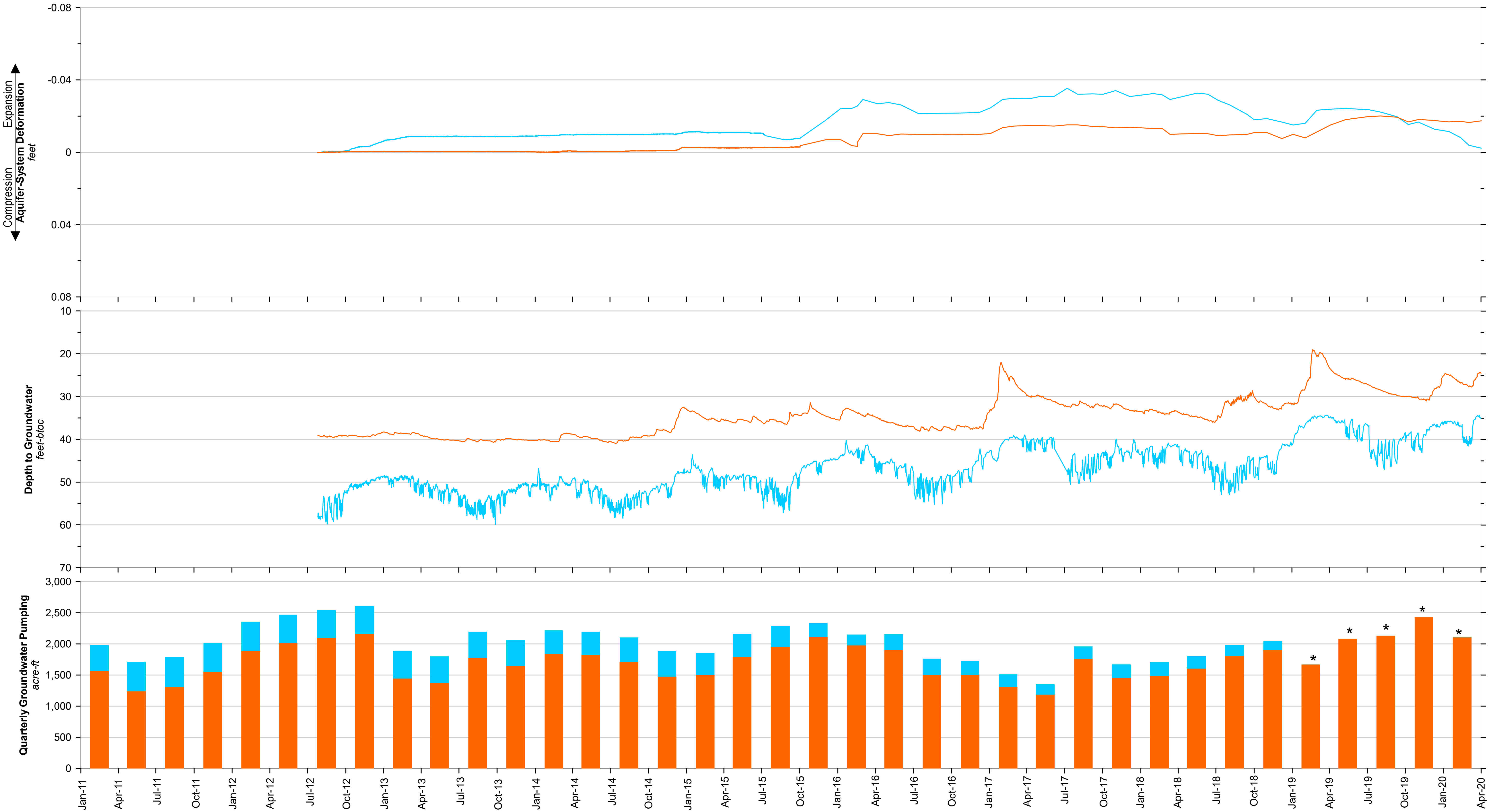
Vertical Ground Motion across the Southeast Area
2019/20

Figure 3-8



Aquifer-System Deformation (Extensometer Depth Interval)
- Shallow Extensometer CCX-1 (50-140 ft-bgs)
- Deep Extensometer CCX-2 (50-610 ft-bgs)

Hydraulic Heads (Top-Bottom of Screen Interval)
- Shallow Piezometer CCPA-1 (100-130 ft-bgs)
- Deep Piezometer CCPA-2 (235-295 ft-bgs)

CDA Groundwater Pumping
- Shallow Aquifer[1]
- Deep Aquifer[2]

1 = CDA-5 through 11, 16, 17, 20 and 21
2 = CDA-1 through 4

* CDA groundwater pumping from the deep aquifer < 2 af

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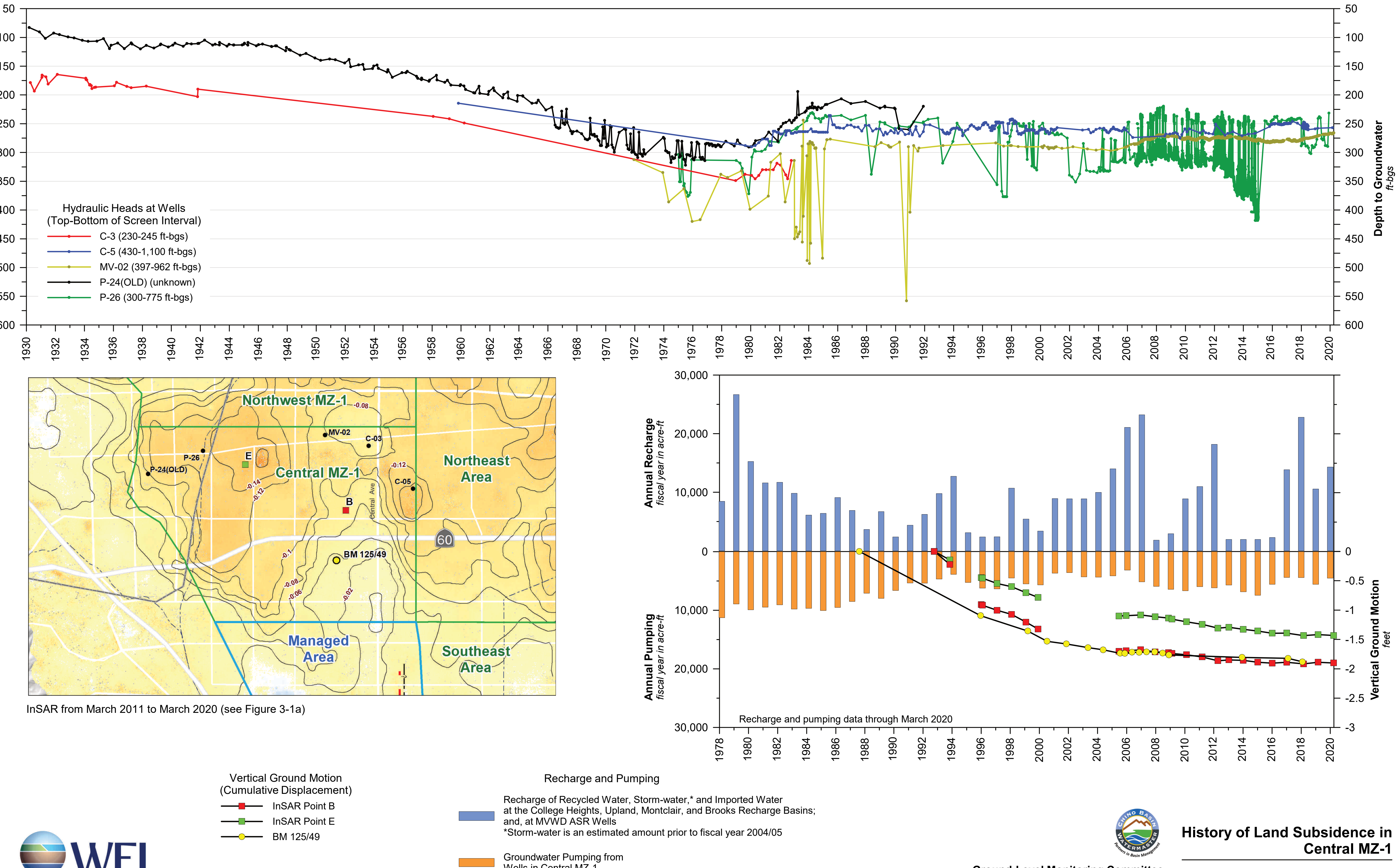
Stress and Strain within the Southeast Area

Figure 3-9



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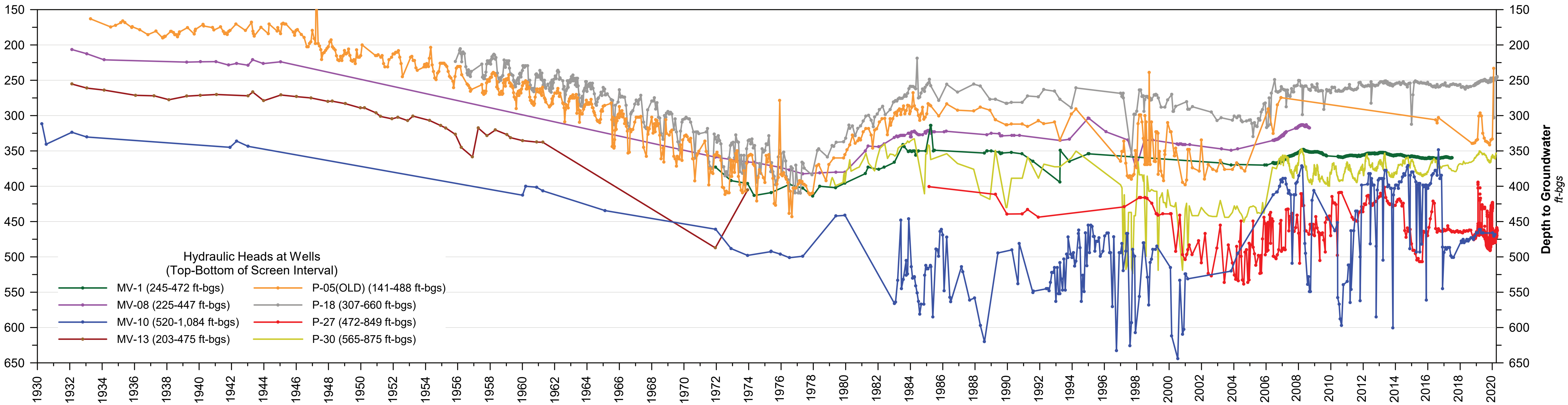
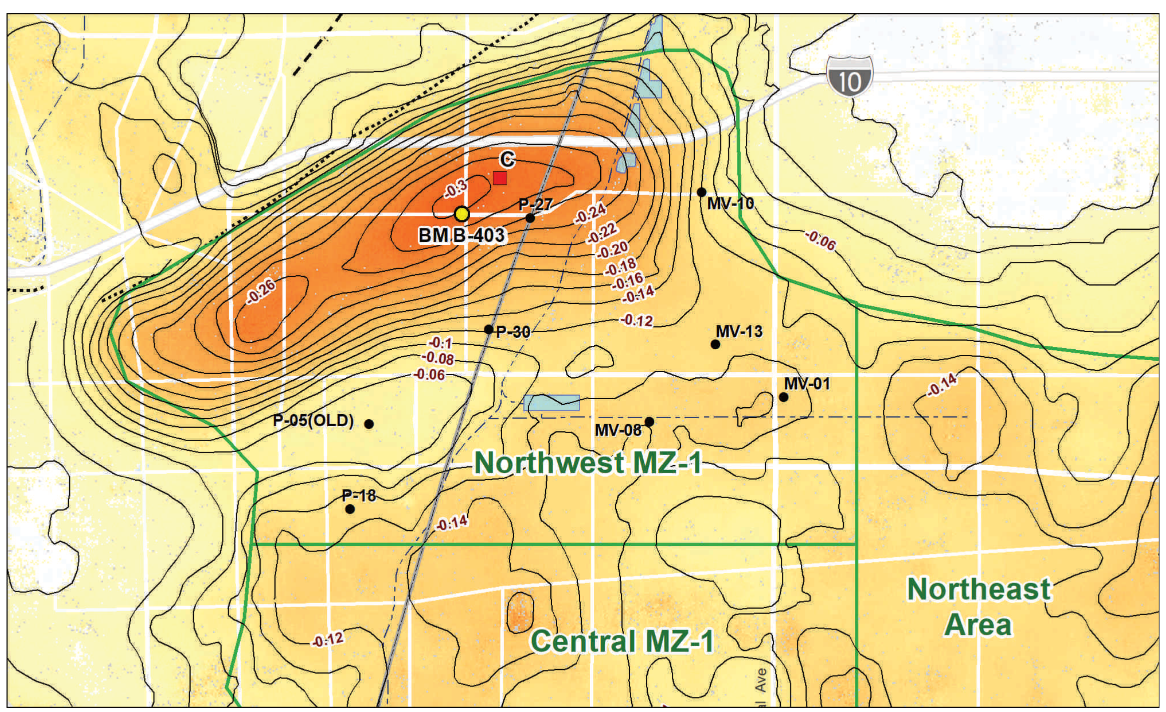
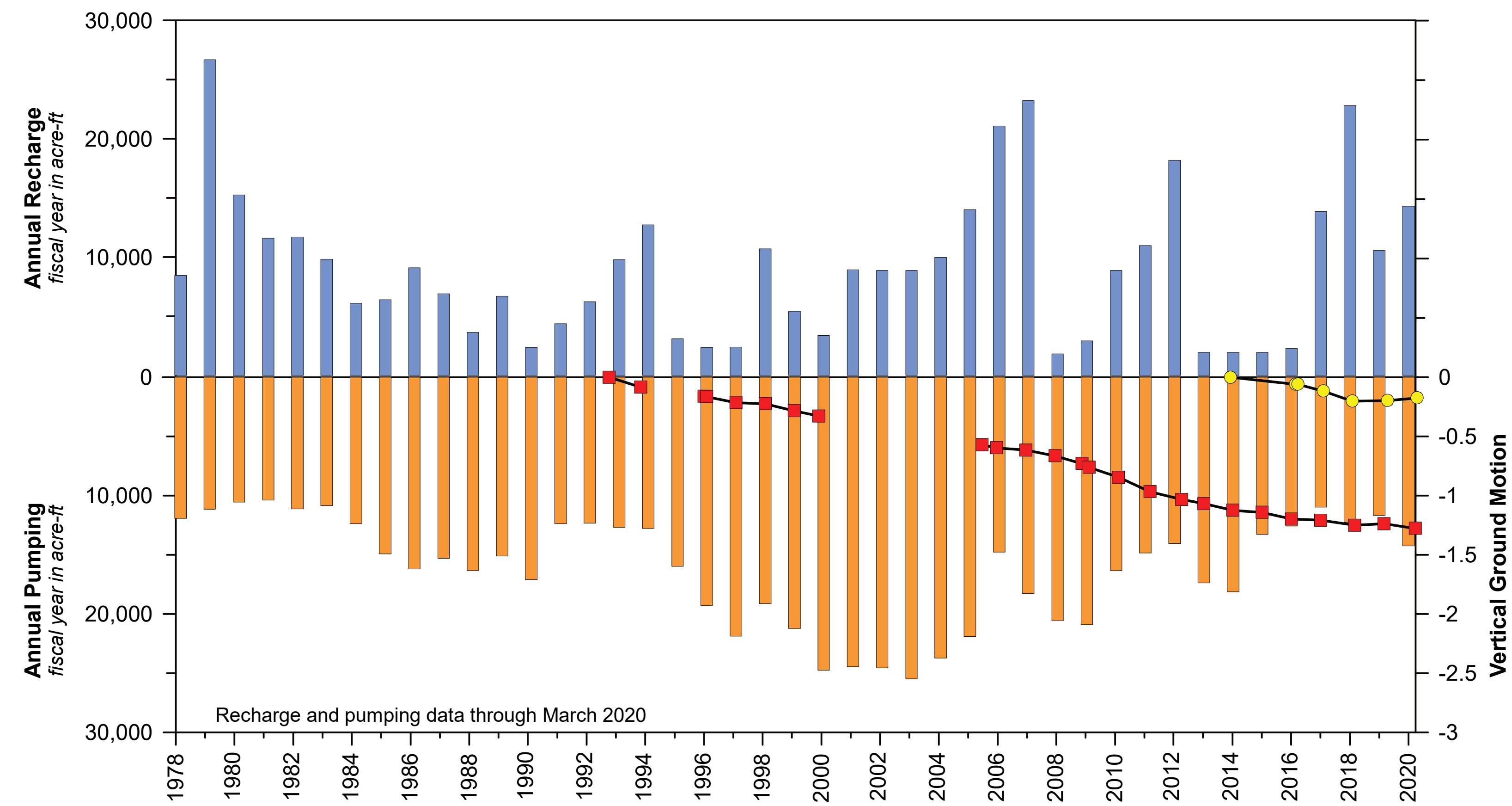
History of Land Subsidence in Central MZ-1

Figure 3-10





InSAR from March 2011 to March 2020 (see Figure 3-1a)



Vertical Ground-Motion
(Cumulative Displacement)

BM B-403

InSAR at Point C

Recharge and Pumping

Recharge of Recycled Water, Storm-water,* and Imported Water at the College Heights, Upland, Montclair, and Brooks Recharge Basins; and, at MVWD ASR Wells
*Storm-water is an estimated amount prior to fiscal year 2004/05

Groundwater Pumping from Wells in the Northwest MZ-1

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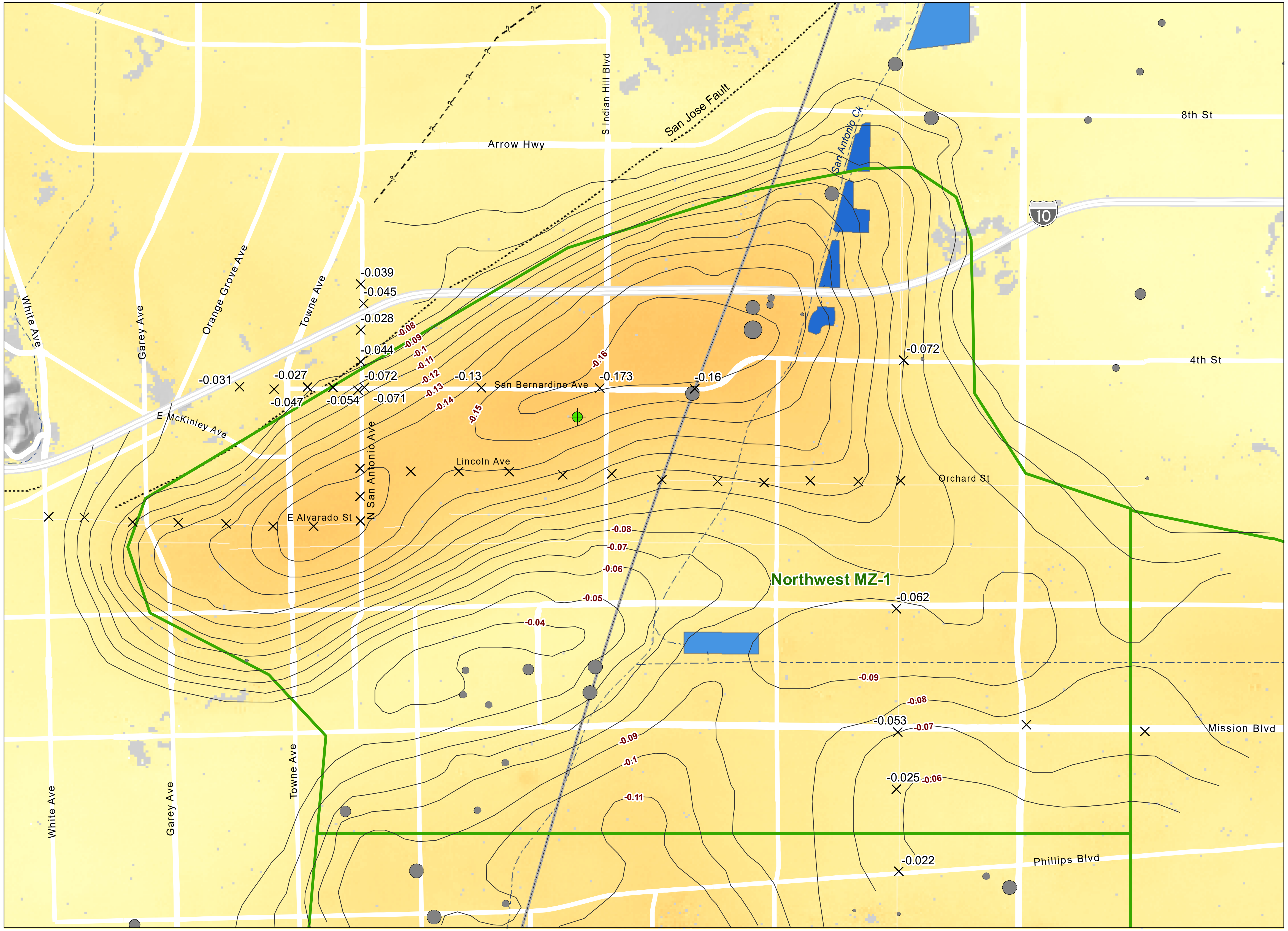
History of Land Subsidence in Northwest MZ-1

Figure 3-11



Relative Change in Land Surface Elevation as Estimated by InSAR January 2014 to March 2020

+ 0.25 ft
0 ft
- 0.25 ft

InSAR absent or incoherent

Average Annual Groundwater Pumping April 1, 2014 to March 31, 2020 (afy)

- 0 - 100
- 100 - 500
- 500 - 1,000
- 1,000 - 2,000

Average Annual Basin Recharge April 1, 2014 to March 31, 2020 (afy)

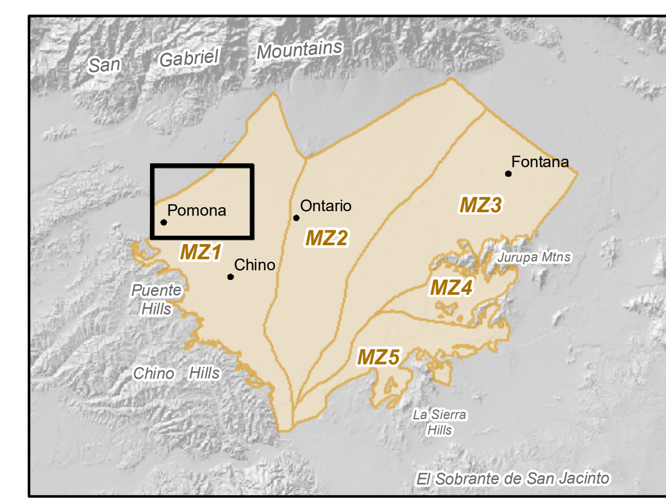
- 0
- <1,000
- 1,000 - 2,500
- 2,500 - 5,000

Pomona Extensometer Facility

Ground-Level Survey Benchmark (Measured April 21, 2020) Labeled by Vertical Ground Motion (in feet from December 2013 to April 2020)

Areas of Subsidence Concern

Fault (solid where accurately located; dashed where approximately located or inferred; dotted where concealed)



WEI
Wildermuth Environmental, Inc.

Author: RT
Date: 9/14/2020
Document Name: Figure_3-12a_2019_20_NWgroundmotion

0 0.5 1 Miles
0 0.5 1 Kilometers

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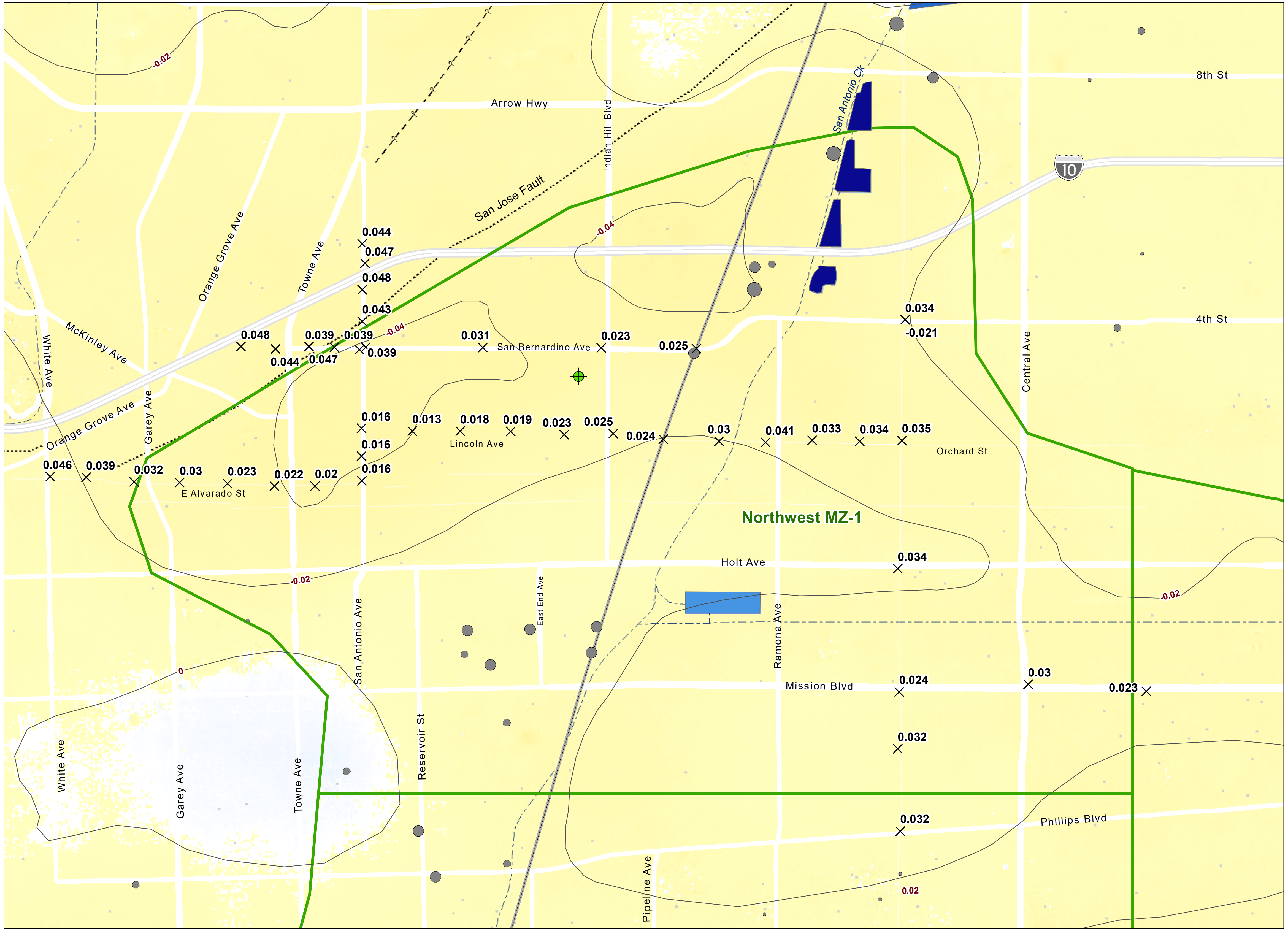
2019/20 Annual Report

Vertical Ground Motion across Northwest MZ-1
2014-2020

Figure 3-12a



Relative Change in Land Surface Elevation as Estimated by InSAR March 2019 to March 2020

+ 0.25 ft

0 ft

- 0.25 ft

InSAR absent or incoherent

Groundwater Pumping April 1, 2019 to March 31, 2020 (afy)

- 0 - 100
- 100 - 500
- 500 - 1,000
- 1,000 - 2,000
- >2,000

Average Annual Basin Recharge April 1, 2019 to March 31, 2020 (afy)

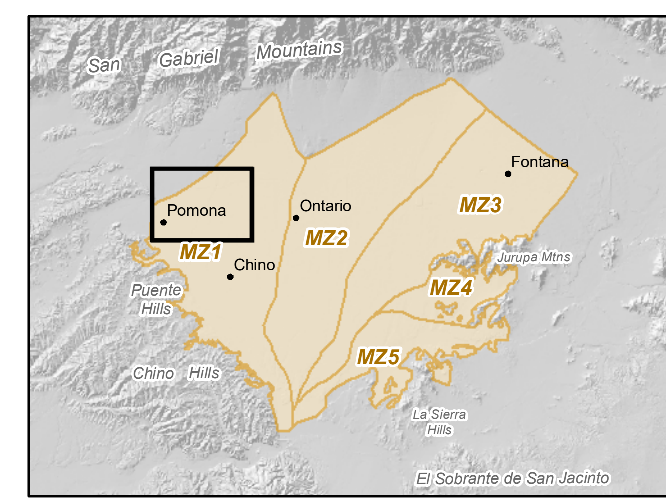
- 1,000 - 2,500
- >7,500

Pomona Extensometer Facility

Ground-Level Survey Benchmark (Measured April 21, 2020) Labeled by Vertical Ground Motion (in feet from April 2019 to April 2020)

Areas of Subsidence Concern

Fault (solid where accurately located; dashed where approximately located or inferred; dotted where concealed)



WEI
Wildermuth Environmental, Inc.

Author: RT
Date: 9/14/2020
Document Name: Figure_3-12b_2019_20_NWgroundmotion

0 0.5 1 Miles

0 0.5 1 Kilometers

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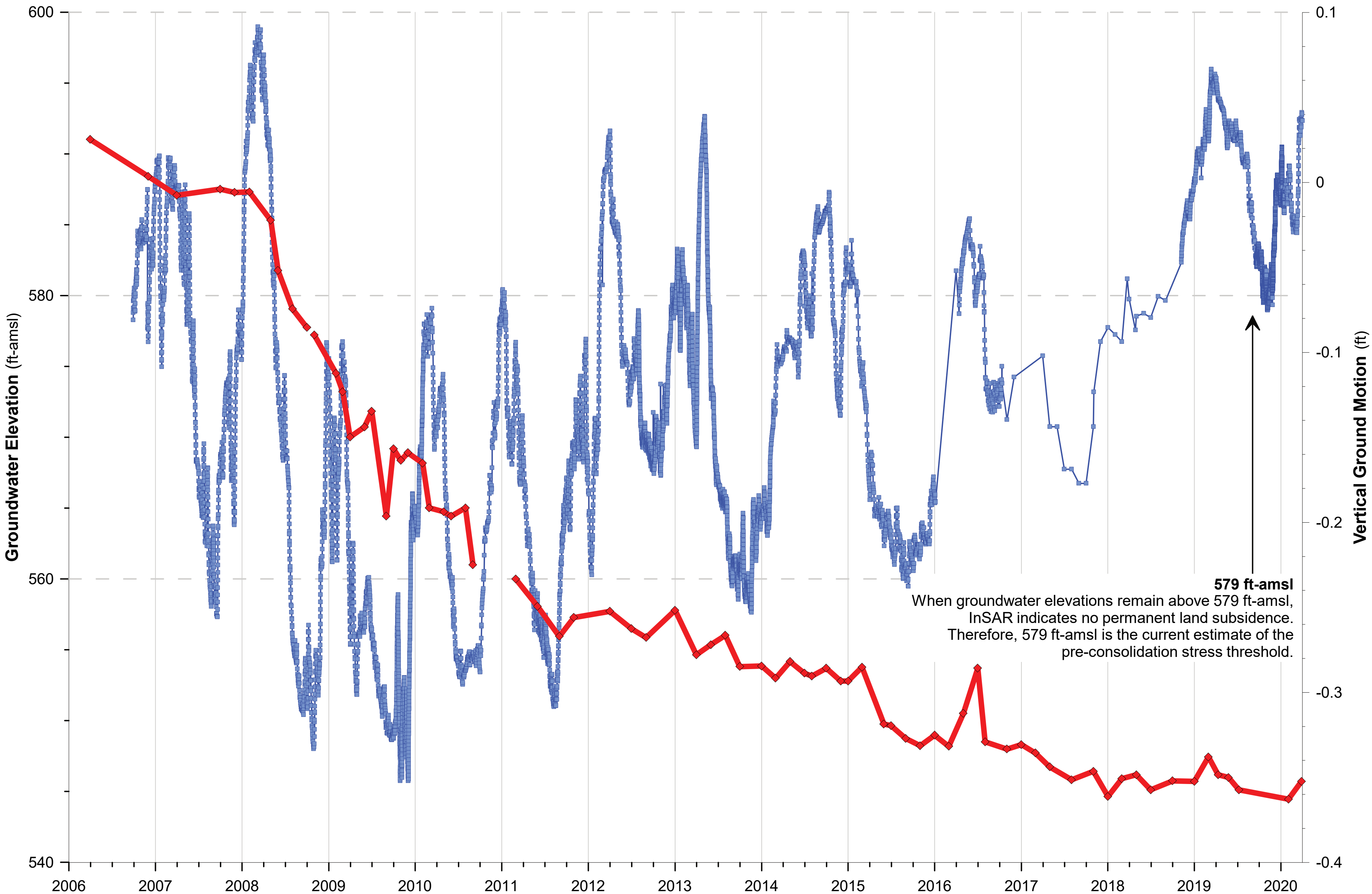
Vertical Ground Motion across Northwest MZ-1
2019/20

Figure 3-12b



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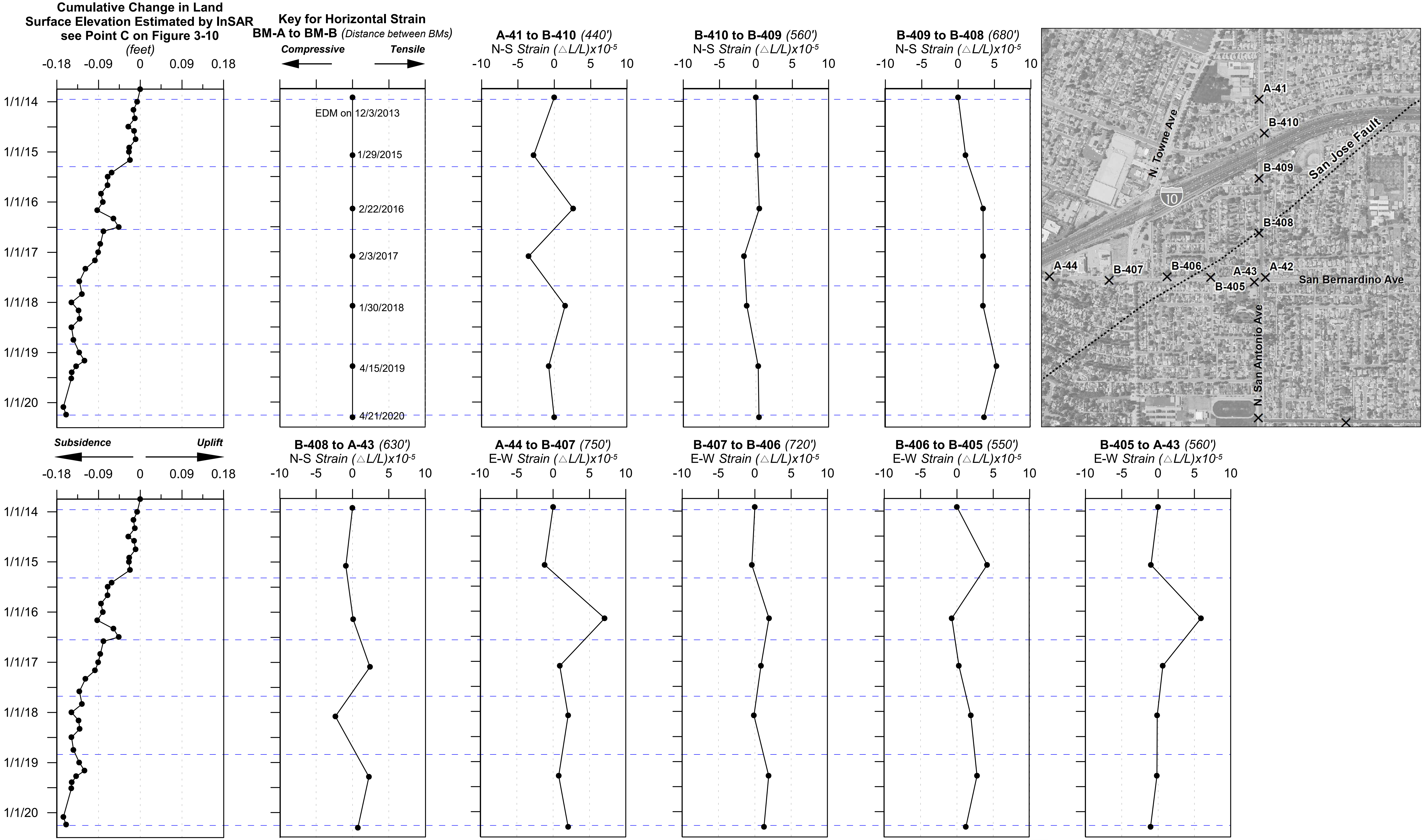
Hydraulic Heads at P-30 Versus Vertical Ground Motion

Figure 3-13



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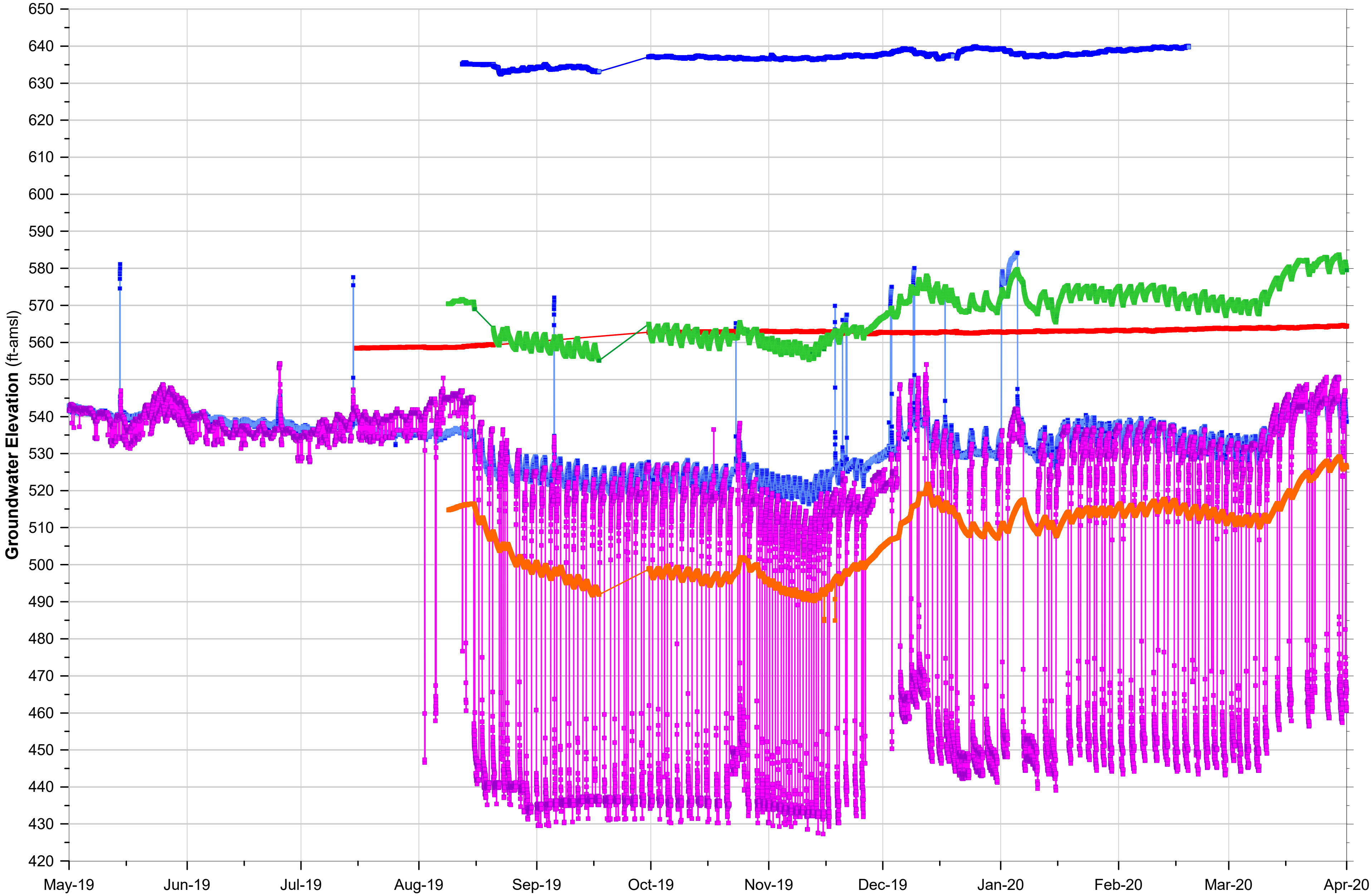
Horizontal Strain across the San Jose Fault as Calculated from Electronic Distance Measurements
2013-2020

Figure 3-14



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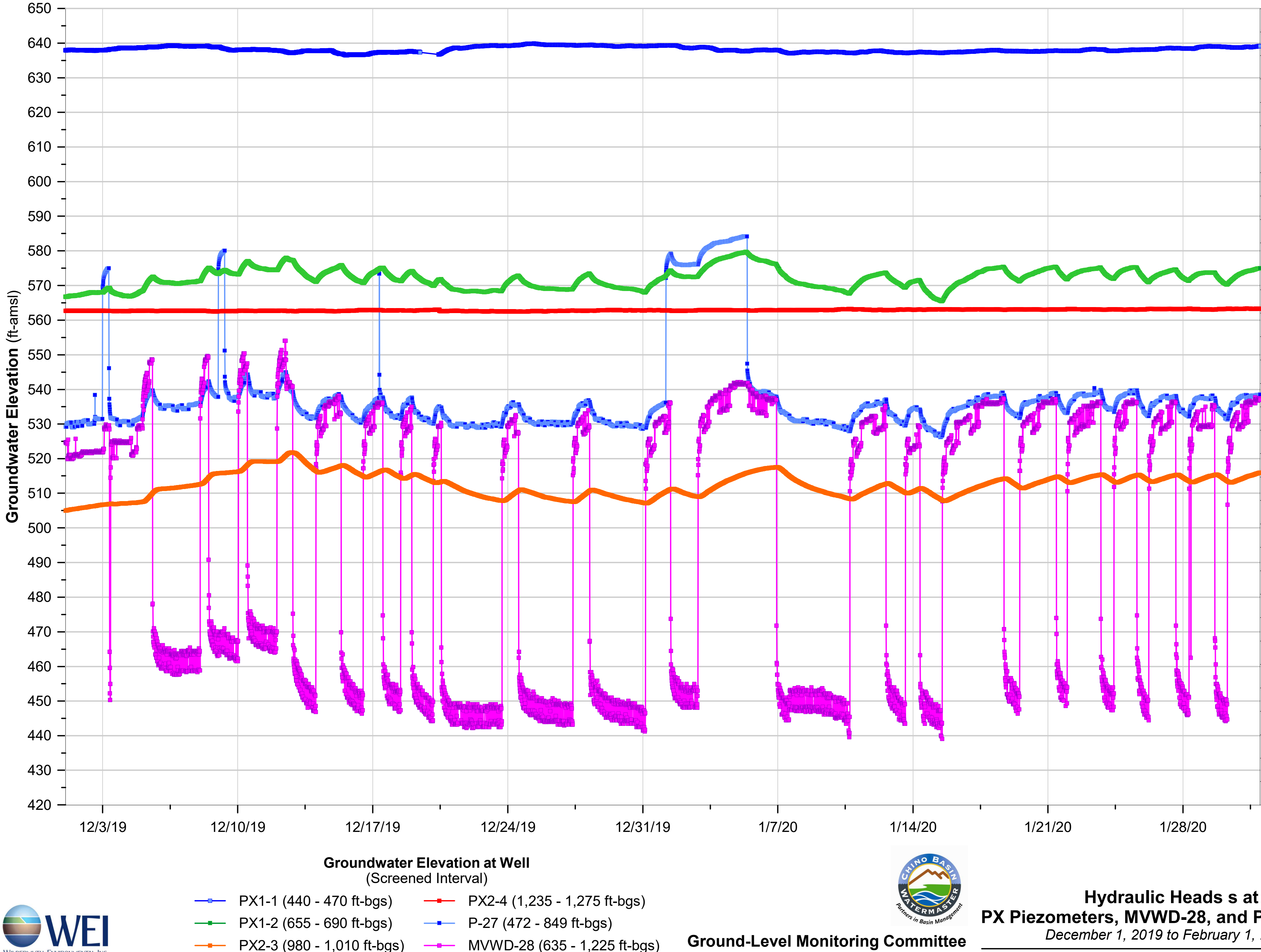
Hydraulic Heads at the PX Piezometers, MVWD-28, and P-27
May 2019 to March 2020

Figure 3-15



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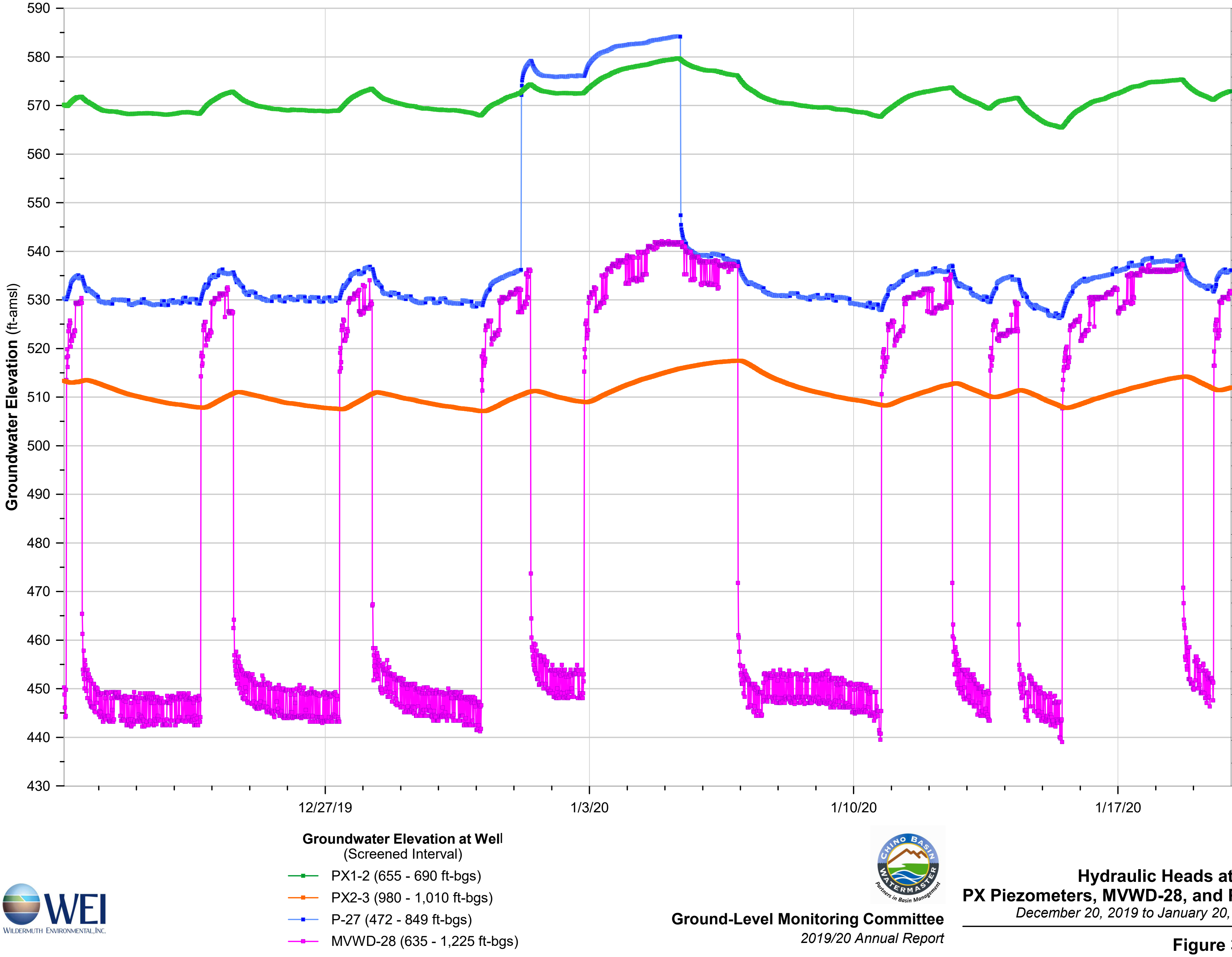
Hydraulic Heads s at the
PX Piezometers, MVWD-28, and P-27
December 1, 2019 to February 1, 2020

Figure 3-16



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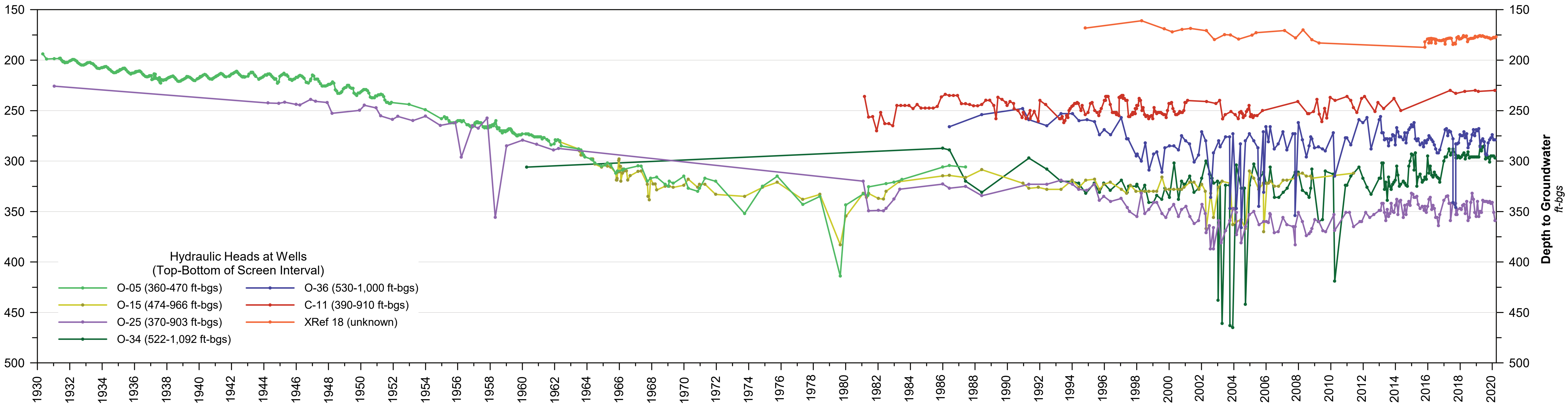
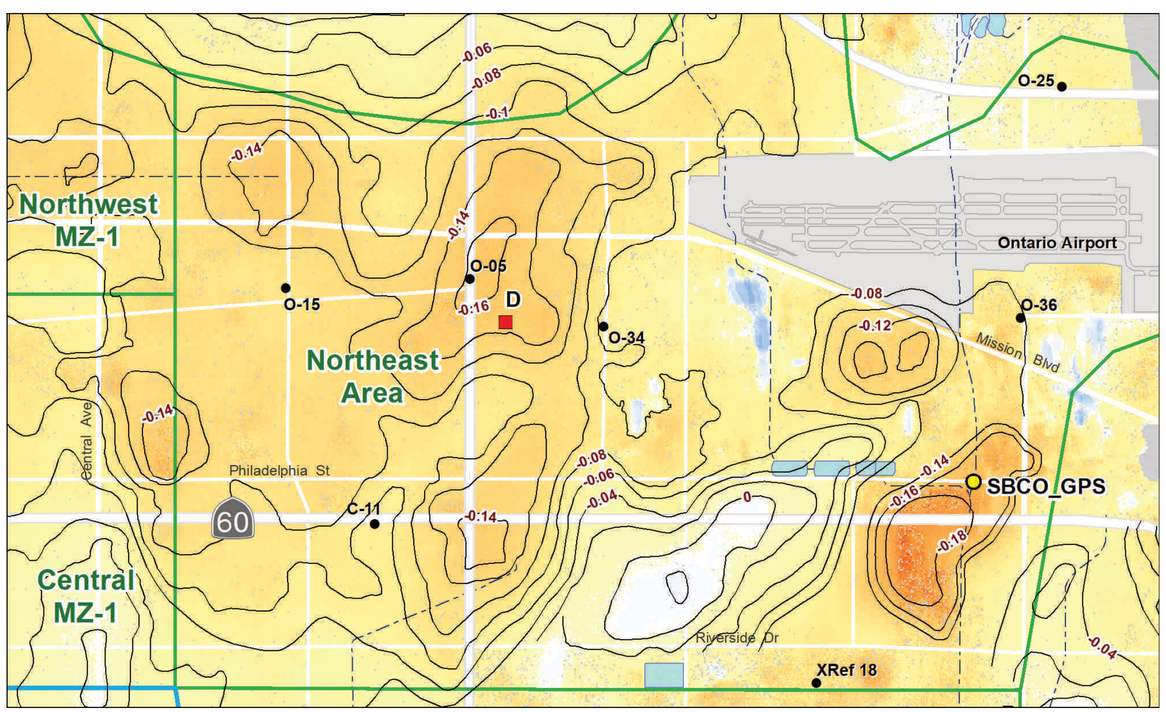
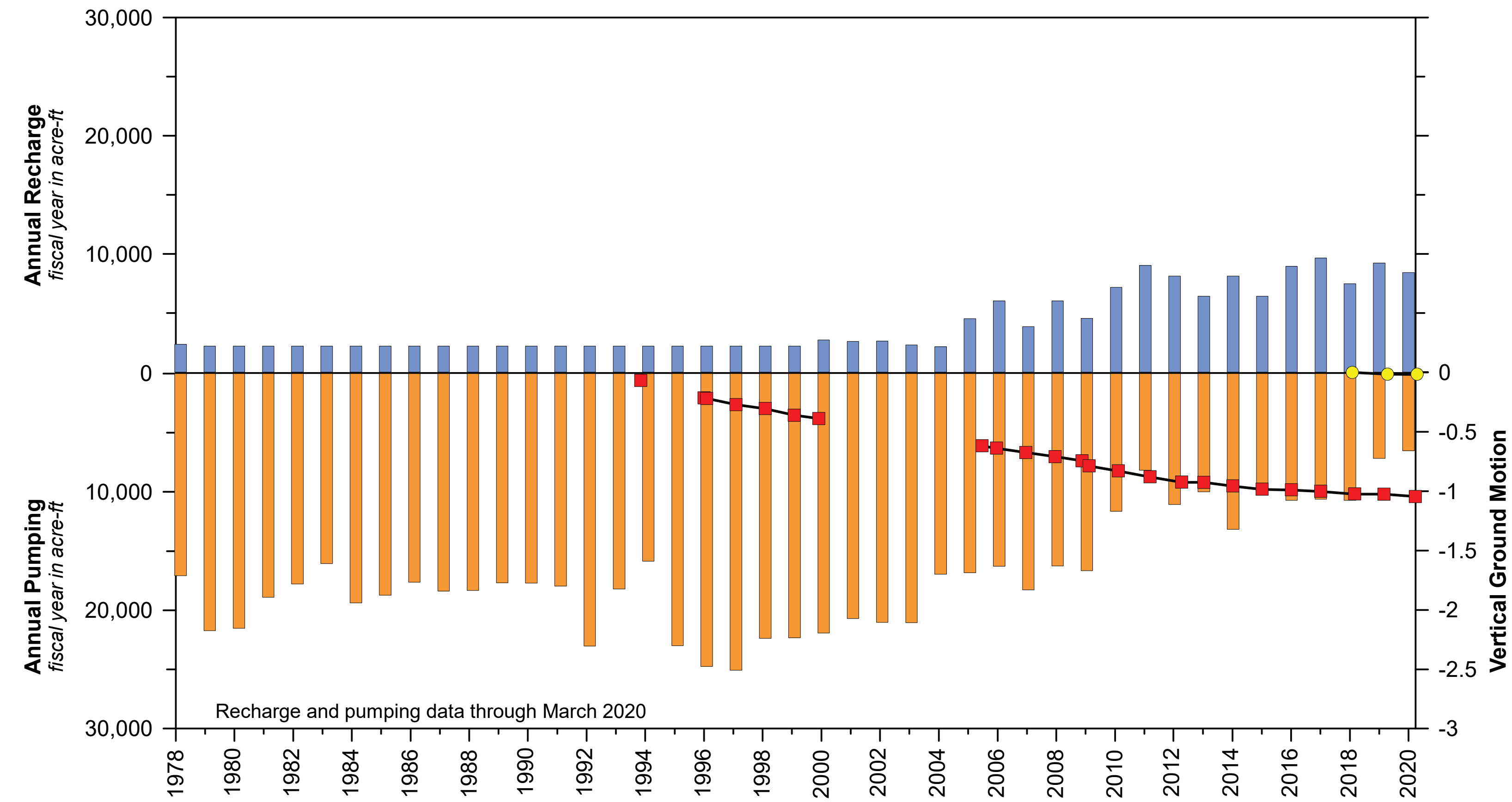
Hydraulic Heads at the PX Piezometers, MVWD-28, and P-27
December 20, 2019 to January 20, 2020

Figure 3-17





InSAR from March 2011 to March 2020 (see Figure 3-1a)



Vertical Ground-Motion
(Cumulative Displacement)

SBCO_GPS

InSAR at Point D

Recharge and Pumping

Recharge of Recycled, Storm-water,* and Imported Water
at the Ely, Grove, Turner, 7th Street and 8th Street Recharge Basins
*Storm-water is an estimated amount prior to fiscal year 2004/05

Groundwater Pumping from
Wells in the Northeast Area

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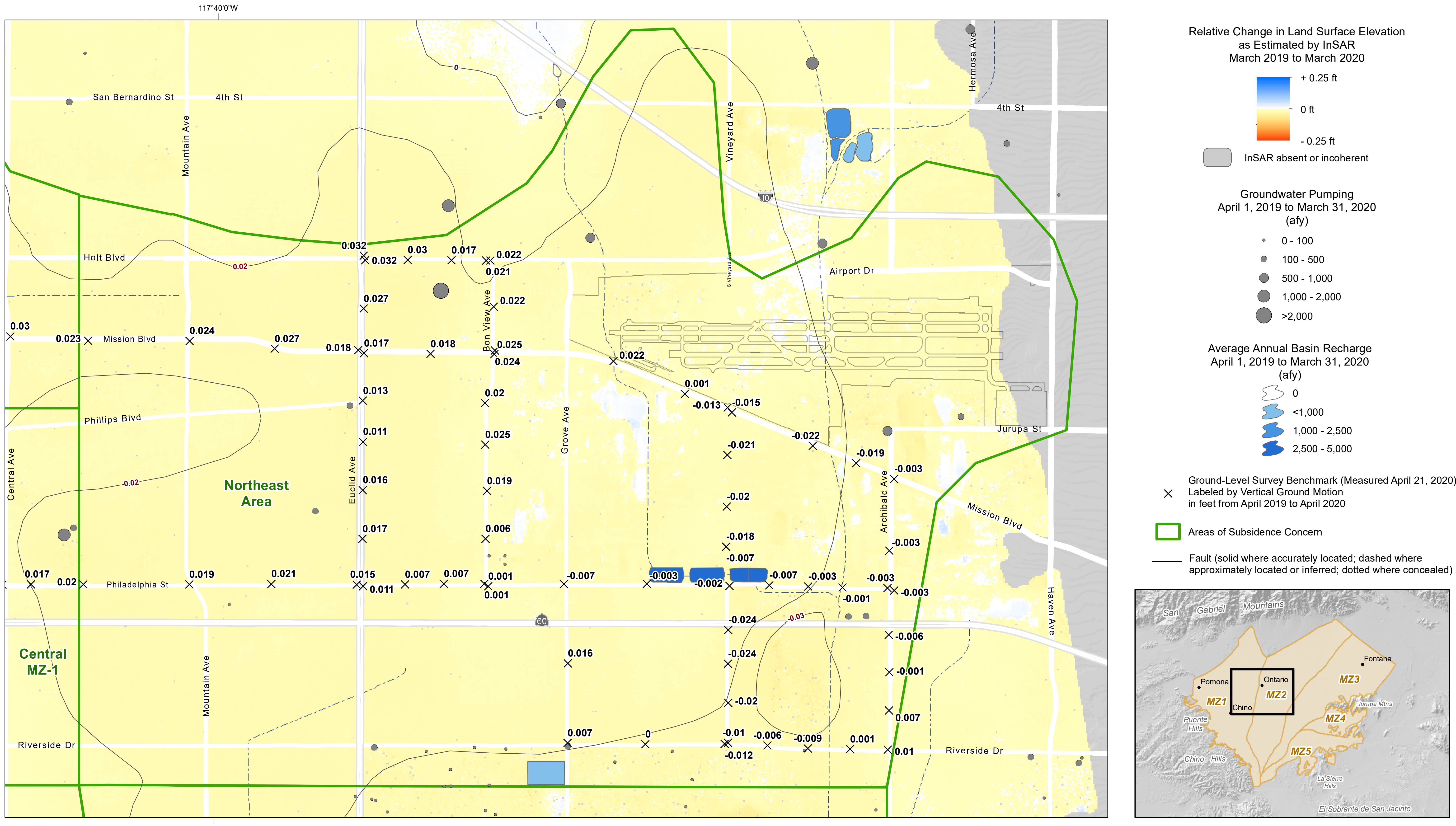
History of Land Subsidence in the Northeast Area

Figure 3-18



0 0.5 1 Miles

0 0.5 1 Kilometers

WEI
Wildermuth Environmental, Inc.

Author: RT
Date: 9/14/2020
Document Name: Figure_3-19_2019_20_NEgroundmotion

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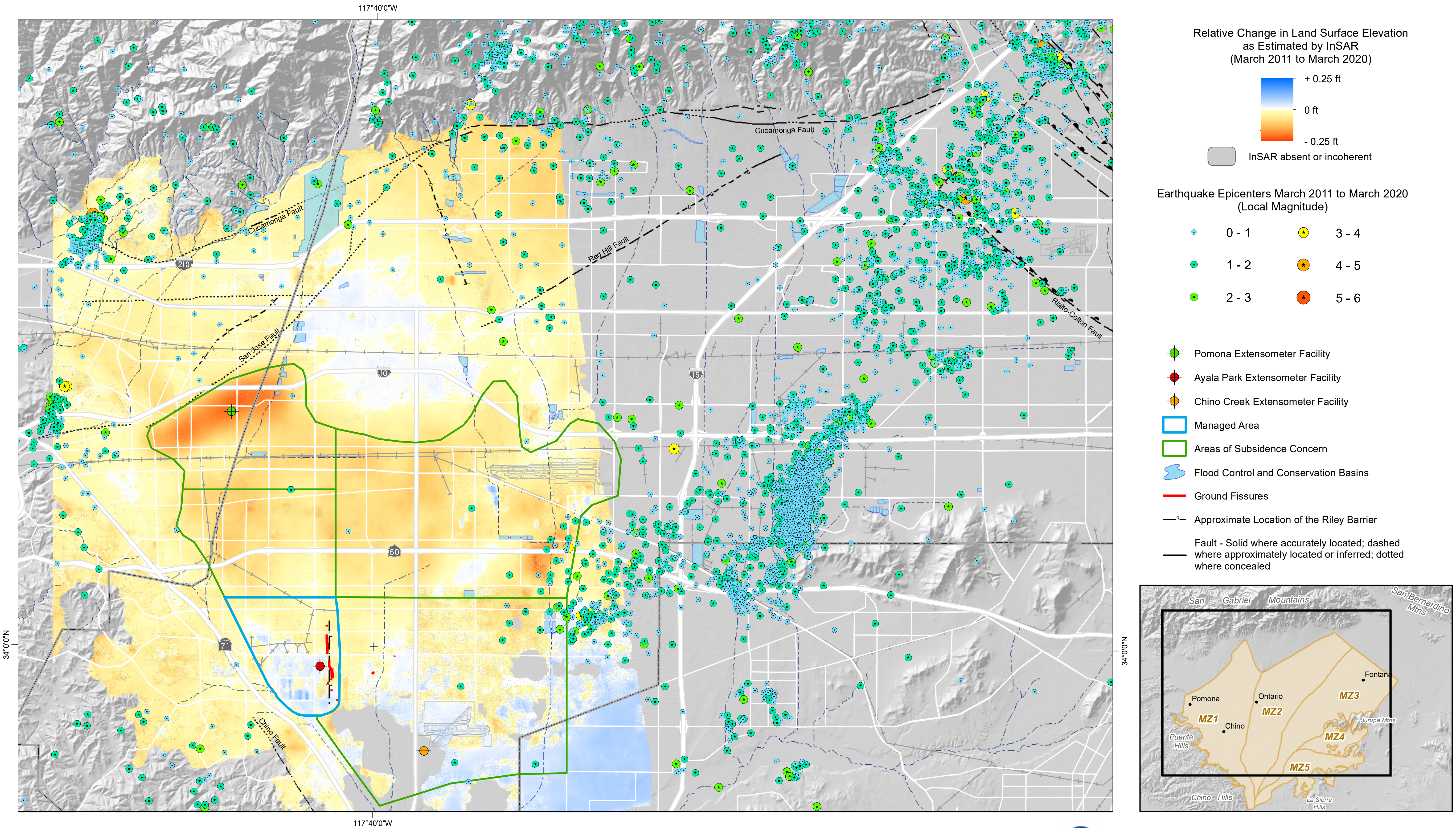
2019/20 Annual Report

Vertical Ground Motion across the Northeast Area
2019/20

Figure 3-19



WEI
Wildermuth Environmental, Inc.

Author: RT
Date: 9/10/2020
Document Name: Figure_3-20_2019_20_EQ_ZoomOut

Ground-Level Monitoring Committee
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Seismicity across the Chino Basin
2011-2020

Figure 3-20

Section 4 – Conclusions and Recommendations

4.1 Conclusions and Recommendations

The major conclusions and recommendations of this 2019/20 Annual Report of the GLMC are:

- At the Ayala Park Extensometer in the Managed Area, hydraulic heads within the shallow and deep aquifer-systems increased to their highest levels since the inception of the GLMP in 2003, and the Ayala Park Extensometers recorded elastic expansion of the aquifer-system during the current reporting period of March 2019 to March 2020. The increases in hydraulic head were due to the virtual cessation of pumping in the Managed Area during the reporting period. The reduced pumping is largely due to the presence of water-quality contaminants in groundwater that constrain its use as drinking water. Heads in the deep aquifer-system remain well above the Guidance Level, and the Ayala Park Extensometers recorded no inelastic compaction of the aquifer-system during the current reporting period of March 2019 to March 2020.

- Across most of the other Areas of Subsidence Concern, prior annual reports have noted long-term trends of gradual land subsidence from 1992-2020, even during periods of stable or increasing heads. The long-term trends in downward vertical ground motion have been of particular concern in Northwest MZ-1, where subsidence occurs differentially across the San Jose Fault and differential subsidence poses a threat for ground fissuring. The long-term trends of land subsidence have been attributed to the delayed drainage and compaction of aquitards as they slowly equilibrate with lower heads in the aquifers that were caused by historical pumping. Over the past several years, pumping has decreased across much of the western Chino Basin due to the presence of contaminants in groundwater that constrain its use as drinking water. Also, artificial recharge of imported water has increased mainly due to a "put" cycle in the Dry-Year Yield Program. The decreases in pumping and increases in recharge have caused heads to stabilize or increase, and InSAR estimates of ground motion across most of the Areas of Subsidence Concern have shown that the long-term trends of land subsidence have slowed. These observations suggest that the reductions in pumping, increases in recharge, and increases in hydraulic head may be causing equilibration of hydraulic heads in the aquitards and aquifers, which is slowing the drainage and compaction of the aquitards.

- The recent reduction in the rates of land subsidence across the Areas of Subsidence Concern does not mean that the future occurrence of subsidence and ground fissuring is no longer a threat. Future declines in hydraulic heads, which may be caused by increases in pumping or decreases in recharge, among other causes, may cause aquitard compaction and rates of land subsidence to increase. However, these recent observations may be indicating hydraulic head "thresholds" that, if achieved and maintained, could abate the future occurrence of permanent land subsidence. These hydraulic head thresholds, and various pumping and recharge strategies to maintain heads above these thresholds, were explored by the GLMC in 2017 using a numerical, one-dimensional aquifer-system compaction model in Northwest MZ-1 (WEI, 2017b).

The past few years of reduced pumping and increased recharge in Northwest MZ-1 functioned as an empirical test of the model simulations performed in 2017 and generally confirmed the model results that decreased pumping and increased recharge could elevate hydraulic heads and minimize or abate ongoing subsidence.

- It is unlikely that the reduced pumping and increased recharge that has occurred over the past few years in Northwest MZ-1 will persist into the future. The pumpers in this area will likely increase pumping and devise and implement strategies to remove groundwater contaminants through treatment, and the "put" cycles for the Dry-Year Yield Program occur only periodically. The future occurrence of subsidence remains a threat if increased pumping or decreased recharge cause future head declines. RECOMMENDATION: The Watermaster should continue implementation of the *Work Plan to Develop a Subsidence-Management Plan for the Northwest MZ-1 Area* to develop management strategies to avoid future occurrences of subsidence. In FY 2020/21, this will include:

    1) Completing the installation of the PX.

    2) Conducting one-year of passive monitoring across Northwest MZ-1 by analyzing hydraulic head data from Pomona and MVWD wells equipped with pressure transducers.

    3) Updating the Northwest MZ-1 hydrogeologic conceptual model by constructing and calibrating a one-dimensional compaction model at the PX location.

    4) Updating Watermaster's MODFLOW model to simulate land subsidence across the Chino Basin.

    5) Using the updated MODFLOW model to characterize the Baseline Management Alternative and the Initial Subsidence Management Alternative.[15,16]

    6) Developing and evaluating additional subsidence-management alternatives in order to minimize or eliminate the future occurrence of subsidence in Northwest MZ-1.[16]

- Since the inception of the GLMP, Watermaster has employed various methods to monitor ground motion via extensometers, InSAR, and traditional ground-level surveys. Analysis of these data over time has shown that InSAR has become an increasingly reliable and accurate method for monitoring of vertical ground motion across most of the Areas of Subsidence Concern for the following reasons:

[15] The development and evaluation of the BMA and ISMA were reported on here: https://cbwm.syncedtool.com/shares/folder/e83081106c3072/?folder_id=1126

[16] Characterizing the Baseline Management Alternative, Initial Subsidence Management Alternative, and developing and evaluating additional subsidence-management alternatives is contingent on the successful completion, calibration, and GLMC review of the updated Watermaster's MODFLOW model that simulates subsidence across the Chino Basin. The completion dates for these tasks may need to be adjusted.

1) Improvements in satellite technology over time have increased the spatial resolution, temporal resolution, and accuracy of InSAR. InSAR provides higher spatial and temporal resolution compared to traditional leveling surveys.

2) General Atomics (formerly Neva Ridge Technologies, Inc.) and long-time subconsultant to the Watermaster, has been able to stay abreast of the newest InSAR products and processing techniques which in turn provides InSAR deliverables to the GLMC with high accuracy, resolution, and coherence.

3) Where and when the extensometer, InSAR, and traditional ground leveling datasets overlap, InSAR shows a similar spatial pattern and magnitude of ground motion compared to the extensometers and ground level surveys. Research performed by the GLMC has shown that the errors inherent in InSAR and traditional ground level methods are similar.

4) Land-use changes from agricultural to urban have added hard, consistent radar wave reflectors to the ground surface over time. InSAR results are now coherent and useful across most of the Areas of Subsidence Concern.

RECOMMENDATION: The GLMC should preferentially rely on InSAR over traditional ground leveling techniques to monitor ground motion as a cost-saving strategy. However, the GLMC should consider employing methods to verify the InSAR estimates of vertical ground motions via techniques such as GPS, extensometers, and less-frequent leveling surveys.

- The comparison of InSAR estimates of vertical ground motion and high-frequency head measurements at Well C-15 and P-30 (discussed in Section 3) demonstrates the usefulness and efficacy of this type of monitoring and data analysis to reveal the nature of aquifer-system deformation (i.e. elastic versus inelastic deformation) over short- and long-term time scales. This type of monitoring also can provide information on hydraulic head "thresholds" that could be used as management criteria to protect against the future occurrence of land subsidence. RECOMMENDATION: The GLMC should consider performing this type of monitoring and data analysis in other Areas of Subsidence Concern where such datasets exist (or can exist). However, if depth-specific understanding of head and aquifer-system compaction are necessary to develop subsidence-management criteria, then depth-specific extensometers are the more appropriate monitoring strategy.

- In the Northeast Area, the long- and short-term InSAR estimates indicate that persistent downward ground motion has occurred in a concentrated area south of the Ontario Airport between Vineyard Avenue and Archibald Avenue. The western edge of this subsiding area exhibits a steep subsidence gradient, or "differential subsidence." Subsidence may have occurred in this area in response to declining hydraulic heads, but there is not enough historical hydraulic head data in this area to confirm this relationship. RECOMMENDATION: The GLMC should discuss this area of concern and recommend ways to investigate the occurrence and mechanisms of the observed subsidence in this area.

- In the scope-of-work for GLMP for FY 2020/21, Watermaster's Engineer recommended developing concepts for streamlining the annual reporting process for future years. RECOMMENDATION: The GLMC should explore concepts to streamline the annual reporting process during its scheduled meetings in FY 2020/21.

4.2 Recommended Scope and Budget for Fiscal Year 2020/21

The scope-of-work for the GLMP for FY 2020/21 was recommended by the GLMC in April 2020 and approved by Watermaster on May 28, 2020. Appendix A is the technical memorandum prepared by the GLMC, titled *Recommended Scope and Budget of the Ground-Level Monitoring Committee for FY 2020/21*.

In March 2021, Watermaster staff and the Watermaster Engineer will present the preliminary results of the GLMP through 2020 and a recommended FY 2021/22 scope and budget to the GLMC for consideration. As is typically done, the GLMC will recommend changes to the then-current scope of work for the GLMP.

4.3 Changes to the Subsidence Management Plan

The Subsidence Management Plan states that if data from existing monitoring efforts in the Areas of Subsidence Concern indicate the potential for adverse impacts due to subsidence, Watermaster will revise the Subsidence Management Plan pursuant to the process outlined in Section 4 of the Subsidence Management Plan. Currently, there are no recommended changes to the Subsidence Management Plan.

The following glossary contains the terms and definitions used in this report and generally in the discussions at GLMC meetings.

Aquifer – A saturated, permeable, geologic unit that can transmit significant quantities of groundwater under ordinary hydraulic gradients and is permeable enough to yield economic quantities of water to wells.

Aquifer-system – A heterogeneous body of interbedded permeable and poorly permeable geologic units that function as a water-yielding hydraulic unit at a regional scale. The aquifer-system may comprise one or more aquifers within which aquitards are interspersed. Confining units may separate the aquifers and impede the vertical exchange of groundwater between aquifers within the aquifer-system.

Aquitard – A saturated, but poorly permeable geologic unit that impedes groundwater movement and does not yield water freely to wells but may transmit appreciable water to and from adjacent aquifers and, where sufficiently thick, may constitute an important groundwater storage unit. Areally, extensive aquitards may function regionally as confining units within aquifer-systems.

Artesian – An adjective referring to confined aquifers. Sometimes the term artesian is used to denote a portion of a confined aquifer where the altitudes of the potentiometric surface are above land surface (flowing wells and artesian wells are synonymous in this usage). But, more generally, the term indicates that the altitudes of the potentiometric surface are above the altitude of the base of the confining unit (artesian wells and flowing wells are not synonymous in this case).

Compaction – Compaction of the aquifer-system reflects the rearrangement of the mineral grain pore structure and largely non-recoverable reduction of the porosity under stresses greater than the pre-consolidation stress. Compaction, as used here, is synonymous with the term "virgin consolidation" used by soils engineers. The term refers to both the process and the measured change in thickness. As a practical matter, a very small amount (1 to 5 percent) of compaction is recoverable as a slight elastic rebound of the compacted material if stresses are reduced.

Compression – A reversible compression of sediments under increasing effective stress; it is recovered by an equal expansion when aquifer-system heads recover to their initial higher values.

Consolidation – In soil mechanics, consolidation is the adjustment of a saturated soil in response to increased load, involving the squeezing of water from the pores and a decrease in the void ratio or porosity of the soil. For the purposes of this report, the term "compaction" is used in preference to consolidation when referring to subsidence due to groundwater extraction.

Confined Aquifer-system – A system capped by a regional aquitard that strongly inhibits the vertical propagation of head changes to or from an overlying aquifer. The heads in a confined aquifer-system may be intermittently or consistently different than in the overlying aquifer.

Deformation, Elastic – A fully reversible deformation of a material. In this report, the term "elastic" typically refers to the reversible (recoverable) deformation of the aquifer-system sediments or the land surface.

Deformation, Inelastic – A non-reversible deformation of a material. In this report, the term "inelastic" typically refers to the permanent (non-recoverable) deformation of the aquifer-system sediments or the land surface.

Differential Land Subsidence – Markedly different magnitudes of subsidence over a short horizontal distance, which can be the cause of ground fissuring.

Drawdown – Decline in aquifer-system head typically due to pumping by a well.

Expansion – In this report, expansion refers to the expansion of sediments. A reversible expansion of sediments under decreasing effective stress.

Extensometer – A monitoring well housing a free-standing pipe or cable that can measure vertical deformation of the aquifer-system sediments between the bottom of the pipe and the land surface datum.

Ground Fissures – Elongated vertical cracks in the ground surface that can extend several tens of feet in depth.

Hydraulic Conductivity – A measure of the medium's capacity to transmit a particular fluid. The volume of water at the existing kinematic viscosity that will move in a porous medium in unit time under a unit hydraulic gradient through a unit area. In contrast to permeability, it is a function of the properties of the liquid as well as the porous medium.

Hydraulic Gradient – Change in head over a distance along a flow line within an aquifer-system.

Hydraulic Head – A measure of the potential for fluid flow. The height of the free surface of a body of water above a given subsurface point.

InSAR (Synthetic Aperture Radar Interferometry) – A remote-sensing method (radar data collected from satellites) that measures ground-surface displacement over time.

Linear Potentiometer – A highly sensitive electronic device that can generate continuous measurements of displacement between two objects. Used to measure movement of the land-surface datum with respect to the top of the extensometer measuring point.

Nested Piezometer – A single borehole containing more than one piezometer.

Overburden – The weight of overlying sediments, including their contained water.

Piezometer – A monitoring well that measures groundwater levels, or piezometric level, at a point, or in a very limited depth interval, within an aquifer-system.

Piezometric (Potentiometric) Surface – An imaginary surface representing the total head of groundwater within a confined aquifer-system, defined by the level to which the water will rise in wells or piezometers that are screened within the confined aquifer-system.

Pore pressure – Water pressure within the pore space of a saturated sediment.

Rebound – Elastic rising of the land surface.

Stress, Effective – The difference between the geostatic stress and fluid pressure at a given depth in a saturated deposit, representing the portion of the applied stress that becomes effective as intergranular stress.

Stress, Pre-consolidation – The maximum antecedent effective stress to which a deposit has been subjected and can withstand without undergoing additional permanent deformation. Stress changes in the range less than the pre-consolidation stress produce elastic deformations of small magnitude. In fine-grained materials, stress increases beyond the pre-consolidation stress produce much larger deformations that are principally inelastic (non-recoverable). Synonymous with "virgin stress."

Stress – Stress (pressure) that is borne by and transmitted through the grain-to-grain contacts of a deposit, thus affecting its porosity and other physical properties. In one-dimensional compression, effective stress is the average grain-to-grain load per unit area in a plane normal to the applied stress. At any given depth, the effective stress is the weight (per unit area) of sediments and moisture above the water table plus the submerged weight (per unit area) of sediments between the water table and a specified depth plus or minus the seepage stress (hydrodynamic drag) produced by downward or upward components, respectively, of water movement through the saturated sediments above the specified depth. Effective stress may also be defined as the difference between the geostatic stress and fluid pressure at a given depth in a saturated deposit and represents the portion of the applied stress that becomes effective as intergranular stress.

Subsidence – Permanent or non-recoverable sinking or settlement of the land surface due to any of several processes.

Transducer, Pressure – An electronic device that can measure piezometric levels by converting water pressure to a recordable electrical signal. Typically, the transducer is connected to a data logger, which records the measurements.

Water Table – The surface of a body of unconfined groundwater at which the pressure is equal to atmospheric pressure and is defined by the level to which the water will rise in wells or piezometers that are screened within the unconfined aquifer-system.

Fife, D.L., Rodgers, D.A., Chase, G.W., Chapman, R.H., and E.C. Sprotte. (1976). *Geologic Hazards in Southwestern San Bernardino County, California*: California Division of Mines and Geology Special Report 113, 40 p.

Geomatrix Consultants, Inc. (1994). *Final Report Ground Fissuring Study, California Department of Corrections, California Institution for Men, Chino, California*. Project No. 2360. San Francisco, CA.

GEOSCIENCE, Support Services, Inc. (2002). *Preliminary Geohydrologic Analysis of Subsidence in the Western Portion of the Chino Basin*. Prepared for the City of Chino Hills. August 29, 2002.

Harris, R. A. (2017). *Large earthquakes and creeping faults*, Rev. Geophys., 55, 169-198, doi:10.1002/2016RG000539.

Kleinfelder, Inc. (1993). *Geotechnical Investigation, Regional Subsidence and Related Ground Fissuring, City of Chino, California*. Project No. 58-3101-01. Diamond Bar, CA.

Kleinfelder, Inc. (1996). *Chino Basin Subsidence and Fissuring Study, Chino, California*. Project No. 58-5264-02. Diamond Bar, CA.

Morton, D.M., and Yerkes, R.F. (1974). *Spectacular scarps of the frontal fault system, eastern San Gabriel Mountains.* Geological Society of America Abstracts with Programs, v. 6, no. 3, p. 223-224.

Morton, D.M., Matti, J.C., and Tinsley, J.C. (1982). *Quaternary history of the Cucamonga fault zone, southern California.* Geological Society of America Abstracts with Programs, v. 14, no. 4, p. 218.

Morton, D.M., and Matti, J.C. (1987). *The Cucamonga fault zone: Geologic setting and Quaternary history, in Morton, D.M., and Yerkes R.F., eds., Recent reverse faulting in the Transverse Ranges, California.* U.S. Geological Survey Professional Paper 1339, p. 179-203.

Myers, W.B. and Hamiliton, W. (1964). *Deformation Accompanying the Hebgen Lake Earthquake of August 17. 1959.* U.S. Geological Survey Professional Paper 435-1, p. 55-98.

Plafker, G.G. (1965). *Tectonic Deformation Associated with the 1964 Alaska Earthquake of March 27, 1964*. Science, v. 148, no. 3678, p. 1675-1687.

Riley, F.S. (1986). *Developments in borehole extensometry,* in Johnson, A.I., Carbognin, L., and Ubertini, L., eds., Proceedings, Land Subsidence – Third International Symposium on Land Subsidence, Venice, Italy, March 1984: International Association of Hydrological Sciences Publication, p. 343-355.

United States Geological Survey (USGS). (1999). *Land subsidence in the United States* (Devin Galloway, David R. Jones, S.E). Ingebritsen. USGS Circular 1182. 175 p.

Weischet, W. (1963). *Further Observations of Geologic and Geomorphic Changes Resulting from the Catastrophic Earthquakes of May 1960, in Chile* (translated by R. Von Huene). Seismology Society America Bulletin, v. 53, no. 6, p. 1237-1257.

Wildermuth Environmental, Inc. (WEI). (1999). *Optimum Basin Management Program. Phase I Report*. Prepared for the Chino Basin Watermaster. August 19, 1999.

Wildermuth Environmental, Inc. (WEI). (2003). *Management Zone 1 (MZ-1) Interim Monitoring Program*. Prepared for the Chino Basin Watermaster. January 2003.

Wildermuth Environmental, Inc. (WEI). (2006). *Optimum Basin Management Program. Management Zone 1 Interim Monitoring Program. MZ-1 Summary Report*. Prepared for the Chino Basin Watermaster. February 2006.

Wildermuth Environmental, Inc. (WEI). (2007). *Chino Basin Optimum Basin Management Program. Management Zone 1 Subsidence Management Plan*. Prepared for the Chino Basin Watermaster. October 2007.

Wildermuth Environmental, Inc. (WEI). (2013). *2012 State of the Basin Atlas*. Prepared for the Chino Basin Watermaster. June 2013.

Wildermuth Environmental, Inc. (WEI). (2015a). *Chino Basin Subsidence Management Plan*. Prepared for the Chino Basin Watermaster. July 23, 2015.

Wildermuth Environmental, Inc. (WEI). (2015b). *Work Plan to Develop a Subsidence-Management Plan for the Northwest MZ-1 Area*. Prepared for the Chino Basin Watermaster. July 23, 2015.

Wildermuth Environmental, Inc. (WEI). (2016). *2016 Annual Report of the Ground-Level Monitoring Committee*. Prepared for the Chino Basin Watermaster. September 2017.

Wildermuth Environmental, Inc. (WEI). (2017a). *Initial Hydrologic Conceptual Model and Monitoring and Testing Program for the Northwest MZ-1 Area*. Prepared for the Chino Basin Watermaster. December 2017.

Wildermuth Environmental, Inc. (WEI). (2017b). *Task 3 and Task 4 of the Work Plan to Develop a Subsidence Management Plan for the Northwest MZ-1 Area: Development and Evaluation of Baseline and Initial Subsidence-Management Alternatives*. Prepared for the Ground-Level Monitoring Committee of the Chino Basin Watermaster. December 13, 2017.

Appendix A

Recommended Scope and Budget of the Ground-Level Monitoring Committee for FY 2020/21

TECHNICAL MEMORANDUM

March 23, 2020

TO: Ground-Level Monitoring Committee

FROM: Chino Basin Watermaster Engineer – Wildermuth Environmental Inc.

RE: Recommended Scope and Budget of the Ground-Level Monitoring Committee for Fiscal Year 2020/21 (Final)

Background and Purpose

Pursuant to the Optimum Basin Management Program Implementation Plan and the Peace Agreement, the Chino Basin Watermaster (Watermaster) implements a Subsidence Management Plan for the Chino Basin to minimize or stop the occurrence of land subsidence and ground fissuring. The Subsidence Management Plan outlines a program of monitoring, data analysis, and annual reporting. A key element of the Subsidence Management Plan is its adaptive nature—Watermaster can adjust the Subsidence Management Plan as warranted by the data.[1]

The Watermaster Engineer, with the guidance of the Ground-Level Monitoring Committee (GLMC), prepares the annual reports which include the results of the monitoring program, interpretations of the data, recommendations for the Ground-Level Monitoring Program (GLMP) for the following fiscal year, and recommendations for adjustments to the Subsidence Management Plan, if any.

This memorandum describes the Watermaster Engineer's recommended activities for the GLMP for FY 2020/21 in the form of a proposed scope-of-work and budget.

Members of the GLMC are asked to:

1. Review this memorandum prior to March 5, 2020.
2. Attend a meeting of the GLMC at 9:00 am on March 5, 2020 at Watermaster to discuss the proposed scope-of-work and budget for FY 2020/21.
3. Submit comments and suggested revisions on the proposed scope-of-work and budget for FY 2020/21 to the Watermaster by March 19, 2020.

[1] The Court approved the Subsidence Management Plan and ordered its implementation in November 2007. The Subsidence Management Plan was updated in 2015, and can be downloaded at this link.

Wildermuth Environmental, Inc.
23692 Birtcher
Lake Forest, CA 92630

4. Attend a meeting of the GLMC at 9:00 am on April 2, 2020 at Watermaster to discuss comments and revisions to the proposed scope-of-work and budget for FY 2020/21 (if needed).

The final scope-of-work and budget that is recommended by the GLMC will be included in the Watermaster's FY 2020/21 budget. The final scope-of-work, budget, and schedule for FY 2020/21 will be included in Section 4 of the *2019/20 Annual Report of the GLMC*.

Recommended Scope of Work and Budget – FY 2020/21

A proposed scope-of-work for the GLMP for FY 2020/21 is shown in Table 1 as a line-item cost estimate. The proposed scope-of-work is summarized below:

Task 1—Setup and Maintenance of the Monitoring Network

The Chino Basin extensometer facilities are key monitoring facilities for the GLMP. They require regular and as-needed maintenance and calibration to remain in good working order and to ensure the recording of accurate measurements.

Task 1.1—Maintain Extensometer Facilities.

This subtask includes performing monthly visits to the Ayala Park, Chino Creek, and Pomona Extensometer facilities to ensure functionality and calibration of the monitoring equipment and data loggers.

Task 1.2—Annual Lease Fees for CCX Extensometer Site.

Task 2—Aquifer-System Monitoring and Testing

This task involves the collection and compilation of hydraulic head and aquifer-system deformation data from the Ayala Park, Chino Creek, and Pomona Extensometer facilities.

Task 2.1—Conduct Quarterly Data Collection from Extensometers; Data Checking and Management.

This subtask involves the routine quarterly collection and checking of data from the extensometer facilities. Quarterly data collection is necessary to ensure that the monitoring equipment is in good working order and to minimize the risk of losing data because of equipment malfunction. For FY 2020/21, this task includes collection and checking of data from the newly installed Pomona Extensometer facility.

Task 2.2—Conduct Pilot Injection Test in the Managed Area.

This sub-task involves the work to implement a Pilot Injection Test in the Managed Area at City of Chino Hills well CH-16 to test the effectiveness of injection as a tool to manage hydraulic head and land subsidence in the Managed Area. The work involved in this task includes coordinating the injection test with the City of Chino Hills and collecting and compiling the injection/production data at CH-16 (e.g. timing of injection, injection rates, water levels at CH-16, etc.). The results of the test will be documented in a subsequent Annual Report of the GLMC.

This sub-task will not be implemented in FY 2020/21 due to water-quality issues reported by the City of Chino Hills at well CH-16 (M. Wiley, personal communication, January 20, 2020).

Task 3—Basin-Wide Ground-Level Monitoring Program (InSAR)

This task involves the annual collection and analysis of Synthetic Aperture Radar (SAR) scenes to estimate the vertical ground motion that occurred across the western portion of Chino Basin from March 2020 to March 2021.

Task 3.1—Acquire SAR Data from TerraSAR-X (German Aerospace Center) and Prepare Interferograms for 2020/21.

In this sub-task, six SAR scenes that will be acquired by the TerraSAR-X satellite from March 2020 to March 2021 are purchased from the German Aerospace Center. Neva Ridge Technologies of Boulder, CO (Neva Ridge) uses the SAR scenes to prepare 12 interferograms that describe the incremental and cumulative vertical ground motion that occurred from March 2020 to March 2021 and since 2011.

Task 3.2—Convert Interferograms to GIS Rasters and Check Results.

In this sub-task, the Watermaster Engineer converts the interferograms into GIS rasters of vertical ground motion across western Chino Basin and performs checks for reasonableness and accuracy.

Task 3.3—Conduct a Pilot Study with the new Sentinel-1A Satellite.

Over recent years, the GLMC has chosen to acquire and use a single SAR scene from the TerraSAR-X satellite that covers just the western portion of the basin. This decision was made because land subsidence concerns are typically within the western portion of the basin, and to avoid the costs associated with acquiring and analyzing an additional scene across the eastern portion of the basin.

One of the recommendations from the *2018/19 Annual Report of the Ground-Level Monitoring Committee* was to perform a pilot study using a new SAR satellite, the Sentinel-1A satellite, which became active in 2015. The advantage of Sentinel-1A is that a single SAR scene covers the entire Chino Basin, while the disadvantage is lower spatial resolution of the SAR imagery.

At its September 26, 2019 meeting, the GLMC directed Watermaster Engineer to obtain costs to perform a pilot study using the new Sentinel-1A satellite. Specifically, two types of questions should be answered by the pilot study:

1. Has land subsidence occurred in the eastern portion of Chino Basin during the period 2015 to 2018 as hydraulic heads have declined over this period? If so, how much? What is its spatial distribution? Does the GLMC see a concern that would warrant ongoing monitoring of the eastern Chino Basin via InSAR?
2. Across the western portion of the Chino Basin, how do the estimates of vertical ground motion derived from TerraSAR-X and Sentinel-1A compare in terms of spatial distribution, magnitude, coherence, and accuracy? If the GLMC were to switch to using Sentinel-1A, would the monitoring program be compromised? If so, how?

To answer these questions: (i) Watermaster Engineer will identify, download, and compile InSAR rasters (available from the California's Department of Water Resources SGMA Data Viewer[2]), showing monthly vertical ground motion displacement from Sentinel-1A for the entire Chino Basin over the three-year period 2015 and 2018; (ii) Watermaster Engineer will compare various aspects of the TerraSAR-X and Sentinel-1A SAR data – namely the magnitude of vertical ground motion, coherence of the InSAR data sets, and the spatial resolution of ground motion across the Chino Basin using tables and maps; (iii) Watermaster Engineer will compare the InSAR estimates of vertical ground motion against the ground-elevation-survey results at select benchmarks across the western Chino Basin; and (iv) Watermaster Engineer will prepare a technical memorandum to document the purpose of the pilot study, methods, results and interpretations, and recommendations to the GLMC on the future use of the Sentinel-1A satellite for the GLMP.

Task 4—Perform Ground-Level Surveys

This task involves conducting elevation surveys at benchmark monuments across defined areas of western Chino Basin to estimate the vertical ground motion that occurred since the prior survey. Electronic distance measurements (EDM surveys) are also performed between benchmark monuments to estimate horizontal ground motion in areas where ground fissuring due to differential land subsidence is a concern. The table below documents the areas surveyed over the last five years as part of the GLMP.

Ground-Level Survey Area	**Ground-Level Survey Completed (Y/N)?**					
	2015	**2016**	**2017**	**2018**	**2019**	**2020****
Managed Area	Y	Y	N	Y	N	N
Fissure Zone Area*	Y	Y	N	Y	N	N
Central Area	N	N	N	N	N	N
Northwest Area	N	Y	Y	Y	Y	Y
San Jose Fault Zone Area*	N	Y	Y	Y	Y	Y
Southeast Area	Y	Y	Y	Y	N	N
Northeast Area	N	N	N	Y	Y	Y

*Denotes EDM survey area

**The 2020 ground-level surveys are scheduled to begin in late February 2020.

The ground-level surveys efforts recommended for FY 2020/21 include:

Task 4.1—Conduct Spring-2020 Elevation and EDM surveys in Northwest MZ-1.

In this subtask, the surveyor conducts elevation and EDM surveys at the established benchmarks in Northwest MZ-1 in spring 2021. The elevation survey will begin at the new Pomona

[2] https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels

Extensometer Facility and includes benchmarks across Northwest MZ-1 shown on Figure 1. The elevation survey will be referenced to a newly established elevation datum at the Pomona Extensometer. The EDM survey is performed across the San Jose Array of benchmark monuments shown on Figure 1.

These surveys are recommended in FY 2020/21 because of the recent subsidence that has occurred in Northwest MZ-1 and will support the development of a subsidence management plan in Northwest MZ-1.

Task 4.5—Replace Destroyed Benchmarks (if needed).

In this sub-task, the surveyor replaces benchmark monuments that have been destroyed since the last survey, if any.

Task 4.6—Process, Check, and Update Database.

In this sub-task, the Watermaster Engineer receives and catalogs the survey results provided by the surveyor, prepares the data for display as a GIS layer, and performs checks against InSAR and extensometer data for reasonableness and accuracy.

The ground-level surveys efforts **not** recommended for FY 2020/21 include:

Task 4.2—Conduct Spring-2020 Elevation Survey in the Northeast Area.

This survey is not recommended for FY 2020/21 because heads have been relatively stable or increasing across most of this area and recent ground motion as measured by InSAR and ground-level surveys has been minor in this area.

Task 4.3—Conduct Spring-2020 Elevation in the Southeast Area.

This survey is not recommended for FY 2020/21 because over the past several years hydraulic heads have been relatively stable in this area; recent ground motion as measured by InSAR, ground-level surveys, and the Chino Creek Extensometer has been minor in this area; hydraulic heads are not projected to significantly decline in this area over the next year.

Task 4.4—Conduct Spring-2020 Elevation and EDM Surveys in the Managed Area.

This survey is not recommended for FY 2020/21 because over the past several years hydraulic heads have been relatively stable in this area; recent ground motion as measured by InSAR, ground-level surveys, and the Ayala Park Extensometer has been minor in this area.

Task 5—Data Analysis and Reporting

Task 5.1—Prepare Draft 2019/20 Annual Report of the Ground-Level Monitoring Committee.

Prepare the text, tables, and figures for a draft 2019/20 Annual Report of the GLMC and submit the report to the GLMC by September 25, 2020 for review and comment.

One of the recommendations from the *2018/19 Annual Report of the GLMC* was to perform a comparison of InSAR estimates of vertical ground motion and high-frequency head measurements in other Areas of Subsidence Concern – identical to the data analysis performed at well C-15 (see Section 3 of the *2018/19 Annual Report of the GLMC*).[3] This task will include data collection, processing, and analysis of InSAR estimates of vertical ground motion and high-frequency head measurements at up to two locations in the western Chino Basin. The analysis locations will be dependent on where InSAR has been consistently coherent since 2011 and high-frequency head measurements are available since 2011 through present-day.

Also, as part of Task 5, Watermaster's Engineer will work with the GLMC to develop concepts for streamlining the Annual Report of the Ground-Level Monitoring Committee and the reporting process for future years. Watermaster's Engineer will use the scheduled meetings of the GLMC in FY 2020/21 to discuss with the GLMC concepts for streamlining the annual report and reporting process.

Task 5.2—Prepare Final 2019/20 Annual Report of the Ground-Level Monitoring Committee.
Update the text, tables, and figures based on the comments received from the GLMC and prepare a final *2019/20 Annual Report of the GLMC* by October 30, 2020. Responses to comments will be included as an appendix to the final report. The report will be included in the agenda packet for the November 2020 Watermaster meetings for approval.

Task 5.3—Compile and Analyze Data from the 2020/21 Ground-Level Monitoring Program.
In this task, monitoring data generated from the GLMP during 2020/21 is checked, mapped, charted, and analyzed as the first step in the preparation of the subsequent annual report. Some of the maps, charts, and tables are shared with the GLMC at its meetings in early 2021 during the development of a recommended scope and budget for FY 2021/22.

Task 6—Develop a Subsidence-Management Plan for Northwest MZ-1

The development of the subsidence management plan for Northwest MZ-1 is a multi-year effort with the objective to minimize or stop the occurrence of subsidence in this area. Background information and the conceptual framework for this effort is described in detail in the *Work Plan to Develop a Subsidence-Management Plan for Northwest MZ-1*.[4]

The Pomona Extensometer (PX) is the main monitoring facility that was constructed at part of the Work Plan and will be fully operational in spring 2020. Several subsequent tasks in the Work Plan are recommended for implementation in FY 2020/21, including:

Task 6.1—Conduct One-Year of Passive Monitoring.
The monitoring of piezometric levels and pumping at wells in Northwest MZ-1 will continue through various techniques, including: (i) SCADA-based monitoring by the Monte Vista Water District; (ii) monitoring of piezometric levels via sonar[5]; (iii) monitoring of piezometric levels via pressure transducers at City of Pomona production wells; and (iv) manual measurements of

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[3] http://www.cbwm.org/rep_engineering.htm
[4] http://www.cbwm.org/docs/engdocs/Land%20Subsidence/20150724%20-%20Chino%20Basin%20Subsidence%20Management%20Plan%202015/FINAL_CBSMP_Appendix_B.pdf
[5] The use of sonar technology to measure piezometric levels in wells in currently being used in Monte Vista Water District wells 28 and 31.

piezometric levels. The PX facility will measure and record piezometric and aquifer-system-deformation data. These data will improve the understanding of the hydrogeology in Northwest MZ-1 and will be used to construct and calibrate computer-simulation models of groundwater flow and aquifer-system compaction. The data and model results will be used to develop the Subsidence Management Plan for Northwest MZ-1 and update the plan in the future as appropriate.

In this subtask, all data is collected, compiled, and analyzed every two months. Charts and data graphics of pumping, piezometric levels, and aquifer-system deformation will be prepared and shared regularly with the GLMC for review and comment.

Task 6.2—Update the Hydrogeologic Conceptual Model.

The objective of this task is to update the hydrogeologic conceptual understanding of Northwest MZ-1, particularly for the parameters that affect aquifer-system deformation and land subsidence. The information generated in this task will form the basis for updating Watermaster's current groundwater model (Task 6.3) so it can simulate land subsidence and evaluate subsidence-management alternatives.

In this task, a one-dimensional (1D) compaction model will be constructed and calibrated to represent the aquifer-system at the PX location. The lithologic and geophysical data collected from the PX borehole will be used to construct the 1D model. Piezometric data from wells in the area and vertical ground motion data from InSAR will be used to calibrate the 1D model. The calibration results will generate estimates of the hydraulic and mechanical properties of the aquifer-system and the pre-consolidation stress(es).

Task 6.3—Update the Chino Basin MODFLOW Model to Enable Simulations of Subsidence.

The objective of this task is to update Watermaster's MODFLOW model so it can be used to simulate land subsidence and evaluate subsidence-management alternatives. The subsidence package (SUB) in MODFLOW will be added to the model, including the aquifer-system properties estimated by the 1D models at the PX, the Ayala Park Extensometer, and MVWD Well 28. The SUB package will be calibrated across all Areas of Subsidence Concern using estimates of vertical ground-motion from InSAR, ground-level surveys, and the Ayala Park Extensometer.

A draft technical memorandum—*Updated Chino Basin Groundwater Model with SUB Package*—will be prepared to describe the model update and calibration results. The draft memorandum will be distributed to the GLMC for review and comment. A meeting of the GLMC will be held to discuss the memorandum and receive verbal feedback. The GLMC will submit written comments and suggested revisions to Watermaster. A final technical memorandum will be prepared that incorporates the feedback and comments from the GLMC.

Task 6.4—Refine and Evaluate the Subsidence-Management Alternatives.

The objective of this task is to develop and evaluate additional subsidence-management alternatives to minimize or eliminate the future occurrence of subsidence in Northwest MZ-1.

First, the updated Chino Basin MODFLOW model will be used to characterize the basin response to Baseline Management Alternative (BMA) and the Initial Subsidence Management Alternative (ISMA),[6] their ability to raise and hold piezometric levels above the pre-consolidation stress, and their ability to minimize or abate the ongoing subsidence in Northwest MZ-1. The alternatives also will be evaluated on the institutional changes that will need to occur and the costs of the associated water-supply plans.

Using the results of the ISMA, a new method to increase and hold piezometric levels at the estimated pre-consolidation stress will be described and called Subsidence-Management Alternative 2 (SMA-2). The assumptions of the SMA-2, including the groundwater production and replenishment plans of the Chino Basin parties, will be described and agreed upon by the GLMC. The updated Chino Basin MODFLOW model will be used to characterize the basin response to SMA-2, its ability to raise and hold piezometric levels above the pre-consolidation stress, and its ability to minimize or abate the ongoing subsidence in Northwest MZ-1. The alternative also will be evaluated on the institutional changes that will need to occur and the costs of the associated water-supply plans.

A GLMC meeting will be held to review the model results and evaluations. The GLMC can select a recommended subsidence-management alternative or choose to develop and evaluate additional subsidence-management alternatives in the following fiscal year. In the following fiscal year, a draft and final technical memorandum will be prepared to document the evaluation of all subsidence-management alternatives and the preferred alternative as recommended by the GLMC.

Task 7—Meetings and Administration

Task 7.1—Prepare for and Conduct Four Meetings of the Ground-Level Monitoring Committee.

This sub-task includes preparing for and conducting four meetings of the GLMC:

- July 2020 – Implementation of the GLMP for FY 2020/21.
- September 2020 – Review the draft *2019/20 Annual Report of the Ground-Level Monitoring Committee.*
- February 2021 – Review the draft recommended scope and budget for FY 2021/22.
- March 2021 – Review the final recommended scope and budget for FY 2021/22 (if needed).

Task 7.2—Prepare for and Conduct One As-Requested Ad-Hoc Meeting.

This sub-task includes preparing for and conducting one ad-hoc meeting of the GLMC, as requested by the GLMC or Watermaster staff.

[6] The development and evaluation of the BMA and ISMA were reported on here: https://cbwm.syncedtool.com/shares/folder/e83081106c3072/?folder_id=1126

Task 7.3—Perform Monthly Project Management.

This sub-task includes monthly project administration and management, including staffing, financial and schedule reporting to Watermaster and sub-contractor coordination.

Task 7.4—Prepare a Recommended Scope and Budget for the GLMC for FY 2021/22.

This sub-task includes preparing a draft and final recommended scope and budget for FY 2021/22 for the GLMC to support the Watermaster's budgeting process.

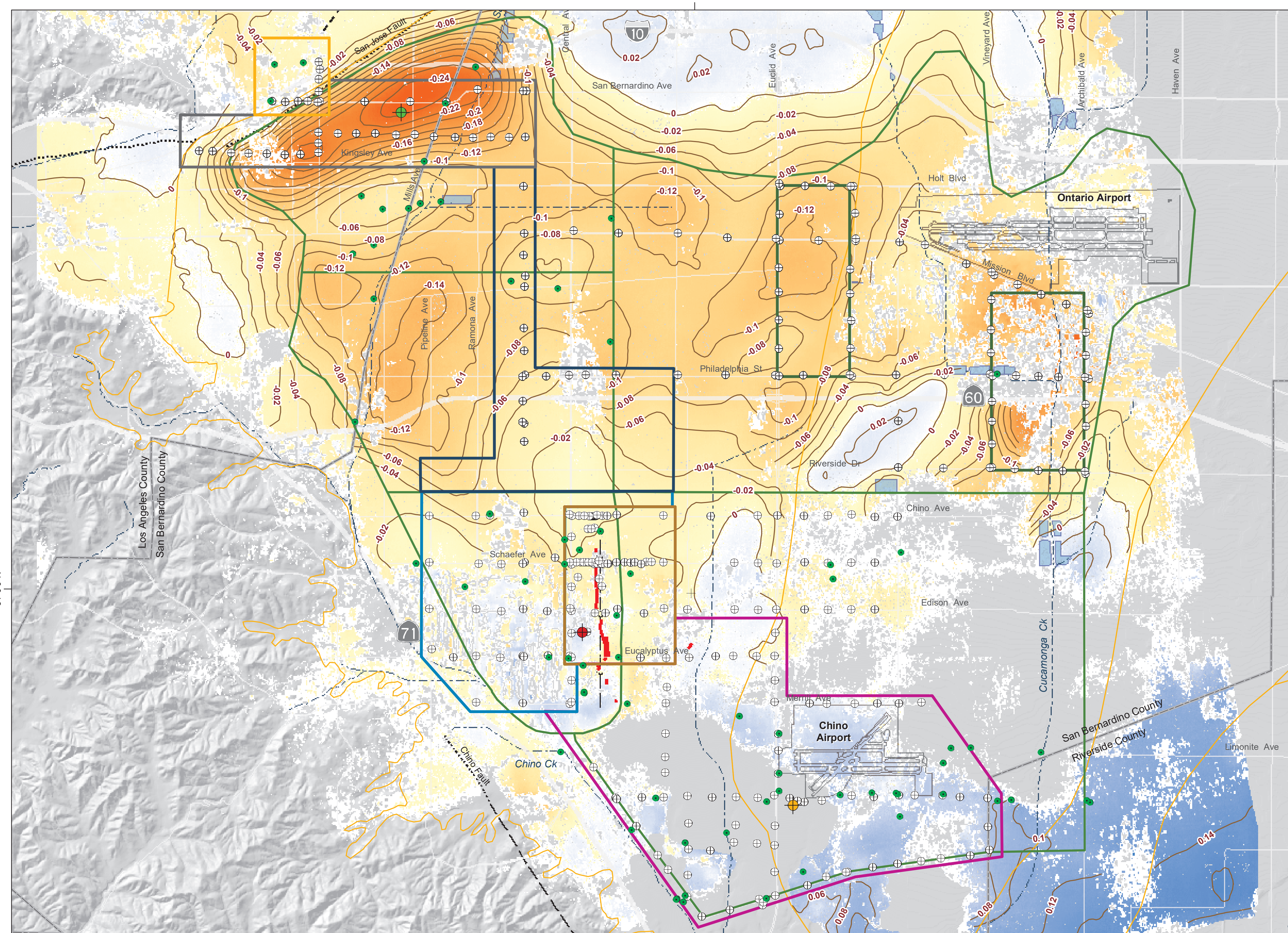
Encl.:

Table 1. Work Breakdown Structure and Cost Estimates – Ground-Level Monitoring Program: FY 2020/21

Figure 1. Ground-Level Monitoring Program – Fiscal Year 2020/21

Table 1
Work Breakdown Structure and Cost Estimates
Ground-Level Monitoring Program: FY 2020/21

Task Description	Labor		Other Direct Costs						Totals					
	Person Days	Total	Travel	New Equip.	Equip. Rental	Outside Pro	Misc.	Total	Totals by Task	Recommended Budget *FY 2020/21*	Approved Budget *FY 2019/20*	Net Change *FY 2019/20 to 2020/21*	Potential Carry-Over *FY 2020/21*	Budget with Carry-Over *FY 2020/21*
										a	*b*	*a - b*	*c*	*a - c*
Task 1 -- Setup and Maintenance of the Monitoring Network		**$25,600**						**$7,388**	**$32,988**	**$32,988**	**$36,857**	**-$3,869**	**$0**	**$32,988**
1.1 Maintain Extensometer Facilities														
1.1.1 Routine maintenance of Ayala Park, Chino Creek, and Pomona extensometer facilities	14	$19,360	$1,056	$250	$152			$1,458	$20,818	$20,818	$23,813	-$2,995	$0	$20,818
1.1.2 Replacement/repair of equipment at extensometer facilities	4	$6,240	$264	$2,000	$70	$2,000		$4,334	$10,574	$10,574	$11,448	-$874	$0	$10,574
1.2 Annual Lease Fees for the Chino Creek extensometer facility	0	$0					$1,596	$1,596	$1,596	$1,596	$1,596	$0	$0	$1,596
Task 2 -- MZ-1: Aquifer-System Monitoring and Testing		**$26,712**						**$680**	**$27,392**	**$27,392**	**$34,686**	**-$7,294**	**$0**	**$27,392**
2.1 Conduct Quarterly Data Collection from Extensometers; Data Checking and Management														
2.1.1 Download data from the Ayala Park Extensometer facility	2	$2,624	$230		$76			$306	$2,930	$2,930	$2,895	$35	$0	$2,930
2.1.2 Download data from the Chino Creek Extensometer facility	2	$2,624	$26					$26	$2,650	$2,650	$2,662	-$12	$0	$2,650
2.1.3 Download data from Pomona Extensometer facility	4	$5,248	$272		$76			$348	$5,596	$5,596	$5,433	$163	$0	$5,596
2.1.4 Process, check, and upload data to database	11	$16,216						$0	$16,216	$16,216	$15,712	$504	$0	$16,216
2.2 Conduct Pilot Injection Test in the Managed Area														
2.2.1 Coordinate testing with pumpers	0	$0						$0	$0	$0	$1,512	-$1,512	$0	$0
2.2.2 Equip CH-15B and CH-17 with high-frequency water-level monitoring devices	0	$0						$0	$0	$0	$6,472	-$6,472	$0	$0
Task 3 -- Basin Wide Ground-Level Monitoring Program (InSAR)		**$29,694**						**$85,000**	**$114,694**	**$114,694**	**$90,362**	**$24,332**	**$0**	**$114,694**
3.1 Acquire SAR data from TerraSAR-X and prepare interferograms for 2020/21	1	$1,808				$85,000		$85,000	$86,808	$86,808	$86,752	$56	$0	$86,808
3.2 Convert interferograms to raster datasets and check results	2	$3,194						$0	$3,194	$3,194	$3,610	-$416	$0	$3,194
3.3 Conduct a pilot study with the new Sentinel-1A satellite								$0	$0	$0	$0	$0	$0	$0
3.3.1 Download and compile the Sentinel-1A monthly InSAR raster datasets between 2015 and 2018	1.25	$1,764						$0	$1,764	$1,764	$0	$1,764	$0	$1,764
3.3.2 Prepare maps of the Sentinel-1A estimates of vertical ground motion for the eastern Chino Basin between 2015 and 2018; and maps and charts comparing the TerraSAR-X and Sentinel-1A estimates (downloaded from DWR) of vertical ground motion across the western Chino Basin. The estimates of the vertical ground motion across the western Chino Basin will also be compared against the ground level survey results.	8	$12,776						$0	$12,776	$12,776	$0	$12,776	$0	$12,776
3.3.3 Prepare a Technical Memorandum summarizing the results from the Sentienl-1A pilot study	6	$10,152						$0	$10,152	$10,152	$0	$10,152	$0	$10,152
Task 4 -- Perform Ground-Level Surveys		**$6,648**						**$183,816**	**$190,464**	**$51,828**	**$124,878**	**-$73,050**	**$0**	**$51,828**
4.1 Conduct Spring-2021 Elevation and EDM surveys in Northwest MZ-1	0.5	$904				$33,880		$33,880	$34,784	$34,784	$29,476	$5,308	$0	$34,784
4.2 Conduct Spring-2021 Elevation Survey in the Northeast Area	0	$0				$43,208		$43,208	$43,208	$0	$38,056	-$38,056	$0	$0
4.3 Conduct Spring-2021 Elevation Survey in the Southeast Area	0	$0				$43,208		$43,208	$43,208	$0	$0	$0	$0	$0
4.4 Conduct Spring 2021-Elevation and EDM Surveys in the Managed Area/Fissure Zone Area	0	$0				$47,320		$47,320	$47,320	$0	$31,570	-$31,570	$0	$0
4.5 Replace Destroyed Benchmarks (if needed)	0	$0				$16,200		$16,200	$16,200	$11,300	$9,700	$1,600	$0	$11,300
4.6 Process, Check, and Update Database	4	$5,744						$0	$5,744	$5,744	$6,076	-$332	$0	$5,744
4.7 New Surveyor Support	0	$0						$0	$0	$0	$10,000	-$10,000	$0	$0
Task 5 -- Data Analysis and Reporting		**$74,932**						**$0**	**$74,932**	**$74,932**	**$63,842**	**$11,090**	**$0**	**$74,932**
5.1 Prepare Draft 2019/20 Annual Report of the Ground-Level Monitoring Committee	22.5	$35,196						$0	$35,196	$35,196	$35,312	-$116	$0	$35,196
5.2 Prepare Final 2019/20 Annual Report of the Ground-Level Monitoring Committee	10.5	$19,088						$0	$19,088	$19,088	$8,584	$10,504	$0	$19,088
5.3 Compile and Analyze Data from the 2020/21 Ground-Level Monitoring Program	14	$20,648						$0	$20,648	$20,648	$19,946	$702	$0	$20,648
Task 6 -- Develop a Subsidence-Management Plan for Northwest MZ-1		**$251,972**						**$167**	**$252,139**	**$252,139**	**$7,500**	**$244,639**	**$30,000**	**$222,139**
6.1 Conduct One-Year of Passive Monitoring														
6.1.1 Collect pumping and piezometric level data from agencies every two months; check and upload data to HDX	9.75	$10,599						$0	$10,599	$10,599	$7,500	$3,099	$15,000	-$4,401
6.1.2 Prepare and analyze charts and data graphics of pumping, piezometric levels, and aquifer-system deformation; share with the GLMC	8.25	$11,634						$0	$11,634	$11,634	$0	$11,634	$15,000	-$3,366
6.2 Update the Hydrogeologic Conceptual Model														
6.2.1 Construct a one-dimensional (1D) compaction model at the PX location	8.875	$17,637						$0	$17,637	$17,637	$0	$17,637	$0	$17,637
6.2.2 Calibrate 1D model to derive hydraulic and mechanical properties of aquifers/aquitards and estimate the pre-consolidation stress(es)	8.25	$16,442						$0	$16,442	$16,442	$0	$16,442	$0	$16,442
6.3 Update the Chino Basin MODFLOW Model to Enable Simulations of Subsidence														
6.3.1 Add SUB package to the MODFLOW model utilizing results from 1D models at PX, MVWD-28, and AP	20	$39,432						$0	$39,432	$39,432	$0	$39,432	$0	$39,432
6.3.2 Calibrate SUB package utilizing ground motion data from InSAR, surveys, and extensometers	15	$29,984						$0	$29,984	$29,984	$0	$29,984	$0	$29,984
6.3.3 Prepare a draft technical memorandum summarizing the model updates and distribute to the GLMC	21.5	$36,988						$0	$36,988	$36,988	$0	$36,988	$0	$36,988
6.3.4 Prepare for and conduct a meeting to receive feedback and comments on draft memorandum	3.75	$7,058	$84					$84	$7,142	$7,142	$0	$7,142	$0	$7,142
6.3.5 Incorporate the GLMC comments and prepare a final technical memorandum	3	$5,326						$0	$5,326	$5,326	$0	$5,326	$0	$5,326
6.4 Refine and Evaluate Subsidence-Management Alternatives														
6.4.1 Re-evaluate the Baseline and Initial Subsidence-Management Alternatives	10	$20,060						$0	$20,060	$20,060	$0	$20,060	$0	$20,060
6.4.2 Develop Subsidence-Management Alternative 2 (SMA-2)	4	$8,072						$0	$8,072	$8,072	$0	$8,072	$0	$8,072
6.4.3 Prepare and present straw-man SMA-2 to GLMC	2	$3,912	$84					$84	$3,996	$3,996	$0	$3,996	$0	$3,996
6.4.4 Review with other agencies that will be required to implement the SMA-2	1.5	$2,860						$0	$2,860	$2,860	$0	$2,860	$0	$2,860
6.4.5 Revise SMA-2 based on comments; circulate to the GLMC and other agencies for comments	2	$3,944						$0	$3,944	$3,944	$0	$3,944	$0	$3,944
6.4.6 Finalize SMA-2	2	$3,964						$0	$3,964	$3,964	$0	$3,964	$0	$3,964
6.4.7 Update groundwater production and replenishment plans per SMA-2	4.5	$8,944						$0	$8,944	$8,944	$0	$8,944	$0	$8,944
6.4.8 Run groundwater model to evaluate the basin response to SMA-2	4	$7,968						$0	$7,968	$7,968	$0	$7,968	$0	$7,968
6.4.9 Prepare maps, charts, and tables to characterize the basin response to SMA-2	7.25	$12,694						$0	$12,694	$12,694	$0	$12,694	$0	$12,694
6.4.10 Summarize evaluation of SMA-2 and present results to the GLMC	2.25	$4,454						$0	$4,454	$4,454	$0	$4,454	$0	$4,454
Task 7 -- Meetings and Administration		**$50,832**						**$418**	**$51,250**	**$51,250**	**$47,194**	**$4,056**	**$0**	**$51,250**
7.1 Prepare for and Conduct Four Meetings of the Ground-Level Monitoring Committee	14	$25,504	$334					$334	$25,838	$25,838	$22,478	$3,360	$0	$25,838
7.2 Prepare for and Conduct One As-Requested Ad-Hoc Meeting	3	$5,720	$84					$84	$5,804	$5,804	$5,620	$184	$0	$5,804
7.3 Perform Monthly Project Management	6	$10,848						$0	$10,848	$10,848	$13,560	-$2,712	$0	$10,848
7.4 Prepare a Recommended Scope and Budget for the GLMC for FY 2021/22	4.75	$8,760						$0	$8,760	$8,760	$5,536	$3,224	$0	$8,760
Totals										**$605,223**	**$405,318**	**$199,905**	**$30,000**	**$575,223**



Relative Change in Land Surface Altitude as Measured by InSAR March 2011 to March 2019

+ 0.25 ft
0
-0.20
- 0.25 ft

InSAR absent or incoherent

Groundwater-Level and Aquifer-System Deformation Monitoring

- Well Equipped with Pressure Transducer (2018/19)
- Ayala Park Extensometer
- Chino Creek Extensometer
- Pomona Facility Extensometer

Ground-Level Survey Areas

- Ground-Level Survey Benchmark
- Northeast Area
- Managed Area
- Fissure Zone
- Southeast
- Central
- Northwest MZ-1
- San Jose Fault Zone

- Areas of Subsidence Concern
- Flood Control and Conservation Basins
- Ground Fissures
- Approximate Location of the Riley Barrier
- Fault - Solid where accurately located. Dashed where approximately located or inferred; dotted where concealed.

WILDERMUTH ENVIRONMENTAL, INC.

Author: MAB
Date: 2/18/2020
Document Name: FY_2020_21

0 2 4 Miles
0 2 4 Kilometers

Ground-Level Monitoring Committee
Ground-Level Monitoring Program

Ground-Level Monitoring Program
Fiscal Year 2020/21

Figure 1

Appendix B

Comments and Responses

Appendix B - Response to GLMC Comments

2019/20 Annual Report of the GLMC

Christopher Quach, City of Ontario

Comment 1 – Northeast Area and InSAR

I just wanted to follow up on the discussion during the October 1 GLMC meeting, specifically regarding the recently observed subsidence in the Northeast Area south of the Ontario Airport. Our initial reaction is that the monitoring currently being performed should be continued to confirm the accuracy of the new data. Especially since monitoring just recently switched to a new data set, we think more information is needed. We would support the consensus during the meeting to have the consultant present on the methodology & data interpolation technique used to determine the level of subsidence.

Response:

Thank you for your comment. For clarification, Watermaster did not switch to a "new [InSAR] data set." The InSAR subconsultant, General Atomics, used alternative data-processing methods which improved the "coherence" of the interferogram, and hence, allowed for estimates of vertical ground motion in areas that were previously incoherent. In 2020/21, we plan for: (i) General Atomics to present their alternative data-processing methods at the next GLMC meeting, (ii) the continuance of the ground-level monitoring program (including monitoring via InSAR) across the western Chino Basin, and (iii) the GLMC to discuss methods to understand why the subsidence has been occurring in this area.

Comment 2

We reviewed the 2019/20 Annual Report and our only comment is related to the Northeast Area of Concern. Just to reiterate my previous email, since this is the first year using TerraSAR-X data, interferograms, and a new interpolation method of previously incoherent areas, we recommend continued monitoring via InSAR for additional data. In addition, it may be beneficial to bring up in committee discussions to periodically perform ground-level surveys to empirically validate the results of the new processing methodology.

Also, I had a question that maybe Mike and Andy can answer. In comparing the new TerraSAR-X data to the historical InSAR data that was used until 2019, were there any significant discrepancies in the observed vertical ground motion? As in, did the two data sets seem consistent to each other or were there significant discrepancies.

Response:

The scope of work for 2020/21 includes the continuance of monitoring of vertical ground motion via InSAR across the western Chino Basin.

For clarification, the GLMC has been utilizing the TerraSAR-X data since 2011. The only difference in 2019/20 was the improved coherence of the interferogram in some areas that were previously incoherent, so comparisons to past estimates of InSAR are not possible.

The GLMC has established an array of benchmark monuments across the Northeast Area and has performed multiple elevation surveys this network. The general conclusion from these surveys are that they show a similar pattern of ground motion, but the magnitudes of vertical displacement do not match perfectly with the InSAR estimates of vertical ground motion. This difference is likely due to the relatively long distance that the leveling surveys must travel from the starting benchmark at Ayala Park in the City of Chino. The GLMC should discuss and consider alternative methods to measure vertical groundwater motion in the Northeast Area to verify the InSAR results—perhaps as part of a study of the area of recent subsidence south of the Ontario Airport.

State of California Department/Wood Environment and Infrastructure Solutions, Inc., Richard Rees

Comment 1 – Northwest MZ-1 Work Plan Schedule

Several actions are recommended in relation to continued study and plan development for Northwest MZ-1. Some of these actions (e.g., updating the Northwest MZ-1 hydrogeologic conceptual model by constructing and calibrating a one-dimensional compaction model at the PX location, updating Watermaster's MODFLOW model to simulate land subsidence across the Chino Basin, using the updated MODFLOW model to characterize the Baseline Management Alternative and the Initial Subsidence Management Alternative, and developing and evaluating additional subsidence-management alternatives in order to minimize or eliminate the future occurrence of subsidence in Northwest MZ-1) are presented for completion in FY 2020/21 but may rely on collection of necessary data from the aquifer stress testing to be done using the extensometer, piezometers, and other features in this area. Given the delays in completion of the Pomona extensometer, is the schedule for aquifer stress testing and other related work in this area still expected to allow completion of the referenced actions in FY 2020/21? If not, we suggest acknowledging in the current report that the schedule may need to be adjusted. Similarly, we note that Section 4.1 (first full bullet on page 4-2) refers to developing and evaluating additional subsidence-management alternatives in order to minimize or eliminate the future occurrence of subsidence in Northwest MZ-1 in FY 2020/21, but Section 2.2.3 (Task 9, page 2-8) indicates an estimated completion of this task in FY 2021/22.

Response:

Thank you for your comments and suggestions. The schedule to update the Northwest MZ-1 hydrogeologic conceptual model (i.e. PX 1D compaction model), update the Watermaster's MODLOW model with a subsidence package, and using the updated model to characterize the BMA and ISMA in FY 2020/21 is our preliminary schedule. We have completed the PX 1D model and will begin updating the MODFLOW model in November 2020. We anticipate the model will be calibrated by April 2021. Feedback received by the GLMC on the model and/or model documentation will be addressed before characterizing the BMA and ISMA. Characterizing the BMA and ISMA and developing additional subsidence-management alternatives will be contingent on the GLMC's review of the technical memorandum that document the model update and calibration results. The schedule for this project is dependent on the pace of completion of model calibration and the feedback received from the GLMC on the results and work products. The annual report has been updated (see Sections 2.2.3 and 4.1) to acknowledge that completion of certain tasks in the Northwest MZ-1 Work Plan may need to be adjusted. All Northwest MZ-1 Work Plan milestones dates have also been updated for consistency.

Regarding the need for conducting controlled aquifer-system stress test(s) in Northwest MZ-1, these tests are not required to build and calibrate the SUB package in MODFLOW. This model update can be performed based on the existing database of hydrogeologic and ground motion. Controlled aquifer stress testing may be necessary in the future, but only if specific questions need to be answered to develop the subsidence management plan in Northwest MZ-1.

Comment 2 – Figures

In Figure 3-5B, Chino Well C-13 is mislabeled as CIM-13.

Response:

The figure has been modified to address this comment.

Comment 3 – Editing

We noted several instances where editing is needed, for example, singular/plural disagreement in the fourth bullet in Section 2.1.1, and incorrect dates listed in the heading for Section 4.2. We assume the report will be given a thorough editorial review before it is finalized.

Response:

The report has been given another editorial review, and the text has been updated where appropriate to address this comment.

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