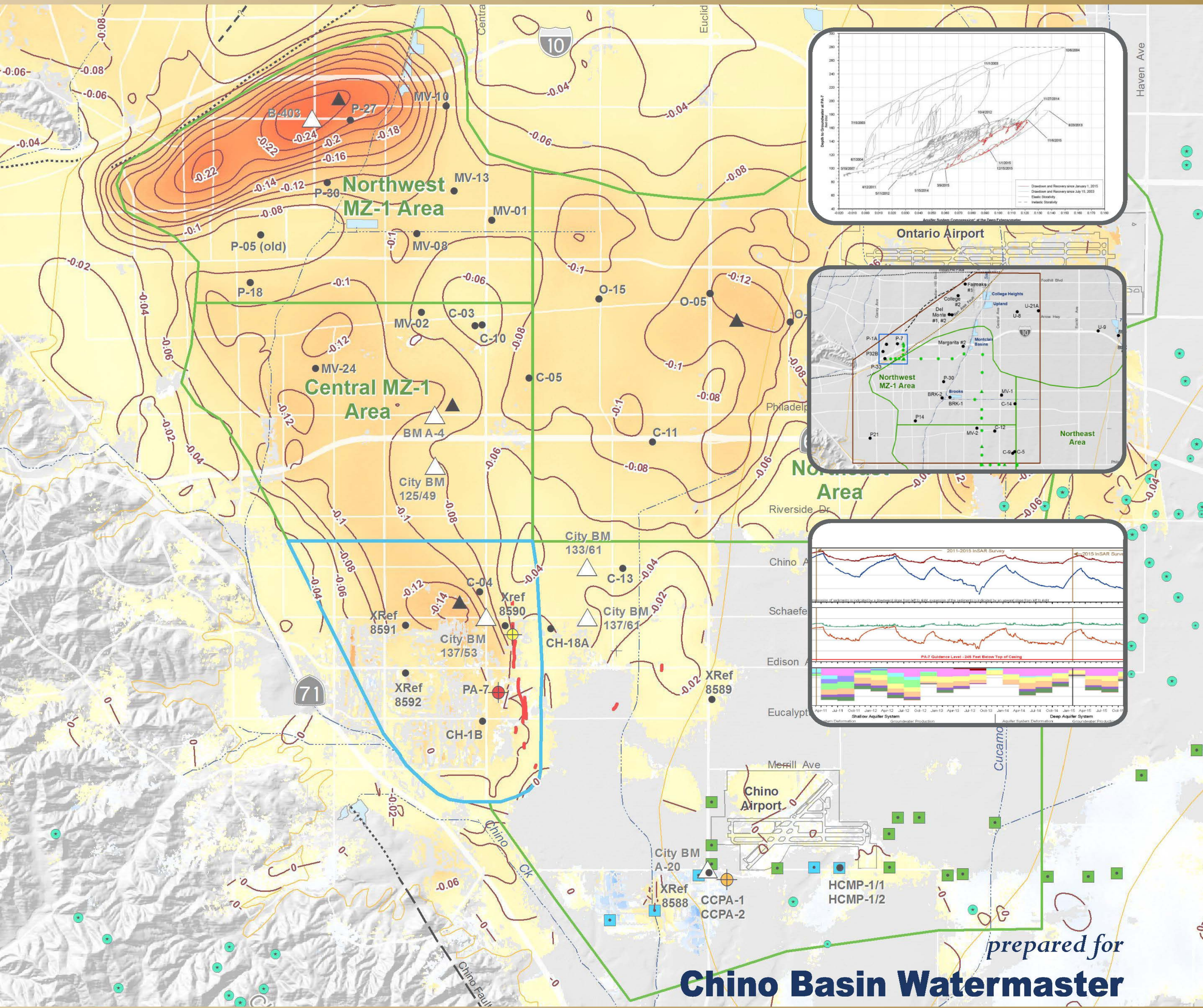
2015 Annual Report of the Ground-Level Monitoring Committee

Final



prepared for

Chino Basin Watermaster

September 2016

WEI
WILDERMUTH ENVIRONMENTAL, INC.

Table of Contents

List of Tables

List of Figures

Acronyms, Abbreviations, and Initialisms

acre-ft/yr	acre-feet per year
ASR	Aquifer Storage and Recovery
BM	Benchmark
CCX	Chino Creek Extensometer Facility
CIM	California Institution for Men
DHX	Daniels Horizontal Extensometer
EDM	Electronic Distance Measurement
ft-bgs	feet below ground surface
ft-btoc	feet below top of casing
GLMC	Ground-Level Monitoring Committee
GLMP	Ground-Level Monitoring Program
GSWC	Golden State Water Company
IEUA	Inland Empire Utilities Agency
IMP	Interim Monitoring Program
InSAR	Interferometric Synthetic Aperture Radar
ISMA	Initial Subsidence Management Alternative
LGA	Local Groundwater Assistance
MVWD	Monte Vista Water District
MZ-1	Management Zone 1
OBMP	Optimum Basin Management Plan
PE1	Program Element 1
SAWCo	San Antonio Water Company
SMP	2015 Chino Basin Subsidence Management Plan
USGS	United States Geological Survey
WEI	Wildermuth Environmental Inc.

1.1 Background

In general, land subsidence is the sinking or settlement of the Earth's surface due to the rearrangement of subsurface Earth materials. In the United States alone, over 17,000 square miles in 45 states have experienced land subsidence (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 all 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 permanent (non-recoverable) sinking of the land surface. The term inelastic (i.e. non-recoverable) typically refer to permanent 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.

1.1.1 Subsidence and Fissuring in Chino Basin

One of the earliest indications of land subsidence in Chino Basin was the appearance of ground fissures within Management Zone 1 (MZ-1) of the Chino Basin, in 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 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 Plan (OBMP) Phase I Report (WEI, 1999) identified the pumping-induced decline of piezometric levels and subsequent aquifer-system compaction as the most likely cause of the land subsidence and ground fissuring observed in MZ-1. Program Element 4 of the OBMP, *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:

- Minimize subsidence and fissuring in the short-term.
- Collect the information necessary to understand the extent, rate, and mechanisms of subsidence and fissuring.
- Formulate a management plan to 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 (second and third bullets above). This investigation was titled the MZ-1 Interim Monitoring Program (IMP), which is described below.

The OBMP Phase I Report also noted that land subsidence was occurring in other parts of the Basin besides the City of Chino. Program Element 1 (PE1) of the OBMP Implementation Plan, *Develop and Implement a Comprehensive Monitoring Program*, called for a basin-wide analysis of land subsidence via ground-level surveys and remote-sensing (specifically, interferometric synthetic aperture radar or InSAR) and for ongoing monitoring based on the analysis of the subsidence 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 (now called the Ground-Level Monitoring Committee or GLMC). 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; the Golden State Water Company; and the State of California, California Institution for Men (CIM).

The IMP consisted of three main monitoring elements: ground-level surveys, InSAR, and aquifer-system monitoring. The ground-level surveys and InSAR analyses were used to monitor deformation of the ground surface. Aquifer-system monitoring measured the hydraulic and mechanical changes within the aquifer-system that cause ground-surface deformation (WEI, 2003). In addition, groundwater pumping information was collected from the wells surrounding Rubin S. Ayala Park (Ayala Park) in Chino, CA.

The monitoring program was implemented in two phases: the Reconnaissance Phase and the Comprehensive Phase. The Reconnaissance Phase consisted of the construction of two multiple-depth piezometers—totaling 11 casings, screened at various depths—at Ayala Park and the installation and monitoring of pressure transducers to measure piezometric levels at surrounding pumping and monitoring wells, followed by several months of aquifer-system monitoring and testing. Testing included additional aquifer-system stress tests applied by pumping wells in the surrounding area (WEI, 2003).

The Comprehensive Phase consisted of the construction of a dual-borehole pipe extensometer at Ayala Park (the Ayala Park Extensometer) near the area of historical fissuring and within the City of Chino and Chino Hills' well field. Passive aquifer-system monitoring was followed by two aquifer-system stress tests.

During implementation of the IMP, Watermaster's Engineer made data available to the MZ-1 Technical Committee and prepared quarterly progress reports that were submitted to the MZ-1 Technical Committee, the Watermaster Pools, and, ultimately, the Court. The reports contained data and analyses from the IMP and a summary of the content of any Technical Committee meetings. The main conclusions derived from the IMP were:

- Groundwater pumping from the deep, 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 piezometric-level decline that is much greater in magnitude and lateral extent than the piezometric-level decline caused by pumping of the shallow aquifer system.[1]

- Piezometric-level decline due to pumping of 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 piezometric levels in the deep aquifer system fell below a depth of about 250 feet in Watermaster's PA-7 piezometer at Ayala Park.
- The state of aquifer-system deformation in southern MZ-1 (in the vicinity of Ayala Park) was essentially elastic during the Reconnaissance Phase of the IMP. Very little inelastic compaction was occurring in this area, which was in contrast to the recent past when about 2.2 feet of land subsidence occurred from about 1987 to 1995 and was accompanied by ground fissuring. Figure 1-1 shows the land subsidence 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. The barrier was named the "Riley Barrier" after Francis S. Riley, the 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 piezometric-level decline did not propagate eastward across the barrier. Thus, compaction occurred within the deep 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.
- InSAR and ground-level survey data indicated that subsidence in the central region of MZ-1 had occurred in the past and was continuing to occur. The InSAR data also suggested that the groundwater barrier extends northward into central MZ-1. These observations suggested that the conditions that very likely caused ground fissuring near Ayala Park in the 1990s are also present in central MZ-1; however, there is not enough historical piezometric-level data in this area to confirm this relationship. If subsidence continues or increases, the mechanisms that cause the land subsidence should be studied in more detail.

The methods, results, and conclusions of the IMP are described in detail in the MZ-1 Summary Report (WEI, 2006). The IMP provided enough information for Watermaster to develop Guidance Criteria for the MZ-1 producers in the investigation area that, if followed, would minimize the potential for subsidence and fissuring during the completion of the MZ-1 Subsidence Management Plan (MZ-1 Plan; WEI, 2007).

The Guidance Criteria are listed below (WEI, 2006):

[1] Pumping from the deep aquifer system within the Managed Area generally occurs from wells that are screened deeper than 400 feet below ground surface (WEI, 2007).

1. Table 1-1 lists the existing wells with screens completed into the deep aquifer system (hereafter the Managed Wells) and their owners (hereafter the Parties) that are the subject of these Guidance Criteria.
2. Figure 1-1 shows the area addressed by these Guidance Criteria (hereafter the Managed Area). Within the boundaries of this area, both existing and newly constructed wells are subject to being classified as Managed Wells. This is based on the observed and/or predicted effects of pumping on piezometric levels and aquifer-system deformation. Initial Managed Well designations for wells that pumped during the IMP were based on effects measured at the Ayala Park Piezometer/Extensometer Facility. Additional Managed Well designations were made based on analyses of well construction and geology.
3. The Guidance Level is a specified depth to water measured in Watermaster's PA-7 piezometer at Ayala Park. It is defined as the threshold piezometric level at the onset of inelastic compaction of the aquifer system as recorded by the extensometer, minus 5 feet. The 5-foot reduction is meant to be a safety factor to ensure that inelastic compaction does not occur. The Guidance Level is established by Watermaster based on the periodic review of monitoring data collected by Watermaster. The initial Guidance Level is 245 feet below the top of the PA-7 well casing.
4. If the piezometric level in PA-7 falls below the Guidance Level, Watermaster recommends that the Parties curtail their pumping from designated Managed Wells, as required to maintain the piezometric level in PA-7 above the Guidance Level.
5. Watermaster will provide the Parties with real-time piezometric level data from PA-7.
6. The Parties are 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 Parties are requested to promptly notify Watermaster of all operational changes made to maintain the piezometric level in PA-7 above the Guidance Level.
7. Watermaster recommends that the Parties allow Watermaster to continue monitoring piezometric levels at their wells.
8. Watermaster and Watermaster's Engineer will evaluate the data collected as part of the MZ-1 Monitoring Program (now called the Ground-Level Monitoring Program or GLMP) at the conclusion of each fiscal year (June 30) and determine if modifications, additions, and/or deletions to the Guidance Criteria are necessary. These changes to the Guidance Criteria could include (1) additions or deletions to the list of Managed Wells, (2) re-delineation of the Managed Area, (3) raising or lowering of the Guidance Level, or (4) additions and/or deletions to the Guidance Criteria (including the need to have periods of piezometric level recovery).
9. Watermaster cautions that some subsidence and fissuring may occur in the future even if these Guidance Criteria are followed. Watermaster makes no warranties that faithful adherence to these Guidance Criteria will eliminate subsidence or fissuring.

1.1.4 MZ-1 Subsidence Management Plan

The Guidance Criteria formed the basis for the MZ-1 Plan, which was developed by the MZ-1 Technical Committee and approved by Watermaster in October 2007. In November 2007, the San Bernardino County Superior 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 Parties manage their groundwater pumping such that the piezometric level in PA-7 remains above the Guidance Level.

The MZ-1 Plan calls 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 calls for: (1) the continued scope and frequency of monitoring implemented during the IMP within the Managed Area and (2) 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, and Southeast Areas. The expanded monitoring efforts outside of the Managed Area are consistent with the requirements of OBMP PE1 and its implementation plan contained in the Peace Agreement.

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 those Parties affected by the MZ-1 Plan. The 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 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 MZ-1 Plan in an attempt to avoid the adverse impacts. The 2014 Annual Report of the GLMP recommended that the MZ-1 Plan be updated to better describe Watermaster's efforts and obligations with regard to land subsidence that included areas outside of MZ-1. As such, the update of the plan included a name change to the 2015 Chino Basin Subsidence Management Plan (SMP; WEI 2015a). The recommendation included the development of a subsidence management plan for the Northwest MZ-1 Area with the long-term objective to minimize or abate the occurrence of the differential land subsidence. Land subsidence in the Northwest MZ-1 Area was first identified as a concern in 2006 in the MZ-1 Summary Report and again in 2007 in the MZ-1 Plan. Since then, Watermaster has been monitoring vertical ground motion in this area via InSAR and piezometric levels with pressure transducers at selected wells.

Of particular concern is that the subsidence in the Northwest MZ-1 Area across the San Jose Fault 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 the Northwest MZ-1 Area has been discussed at prior GLMC meetings, and the subsidence has been documented and described as a concern in past State of the Basin Reports (WEI 2013) and the annual reports of the GLMC. Watermaster increased monitoring efforts in the Northwest MZ-1 Area beginning in winter 2012-2013 to include elevation surveys and electronic distance measurements (EDMs) to monitor the ground motion and 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), which includes a description of the multi-year effort with cost estimates and a schedule and is characterized as an ongoing effort of Watermaster. The Work Plan was included in the SMP as Appendix B. Implementation of the Work Plan began in July 2015.

1.1.6 Annual Report of the Ground-Level Monitoring Committee

The SMP states that Watermaster will produce an annual report that includes the results of ongoing monitoring efforts, interpretations of the data, and recommended adjustment to the SMP, if any. This annual report of the GLMC includes results and interpretations for data that were collected through calendar year 2015 and includes recommendations for Watermaster's GLMP for fiscal year 2016-17.

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, the formation of the Ground-Level Monitoring Committee and its responsibilities, and a description of the development and implementation of the SMP.

Section 2 – Ground-Level Monitoring Program (2015). This section describes the monitoring and testing activities that were performed by Watermaster for its GLMP during 2015.

Section 3 – Results and Interpretations. This section discusses and interprets the monitoring data collected through 2015, including the basin stresses of groundwater pumping and recharge and the basin responses, which include changes in piezometric levels, aquifer-system deformation, and ground motion.

Section 4 – Conclusions and Recommendations. This section summarizes the main conclusions derived from the monitoring program as of December 2015 and describes recommended activities for the program during fiscal year 2016-17 in the form of a proposed scope-of-work, schedule, and budget.

Section 5 – Glossary. This section includes the glossary of terms and definitions that are utilized within this report and in the discussions at meetings of the Ground-Level Monitoring Committee.

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

Table 1-1
Managed Wells*

CBWM ID	Owner	Well Name	Status[1]	Well Screen Intervals *ft-bgs*
3600461	Chino	C-7	Not Equipped	180-780
600670	Chino	C-15	Not Equipped	270-400, 626-820
600487	Chino Hills	CH-1B	Inactive	440-470, 490-610, 720-900, 940-1180
600687	Chino Hills	CH-7C	Not Equipped	550-950
600498	Chino Hills	CH-7D	Inactive	320-400, 410-450, 490-810, 850-930
600488	Chino Hills	CH-15B	Inactive	360-440, 480-900
600489	Chino Hills	CH-16	Inactive	430-940
600499	Chino Hills	CH-17	Active	300-460, 500-980
600500	Private	CH-19	Not Equipped	340-420, 460-760, 800-1000
3602461	CIM	CIM-11A	Active	174-187, 240-283, 405-465 ft bgs[2]

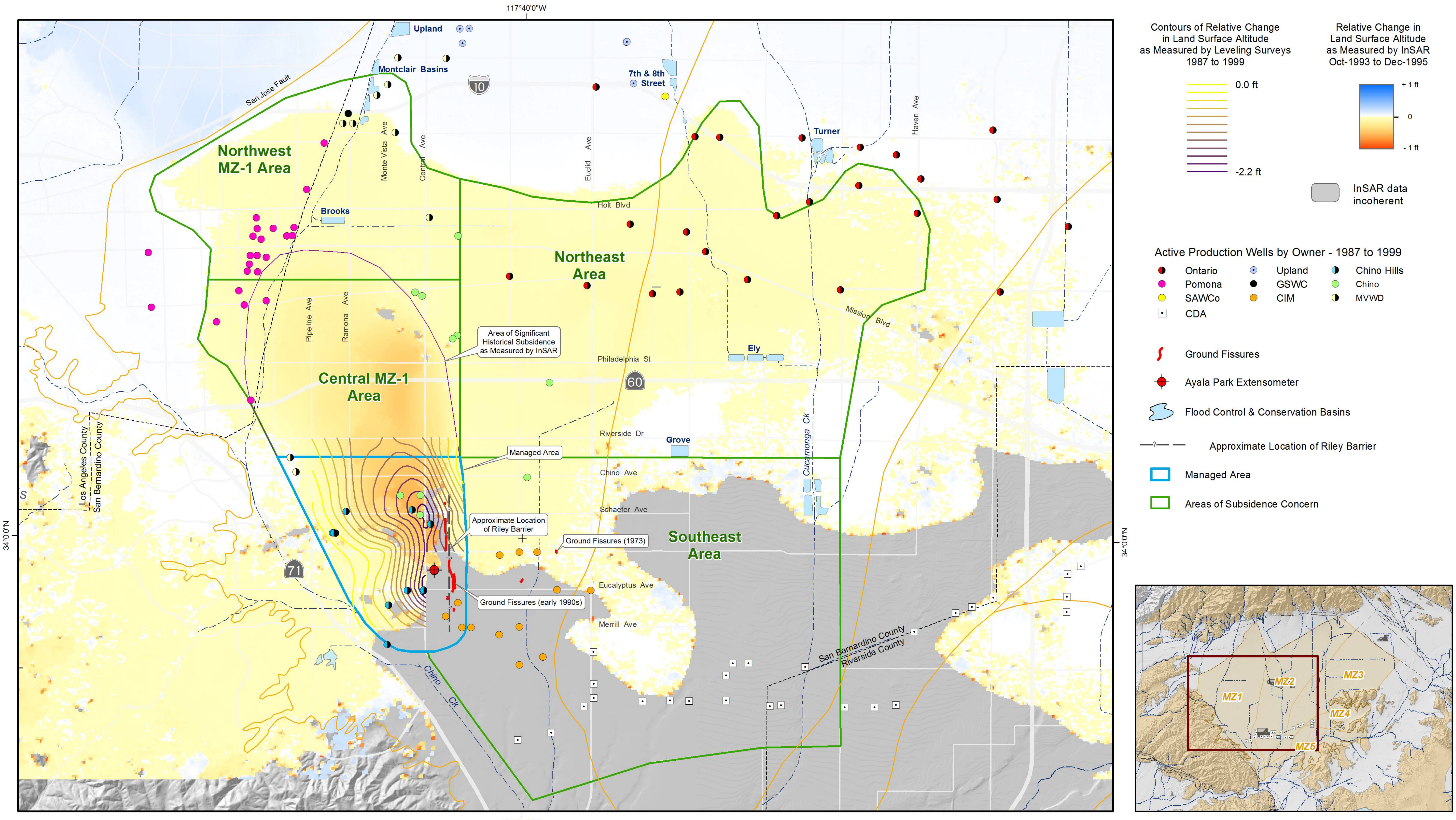
*The MZ-1 Subsidence Management Plan identified the Managed Wells that are the subject of the Guidance Criteria for the Managed Area that, if followed, would minimize the potential for subsidence and fissuring.

[1] Active: Well is currently being used for water supply.

Inactive: Well can pump groundwater with little or no modifications, but no pumping is planned for the current year.

Not Equipped: Unable to pump the well without major modifications, and no pumping is planned for the current year.

[2] 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 470.5 ft- bgs in 2011. A liner was installed to 470 ft-bgs with a screen interval from 155 to 470 ft-bgs.



Prepared by:

WEI
Wildermuth Environmental, Inc.

Author: TCR
Date: 20160630
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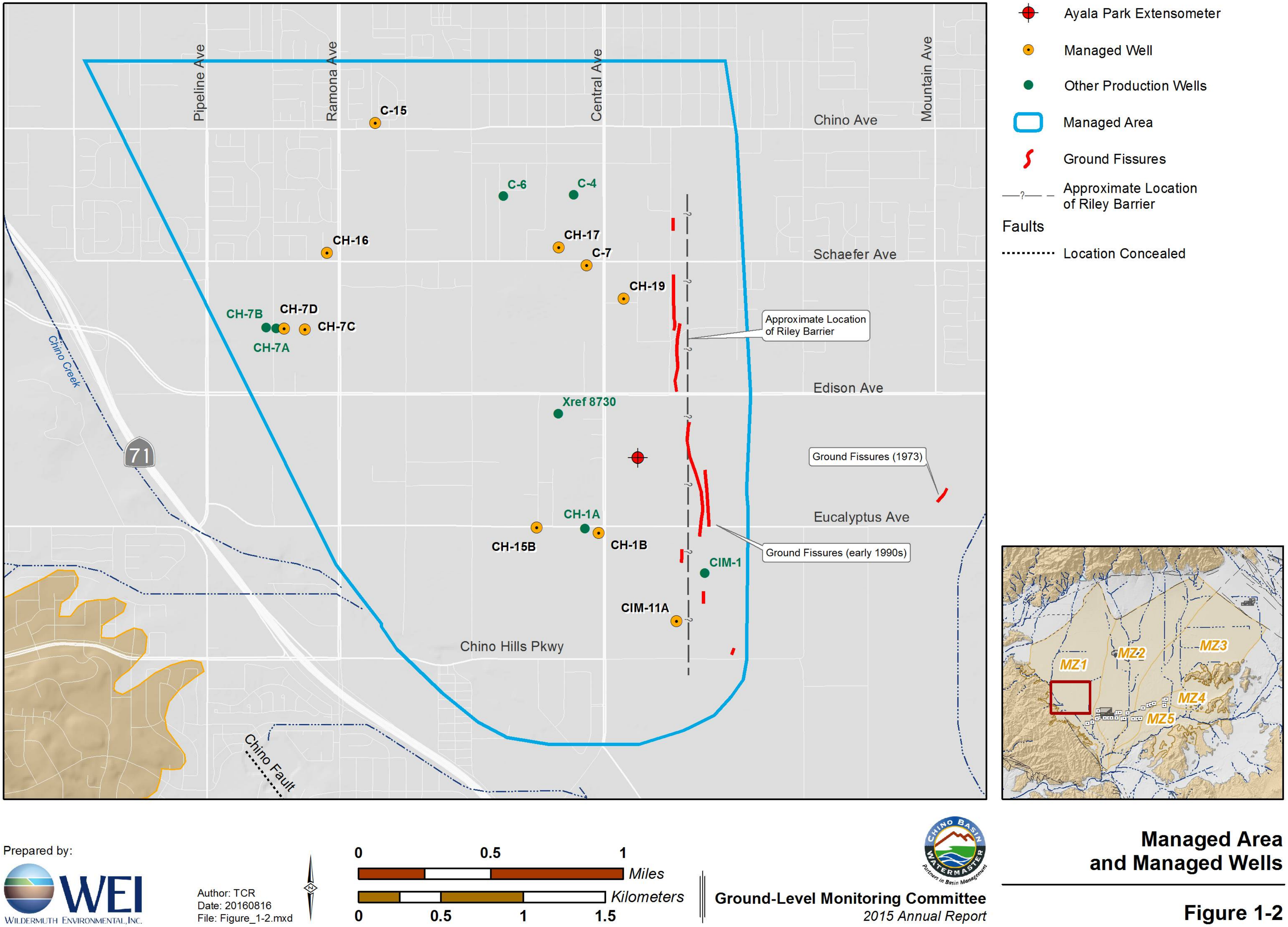
Ground-Level Monitoring Committee
2015 Annual Report

Historical Land Surface Deformation in Management Zone 1
Leveling Surveys (1987 to 1999) and InSAR (1993 to 1995)

Figure 1-1



Prepared by:

WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: TCR
Date: 20160816
File: Figure_1-2.mxd

Ground-Level Monitoring Committee
2015 Annual Report

Managed Area and Managed Wells

Figure 1-2

Section 2 – 2015 Ground-Level Monitoring Program

This section describes the activities performed by Watermaster for its GLMP during 2015. The activities included:

- Implementing the ongoing monitoring program in the Managed Area and other Areas of Subsidence Concern

- Performing site-specific investigations of land subsidence

Figures 2-1 and 2-2 are reference figures for this section, that show the facilities that comprise Watermaster's ground-level monitoring network. Figure 2-1 shows the groundwater pumping and recharge facilities in western Chino Basin that impart pumping and recharge stresses to the aquifer system. Figure 2-2 shows the locations of monitoring facilities in Watermaster's ground-level monitoring network, including: wells equipped with pressure transducers that measure piezometric levels; extensometers that measure aquifer-system deformation; and elevation and EDM survey benchmarks that are used to measure vertical and horizontal ground surface deformation. InSAR is used to estimate vertical ground motion across western Chino Basin.

2.1 Ongoing Ground-Level Monitoring Program

Watermaster conducts its GLMP in the Managed Area and other Areas of Subsidence Concern pursuant to the SMP and the recommendations of the GLMC. Monitoring network setup, maintenance, and the monitoring activities conducted by Watermaster during 2015 are described below.

2.1.1 Setup and Maintenance of the Monitoring Network

2.1.1.1 Setup of New Monitoring Facilities

Activities performed to setup new monitoring facilities in 2015:

- Installed telemetry at the Chino Creek Extensometer (CCX) to allow remote data collection from the monitoring site.

2.1.1.2 Maintenance of Monitoring Network

Activities performed to maintain the existing monitoring network in 2015:

- Replaced four malfunctioning pressure transducers at wells.

- Performed maintenance activities at the extensometer facilities, which included the following tasks:
    - Replaced the aging hardware and electronics at the Ayala Park Extensometer facility.
    - Performed work to protect the PA piezometer vault at Ayala Park against surface-water intrusion during storm events.

- Maintained Watermaster's website to display piezometric-levels at the PA-7 piezometer at Ayala Park.
- Fabricated additional counter weights for the deep cable extensometer at the CCX to increase cable tension to improve the measurement of aquifer-system deformation. The counter weights were installed in early 2016.
- Conducted maintenance of the Daniels Horizontal Extensometer (DHX) facility. The DHX was flooded in November 2013, which caused damage to the electronic monitoring equipment. Repairs to the facility began in 2014 and were completed in February 2015.
- In June 2015, the property where the DHX resided was sold. In August 2015, Watermaster was notified that development on the property was planned to begin in June 2016 and that the DHX needed be removed. During 2015, Watermaster coordinated with the property owners and the City of Chino for the removal of the DHX in April 2016.

2.1.2 Monitoring Activities during 2015

Changes in piezometric levels are caused by the stresses of groundwater pumping and recharge. Change in piezometric level is 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 production, recharge, piezometric levels, aquifer-system deformation, and vertical and horizontal ground motion across the western portion of the Chino Basin.

This section describes Watermaster's 2015 monitoring activities that are called for by the SMP and in accordance of the recommendations of the GLMC. Figures 2-1 and 2-2 show the locations of the facilities described below.

2.1.2.1 Monitoring of Production, Recharge, and Piezometric Levels

Watermaster collects and compiles quarterly groundwater production data from the owners of wells in the Managed Area and the Areas of Subsidence Concern. The locations of wells that pumped groundwater during 2015 are shown in Figure 2-1.

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

During 2015, piezometric levels were measured and recorded once every 15 minutes using pressure transducers maintained by Watermaster at approximately 80 wells in the Managed Area, Central MZ-1 Area, Northwest MZ-1 Area, and Southeast Area, shown in Figure 2-2.

2.1.2.2 Monitoring of Vertical Aquifer-System Deformation

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

2.1.2.3 Monitoring of Vertical Ground-Surface Deformation

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

Watermaster retained Parsons Brinkerhoff to conduct the ground-level surveys at selected benchmark monuments in the western part of the Chino Basin. Ground-level surveys were conducted within the following areas, shown in Figure 2-2:

- The *Southeast Area* (around the Chino Creek Well Field) in January 2015 and January 2016 (66 benchmarks).
- The *San Jose Fault Zone* in February 2015 and February 2016 (25 benchmarks).
- The *Managed Area* in March 2015 (116 benchmarks).

Watermaster retained Neva Ridge Technologies to acquire and post-process InSAR 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.[2] Six Synthetic Aperture Radar (SAR) data shots were collected: January 2015, March 2015, June 2015, September 2015, November 2015, and January 2016. The SAR data frames were used to create twelve interferograms[3] to measure short-term and long-term vertical ground motion over the following periods:

- March 2011 to January 2016
- December 2015 to January 2015
- December 2015 to March 2015
- December 2015 to June 2015
- December 2015 to September 2015
- December 2015 to November 2015

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

[3] Two or more SAR shots 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 uplift/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 leaves moving, vegetation growing, weather changing the ground surface, water flowing, harvesting crops 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.”

- December 2015 to January 2016
- January 2015 to March 2015
- March 2015 to June 2015
- June 2015 to September 2015
- September 2015 to November 2015
- November 2015 to January 2016

2.1.2.4 Monitoring of Horizontal Ground-Surface Deformation

Watermaster measured horizontal ground motion across areas that are susceptible to ground fissuring via EDMs and horizontal extensometers.

EDMs were performed between the benchmarks shown in Figure 2-2 within the following areas:

- *Fissure Zone* along Schaefer Avenue, G Street, and Chino Avenue in March 2015 (50 benchmarks).
- *San Jose Fault Zone* along San Bernardino Avenue and North San Antonio Avenue in February 2015 and February 2016 (25 benchmarks).

Watermaster also measured horizontal ground motion within the shallow soils across the historic fissure zone in the Managed Area at the DHX. The DHX is composed of an in-line series of nine quartz-tube horizontal extensometers that measure and record expansion and compression within the shallow soils once every 15 minutes.

2.2 Land-Subsidence Investigations

Watermaster performs land-subsidence investigations pursuant to the SMP, the recommendations of the GLMC, and approval of scope-of-work and budget by the Watermaster Pool Committees, Advisory Committee and Watermaster Board. Past and current investigations typically include aquifer-stress tests (e.g. pumping, injection) and the simultaneous monitoring of piezometric levels, 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 groundwater management plans that will not cause damage to the ground surface and overlying infrastructure.

This section describes the activities conducted during 2015 for land-subsidence investigations that are called for by the SMP. Figures 2-1 and 2-2 show the locations of the facilities described below.

2.2.1 Long-Term Pumping Test in the Managed Area

The MZ-1 Plan states that Watermaster will assist the Parties with "additional testing and monitoring to refine the Guidance Criteria" and the "development of alternative pumping plans" to "produce a reasonable quantity of groundwater from MZ-1." The GLMC developed the Long-Term Pumping Test in the Managed Area in response to these directives in the MZ-1 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 without causing damage to the ground surface or the area's infrastructure. Specific questions that the program is designed to answer are:

1. Is the Guidance Level for the Managed Area, as currently defined, appropriate? If no, 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 vertical ground motion 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 piezometric levels 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 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 piezometric level at PA-7 to fall below the Guidance Level and may cause a small amount of subsidence.[4] The test will be closely monitored at the Ayala Park Extensometer and the horizontal monitoring facilities and will be stopped at the first clear indication of inelastic compaction. Piezometric levels recorded at 15-minute intervals at PA-7 will be updated every three-hours on Watermaster's website. When the piezometric level declines to within 20 feet of the Guidance Level, data from the Ayala Park Extensometer will be downloaded and used to prepare a stress-strain diagram. The stress-strain diagram will be distributed promptly to the GLMC by email. Watermaster staff and the Watermaster engineer will remain in close telephonic contact with staff at the City of Chino, the City of Chino

[4] 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 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 than the +/- 0.1 ft of elastic vertical ground motion that occurs seasonally in this area.

Hills, and CIM to review and interpret the stress-strain diagram, to plan for the preparation of the next stress-strain diagram, or to make the determination to stop the test when appropriate.

2. Stop the pumping test and allow for partial recovery of piezometric levels.

3. Conduct two cycles of injections at CH-16 to see how injection may accelerate the recovery of the regional piezometric levels that were lowered by pumping at CH-17 and CH-15B.

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 and the DHX once every 15 minutes throughout the test.

5. After injection tests, allow for full recovery of piezometric levels at PA-7 to pre-test conditions. Check stress-strain diagrams from the Ayala Park Extensometer for inelastic compaction of the aquifer system in the Managed Area. Check stress-strain diagrams from the DHX for inelastic horizontal deformation across the fissure zone. Analyze ground-level survey, InSAR, and EDM data for inelastic horizontal and vertical ground deformation within the Managed Area (WEI, 2007).

The SMP calls for an injection feasibility study at a deep-aquifer production well within the Managed Area, conceptualized as part of the Long-Term Pumping Test above. 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 of an existing production well (City of Chino Hills Well 16 [CH-16]) to an aquifer storage and recovery (ASR) well and conducting a pilot injection test.

Watermaster's assistance to Chino Hills in this study has included: assistance in applying for and acquiring a Local Groundwater Assistance (LGA) grant from the DWR, grant administration, and a cost-share contribution of $368,000 to execute the study.

During 2015, the following activities were performed by Chino Hills and Watermaster for the DWR grant:

- Prepared and submitted the final report to the DWR for the LGA grant. The report described the work performed for the project, the project schedule, the project costs, the results of the project, and all project deliverables.

- Coordinated with the DWR to complete the LGA grant requirements and complete the grant.

A potable water pipeline connection to CH-16 is needed prior to operation of the well for ASR and performance of the injection test, conceptualized as part of the Long-Term Pumping Test in the Managed Area. This connection was not constructed as of the end of 2015.

During 2015, pumping at CH-15B did not commence, and pumping at CH-17 alone failed to cause piezometric levels to decline below the Guidance Level at the PA-7 piezometer (245 ft-btoc). The maximum depth-to-groundwater at the PA-7 piezometer was about 170 ft-btoc before pumping ceased at CH-17 in November 2015.

2.2.2 Develop a Subsidence Management Plan for the Northwest MZ-1 Area

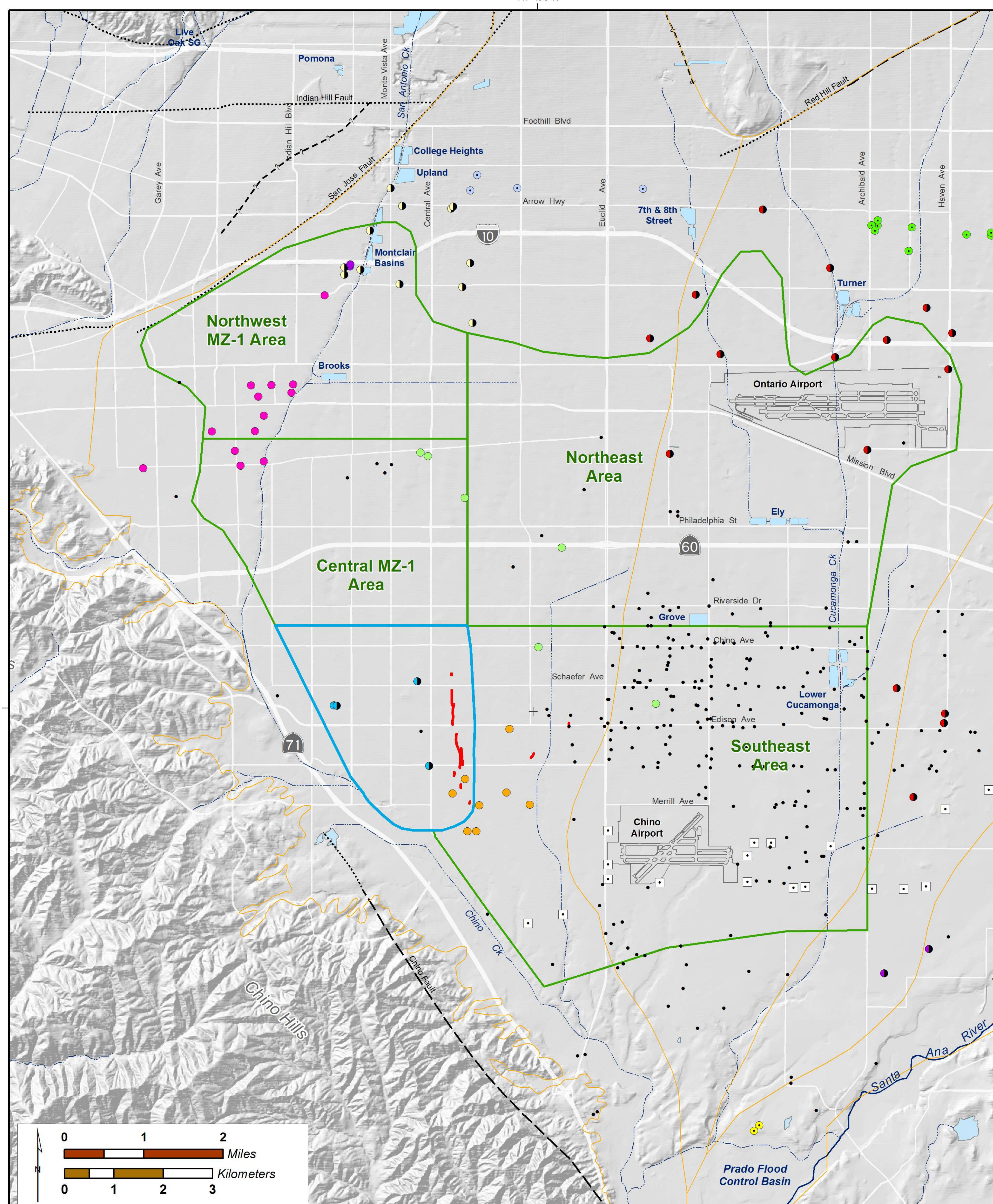
In 2015, Watermaster's Engineer developed the Work Plan, which includes a description of a multi-year effort with cost estimates and a schedule to develop a subsidence management plan for the Northwest MZ-1 Area. The Work Plan was included in the SMP as Appendix B. The background and objectives of the Work Plan are described in Section 1.1.5 herein.

Watermaster began implementation of the Work Plan in July 2015. The following work was completed during 2015:

- *Task 1 Describe Initial Hydrogeologic Conceptual Modal & the Monitoring and Testing Program* – a draft report was prepared that summarizes the current state of knowledge of the hydrogeology of the Northwest MZ-1, the data gaps that need to be filled in order 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 coordinated with the public agencies that have wells within the Northwest MZ-1 Study Area (Study Area) identified in Task 1 (see Figure 2-2) to collect high accuracy and temporal resolution (15-muinute intervals) groundwater pumping rate and piezometric levels. These agencies include the Cities of Chino, Pomona, and Upland; the Golden State Water Company (GSWC); and the Monte Vista Water District (MVWD). Watermaster's Engineer canvassed 48 wells to assess the feasibility of pressure transducer installation and subsequently installed 19 pressure transducers to record piezometric levels. Collection of well pumping data (pumping rates and well on/off times) from approximately 20 wells in the Study Area began in September 2015.

- *Task 3 Develop and Evaluate the Baseline Management Alternative* – Watermaster's Engineer developed and calibrated a 1-dimentional compaction model that will be used to estimate future subsidence in the Northwest MZ-1 Area.



Active Production Wells by Owner
2015

- Ontario
- Pomona
- SAWCo
- CVWD
- Upland
- GSWC
- Private
- CIM
- JCSD
- Chino Hills
- Chino
- MVWD
- OCWD
- CDA

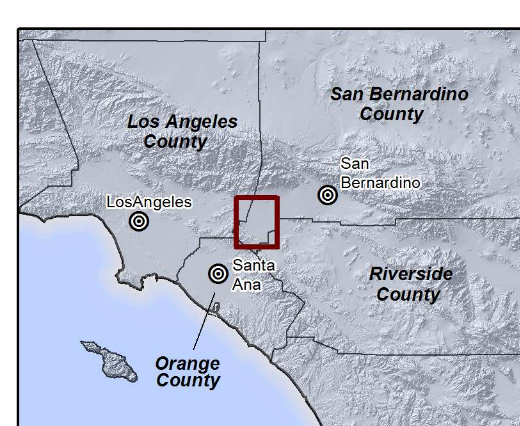
Ground Fissures

MZ-1 Managed Area

Areas of Subsidence Concern

Chino Basin Management Zones

Flood Control & Conservation Basins



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Wildermuth Environmental, Inc.

Author: TCR
Date: 20160309
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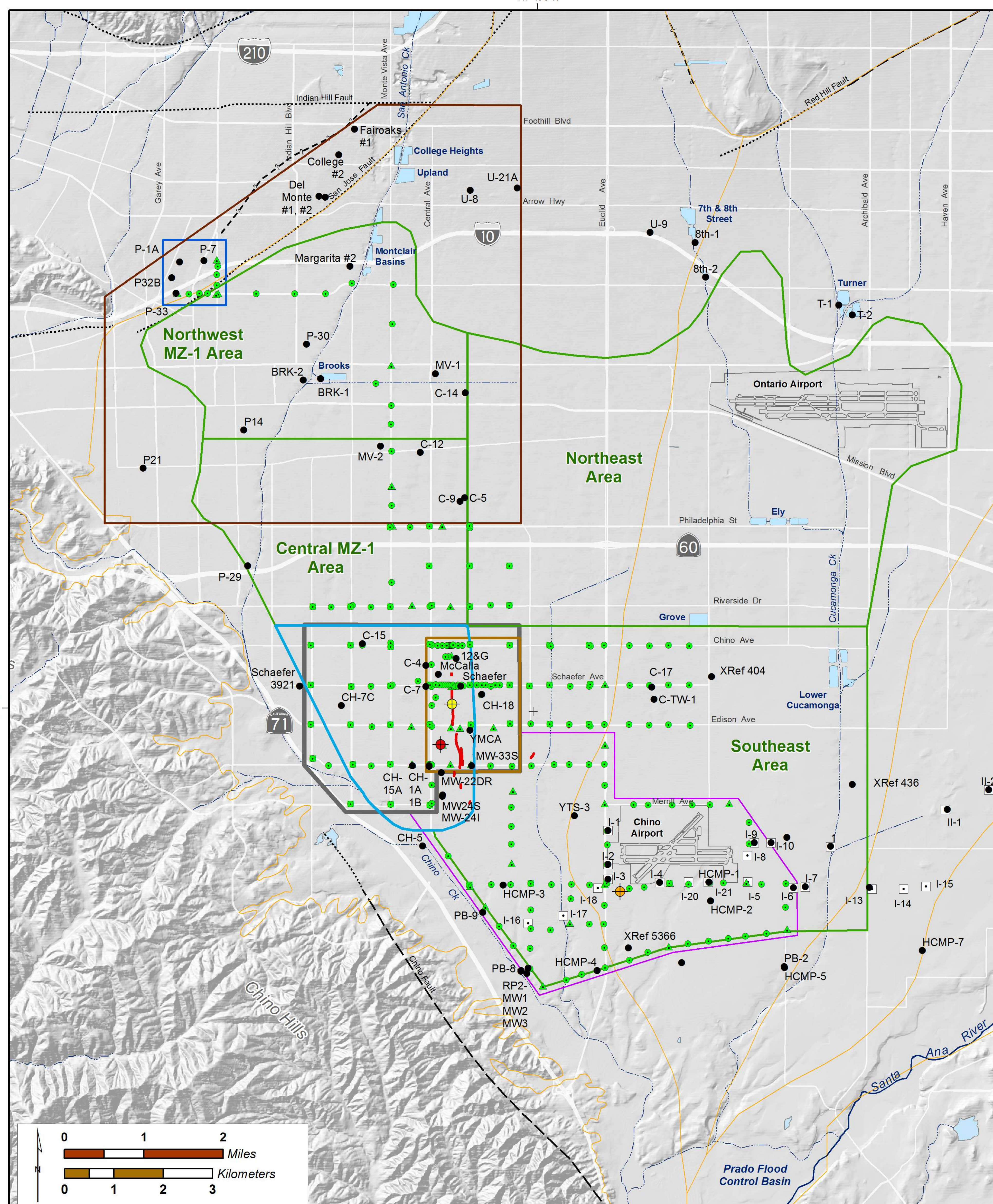
2015 Annual Report

Pumping & Recharge Facilites

Western Chino Basin 2015

Figure 2-1



Survey Benchmarks

- Class A Monuments
- Class B Monuments

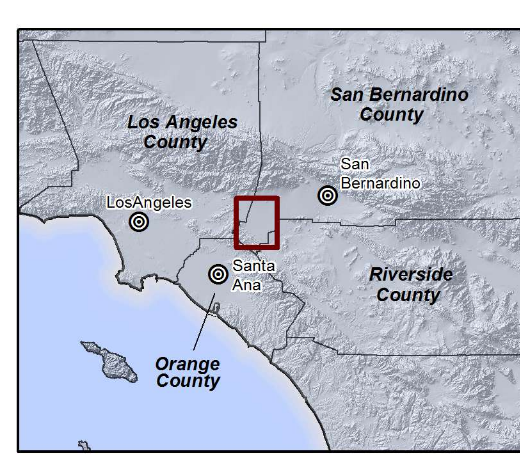
Survey Areas

- Southeast Area
- Fissure Zone
- Managed Area
- San Jose Fault Zone

Wells and Extensometers

- Desalter Well
- Ayala Park Extensometer
- Chino Creek Extensometer
- Daniels Horizontal Extensometer
- Well Monitored by Pressure Transducer as of Dec-2015
- Managed Area
- Areas of Subsidence Concern
- Northwest MZ-1 Study Area

- Ground Fissures
- Flood Control & Conservation Basins
- Chino Basin Management Zones



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WEI
Wildermuth Environmental, Inc.

Author: TCR
Date: 20160309
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Ground-Level Monitoring Committee
2015 Annual Report

Ground-Level Monitoring Network
as of 2015

Figure 2-2

This section describes the results and interpretations derived from the GLMP for the Managed Area and the Areas of Subsidence Concern through December 2015.

Figures 3-1a and 3-1b display vertical ground motion as measured by InSAR across the western portion of the Chino Basin for the periods of March 2011 to January 2016 and January 2015 to January 2016, respectively. Included are the epicenters of earthquakes that occurred during the period of InSAR data shown on each figure and the locations of specific monitoring facilities referenced in this section. The data shown on the figures are described and interpreted in this section.

3.1 Managed Area

The Managed Area is the primary focus of the SMP. The discussion below describes the results of the monitoring program relative to the Guidance Criteria in the SMP.

3.1.1 History of Stress and Strain in the Aquifer-System

Figure 3-2 is a chart that displays and describes the long-term history of land subsidence in the Managed Area. The main observations from this chart and the totality of the information developed by Watermaster are that pumping from the deep aquifer system during the 1990s caused a decline of piezometric levels that coincided 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 2000, pumping has decreased, piezometric levels in the deep aquifer system have recovered, and the rate of land subsidence has declined significantly to about 0.01 ft/yr in the vicinity of Ayala Park. Since 2014, the rate of subsidence in the northern part of the Managed Area has increased to about 0.04 ft-yr.

3.1.2 Recent Stress and Strain in the Aquifer-System

3.1.2.1 Groundwater Production and Piezometric Levels

Table 3-1 summarizes groundwater production by well within the Managed Area for 2015. Approximately 3,700 acre-feet of groundwater was pumped from the Managed Area in 2015—about 70 percent of the total groundwater production was from wells screened in the shallow aquifer system, and 30 percent was from wells screened in both the shallow and deep aquifer systems. This volume and pattern of groundwater production in the Managed Area is similar to recent years.

Figure 3-3 is a time-series chart that displays groundwater production and the resultant piezometric change (stress) and aquifer-system deformation (strain) in the Managed Area for 2011-2015. The chart illustrates the seasonal pattern of production in the Managed Area: increased production during the spring and summer months and decreased production during the fall and winter months.

The time-series of piezometric levels at two piezometers at Ayala Park, PA-7 (deep aquifer system) and PA-10 (shallow aquifer system), depicted in Figure 3-3, show the deep and shallow aquifer system response, respectively, to seasonal groundwater pumping stresses. These data are consistent with the conclusions of the IMP and show that pumping from the deep, confined aquifer system causes a piezometric-level decline that is much greater in magnitude than the piezometric-level decline caused by pumping of the shallow aquifer system—even though more pumping occurs from the shallow aquifer system. In April 2011, the piezometric level at PA-7 was about 89 ft-btoc. Since then, the Managed Area has experienced five cycles of seasonal piezometric-level decline and recovery. The maximum piezometric-level decline occurred when the piezometric level at PA-7 declined to about 190 ft-btoc in August 2013. Piezometric levels recovered to about 95 ft-btoc in January 2014. The calendar year of 2015 was a typical year of seasonal piezometric-level decline and recovery; the piezometric level recovered to about 99 ft-btoc in March 2015, declined to about 170 ft-btoc in November 2015, and recovered to about 120 ft-btoc by the end of 2015, continuing to recover into 2016. The piezometric levels at PA-7 did not decline below the Guidance Level of 245 ft-btoc during 2015.

3.1.2.2 Aquifer-System Deformation

Figure 3-3 includes a time-series of vertical deformation of the aquifer system as measured at the Ayala Park Extensometer facility. These data indicate that the vertical deformation of the aquifer system, in response to the decline and recovery of piezometric levels from January 2015 to January 2016, was mainly elastic. However, the Deep Extensometer recorded about 0.043 ft of compression in the aquifer system between the piezometric level recovery episodes from April 2011 to March 2015. This compression appears to be mostly inelastic compaction, though piezometric levels at PA-7 did not fully recover to spring 2011 levels after 2012.

Figure 3-4 is a stress-strain diagram of piezometric levels measured at PA-7 (stress) versus vertical deformation of the aquifer-system sediments as measured at the Deep Extensometer (strain). The hysteresis loops on this chart represent piezometric decline-recovery cycles and the resultant compression-expansion of the aquifer-system sediments. Piezometric decline is shown as increasing from bottom to top on the Y-axis, and aquifer-system compression is shown as increasing from left to right on the X-axis. From April 2011 to January 2014, the hysteresis loops progressively shift to the right on this chart, which indicates about 0.035 ft of compression, most of which appears to be inelastic compaction of the aquifer-system sediments during this period. The overlapping hysteresis loops during 2014 and 2015 (shown in red) indicate elastic deformation of the aquifer-system sediments during the most recent decline-recovery cycle.

3.1.2.3 Vertical Ground Motion

Vertical ground motion is measured across the Managed Area via InSAR and ground-level surveys. The deep aquifer system in the Managed Area had not fully recovered by the end of 2015, so the ground-level survey that was scheduled for full recovery was not completed during 2015. Full recovery of the deep aquifer system was achieved, and the corresponding ground-level survey was performed, during March 2016; as such, the survey is not included in this report.

Figures 3-5a and 3-5b illustrate vertical ground motion as measured by InSAR and ground-level surveys. The data are mapped in:

- Figure 3-5a for the period March 2011 through February 2016
- Figure 3-5b for January 2015 through February 2016

The InSAR data shown in Figure 3-5a indicate 0.00 to over -0.14 ft of vertical ground motion across the Managed Area for the period March 2011 to January 2016. Figure 3-3 shows that piezometric levels at PA-7 were about 30 ft lower in January 2016 when compared to March 2011, suggesting that the vertical ground motion shown by InSAR in the Managed Area is, in part, elastic and may rebound as piezometric levels recover.

The InSAR data shown in Figure 3-5a are consistent with the Deep Extensometer record at Ayala Park during the period of March 2011 to January 2016: the InSAR data indicate about -0.08 ft of vertical ground motion, and the Deep Extensometer measured about -0.06 ft of aquifer-system deformation.

The InSAR data shown in Figure 3-5b for 2015 are generally incoherent across the southern portion of the Managed Area and around the Ayala Park Extensometer facility so the vertical ground motion cannot be determined by InSAR in this area for 2015. In the northern portion of the Managed Area, the InSAR data are coherent and indicate about -0.04 feet of vertical ground motion in the vicinity of well CH-17 during 2015, which pumps from the deep aquifer system. The InSAR time-history shown in Figure 3-2 indicates that the down-drop of the ground surface in that area from January 2014 to January 2016 occurred at a rate of about -0.04 ft/yr. This observation is inconsistent with the purely elastic aquifer-system deformation recorded in 2015 at the Ayala Park Extensometer (see Figures 3-3 and 3-4). Continued monitoring and a closer examination of the stress-strain relationships in this area in the future are warranted.

3.1.2.4 Horizontal Ground Motion

Horizontal ground motion is measured across the Managed Area via electronic distance measurements and the DHX. In April 2016, the DHX was decommissioned because the property was sold for development. During FY 2016-17, the DHX and EDM data collected in the Managed Area to date will be analyzed with respect to local groundwater levels and vertical ground motion to assess the usefulness of the horizontal extensometer as a tool to measure ground motion and, if deemed useful, to determine a potential location for the re-installation of the DHX in the Managed Area.

3.2 Southeast Area

Figure 3-6 is a time-series chart that displays and describes the long-term history of land subsidence in the Southeast Area. The main observations from this chart are that a total of about 0.5 ft of subsidence has occurred in the Southeast Area since 1987, but recently subsidence virtually ceased, coinciding with the increased reuse of recycled water, decreased groundwater pumping, and stable or increasing piezometric levels.

Vertical ground motion is measured across the Southeast Area via InSAR and traditional ground-level surveys. The InSAR data is generally incoherent across much of this area because the area is largely agricultural which interferes with InSAR measurement. These data are mapped in:

- Figure 3-5a for the period March 2011 through February 2016
- Figure 3-5b for January 2015 through February 2016

The InSAR and ground-level survey data show little recent subsidence across the Southeast Area, and some of the area experienced rebound of the ground surface.

The InSAR and traditional ground-level survey datasets corroborate each other in the pattern and magnitude of vertical ground motion where the datasets overlap. Slight differences in magnitude may be attributed to differences in the timing of the data collection.

Figure 3-7 displays the time series of piezometric levels and vertical aquifer-system deformation recorded at the CCX, which began collecting data in July 2012. In general, piezometric levels have changed very little and have generally recovered from 2012 through 2015. A small amount of expansion of the aquifer-system sediments has been measured by the CCX extensometers, coincident with the piezometric-level recovery. These observations are consistent with the InSAR and ground-level surveys shown in Figures 3-5a and 3-5b, which generally indicate a small amount of rebound of the ground surface in the vicinity of the CCX.

In the second half of 2014, pumping began at three of the five Chino Creek Well Field wells; I-16 and I-17 were on-line, and I-18 was pumped for short-term testing. Pumping from the Chino Creek Well Field has had little, if any, effect on piezometric levels or the aquifer-system deformation at the CCX through 2015.

3.3 Central MZ-1 Area

Figure 3-8 is a time-series chart that displays and describes the long-term history of land subsidence in Central MZ-1. The main observations from this chart are that the time history and magnitude of vertical ground motion in Central MZ-1 is similar to that of the Managed Area. About 1.5 feet of subsidence occurred in the vicinity of Walnut and Monte Vista Avenue (BM 125/49) from 1993 to 2000, and about 0.4 feet of subsidence has occurred since 2000. The similarity to the vertical ground motion that occurred in the Managed Area suggests a relationship to the causes of land subsidence in the Managed Area; however, there is not enough historical piezometric-level data in this area to confirm this relationship.

Figures 3-1a and 3-1b are maps that show recent vertical ground motion in Central MZ-1. About -0.04 to -0.12 ft of vertical ground motion occurred across Central MZ-1 during the period of March 2011 to January 2016. And, about -0.02 to -0.04 ft of vertical ground motion occurred across Central MZ-1 during the period of January 2015 to January 2016. On average, vertical ground motion in Central MZ-1 is occurring gradually and persistently at a rate of about -0.02 ft/yr. This gradual and persistent rate indicates that the down-drop of the ground surface is likely inelastic, but there are not enough paired observations of piezometric and ground-motion data nor lithologic information in this area to confirm this conclusion.

In winter 2013, benchmarks were installed across the Northwest MZ-1 Area as an extension of those already installed across Central MZ-1 (see Figure 2-2). Ground-level surveys were conducted from Ayala Park to the San Jose Fault Zone in January 2014, and the survey was repeated in January 2016. Figure 3-9a is a map that displays vertical ground motion across Central MZ-1 and Northwest MZ-1 from January 2014 to January 2016, as measured by ground-level surveys and InSAR. The InSAR and ground-level survey data show similar patterns and magnitude of vertical ground motion across Central MZ-1. In Central MZ-1, the data indicate as much as -0.06 feet of vertical ground motion during the period of January 2014 to February 2016.

3.4 Northwest MZ-1 Area

Figure 3-10 is a time-series chart that displays and describes the long-term history of land subsidence in the Northwest MZ-1 Area (Northwest MZ-1). The main observations from this chart are that a total of about 1.2 ft of subsidence has occurred in Northwest MZ-1 since 1992 and that the subsidence has continued at an average rate of about 0.05 ft/yr despite the recovery of piezometric levels in the 1980s and the period of 2004 to 2008 and the relatively stable piezometric levels during the period of 2008 to 2015. These observations indicate that the gradual and persistent subsidence is inelastic.

Figures 3-1a and 3-1b are maps that show the pattern of recent vertical ground motion across Northwest MZ-1. About -0.06 to over -0.24 ft of vertical ground motion occurred across Northwest MZ-1 during the period of March 2011 to January 2016. And, about -0.02 to -0.06 ft of vertical ground motion occurred across Northwest MZ-1 during the period of January 2015 to January 2016. Of particular concern in Northwest MZ-1 is that the historical and ongoing subsidence has been differential across the San Jose Fault. Differential subsidence can result in ground fissuring, as in the Managed Area during the 1990s.

Currently, there are not enough data to definitively explain the causes of historical and ongoing subsidence in Northwest MZ-1, but it is likely related to the recent and/or past decline of piezometric levels. If so, subsidence could have begun when piezometric-level decline began in 1930. If subsidence has been occurring at a constant rate of 0.05 ft/yr since 1935, then portions of Northwest MZ-1 have experienced up to 4.3 feet of subsidence since the onset of increased piezometric-level decline, which is more than twice the 2.2 feet of subsidence that accompanied the ground fissuring in the Managed Area.[5]

In winter 2013, benchmarks were installed across Northwest MZ-1 as an extension of those already installed across Central MZ-1 (see Figure 2-2). Ground-level surveys were conducted from Ayala Park to the San Jose Fault in January 2014, and the survey was repeated in January 2016. Figure 3-9a is a map that displays vertical ground motion across Central MZ-1 and Northwest MZ-1 from January 2014 to January 2016, as measured by ground-level surveys and InSAR. The InSAR and ground-level survey data show similar patterns and magnitude of vertical ground motion across Northwest MZ-1. In Northwest MZ-1, the data indicate more than -0.08 feet of vertical ground motion during the period January 2014 to January 2016.

Figure 3-9b is a map that displays vertical ground motion across Northwest MZ-1 from January 2015 to February 2016, as measured by InSAR and ground-level surveys. In February 2015, a ground-level survey was conducted at the benchmarks in the San Jose Fault array but not across the rest of Northwest MZ-1 or Central MZ-1. The InSAR and ground-level survey data show the same historical pattern and magnitude of differential subsidence across the San Jose Fault.

Figure 3-11a, 3-11b, and 3-11c are maps that display vertical and horizontal ground motion across the San Jose Fault for the periods of January 2014 to January 2015, January 2015 to February 2016, and January 2014 to February 2016, respectively. Vertical ground motion was measured by InSAR and horizontal ground motion was measured by EDM surveys. During the

[5] This calculation potentially understates the total subsidence that occurred in this area because it is likely that the rate of subsidence was higher during the earlier period of piezometric-level declines compared to the rate of subsidence observed since 1992.

EDM survey in January 2016, the locations of benchmarks BM 2044, BM 2042 and BM 2041 were measured using the long-occupation GPS method and the distances to the remaining benchmarks were measured using traditional EDM methods. The EDM surveys conducted in January 2014 and January 2015 were recalibrated in the cross-axis direction (i.e. the easting for BM 2041, easting and northing for BM 2042, and the northing for BM 2044) using the GPS locations measured in 2016 to increase horizontal comparability between surveys along the main axis directions in the array (i.e. north-south along San Antonio Avenue and east-west along San Bernardino Avenue).

The data shown in Figure 3-11a indicate that horizontal extension occurred in the shallow soils across the San Jose Fault for the period of January 2014 to January 2015 in both the north-south and the east-west directions. These data indicate that about a total of about 0.01 feet of horizontal extension occurred along the north-south benchmark line and about 0.01 feet of horizontal compression occurred along the east-west benchmark line in the shallow soils across the San Jose Fault during 2014.

The data in Figure 3-11b indicate that horizontal extension occurred in the shallow soils across the San Jose Fault for the period of January 2015 to February 2016 in both the north-south and the east-west directions. The greatest extensional strain was measured at the western end of the benchmark line along San Bernardino Avenue between benchmarks BM 2044 and BM 2407.

The data in Figure 3-11c show the total of the measured ground motion shown in Figures 3-11a and 3-11b. The data indicate that horizontal extension occurred in the shallow soils across the San Jose Fault for the period of January 2014 to February 2016 in both the north-south and the east-west directions. The greatest extensional strain was measured at the western end of the benchmark line along San Bernardino Avenue between benchmarks BM 2044 and BM 2407 and at the southern end of the benchmark line along San Antonio Avenue between benchmarks BM 2042 and BM 2408.

The measured horizontal strain is consistent with the observations of differential vertical ground motion across the San Jose Fault. The extensional strain is an indication of a threat for ground fissuring.

3.5 Northeast Area

Figure 3-12 is a time-series chart that displays and describes the long-term history of land subsidence in the Northeast Area. The main observations from this chart are that about 1.0 ft of subsidence occurred in the Northeast Area from 1992 to 2015 at a gradual and persistent rate of about 0.05 ft/yr, but since about 2011, the rate has declined to about 0.02 ft/yr. This decline coincided with stable or increasing piezometric levels. Nevertheless, these observations indicate that the gradual and persistent subsidence that has occurred is likely inelastic.

Figures 3-1a and 3-1b are maps that show recent vertical ground motion in the Northeast Area. About -0.02 to -0.16 ft of vertical ground motion occurred across the Northeast Area during the period of March 2011 to January 2016. About 0.00 to -0.04 ft of vertical ground motion occurred across the Northeast Area during the period of January 2015 to January 2016. Significantly, very little vertical ground motion occurred during the period of January 2015 to January 2016 in the area between wells O-36 and XRef-18, an area that up until 2015 had been subsiding more than other parts of the Northeast Area.

3.6 Seismicity

The epicenters of the earthquakes that occurred from 2011 through 2015 are shown in Figures 3-1a and 3-1b for the periods of March 2011 through February 2016 and January 2015 through February 2016, respectively. These maps show no spatial correlation between earthquake epicenters and areas where vertical ground motion measured by InSAR is greatest in the Managed, Northwest MZ-1, Central MZ-1 or Southeast Areas. Several earthquake epicenters with 1.5 local magnitude or less occurred in areas east of the Northeast and Southeast Areas during the period of 2011 through 2015, but not enough data exists to indicate a relationship between seismicity and the subsidence measured by InSAR.

Table 3-1
Groundwater Production in the Managed Area for 2015
acre-feet

Well Name	Aquifer Layer	2015 Calendar Year					
		Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual Total	Annual Total by Aquifer Layer
C-4	Shallow	0	0	0	0	**0**	**2,550**
C-6		0	0	0	0	**0**	
CH-1A		62	305	395	130	**893**	
CH-7A		27	102	111	43	**283**	
CH-7B		44	173	186	73	**476**	
CIM-1		185	185	284	241	**896**	
Xref 8730[1]		1	1	1	1	**3**	
CH-17	Deep[2]	91	401	400	168	**1,060**	**1,110**
CH-15B		0	0	0	0	**0**	
CIM-11A		7	12	3	29	**51**	
Totals		**416**	**1,180**	**1,380**	**684**	**3,660**	**3,660**

[1] Well screen interval is unknown, but assumed to be shallow based on typical well construction for other private wells in the general vicinity.

[2] These deep-aquifer wells have screen intervals that extend into the shallow aquifer system, so a portion of this production comes from the shallow aquifer system.

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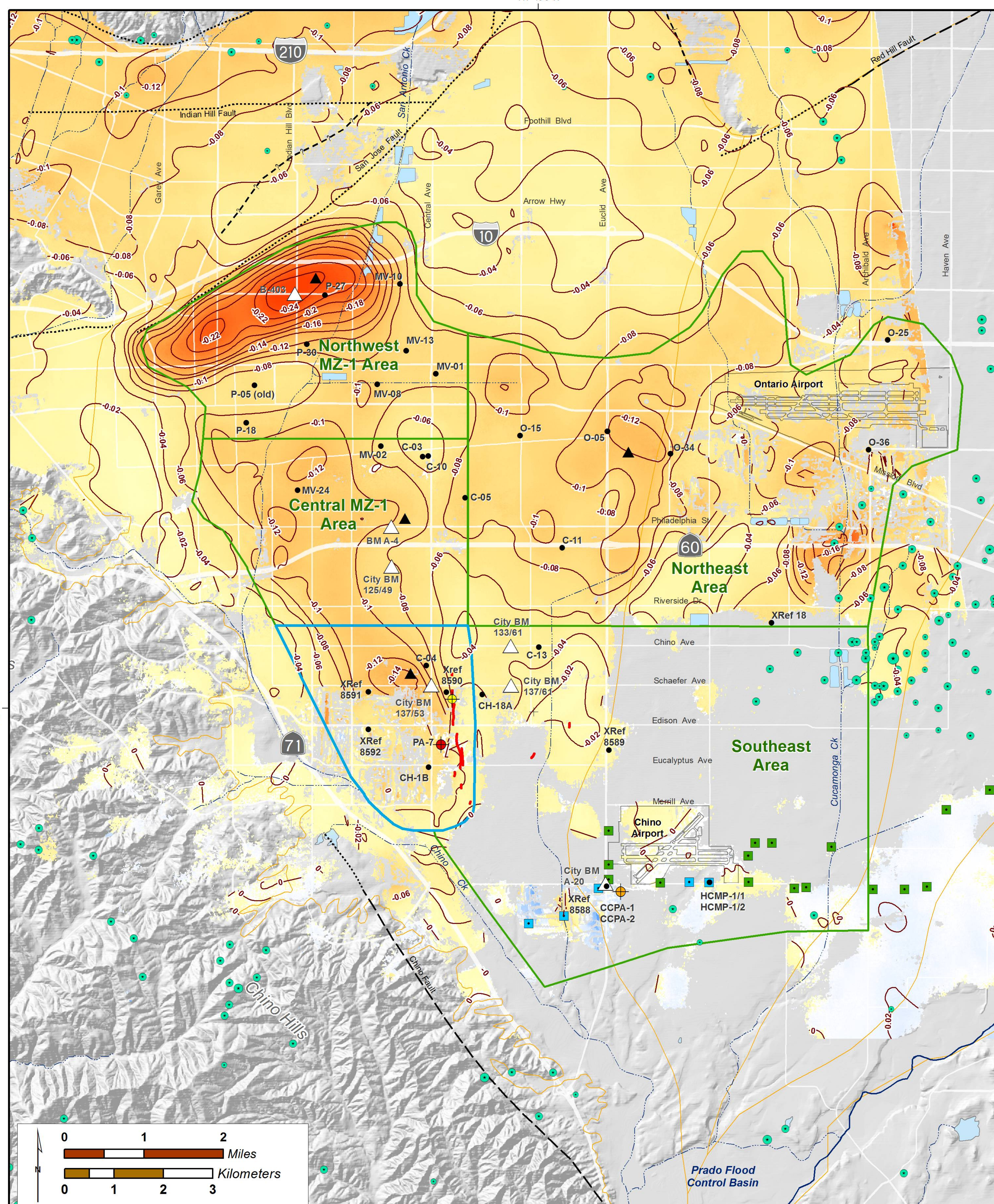


Relative Change in Land Surface Altitude as Measured by InSAR Mar-2011 to Jan-2016

+ 0.25 ft
0
-0.1
- 0.25

InSAR data incoherent

Earthquake Epicenters Mar-2011 to Jan-2016 (Local Magnitude)

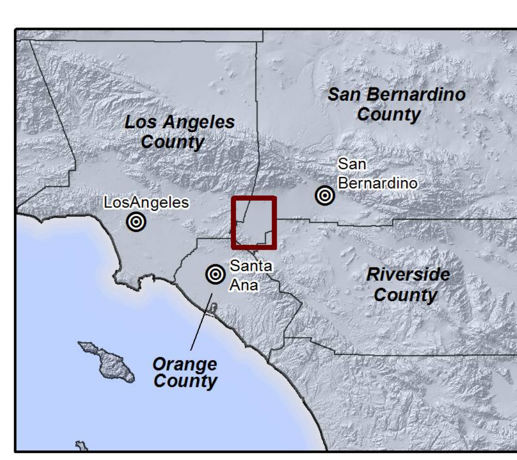
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- < 5

Wells and Extensometers

- Wells with piezometric-level data shown on Figures 3-2, 3-6, 3-8, 3-10, and 3-12
- Chino I & II Desalter Wells
- Chino Creek Desalter Well Field
- Ayala Park Extensometer
- Chino Creek Extensometer
- Daniels Horizontal Extensometer

Chino Basin Management Zones

- Benchmark monument with vertical ground-motion data shown on Figures 3-2, 3-6, 3-8, 3-10, and 3-12
- InSAR measurement point with vertical ground-motion data shown on Figures 3-2, 3-8, 3-10, and 3-12
- Managed Area
- Areas of Subsidence Concern
- Ground Fissures
- Flood Control & Conservation Basins



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WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: TCR
Date: 20160401
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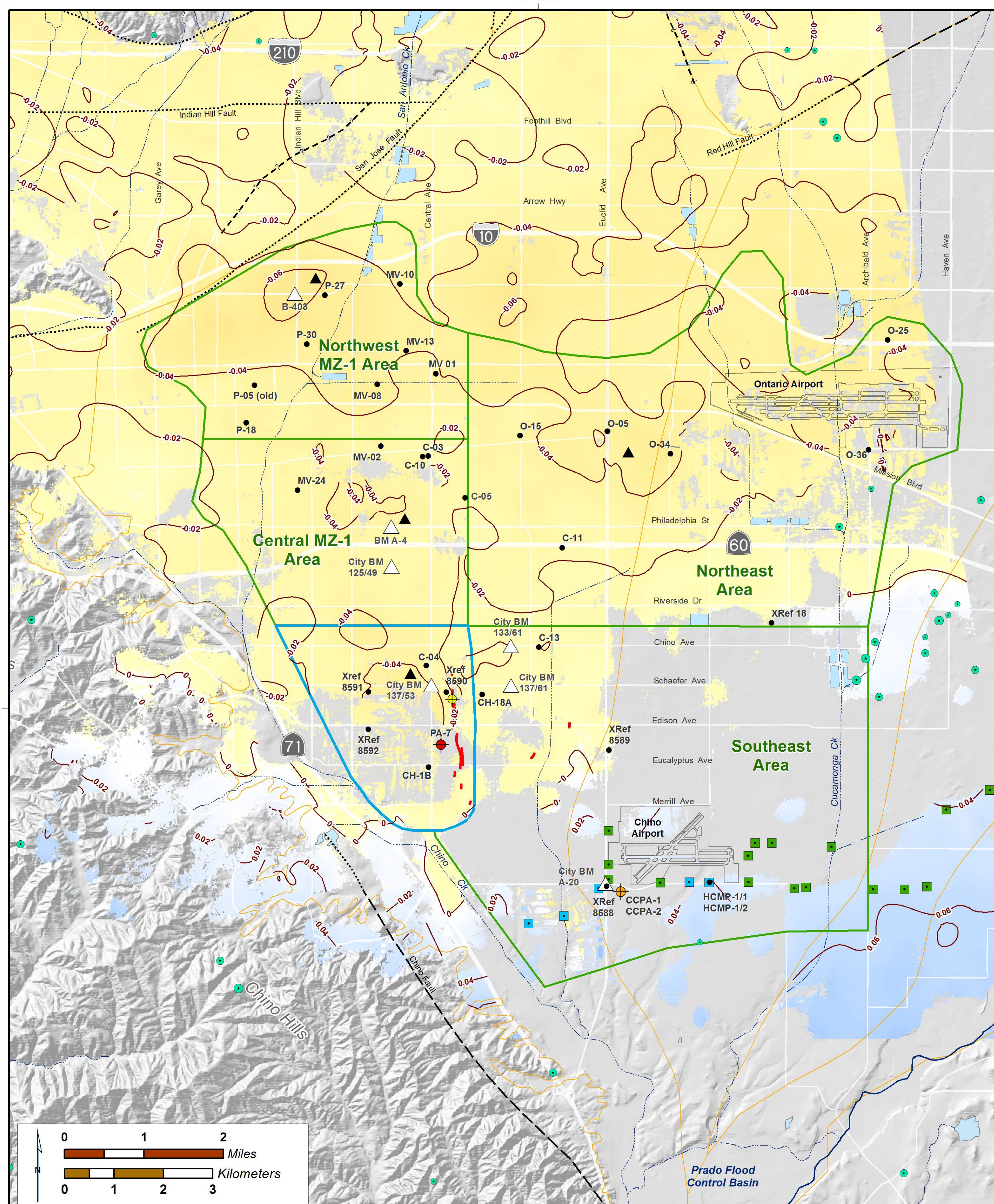
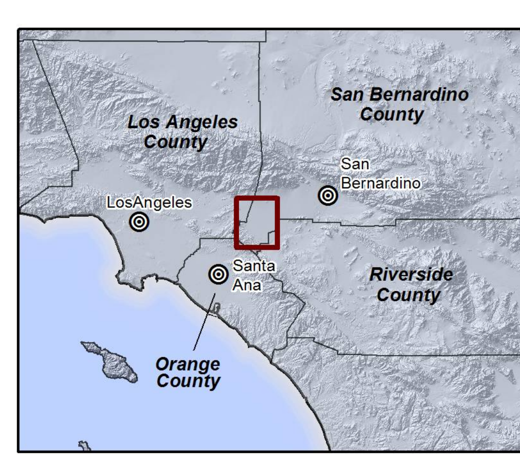
Ground-Level Monitoring Committee
2015 Annual Report

Vertical Ground Motion across Western Chino Basin
March 2011 to January 2016

Figure 3-1a





+ 0.25 ft
0
-0.1
- 0.25
Relative Change in Land Surface Altitude as Measured by InSAR Jan-2015 to Jan-2016

InSAR data incoherent

0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
< 5
Earthquake Epicenters Jan-2015 to Jan-2016 (Local Magnitude)

Wells and Extensometers

Wells with piezometric-level data shown on Figures 3-2, 3-6, 3-8, 3-10 and 3-12

Chino I & II Desalter Wells

Chino Creek Desalter Well Field

Ayala Park Extensometer

Chino Creek Extensometer

Daniels Horizontal Extensometer

Chino Basin Management Zones

Benchmark monument with vertical ground-motion data shown on Figures 3-2, 3-6, 3-8, 3-10 and 3-12

InSAR measurement point with vertical ground-motion data shown on Figures 3-2, 3-8, 3-10 and 3-12

Managed Area

Areas of Subsidence Concern

Ground Fissures

Flood Control & Conservation Basins

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WEI
WILDERMUTH ENVIRONMENTAL, INC.

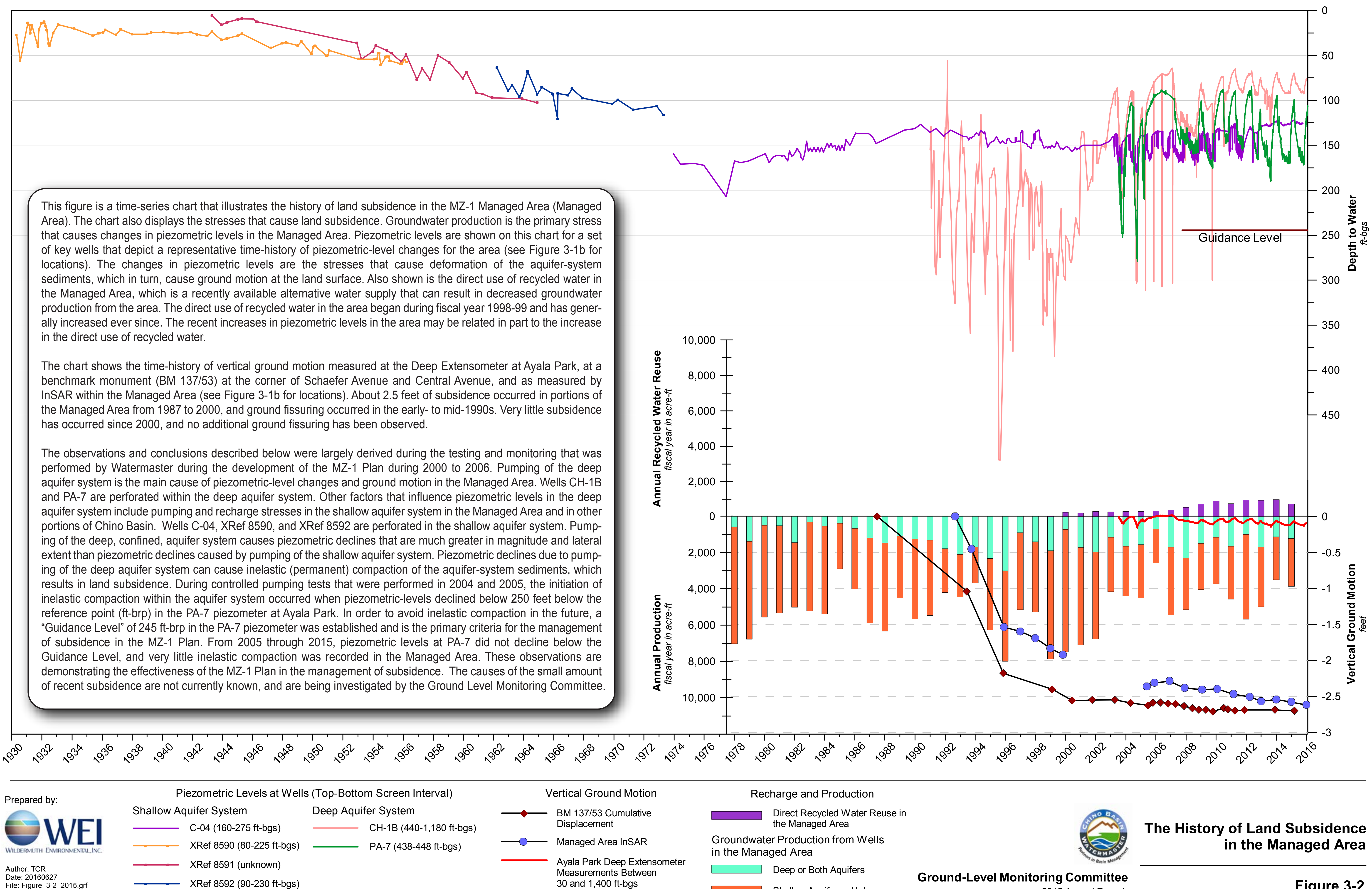
Author: TCR
Date: 20160320
File: Figure_3-1b.mxd

Ground-Level Monitoring Committee
2015 Annual Report

Vertical Ground Motion across Western Chino Basin

January 2015 to January 2016

Figure 3-1b



This figure is a time-series chart that illustrates the history of land subsidence in the MZ-1 Managed Area (Managed Area). The chart also displays the stresses that cause land subsidence. Groundwater production is the primary stress that causes changes in piezometric levels in the Managed Area. Piezometric levels are shown on this chart for a set of key wells that depict a representative time-history of piezometric-level changes for the area (see Figure 3-1b for locations). The changes in piezometric levels are the stresses that cause deformation of the aquifer-system sediments, which in turn, cause ground motion at the land surface. Also shown is the direct use of recycled water in the Managed Area, which is a recently available alternative water supply that can result in decreased groundwater production from the area. The direct use of recycled water in the area began during fiscal year 1998-99 and has generally increased ever since. The recent increases in piezometric levels in the area may be related in part to the increase in the direct use of recycled water.

The chart shows the time-history of vertical ground motion measured at the Deep Extensometer at Ayala Park, at a benchmark monument (BM 137/53) at the corner of Schaefer Avenue and Central Avenue, and as measured by InSAR within the Managed Area (see Figure 3-1b for locations). About 2.5 feet of subsidence occurred in portions of the Managed Area from 1987 to 2000, and ground fissuring occurred in the early- to mid-1990s. Very little subsidence has occurred since 2000, and no additional ground fissuring has been observed.

The observations and conclusions described below were largely derived during the testing and monitoring that was performed by Watermaster during the development of the MZ-1 Plan during 2000 to 2006. Pumping of the deep aquifer system is the main cause of piezometric-level changes and ground motion in the Managed Area. Wells CH-1B and PA-7 are perforated within the deep aquifer system. Other factors that influence piezometric levels in the deep aquifer system include pumping and recharge stresses in the shallow aquifer system in the Managed Area and in other portions of Chino Basin. Wells C-04, XRef 8590, and XRef 8592 are perforated in the shallow aquifer system. Pumping of the deep, confined, aquifer system causes piezometric declines that are much greater in magnitude and lateral extent than piezometric declines caused by pumping of the shallow aquifer system. Piezometric declines due to pumping of the deep aquifer system can cause inelastic (permanent) compaction of the aquifer-system sediments, which results in land subsidence. During controlled pumping tests that were performed in 2004 and 2005, the initiation of inelastic compaction within the aquifer system occurred when piezometric-levels declined below 250 feet below the reference point (ft-brp) in the PA-7 piezometer at Ayala Park. In order to avoid inelastic compaction in the future, a "Guidance Level" of 245 ft-brp in the PA-7 piezometer was established and is the primary criteria for the management of subsidence in the MZ-1 Plan. From 2005 through 2015, piezometric levels at PA-7 did not decline below the Guidance Level, and very little inelastic compaction was recorded in the Managed Area. These observations are demonstrating the effectiveness of the MZ-1 Plan in the management of subsidence. The causes of the small amount of recent subsidence are not currently known, and are being investigated by the Ground Level Monitoring Committee.

Prepared by:

WEI
Wildermuth Environmental, Inc.

Author: TCR
Date: 20160627
File: Figure_3-2_2015.grf

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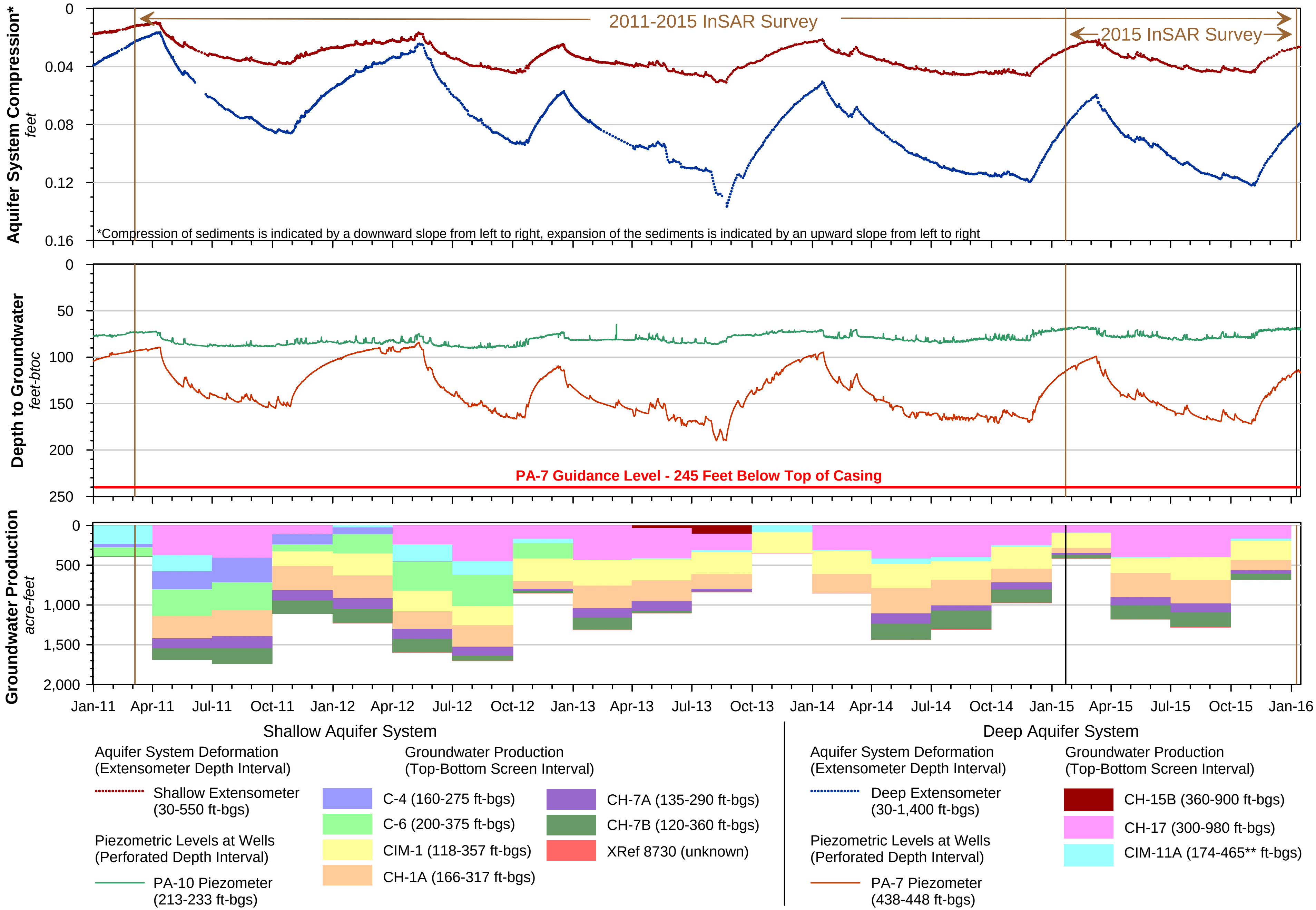
The History of Land Subsidence in the Managed Area

Figure 3-2



**The original casing was perforated from 135-148, 174-187, 240-283, 405-465, 484-512, 518-540 ft-bgs. This casing collapsed below 470 ft-bgs in 2011. A liner was installed to 470.5 ft-bgs with screen interval from 155 to 470 ft-bgs.

Prepared by:

WEI
Wildermuth Environmental, Inc.

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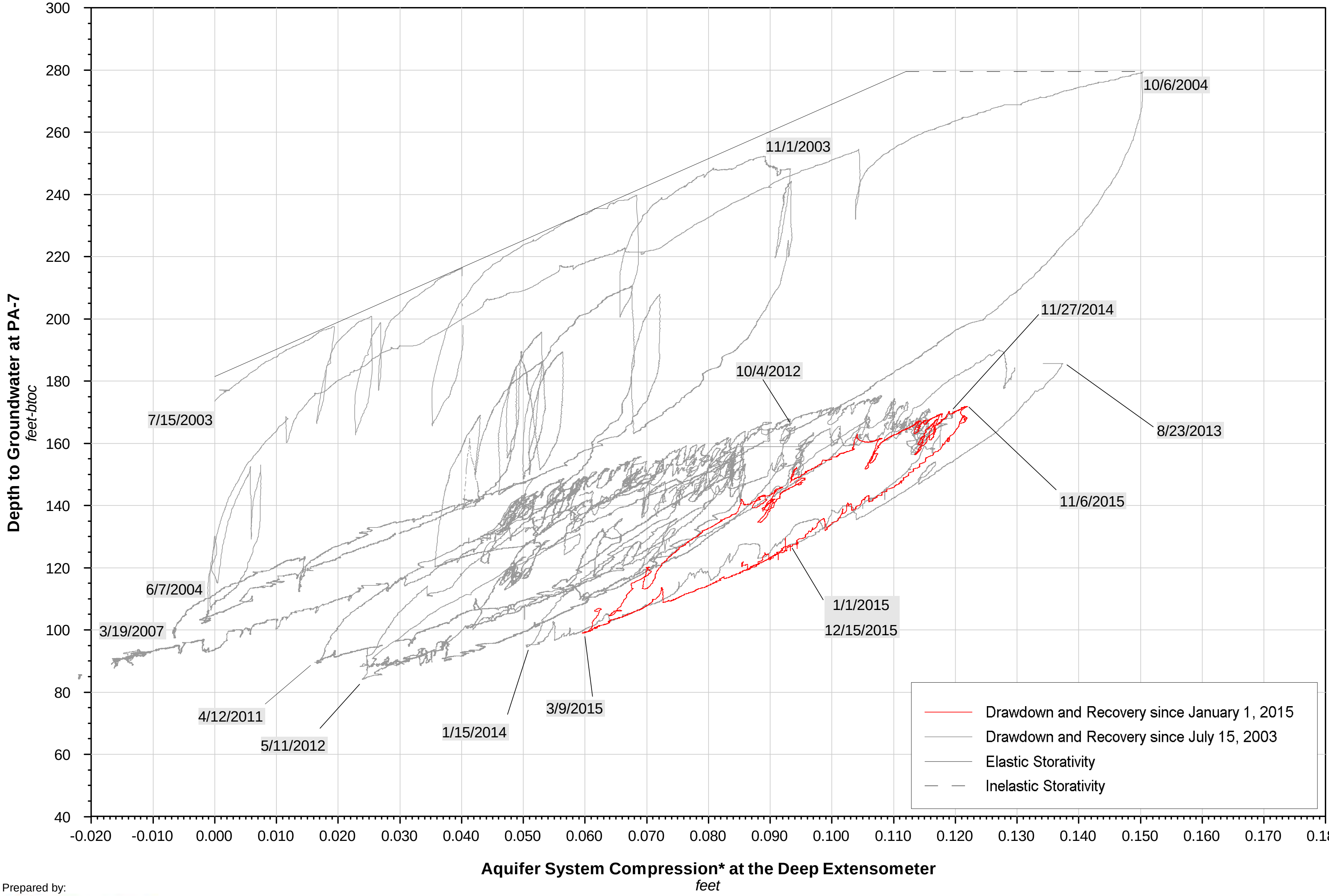
Stress and Strain within the Managed Area

Figure 3-3



Prepared by:

WEI
Wildermuth Environmental, Inc.

Author: TCR
Date: 20160307
Filename: Figure_3-4.grf

PA-7 Well-Screen Interval
= 438-448 ft-bgs

Depth Interval of the Deep Extensometer
= 30-1,400 feet-bgs

*Positive compression values represent compression of soils, negative compression values represent expansion of soils

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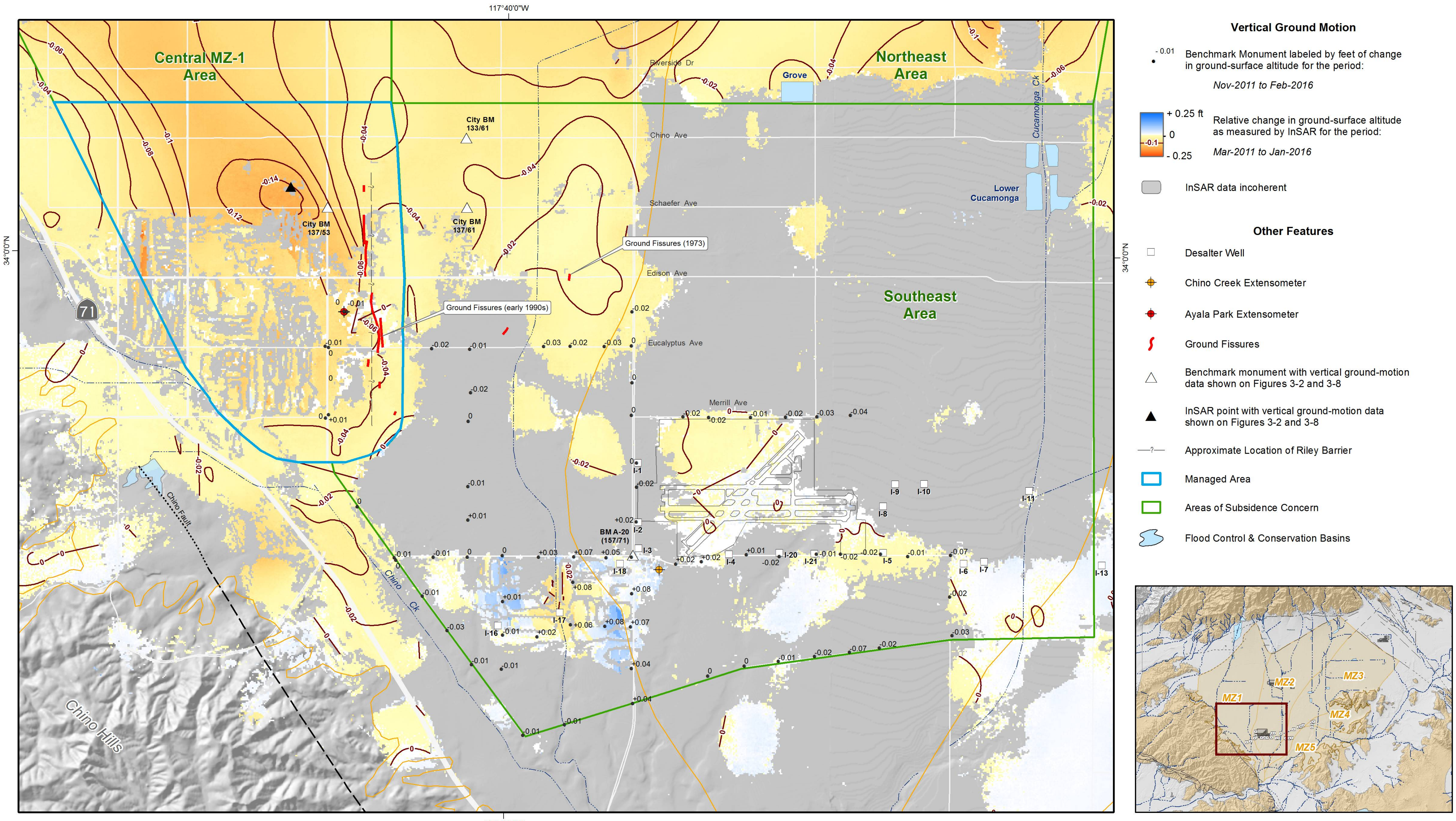
2015 Annual Report

Stress-Strain Diagram
PA-7 Piezometer vs. Deep Extensometer

Figure 3-4



Prepared by:

WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: TCR
Date: 20160315
File: Figure_3-5a.mxd

0 1 2 Miles
0 1 2 3 Kilometers

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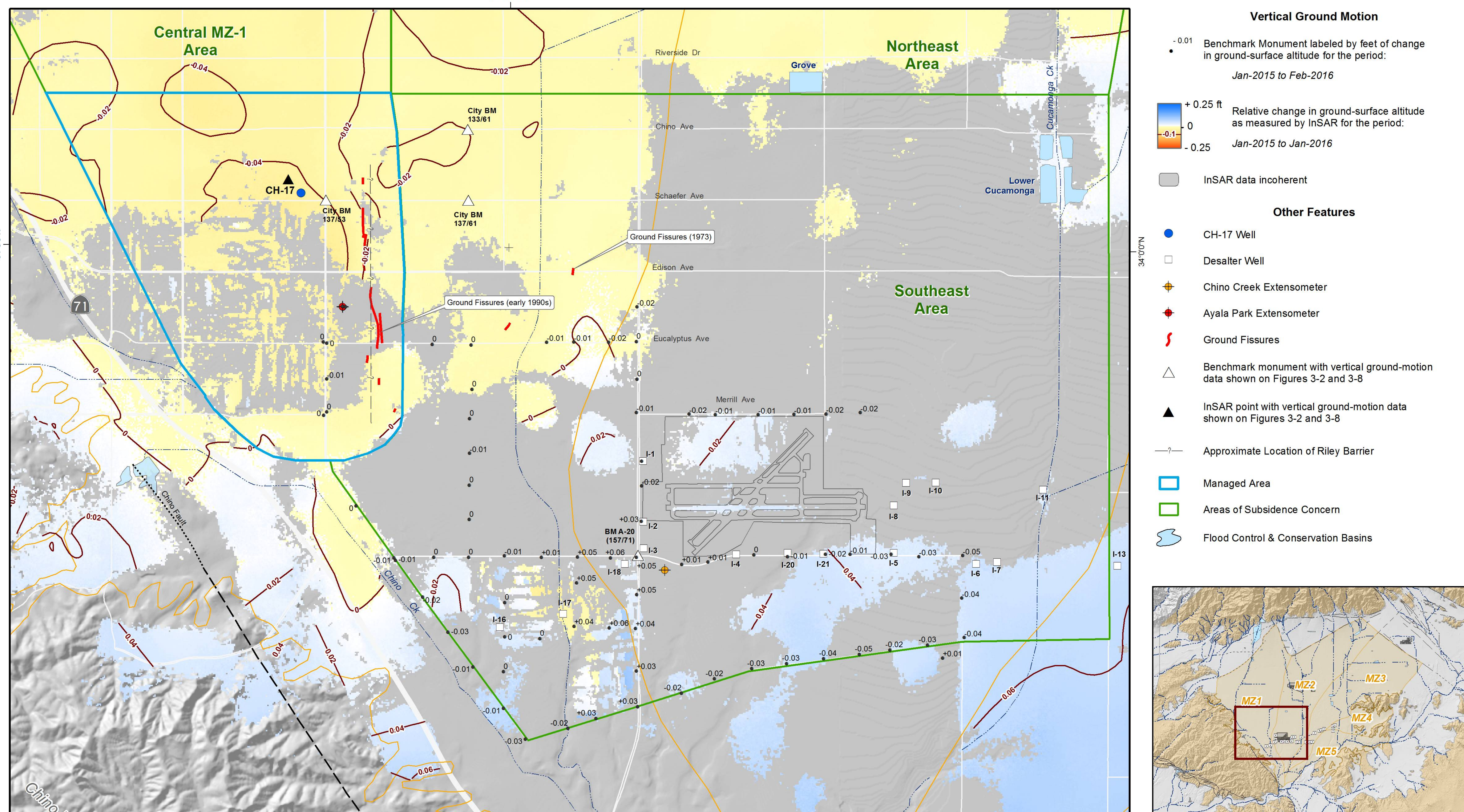
2015 Annual Report

Vertical Ground Motion in the Managed Area and Southeast Area
March 2011 to February 2016

Figure 3-5a



Vertical Ground Motion

- 0.01 Benchmark Monument labeled by feet of change in ground-surface altitude for the period:

Jan-2015 to Feb-2016

+ 0.25 ft / 0 / -0.1 / - 0.25 Relative change in ground-surface altitude as measured by InSAR for the period:

Jan-2015 to Jan-2016

InSAR data incoherent

Other Features

- CH-17 Well
- Desalter Well
- Chino Creek Extensometer
- Ayala Park Extensometer
- Ground Fissures
- Benchmark monument with vertical ground-motion data shown on Figures 3-2 and 3-8
- InSAR point with vertical ground-motion data shown on Figures 3-2 and 3-8
- Approximate Location of Riley Barrier
- Managed Area
- Areas of Subsidence Concern
- Flood Control & Conservation Basins

Prepared by:

WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: TCR
Date: 20160315
File: Figure_3-5b.mxd

0 1 2 Miles

0 1 2 3 Kilometers

Ground-Level Monitoring Committee
2015 Annual Report

Vertical Ground Motion in the Managed Area and Southeast Area

January 2015 to February 2016

Figure 3-5b

The Southeast Area of Subsidence Concern includes the southeast area of MZ-1 and a portion of MZ-2, and is located east of the Managed Area. This figure is a time-series chart that illustrates the history of land subsidence in the Southeast Area. The chart also displays the stresses that cause land subsidence. Groundwater production is the primary stress that causes changes in piezometric levels in the Southeast Area. Piezometric levels are shown on this chart for a set of key wells that depict a representative time-history of piezometric-level changes for the area (see Figure 3-1b for locations). The changes in piezometric levels are the stresses that cause deformation of the aquifer-system sediments, which in turn, cause ground motion at the land surface. Also shown is the direct use of recycled water in the Southeast Area, which is a recently available alternative water supply that can result in decreased groundwater production from the area. The direct use of recycled water in the area began during fiscal year 2003-04 and has generally increased ever since. The recent increases in piezometric levels in the area may be related in part to the increase in the direct use of recycled water.

The chart shows the time-history of vertical ground motion as measured by leveling surveys at benchmark monuments within the Southeast Area and at the deep extensometer at the Chino Creek Extensometer Facility (CCX-2; see Figure 3-1b for locations). InSAR data is typically incoherent (not measurable) in the Southeast Area because the agricultural land uses in the area are not good reflectors of radar waves. The first ground fissures documented in the Chino Basin occurred in the Southeast Area in the early 1970s, and ground fissuring has not been observed in the area since. In the northern portion of the Southeast Area (BM 133/61 and BM 137/61), the ground-level survey data indicate that about 0.5 feet of subsidence has occurred in this area from 1987 through 2015. Piezometric-level data indicate that piezometric levels declined across the Southeast Area by as much as 100 feet since the 1930s. Since 1990, piezometric levels have been relatively stable. The observed slow but continuous land subsidence from 1987 to 2013 is not explained by the concurrent relatively stable piezometric levels. A plausible explanation for the subsidence in this area is that thick, slowly-draining aquitards are compacting in response to the historical decline of piezometric levels that occurred prior to 1990.

In the area near the intersection of Euclid Avenue and Kimball Avenue, where the Chino-I Desalter wells pump groundwater from the deep confined aquifer system, the ground-level survey data (BM A-20) indicate vertical ground motion of about -0.19 feet in this area from 2000 to 2006. The Chino-I Desalter wells began pumping in 2000, and have caused localized decline of piezometric levels within the deep aquifer system that may have been the cause of the observed land subsidence from 2000 to 2006. Another plausible cause for the observed subsidence in this area is that thick, slowly-draining aquitards are compacting in response to the historical decline of piezometric levels that occurred prior to 1990.

Watermaster completed the Chino Creek Extensometer (CCX) facility in July 2012 to (i) characterize the occurrence and mechanisms of the subsidence in the vicinity of the Chino-I Desalter well field and (ii) to record the effects of pumping at the Chino Creek Well Field on piezometric levels and land subsidence. Pumping at the CCWF wells commenced in 2014. Both the deep extensometer at the CCX and the benchmarks show rebound since 2013 concurrent with production from private (agricultural) wells in the area continuing to decline, which had not been fully replaced by the desalter well production through 2015, resulting in recovery of piezometric levels in western part of the Southeast Area.

Prepared by:

WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: TCR
Date: 20160510
File: Figure_3-6_2015_SE.grf

Piezometric Levels at Wells (Top-Bottom Screen Interval)

- CH-18A (420-980 ft-bgs)
- C-13 (290-720 ft-bgs)
- HCMP-1/1 (135-175 ft-bgs)
- HCMP-1/2 (300-320 ft-bgs)
- XRef 8588 (unknown)
- XRef 8589 (unknown)
- CCPA-1 (100-130 ft-bgs)
- CCPA-2 (235-295 ft-bgs)

Vertical Ground Motion

- BM 133/61
- BM 137/61
- BM A-20
- CCX-2 Extensometer (50-610 ft-bgs)

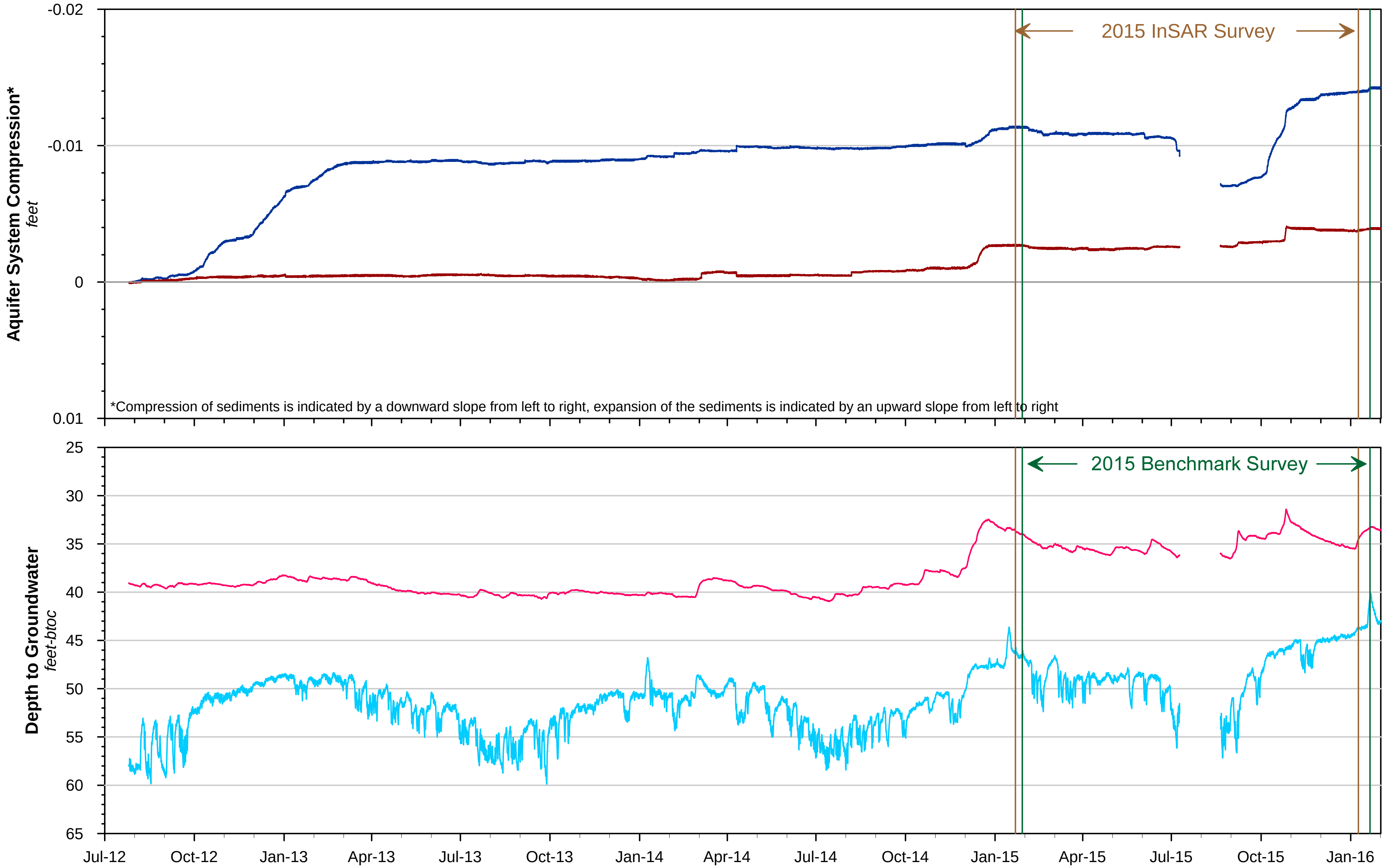
Recharge and Production

- Recycled Water Reuse Applied in the Southeast Area
- Groundwater Production from Upper Aquifer Desalter Wells
- Groundwater Production from Lower Aquifer Desalter Wells
- Groundwater Production from Other Wells in the Southeast Area

Ground-Level Monitoring Committee
2015 Annual Report

The History of Land Subsidence in the Southeast Area

Figure 3-6



Shallow Aquifer System

Aquifer System Deformation (Extensometer Depth Interval)
- CCX-1 Extensometer (50-140 ft-bgs)

Depth to Groundwater (Well-Screen Interval)
- CCPA-1 Piezometer (100-130 ft-bgs)

Deep Aquifer System

Aquifer System Deformation (Extensometer Depth Interval)
- CCX-2 Extensometer (50-610 ft-bgs)

Depth to Groundwater (Well-Screen Interval)
- CCPA-2 Piezometer (235-295 ft-bgs)

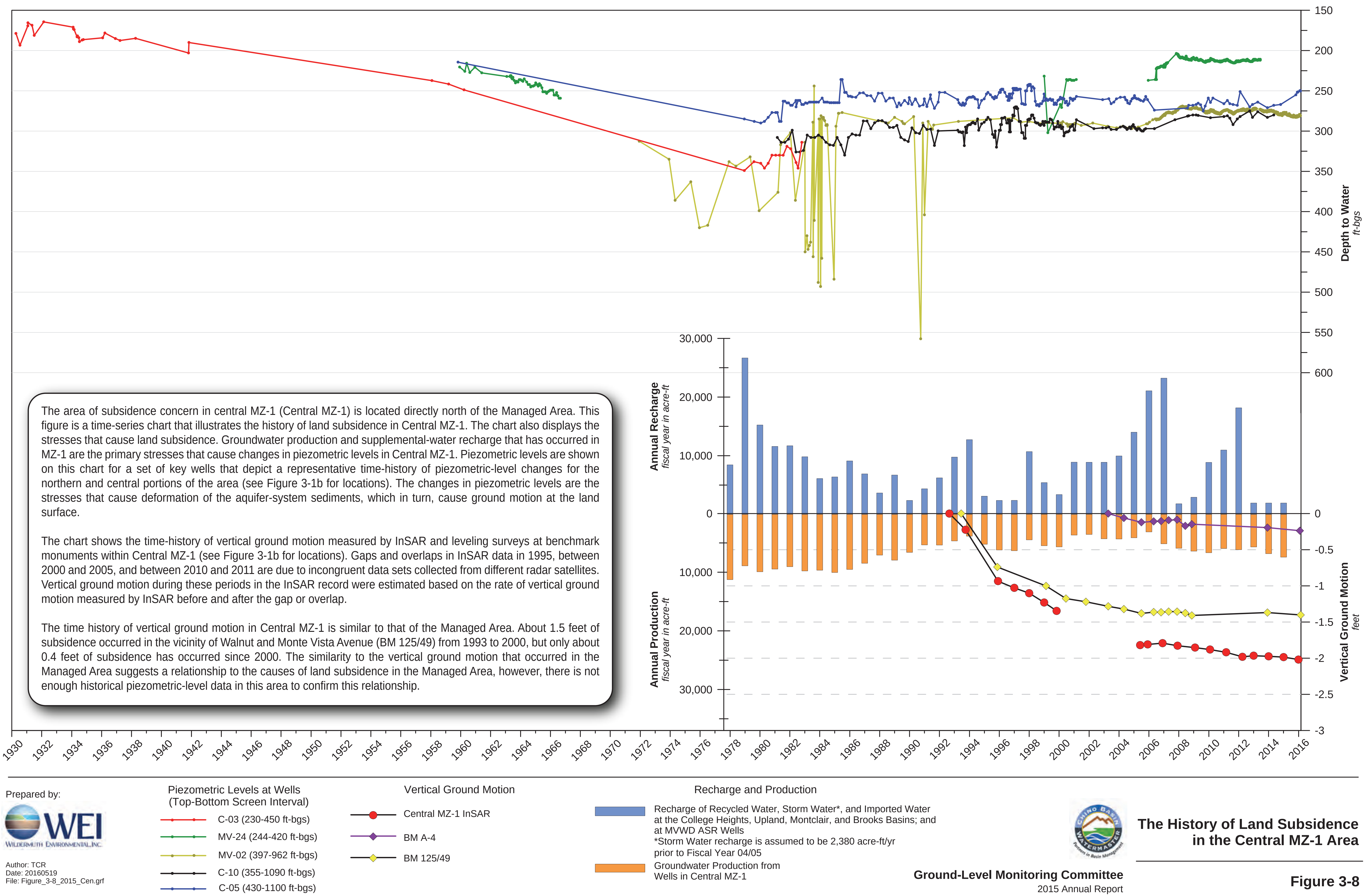
Prepared by:
WEI
Wildermuth Environmental, Inc.

Author: TCR
Date: 20160513
Filename: Figure_3-7_CCX_S-S.grf

Ground-Level Monitoring Committee
2015 Annual Report

Stress and Strain
Chino Creek Extensometer

Figure 3-7



The area of subsidence concern in central MZ-1 (Central MZ-1) is located directly north of the Managed Area. This figure is a time-series chart that illustrates the history of land subsidence in Central MZ-1. The chart also displays the stresses that cause land subsidence. Groundwater production and supplemental-water recharge that has occurred in MZ-1 are the primary stresses that cause changes in piezometric levels in Central MZ-1. Piezometric levels are shown on this chart for a set of key wells that depict a representative time-history of piezometric-level changes for the northern and central portions of the area (see Figure 3-1b for locations). The changes in piezometric levels are the stresses that cause deformation of the aquifer-system sediments, which in turn, cause ground motion at the land surface.

The chart shows the time-history of vertical ground motion measured by InSAR and leveling surveys at benchmark monuments within Central MZ-1 (see Figure 3-1b for locations). Gaps and overlaps in InSAR data in 1995, between 2000 and 2005, and between 2010 and 2011 are due to incongruent data sets collected from different radar satellites. Vertical ground motion during these periods in the InSAR record were estimated based on the rate of vertical ground motion measured by InSAR before and after the gap or overlap.

The time history of vertical ground motion in Central MZ-1 is similar to that of the Managed Area. About 1.5 feet of subsidence occurred in the vicinity of Walnut and Monte Vista Avenue (BM 125/49) from 1993 to 2000, but only about 0.4 feet of subsidence has occurred since 2000. The similarity to the vertical ground motion that occurred in the Managed Area suggests a relationship to the causes of land subsidence in the Managed Area, however, there is not enough historical piezometric-level data in this area to confirm this relationship.

Prepared by:

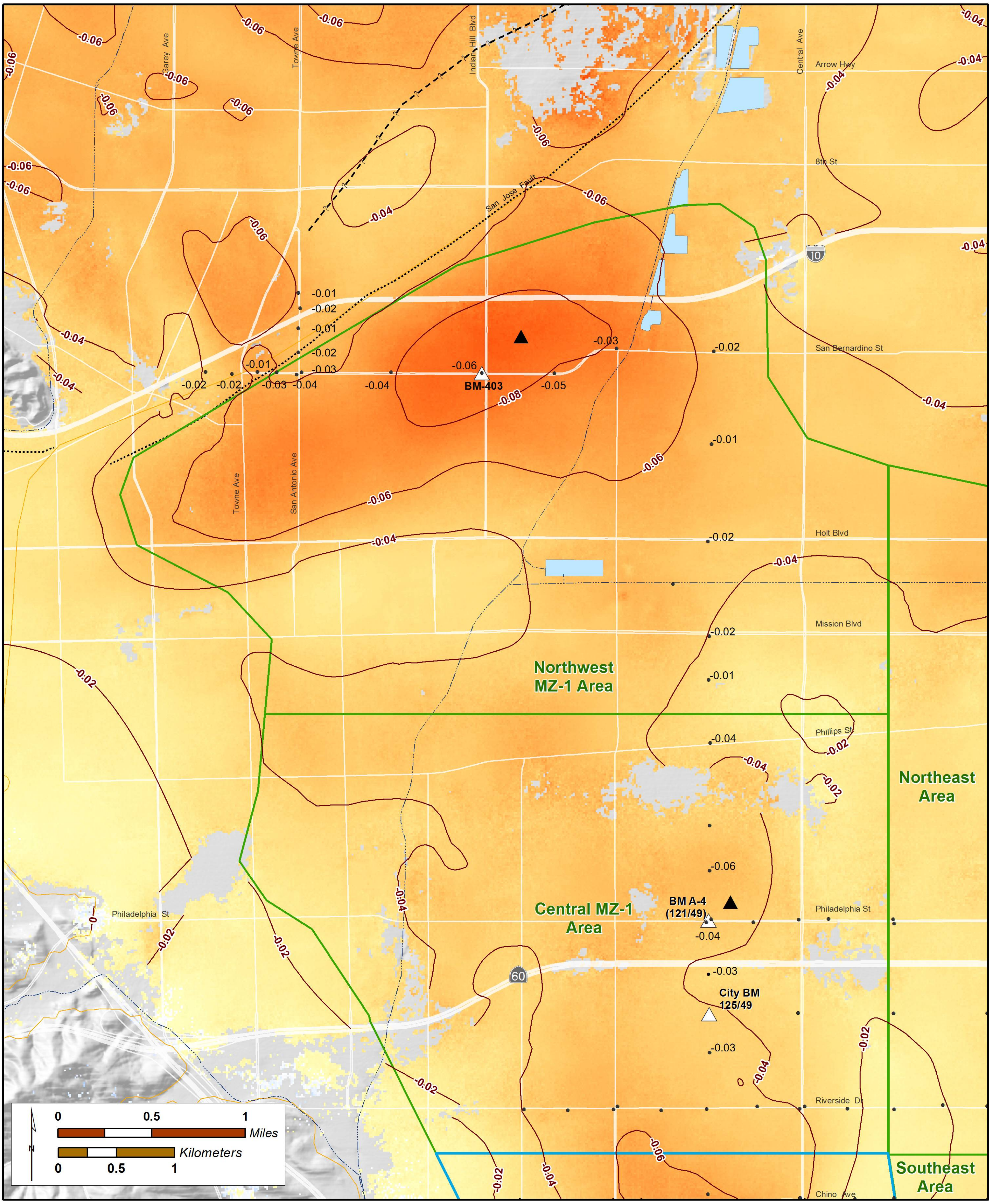
WEI
Wildermuth Environmental, Inc.

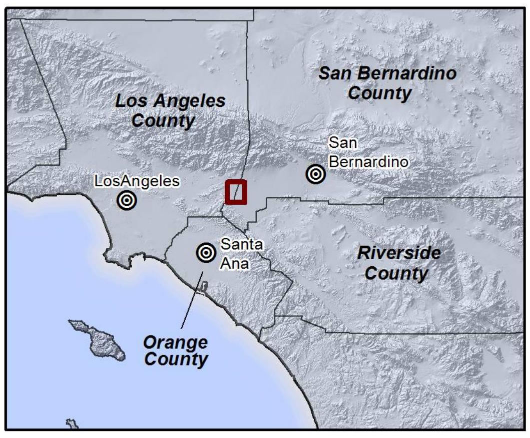
Author: TCR
Date: 20160519
File: Figure_3-8_2015_Cen.grf

The History of Land Subsidence in the Central MZ-1 Area

Ground-Level Monitoring Committee
2015 Annual Report

Figure 3-8





+ 0.10 ft / 0 / -0.05 / - 0.10 — Relative Change in Land Surface Altitude as Measured by InSAR Jan-2014 to Jan-2016

InSAR data incoherent

-0.01 — Benchmark Monument labeled by feet of change in ground-surface altitude for the period: Jan-2014 to Feb-2016

Benchmark monument with vertical ground-motion data shown on Figures 3-8 and 3-10

InSAR measurement point with vertical ground-motion data shown on Figures 3-8 and 3-10

Areas of Subsidence Concern

Managed Area

Flood Control & Conservation Basins

Chino Basin Management Zones

Prepared by:

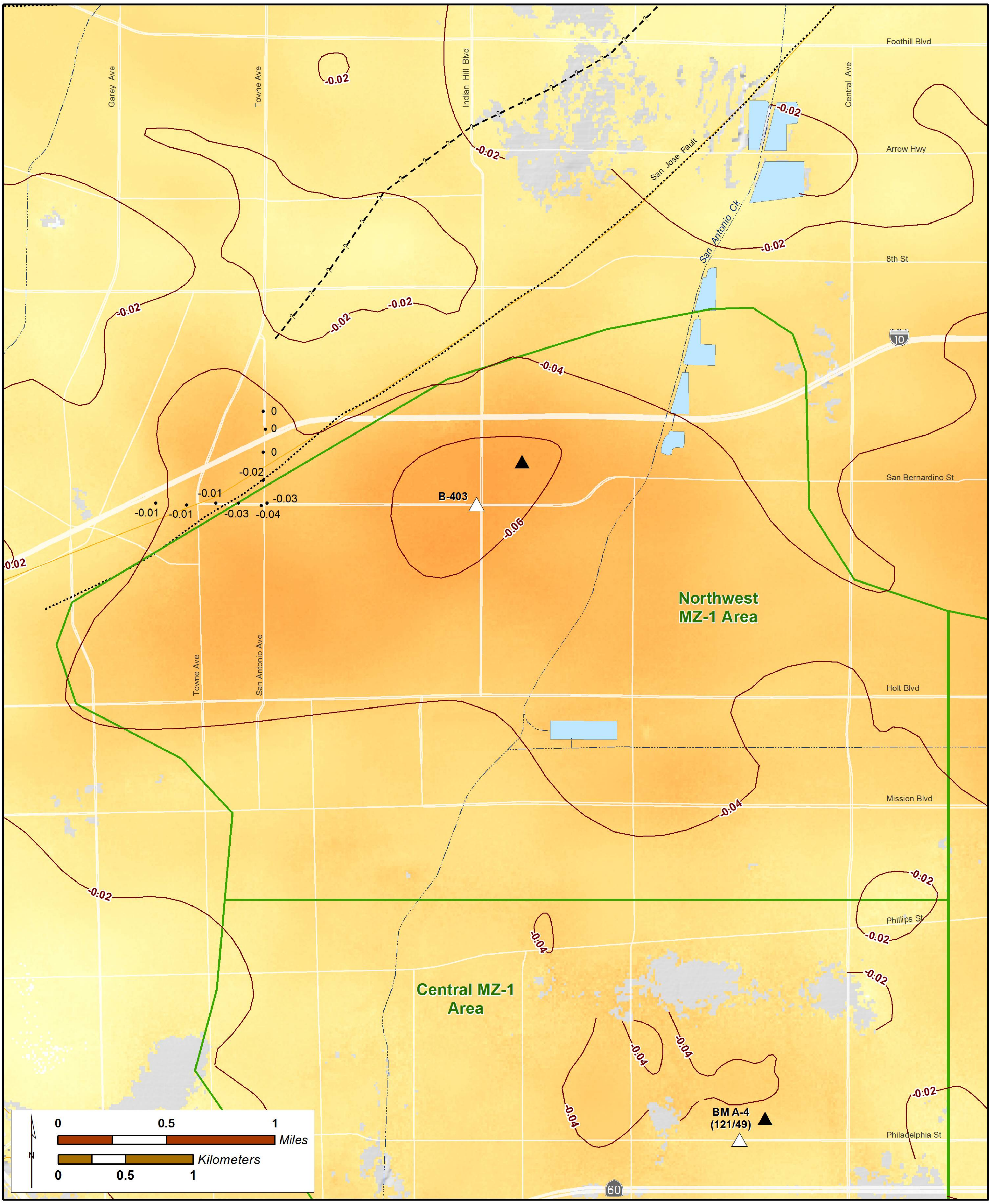
WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: TCR
Date: 20160516
File: Figure_3-9a.mxd

Ground-Level Monitoring Committee
2015 Annual Report

Vertical Ground Motion in the Northwest and Central MZ-1 Areas
January 2014 to February 2016

Figure 3-9a



+ 0.10 ft / 0 / -0.05 / - 0.10 — Relative Change in Land Surface Altitude as Measured by InSAR Jan-2015 to Jan-2016

InSAR data incoherent

- 0.01 — Benchmark Monument labeled by feet of change in ground-surface altitude for the period: Feb-2015 to Feb-2016

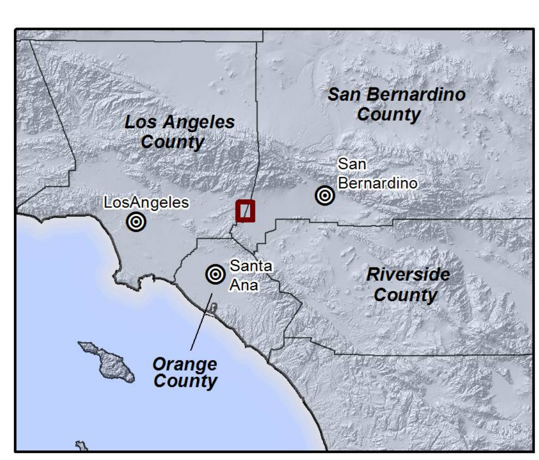
Benchmark monument with vertical ground-motion data shown on Figures 3-8 and 3-10

InSAR measurement point with vertical ground-motion data shown on Figures 3-8 and 3-10

Areas of Subsidence Concern

Flood Control & Conservation Basins

1 2 3 4 5 — Chino Basin Management Zones



Prepared by:

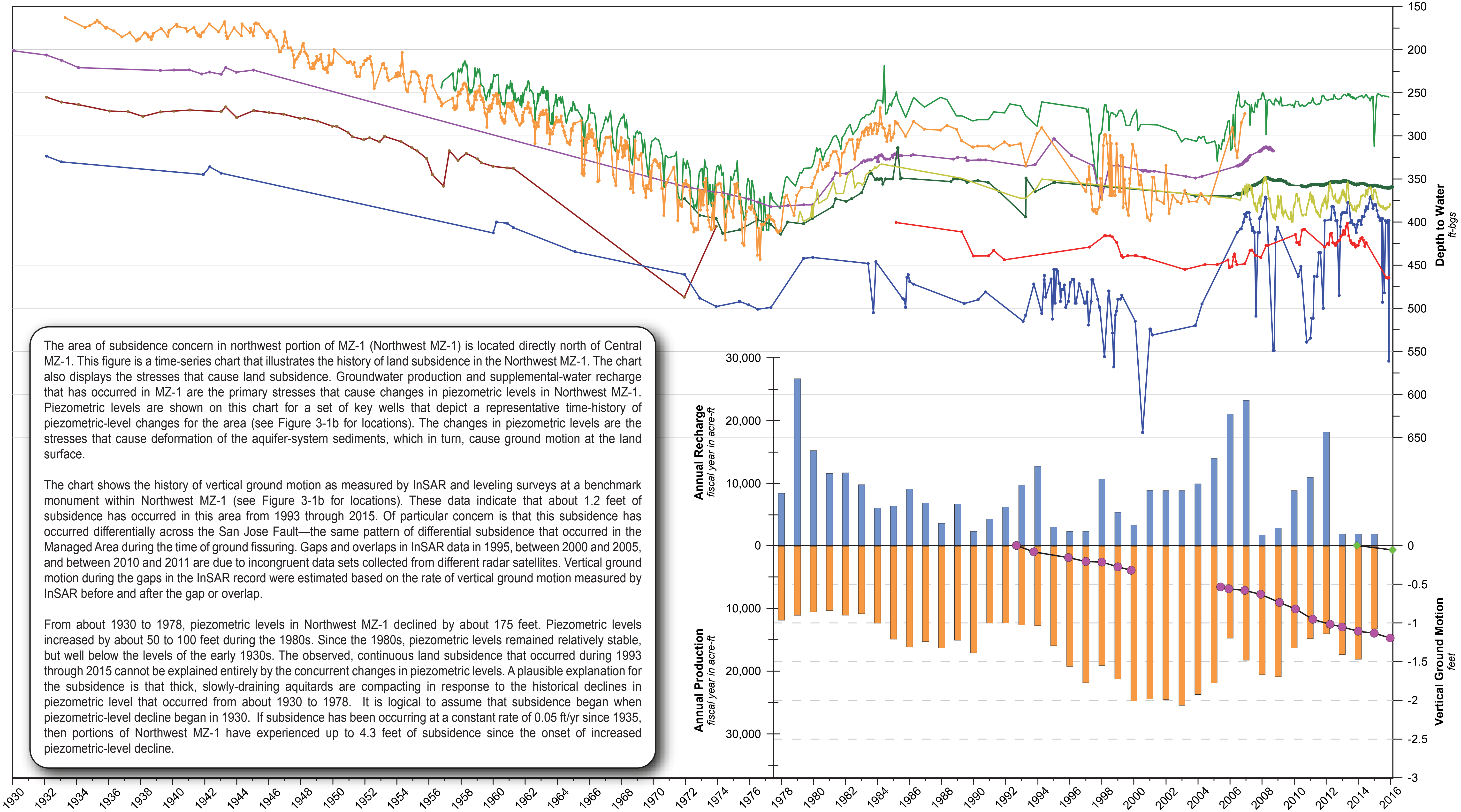
WEI
Wildermuth Environmental, Inc.

Author: TCR
Date: 20160516
File: Figure_3-9b.mxd

Ground-Level Monitoring Committee
2015 Annual Report

Vertical Ground Motion in the Northwest MZ-1 Area
January 2015 to February 2016

Figure 3-9b



The area of subsidence concern in northwest portion of MZ-1 (Northwest MZ-1) is located directly north of Central MZ-1. This figure is a time-series chart that illustrates the history of land subsidence in the Northwest MZ-1. The chart also displays the stresses that cause land subsidence. Groundwater production and supplemental-water recharge that has occurred in MZ-1 are the primary stresses that cause changes in piezometric levels in Northwest MZ-1. Piezometric levels are shown on this chart for a set of key wells that depict a representative time-history of piezometric-level changes for the area (see Figure 3-1b for locations). The changes in piezometric levels are the stresses that cause deformation of the aquifer-system sediments, which in turn, cause ground motion at the land surface.

The chart shows the history of vertical ground motion as measured by InSAR and leveling surveys at a benchmark monument within Northwest MZ-1 (see Figure 3-1b for locations). These data indicate that about 1.2 feet of subsidence has occurred in this area from 1993 through 2015. Of particular concern is that this subsidence has occurred differentially across the San Jose Fault—the same pattern of differential subsidence that occurred in the Managed Area during the time of ground fissuring. Gaps and overlaps in InSAR data in 1995, between 2000 and 2005, and between 2010 and 2011 are due to incongruent data sets collected from different radar satellites. Vertical ground motion during the gaps in the InSAR record were estimated based on the rate of vertical ground motion measured by InSAR before and after the gap or overlap.

From about 1930 to 1978, piezometric levels in Northwest MZ-1 declined by about 175 feet. Piezometric levels increased by about 50 to 100 feet during the 1980s. Since the 1980s, piezometric levels remained relatively stable, but well below the levels of the early 1930s. The observed, continuous land subsidence that occurred during 1993 through 2015 cannot be explained entirely by the concurrent changes in piezometric levels. A plausible explanation for the subsidence is that thick, slowly-draining aquitards are compacting in response to the historical declines in piezometric level that occurred from about 1930 to 1978. It is logical to assume that subsidence began when piezometric-level decline began in 1930. If subsidence has been occurring at a constant rate of 0.05 ft/yr since 1935, then portions of Northwest MZ-1 have experienced up to 4.3 feet of subsidence since the onset of increased piezometric-level decline.

Prepared by:

WEI
Wildermuth Environmental, Inc.

Author: TCR
Date: 20160816
File: Figure_3-10_2015_NW.grf

Piezometric Levels at Wells (Top-Bottom Screen Interval)

- MV-01 (245-472 ft-bgs)
- MV-08 (225-447 ft-bgs)
- MV-10 (520-1084 ft-bgs)
- MV-13 (203-475 ft-bgs)
- P-05 (old) (141-488 ft-bgs)
- P-18 (307-660 ft-bgs)
- P-27 (472-849 ft-bgs)
- P-30 (565-875 ft-bgs)

Vertical Ground Motion

- Northwest MZ-1 InSAR
- BM B-403

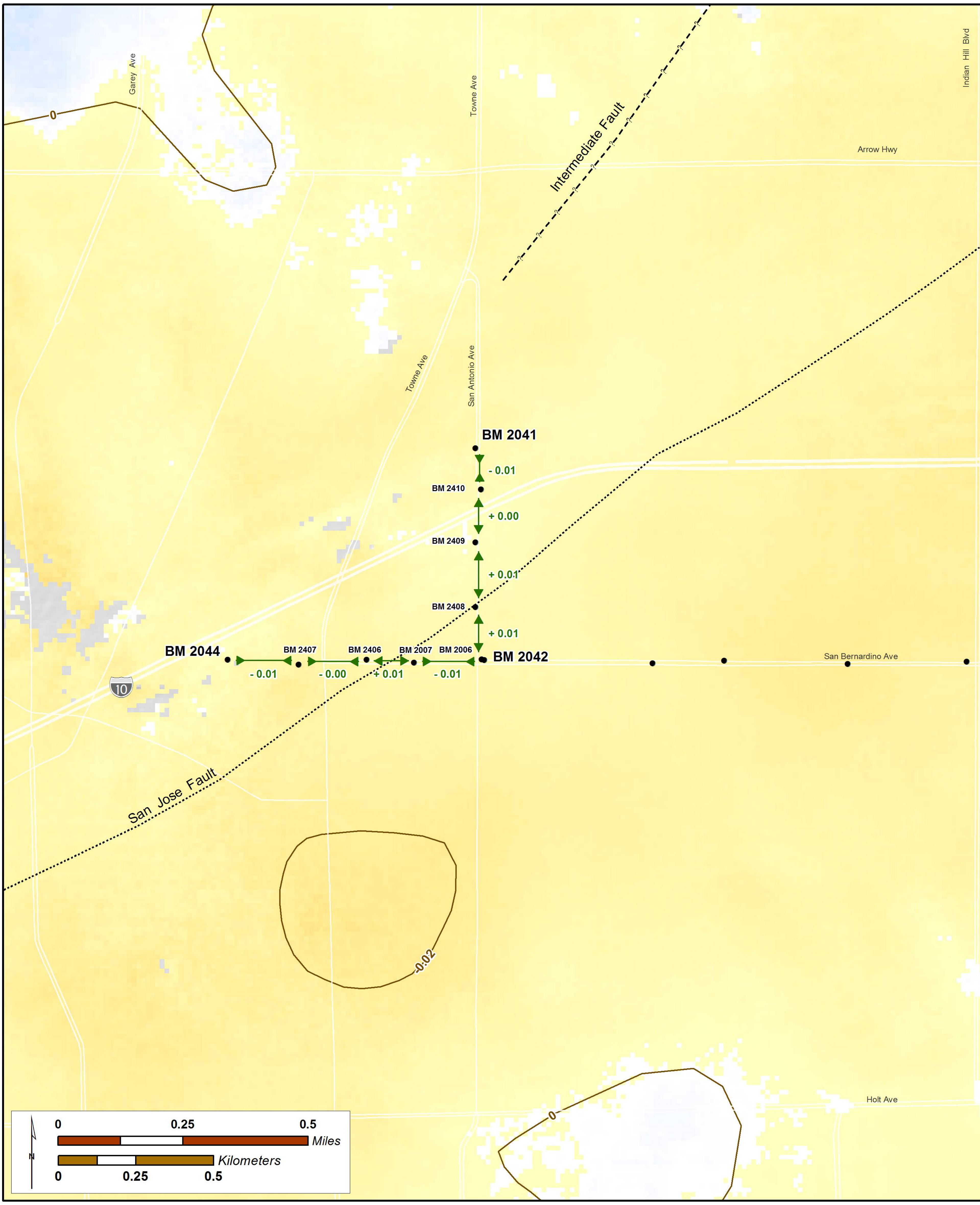
Recharge and Production

- Recharge of Recycled Water, Storm Water*, and Imported Water at the College Heights, Upland, Montclair, and Brooks Basins; and at MVWD ASR Wells
  *Storm Water recharge is assumed to be 2,380 acre-ft/yr prior to Fiscal Year 04/05
- Groundwater Production from Wells in Northwest MZ-1

Ground-Level Monitoring Committee
2015 Annual Report

The History of Land Subsidence in the Northwest MZ-1 Area

Figure 3-10



+ 0.10 ft
0
-0.05
- 0.10

Relative Change in Land Surface Altitude as Measured by InSAR Jan-2014 to Dec-2014 (feet)

InSAR data incoherent

Benchmark Location

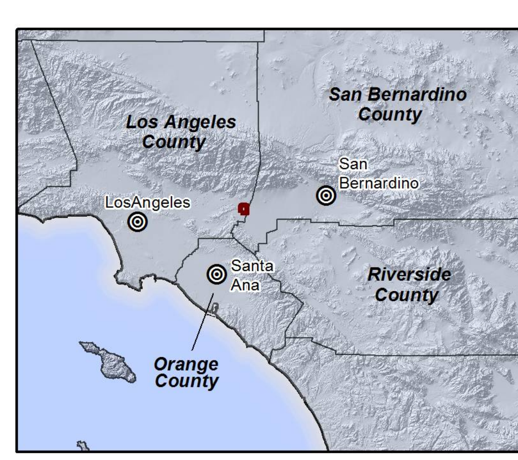
+ 0.02 Horizontal Ground Motion Between Adjacent Benchmarks Jan-2014 to Jan-2015 (feet)

Horizontal ground motion between adjacent benchmarks is shown as extension (+) or compression (-) in either the north-south direction for benchmarks along San Antonio Ave or the east-west direction for benchmarks along San Bernardino Ave.

Benchmarks BM 2041, 2042, and 2044 were measured by long-occupation GPS. Remaining sites were measured by traditional EDM methods.

Horizontal Accuracy Statement

The standard deviations in the distance measurements for each span for the period of Janaury 2014 to January 2015 range from +/-0.02 to +/-0.05 feet.



Prepared by:

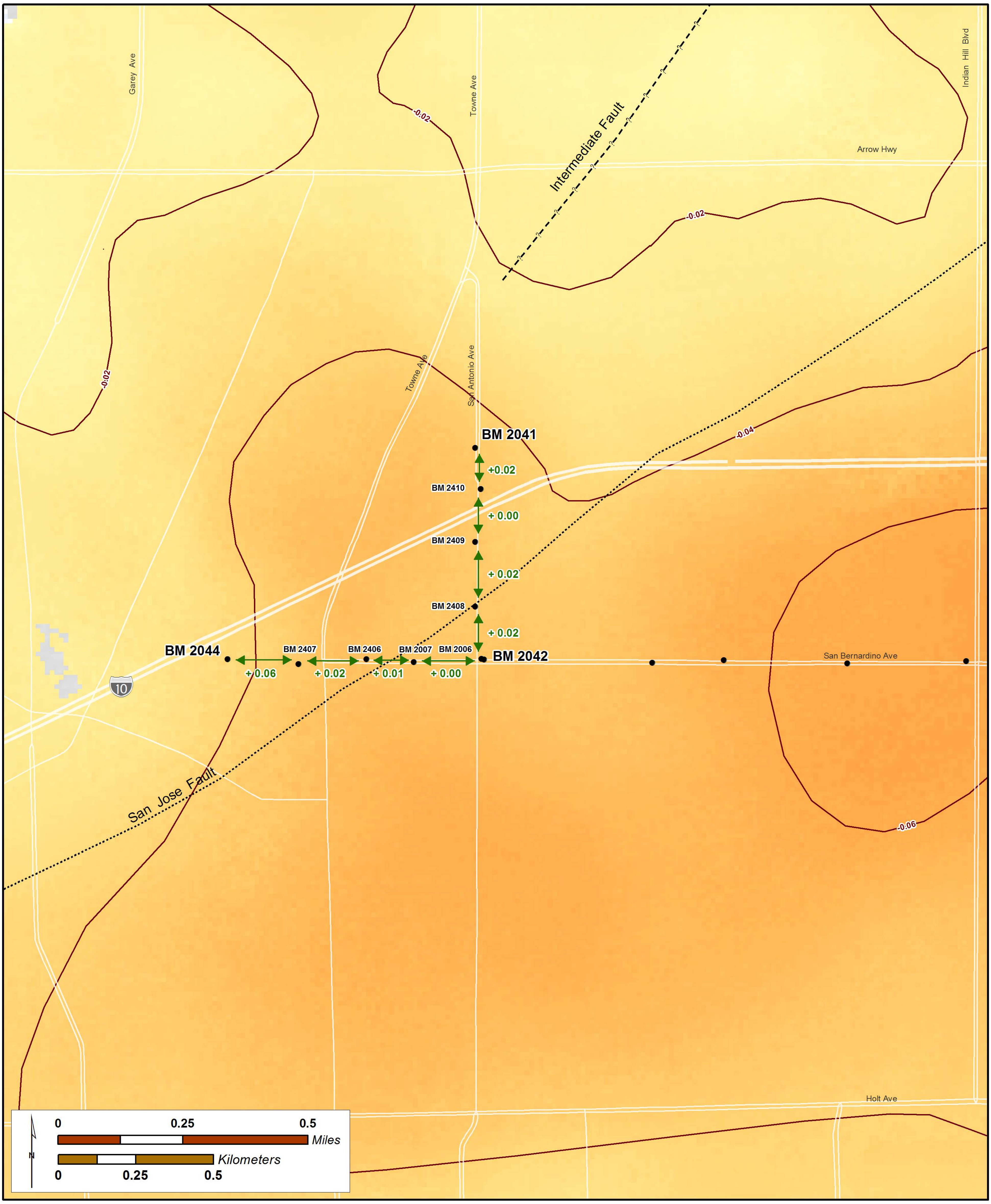
WEI
Wildermuth Environmental, Inc.

Author: TCR
Date: 20160816
File: Figure_3-11a.mxd

Ground-Level Monitoring Committee
2015 Annual Report

Ground Motion across the San Jose Fault
January 2014 to January 2015

Figure 3-11a



+ 0.10 ft
0
-0.05
- 0.10

Relative Change in Land Surface Altitude as Measured by InSAR Jan-2015 to Jan-2016 (feet)

InSAR data incoherent

Benchmark Location

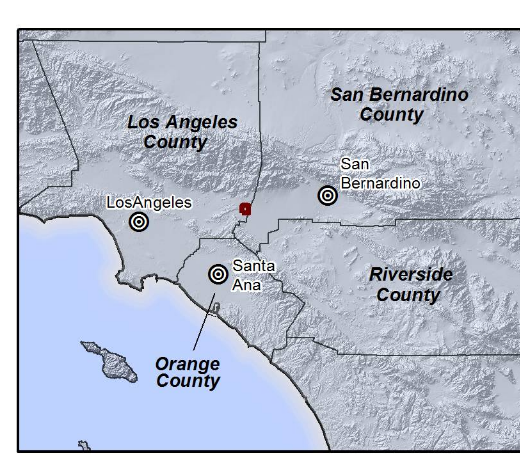
+ 0.02 Horizontal Ground Motion Between Adjacent Benchmarks Jan-2015 to Feb-2016 (feet)

Horizontal ground motion between adjacent benchmarks is shown as extension (+) or compression (-) in either the north-south direction for benchmarks along San Antonio Ave or the east-west direction for benchmarks along San Bernardino Ave.

Benchmarks BM 2041, 2042, and 2044 were measured by long-occupation GPS. Remaining sites were measured by traditional EDM methods.

Horizontal Accuracy Statement

The standard deviations in the distance measurements for each span for the period of Janaury 2015 to February 2016 range from +/-0.02 to +/-0.03 feet.



Prepared by:

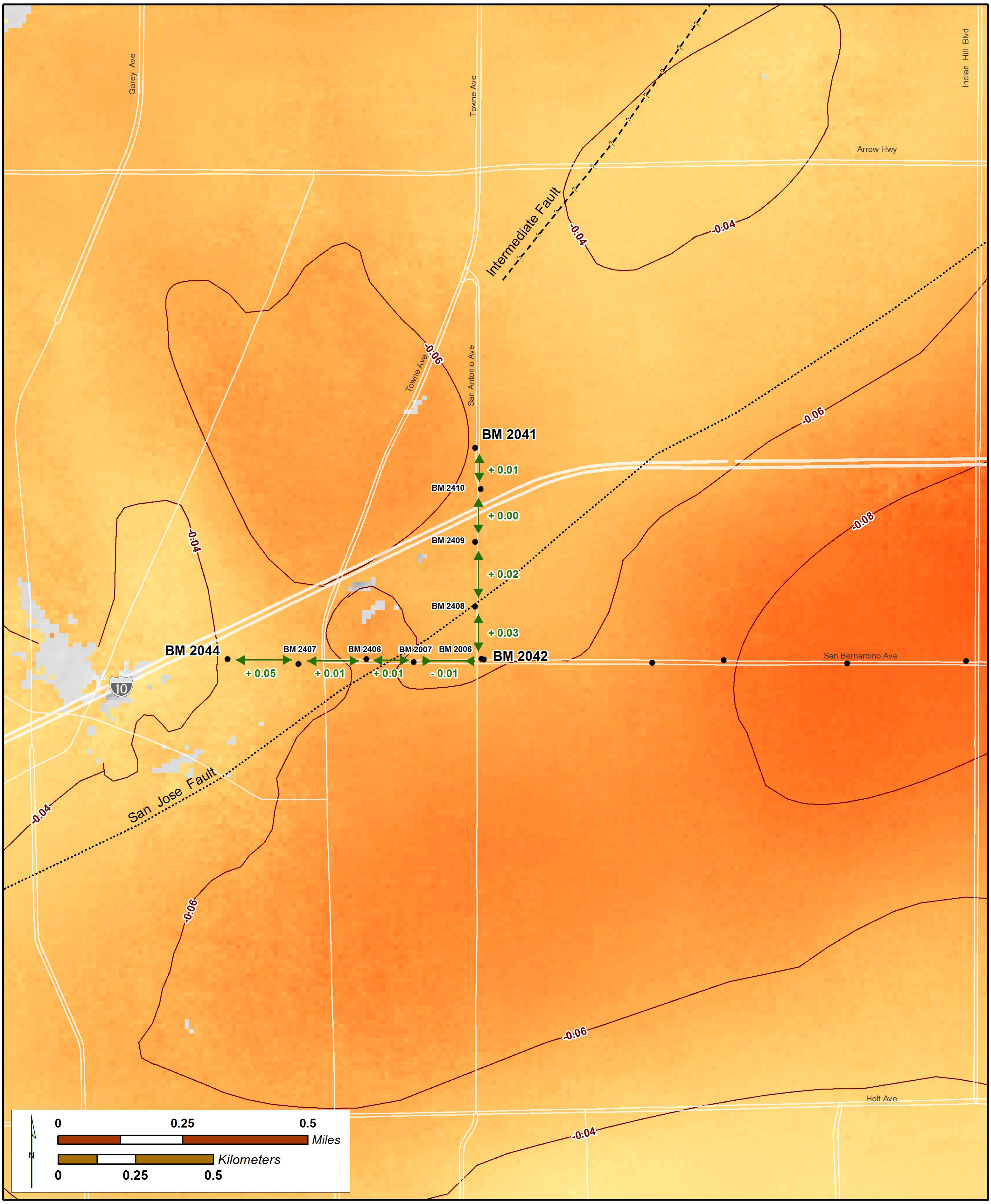
WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: TCR
Date: 20160804
File: Figure_3-11b.mxd

Ground-Level Monitoring Committee
2015 Annual Report

Ground Motion across the San Jose Fault
January 2015 to February 2016

Figure 3-11b



+ 0.10 ft
0
-0.05
- 0.10

Relative Change in Land Surface Altitude as Measured by InSAR Jan-2014 to Jan-2016 (feet)

InSAR data incoherent

Benchmark Location

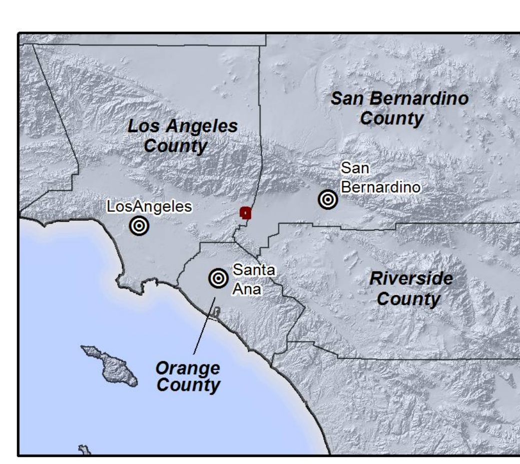
+ 0.02 Horizontal Ground Motion Between Adjacent Benchmarks Jan-2014 to Feb-2016 (feet)

Horizontal ground motion between adjacent benchmarks is shown as extension (+) or compression (-) in either the north-south direction for benchmarks along San Antonio Ave or the east-west direction for benchmarks along San Bernardino Ave.

Benchmarks BM 2041, 2042, and 2044 were measured by long-occupation GPS. Remaining sites were measured by traditional EDM methods.

Horizontal Accuracy Statement

The standard deviations in the distance measurements for each span for the period of Janaury 2014 to February 2016 range from +/-0.02 to +/-0.05 feet.



Prepared by:

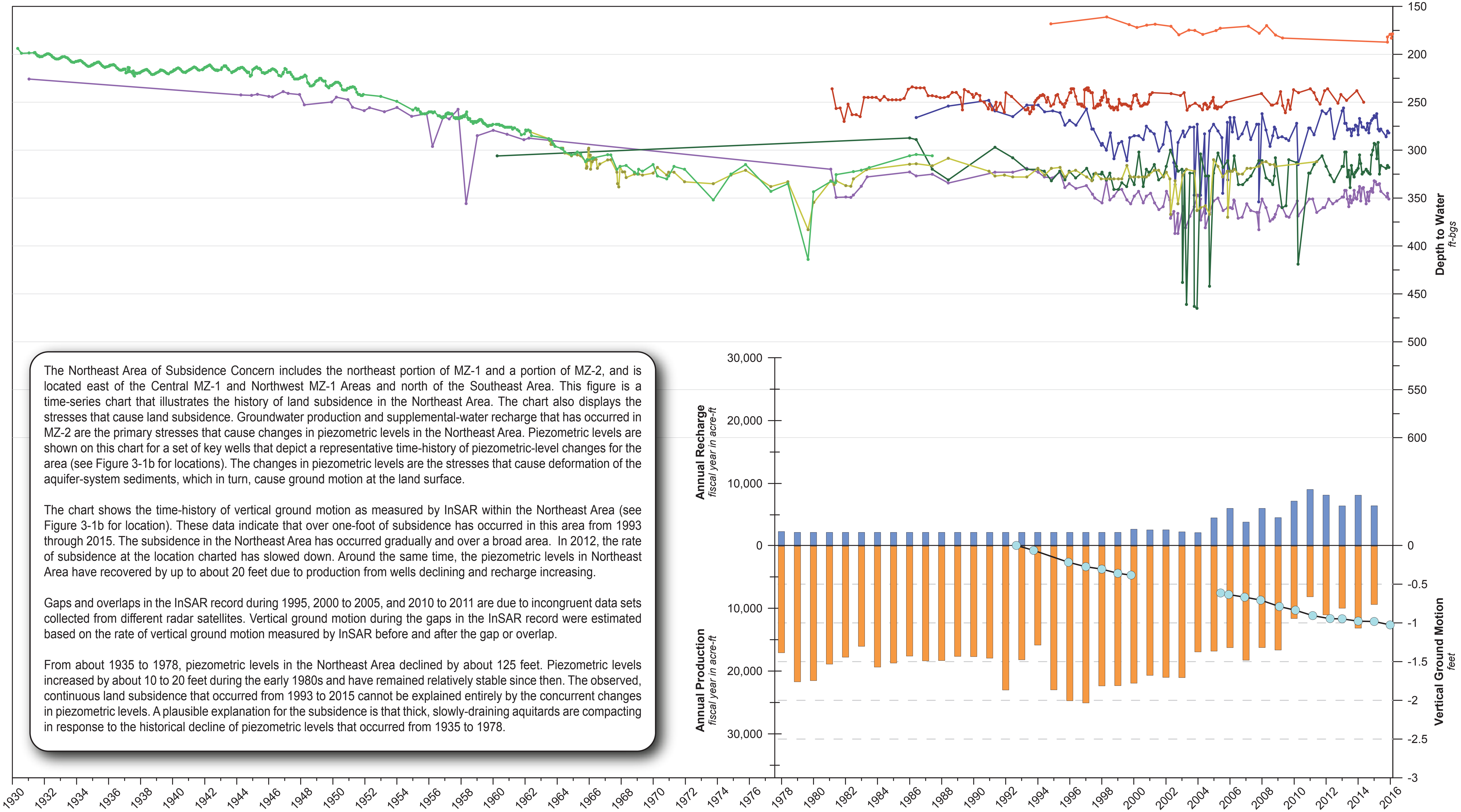
WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: TCR
Date: 20160804
File: Figure_3-11c.mxd

Ground-Level Monitoring Committee
2015 Annual Report

Ground Motion across the San Jose Fault
January 2014 to February 2016

Figure 3-11c



The Northeast Area of Subsidence Concern includes the northeast portion of MZ-1 and a portion of MZ-2, and is located east of the Central MZ-1 and Northwest MZ-1 Areas and north of the Southeast Area. This figure is a time-series chart that illustrates the history of land subsidence in the Northeast Area. The chart also displays the stresses that cause land subsidence. Groundwater production and supplemental-water recharge that has occurred in MZ-2 are the primary stresses that cause changes in piezometric levels in the Northeast Area. Piezometric levels are shown on this chart for a set of key wells that depict a representative time-history of piezometric-level changes for the area (see Figure 3-1b for locations). The changes in piezometric levels are the stresses that cause deformation of the aquifer-system sediments, which in turn, cause ground motion at the land surface.

The chart shows the time-history of vertical ground motion as measured by InSAR within the Northeast Area (see Figure 3-1b for location). These data indicate that over one-foot of subsidence has occurred in this area from 1993 through 2015. The subsidence in the Northeast Area has occurred gradually and over a broad area. In 2012, the rate of subsidence at the location charted has slowed down. Around the same time, the piezometric levels in Northeast Area have recovered by up to about 20 feet due to production from wells declining and recharge increasing.

Gaps and overlaps in the InSAR record during 1995, 2000 to 2005, and 2010 to 2011 are due to incongruent data sets collected from different radar satellites. Vertical ground motion during the gaps in the InSAR record were estimated based on the rate of vertical ground motion measured by InSAR before and after the gap or overlap.

From about 1935 to 1978, piezometric levels in the Northeast Area declined by about 125 feet. Piezometric levels increased by about 10 to 20 feet during the early 1980s and have remained relatively stable since then. The observed, continuous land subsidence that occurred from 1993 to 2015 cannot be explained entirely by the concurrent changes in piezometric levels. A plausible explanation for the subsidence is that thick, slowly-draining aquitards are compacting in response to the historical decline of piezometric levels that occurred from 1935 to 1978.

Prepared by:

WEI
Wildermuth Environmental, Inc.

Author: TCR
Date: 20160315
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Piezometric Levels at Wells (Top-Bottom Screen Interval)

- O-05 (360-470 ft-bgs)
- O-15 (474-966 ft-bgs)
- O-34 (522-1092 ft-bgs)
- O-25 (370-903 ft-bgs)
- O-36 (530-1000 ft-bgs)
- XRef 18 (unknown)
- C-11 (390-910 ft-bgs)

Vertical Ground Motion

- Northeast Area InSAR

Recharge and Production

- Recharge of Recycled, Storm Water*, and Imported Water at the Ely, Grove, Turner, 7th Street, 8th Street, and 15th Street Basins
  *Storm Water recharge is assumed to be 2,380 acre-ft/yr prior to Fiscal Year 04/05
- Groundwater Production from Wells in the Northeast Area

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Ground-Level Monitoring Committee
2015 Annual Report

The History of Land Subsidence in the Northeast Area

Figure 3-12

Section 4 – Conclusions and Recommendations

4.1 Conclusions and Recommendations

The following main conclusions of this annual report are based on the data collected and analyzed for the GLMP through December 31, 2015:

- During 2015, piezometric-levels at the PA-7 piezometer at the Ayala Park Extensometer facility did not decline below the Guidance Level, and the aquifer-system deformation was elastic in this portion of the Managed Area. This indicates that the Guidance Criteria have been protective in this portion of the Managed Area.

- In the northern portion of the Managed Area, the InSAR data indicate that a small and gradual amount of inelastic compaction has been occurring in the aquifer-system even though piezometric levels have not declined below the Guidance Level at Ayala Park since 2004. The threat of future ground fissuring caused by this compaction is unknown. Further investigation is warranted to determine the potential cause(s) of the inelastic deformation. In 2016/17, the GLMC should pursue the following:

    - Examine and characterize the stress-strain relationships in this area, including an analysis of paired observations of piezometric-levels at wells versus vertical ground motion as measured by InSAR and ground-level surveys. The results and interpretations of this analysis should be published in the 2016 annual report.

    - Identify and procure a new location for a horizontal extensometer across the historical fissure zone to replace the DHX.

    - Conduct the Long-Term Pumping Test in a future year after the installation of a new horizontal extensometer. This test and the associated monitoring will provide additional information on the mechanisms that are causing the compaction in this area and may result in a revision to the Guidance Level.

- During 2015, concentrated differential land subsidence continued to occur in Northwest MZ-1 across the San Jose Fault, which is the type of subsidence that can lead to ground fissuring. Extensional strain was measured across the San Jose Fault by the EDM surveys during 2013-2015, which is a further indication of potential for ground fissuring. Based on these observations, the GLMC should pursue the following in 2016/17:

    - Continue the monitoring of vertical and horizontal ground motion via InSAR and elevation/EDM surveys at benchmarks.

    - Continue implementation of the *Work Plan to Develop a Subsidence-Management Plan for the Northwest MZ-1 Area* that includes investigations into the cause(s) of the observed land subsidence and the development and evaluation of subsidence-management alternatives to minimize or abate future subsidence.

- Pumping at the Chino Creek Well Field began in the second quarter of 2014 and continued through 2015. The CCX did not record any decline of piezometric levels associated with pumping from the Chino Creek Well Field. In fact, in 2015 a small increase in piezometric levels at the CCX resulted in a small amount of aquifer-system expansion. Since July 2012, the CCX has recorded very little fluctuation of piezometric levels or vertical deformation of the aquifer system. Since 2011, the ground-level surveys indicate very little, if any, ongoing subsidence in the Southeast Area, in general. Because the majority of the ground surface is agriculture in the Southeast Area, the InSAR data has remained largely incoherent across most of the Southeast Area. In February 2016, two additional Chino Creek Desalter Wells began pumping. In 2016/17, the GLMC should pursue the following:

- Conduct an elevation survey at the existing benchmark monuments in the Southeast Area during fall/winter 2016.
- Continue monitoring of piezometric levels and aquifer-system deformation at the CCX.

4.2 Recommended Scope and Budget for Fiscal Year 2016-17

The scope-of-work for the GLMP for fiscal year 2016-17 is a recommendation of the GLMC, and is shown in Table 4-1 as a work breakdown structure with cost estimates:

- *Task 1—Setup and Maintenance of Monitoring Network.* The extensometers are the key monitoring facilities for the GLMP. They require regular and as-needed maintenance and recalibration to remain in good working order. Specifically, for 2016/17, the Ayala Park Extensometer Facility and the CCX will be checked monthly to ensure functionality and to calibrate, if necessary. In addition, a site for a new horizontal extensometer facility in the Managed Area will be identified to replace the DHX, and, if the GLMC recommends installation of the facility for 2017/18 CEQA analysis will be performed, if necessary, and easements for the site will be acquired.

- *Task 2—Aquifer-System Monitoring and Testing.* Conduct quarterly collection of piezometric-level and aquifer-system deformation data at wells and extensometers within the monitoring network. Quarterly collection and checking of data is necessary to (i) ensure that the monitoring network is in good working order and (ii) minimize the risk of losing data because of equipment malfunction.

- *Task 3—Basin Wide Ground-Level Monitoring Program: Collect and analyze InSAR data during 2016.* The data for InSAR is collected by the TerraSAR-X satellite operated by the German Aerospace Center. Five interferograms will be prepared that will describe the vertical ground motion across the western portion of Chino Basin during 2016. Correlation between InSAR and ground-level survey data (Task 4) will be evaluated in order to validate the reliability of the InSAR data.

- *Task 4—Ground-Level Surveys.*
    - *Conduct ground-level and EDM surveys in the Northwest MZ-1 Area.* The ground-level survey will begin at Ayala Park and include the benchmarks in the

Northwest MZ-1 Area shown in Figure 4-1. An additional line of benchmarks will be installed and surveyed in the area south of San Bernardino Street to transect the southwestern area of maximum on-going subsidence. The ground-level survey data will be referenced to the Ayala Park elevation datum. An EDM survey will be conducted at benchmarks within the San Jose Fault Array to measure horizontal strain across the San Jose Fault to assess the potential for ground fissuring.

- *Conduct an ground-level survey at benchmark monuments in the Southeast Area during fall/winter 2016.* The ground-level survey will begin at Ayala Park and include benchmarks within the Southeast survey area. Figure 4-1 shows the locations of the benchmark monuments. The ground-level survey data will be referenced to the Ayala Park datum. Three new Chino Creek desalter wells began producing groundwater during 2014. The remaining two Chino Creek desalter wells began pumping in February 2016.

- *Task 5—Data Analysis and Reporting.* During the first quarter of 2017, the Watermaster Engineer will analyze the data generated by the GLMP through 2016. This effort will include an analysis of all EDM data collected in the Managed Area to date to assist in the selection of a new site for a horizontal extensometer. The results and interpretations generated from the analysis of the data from the GLMP will be documented in the *2016 Annual Report of the Ground-Level Monitoring Committee*.

- *Task 6—Implementation of the Work Plan to Develop a Subsidence-Management Plan for the Northwest MZ-1 Area.* Watermaster, consistent with the recommendation of the GLMC, updated the SMP in 2015 to include a subsidence management plan for the Northwest MZ-1 Area with the long-term objective to minimize or abate the occurrence of subsidence in this area. The development of the subsidence management plan for the Northwest MZ-1 Area is a multi-year effort. The conceptual framework for this effort is described in the Work Plan. Several tasks outlined in the Work Plan will be implemented in FY 2016-17:

  - *Implement the Initial Monitoring Program.* The Initial Monitoring Program will continue to be implemented. This task will include initiation of monitoring of piezometric levels and production at MVWD wells; continuation of monitoring of piezometric levels and production from wells owned by the cities of Chino, Pomona, and Upland and the Golden State Water Company; conductance of a short-term controlled pumping test(s); analysis of the data generated from the Initial Monitoring Program, and preparation of a Task Memorandum that will document the improved understanding of the aquifer system in the Northwest MZ-1 Area.

  - *Develop and Evaluate the Initial Subsidence-Management Alternative.* The preconsolidation stress in the Northwest MZ-1 Area will be estimated, the Initial Subsidence-Management Alternative (ISMA) will be described and used to characterize and evaluate the basin response to the ISMA, and a Task Memorandum that will be prepared to document the development and evaluation of the ISMA.

  - *Design and Install the Pomona Extensometer Facility*. Easements for the Pomona Extensometer Facility site will be acquired, plans and specifications for the facility will be prepared, and a contractor will be obtained to perform the facility installation.

- *Task 7—Meetings and Administration*. Three meetings of the GLMC are planned to oversee the GLMP: the first meeting is planned for fall 2016 to implement the GLMP for 2016/17; the second is planned for March 2017 to review data collected from the monitoring program through 2016 and recommend a scope of work for fiscal year 2017/18; the third is planned for May 2017 to review the 2016 Annual Report of the GLMC. On-going management of project staffing and financial reporting will be conducted. A scope and budget will be prepared for fiscal year 2017/18 in the first quarter of 2017 based on review data collected from the monitoring program through 2016.

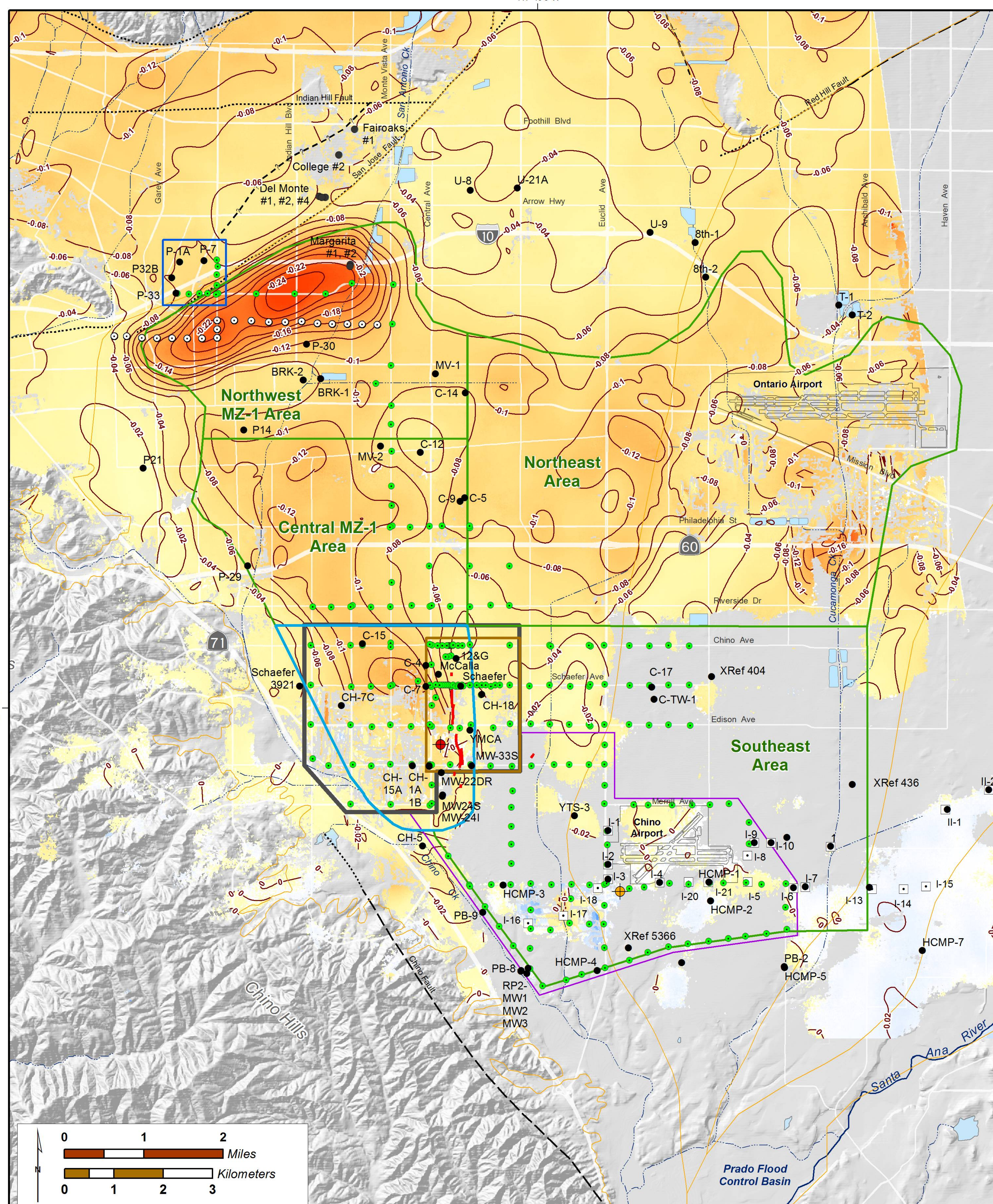
4.3 Changes to the Subsidence Management Plan

The SMP 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 SMP pursuant to the process outlined in Section 4 of the SMP.

Currently, there are no recommended changes to the SMP.

Table 4-1
Work Breakdown Structure and Cost Estimates
Ground-Level Monitoring Program -- FY 2016-17

Task Description	Labor		Other Direct Costs							Totals					
	Person Days	Total	Travel	New Equip.	Equip. Rental	Outside Pro	Repro	Misc.	Total	Totals by Task	Recommended Budget *2016-17*	Budget *2015-16*	Net Change *2015-16 to 2016-17*	Potential Carry-Over *2015-16*	Budget with Carry-Over *2016-17*
											a	*b*	*a - b*	*c*	*a - c*
Task 1 -- Setup/Maintenance of Monitoring Network		**$34,532**							**$30,182**	**$64,714**	**$64,714**	**$46,591**	**$18,123**	**$0**	**$64,714**
1.1 Equipment maintenance															
Routine maintenance of Ayala Park and Chino Creek extensometer facilities	9	$10,992	$583	$500	$152				$1,235	$12,227	$12,227	$9,035	$3,192		$12,227
Maintenance at horizontal extensometer site									$0	$0		$26,252	-$26,252		$0
Replacement/repair of equipment at extensometer facilities	4	$5,296	$73	$3,000	$38	$2,000			$5,111	$10,407	$10,407	$9,708	$699		$10,407
1.2 Annual lease fees for CCX extensometer site	0	$0						$1,596	$1,596	$1,596	$1,596	$1,596	$0		$1,596
1.3 Identify a site and install a horizontal extensometer in the Managed Area															
Coordinate with the City of Chino to Identify Potential Sites	7	$10,104	$194						$194	$10,298	$10,298		$10,298		$10,298
Prepare for and attend a meeting of the GLMC to discuss and approve potential sites	2	$3,352	$46						$46	$3,398	$3,398		$3,398		$3,398
Perform CEQA for the potential new sites and procure permits and easements	4	$4,788				$22,000			$22,000	$26,788	$26,788		$26,788		$26,788
Task 2 -- MZ-1: Aquifer-System Monitoring and Testing		**$15,624**							**$670**	**$16,294**	**$16,294**	**$31,052**	**-$14,758**	**$0**	**$16,294**
2.1 Groundwater-level and extensometer data collection and processing															
Download data from the Ayala Park facility	1.5	$1,920	$259		$76				$335	$2,255	$2,255	$2,164	$91		$2,255
Download data from the Daniels Horizontal Extensometer facility	0	$0							$0	$0		$2,164	-$2,164		$0
Download data from the CCX facility	0.5	$728	$259		$76				$335	$1,063	$1,063	$2,164	-$1,101		$1,063
Process, check, and upload data to database	10	$12,976							$0	$12,976	$12,976	$12,660	$316		$12,976
2.2 Conduct Long-Term Pumping Test in the Managed Area															
Coordinate testing with pumpers	0	$0							$0	$0		$1,320	-$1,320		$0
Collect production data monthly; process, check, and upload to database	0	$0							$0	$0		$2,330	-$2,330		$0
Prepare, analyze, and distribute stress-strain diagrams to GLMC	0	$0							$0	$0		$6,280	-$6,280		$0
Adjust extensometer hardware	0	$0							$0	$0		$1,970	-$1,970		$0
Task 3 -- Basin Wide: InSAR		**$4,082**							**$85,000**	**$89,082**	**$89,082**	**$87,830**	**$1,252**	**$0**	**$89,082**
3.1 InSAR data collection	1	$1,456				$85,000			$85,000	$86,456	$86,456	$86,320	$136		$86,456
3.2 Process, check, and upload data to database/GIS	2	$2,626							$0	$2,626	$2,626	$1,510	$1,116		$2,626
Task 4 -- Ground-Level Surveys		**$7,590**							**$136,335**	**$143,925**	**$71,147**	**$136,335**	**-$65,188**	**$0**	**$71,147**
4.1 Conduct fall 2016 ground-level survey in Southeast Area (CCWF)	0.25	$364				$29,071			$29,071	$29,435	$29,435	$26,645	$2,790		$29,435
4.2 Conduct fall 2016 ground-level and EDM survey in Northwest MZ-1 Area (Ayala Park start)	0.25	$364				$15,077			$15,077	$15,441	$15,441	$24,080	-$8,639		$15,441
4.3 Conduct fall 2016 ground-level and EDM survey at the San Jose Fault Zone (local survey only)	0.25	$364				$7,782			$7,782	$8,146					$0
4.4 Install additional benchmarks and conduct fall 2016 ground-level survey across the NW MZ-1 Area	1	$1,456				$15,000			$15,000	$16,456	$16,456		$16,456		$16,456
4.5 Conduct ground-level and EDM survey in Managed Area at maximum groundwater-level decline	0.25	$364				$31,952			$31,952	$32,316		$36,930	-$36,930		$0
4.6 Conduct ground-level and EDM survey in Managed Area at maximum groundwater-level recovery	0.25	$364				$31,952			$31,952	$32,316		$36,930	-$36,930		$0
4.7 Replace destroyed benchmarks	0	$0				$5,501			$5,501	$5,501	$5,501	$8,000	-$2,499		$5,501
4.8 Process, check, and upload data to database	3.25	$4,314							$0	$4,314	$4,314	$3,750	$564		$4,314
Task 5 -- Data Analysis and Reports		**$75,398**							**$30,000**	**$105,398**	**$105,398**	**$72,180**	**$33,218**	**$0**	**$105,398**
5.1 Analysis of Data from the Areas of Subsidence Concern															
Production/recharge/piezometric/extensometer	4	$5,032				$20,000			$20,000	$25,032	$25,032	$27,360	-$2,328		$25,032
Ground-level survey and Northwest MZ-1 Area EDM data	4	$5,384							$0	$5,384	$5,384	$5,180	$204		$5,384
Perform analysis of EDM and elevations surveys in the Fissure Zone	12	$18,352				$10,000			$10,000	$28,352	$28,352		$28,352		$28,352
InSAR data	4	$5,032							$0	$5,032	$5,032	$1,160	$3,872		$5,032
Tectonic data	0.25	$298							$0	$298	$298	$500	-$202		$298
Recycled water reuse data	2	$2,384							$0	$2,384	$2,384	$3,660	-$1,276		$2,384
5.2 Prepare 2016 Annual Report of the Ground-Level Monitoring Committee															
Prepare draft annual report	23	$31,240							$0	$31,240	$31,240	$27,520	$3,720		$31,240
Prepare final annual report	5.5	$7,676							$0	$7,676	$7,676	$6,800	$876		$7,676
Task 6 -- Work Plan to Develop a Subsidence-Management Plan for the Northwest MZ-1 Area		**$251,302**							**$24,643**	**$275,945**	**$275,945**	**$506,255**	**-$230,310**	**$162,238**	**$113,707**
6.1 Describe Initial Hydrogeologic Conceptual Model & the Monitoring and Testing Program	0	$0							$0	$0		$77,825	-$77,825		$0
6.2 Implement the Initial Monitoring Program	65	$83,400	$1,043		$152		$50		$1,245	$84,645	$84,645	$191,908	-$107,263	$66,102	$18,543
6.3 Develop and Evaluate the Baseline Management Alternative	0	$0							$0	$0		$68,032	-$68,032		$0
6.4 Develop and Evaluate the Initial Subsidence-Management Alternative	64.75	$111,790	$124				$100		$224	$112,014	$112,014	$124,346	-$12,332	$96,136	$15,878
6.5 Design and Install the Pomona Extensometer Facility (design only during FY2016-17)	27	$37,832	$62			$20,000	$50	$3,000	$23,112	$60,944	$60,944	$27,502	$33,442		$60,944
6.11 Meetings and Administration (Annual)	11	$18,280	$62						$62	$18,342	$18,342	$16,642	$1,700		$18,342
Task 7 -- Meetings and Administration		**$35,620**							**$194**	**$35,814**	**$35,814**	**$32,487**	**$3,327**	**$0**	**$35,814**
7.1 Prepare for and attend three Ground-Level Monitoring Committee meetings	9	$14,424	$145						$145	$14,569	$14,569	$13,221	$1,349		$14,569
7.2 Ad hoc meetings	3	$4,808	$48						$48	$4,856	$4,856	$4,406	$451		$4,856
7.3 Project Administration and Financial Reporting	7.5	$11,580							$0	$11,580	$11,580	$10,500	$1,080		$11,580
7.4 Scope and Budget for FY2016/17	3	$4,808							$0	$4,808	$4,808	$4,360	$448		$4,808
Totals										**$731,172**	**$658,394**	**$912,730**	**-$254,336**	**$162,238**	**$496,156**



Relative Change in Land Surface Altitude as Measured by InSAR Mar-2011 to Jan-2016

+ 0.25 ft
0
-0.1
- 0.25

InSAR data incoherent

Survey Areas

- Southeast Area
- Fissure Zone
- Managed Area
- San Jose Fault Zone

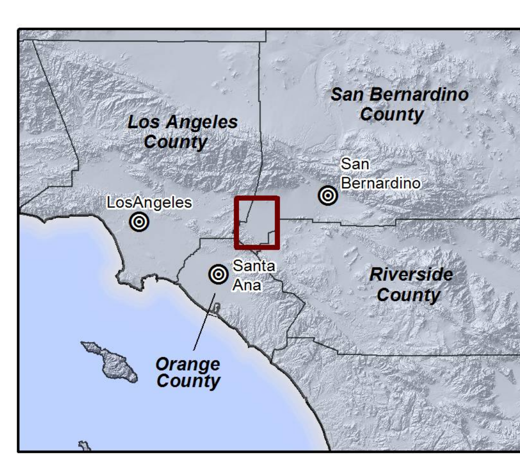
Survey Benchmarks

- Existing Monument
- Proposed Monument

Wells and Extensometers

- Desalter Well
- Ayala Park Extensometer
- Chino Creek Extensometer
- Well Monitored by Pressure Transducer as of Dec-2015

- Managed Area
- Areas of Subsidence Concern
- Ground Fissures
- Flood Control & Conservation Basins
- Chino Basin Management Zones



Prepared by:

WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: TCR
Date: 20160407
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Ground-Level Monitoring Committee
2015 Annual Report

Ground-Level Monitoring Program
Fiscal Year 2016-17

Figure 4-1

The following glossary contains terms and definitions that are used in this report and generally in the discussions at Ground-Level Monitoring Committee meetings (USGS, 1999).

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 which 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 preconsolidation 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 the 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 void ratio or porosity of the soil. For 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 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.

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.

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.

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, and is 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, and represents that portion of the applied stress which becomes effective as intergranular stress.

Stress, Preconsolidation – The maximum antecedent effective stress to which a deposit has been subjected and which it can withstand without undergoing additional permanent deformation. Stress changes in the range less than the preconsolidation stress produce elastic deformations of small magnitude. In fine-grained materials, stress increases beyond the preconsolidation 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, and thus affects 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 the 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 that portion of the applied stress which 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.

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Appendix A

Monitoring Data through December 2015

Appendix B

Comments and Responses

Appendix B
Comments and Responses
on the Draft 2015 Annual Report of the Ground-Level Monitoring Committee

B-1 City of Pomona

Comment Number	Reference	Comment	Response
1	Page 1-5, Section 1.1.4	Given that the Guidance Level has already been established, is it correct to assume that the data gathered and reviewed would be less going forward?	Monitoring is necessary to verify the protectiveness of the Guidance Level. That said, the scope of the monitoring program is reviewed and revised annually based on the recommendations of the Committee. No changes to the report text were made to address this comment.

B-2 MONTE VISTA WATER DISTRICT

Comment Number	Reference	Comment	Response
1	Page 1-4, Section 1.1.3, item 8.	"…raising, lowering, or deletion…"? Is there any situation the GL would be removed? Was the GL meant to exist in perpetuity under any & all circumstances?	The Guidance Level is intended to exist unless and until monitoring and/or testing data from the Ground-Level Monitoring Program indicate that it should be changed. No changes to the report text were made to address this comment.
2	Page 4-1, Section 4.1	Insert "Continue considering the effects of Watermaster performing wet-water recharge in MZ-1 beyond the 6,500 AFY minimum contractual obligation of the Peace Agreements."	The effectiveness of wet-water recharge on mitigating subsidence in Northwest MZ-1 is being analyzed and considered as part of the development of a subsidence management plan. No changes were made to the report to address this comment.
3	Page 4-2, Section 4.2	Is any of the narrative of 4.2 not already explicitly identified in the approved FYE 2017 WM budget?	No. The narrative of Section 4.2 describes the scope of work included in the approved FY 2016-17 Watermaster budget. No changes to the report text were made to address this comment.

B-3 California Institution for Men

Comment Number	Reference	Comment	Response
1	Table 3-1 and Figure 3-3	Deep and shallow aquifer groundwater production in the managed area is summarized in Table 3-1 and shown graphically on Figure 3-3. The location of some of the referenced shallow aquifer wells are not depicted on any figure (e.g., CIM-1 and Xref 8730).	The production wells in the Managed Area that are not Managed Wells will be added to Figure 1-2. These wells will include all wells with production shown in Table 3-1 and Figure 3-3.

Appendix B

Comments and Responses
on the Draft 2015 Annual Report of the Ground-Level Monitoring Committee

B-4 GEOSCIENCE SUPPORT SERVICES INC. FOR THE CITY OF CHINO HILLS, MONTE VISTA WATER DISTRICT, AND THE CITY OF POMONA

Comment Number	Reference	Comment	Response
1	Page 1-1, Section 1.1	Reword and add it as appropriate----However, to be specific and for purposes of this report, subsidence is defined as the non-recoverable compaction of fine-grained materials within aquifer units that result in a permanent lowering of the land surface resulting from withdrawal of groundwater (also see glossary).	The word "subsidence" does not indicate cause in this document. It describes permanent (non-recoverable) sinking of the land surface. No changes have been made to the text to address this comment.
2	Page 1-2, Section 1.1.3	As the original group (Subsidence Monitoring Committee) which is now called the Ground-Level Monitoring Committee realized some time ago that the issue of lowering of the land and fissuring in the MZ-1 area is not just confined to the southern portion of MZ-1. Reports such as GEOSCIENCE (2002) have documented historical Land surface subsidence since the 1930's. Although the phenomenon was a concern in the 1970s and 1980s, increased subsidence observed between 1993 and 1995 coupled with rapid urbanization of the area has resulted in the need to understand all potential causes of subsidence in the Chino area and develop a strategy to mitigate it to the extent necessary and possible. Therefore, one of the main tasks of the current Monitoring Committee is to understand the extent and potential causes throughout all of MZ-1 (and possibly, the Chino Basin in general).	Watermaster Engineer concurs with the comment, and contends that Section 1 adequately describes the objectives of the Watermaster and the GLMC with respect to avoiding adverse impacts associated with land subsidence. No changes have been made to the text to address this comment.
3	Page 1-3, Section 1.1.3	However, there is some disagreement in this regard as previous studies (GEOSCIENCE 2002) have shown long-term lowering of water levels throughout a good part of MZ-1 which may have been a factor in the fissuring in the southern portion of the area of which residual compaction may have played a part (see the 5th bullet below). Nevertheless, it was thought prudent to employ potential safety measures (i.e. guidance criteria and the managed area concept) to curtailing	Watermaster Engineer concurs with the comment, and contends that the Annual Report adequately describes the components of the Subsidence Management Plan that call for monitoring, testing, and assessment of the appropriateness of the Guidance Criteria in the Managed Area. No changes have been made to the text to address this comment.

Comment Number	Reference	Comment	Response
		pumping from the deep aquifer zone until all reasons were fully understood. One of the challenges of the GLMC is to fully understand the reasons for and how to mitigate these impacts.	
4	Page 1-4, Section 1.1.3	due to uncertainties as to causes and timing and location of fissuring and the spatial extent of land level changes and/or fissuring.	This section is a reference from the MZ-1 Summary Report and should not be edited in the annual report. No changes have been made to the text to address this comment.
5	Page 1-5, Section 1.1.5	The hypothesis is that long-term lowering of groundwater levels near the San Jose Fault has caused a differential settlement similar to what was postulated in the southern MZ-1 area.	Watermaster Engineer concurs that the comment states a valid hypothesis for mechanism behind the observed subsidence. It is stated in the *Work Plan to Develop a Subsidence Management Plan for the Northwest MZ-1 Area* that one of the questions to answer is: "What are the mechanisms driving the observed subsidence?" No changes have been made to the text to address this comment.
6	Page 1-6, Section 1.1.5	and associated changes in land surface elevations.	Watermaster Engineer concurs that changes in the land surface elevations are of concern. That said, the paragraph is focused on the main subsidence-related threat, ground fissuring. No changes have been made to the text to address this comment.
7	Page 2-3, Section 2.1.2.3	Use of InSAR is still in somewhat of an experimental phase as to the accuracy and reliability (and coverage) for use as the sole metric for monitoring surface deformation of the land. Until more data are gathered and benchmarked against land leveling surveys, InSAR	Watermaster Engineer disagrees with the comment. InSAR has been used for over 20 years in various scientific studies and practical applications. In addition, satellite technologies and data processing techniques have improved over time.

Comment Number	Reference	Comment	Response
		is still considered somewhat tentative.	The Committee tasked Parsons and Neva Ridge to compare InSAR and ground-level survey data. They concluded that both techniques are comparable in terms of accuracy (about +/- 0.02 ft), and recommended that surveys are best used in areas where InSAR is incoherent. Watermaster Engineer and the Committee have analyzed both data sets where they overlap in space and time, which has shown similar results for the spatial distribution and magnitude of vertical ground motion. No changes have been made to the text to address this comment.
8	Page 2-5, Section 2.2.1	There is still some uncertainty with this method as previous attempts to reproduce non-recoverable compaction have not had consistent results. It is hoped that a more controlled pumping test will result in consistent results.	Watermaster Engineer concurs with the comment. That said, the Engineer and the Committee have continued to recommend that analyzing ongoing monitoring data and conducting the Long-Term Pumping Test are valid methods to evaluate the Guidance Level. No changes have been made to the text to address this comment.
9	Page 2-7, Section 2.2.2	Suggest not use the word subsidence in this area until it is known for sure that it is non recoverable lowering of the land. Probably use words like close monitoring of water levels and land levels. This sounds like there is a forgone conclusion that subsidence has already occurred in this area.	Watermaster Engineer disagrees with the comment. The available data indicates that non-recoverable subsidence is occurring in the Northwest MZ-1 Area. No changes have been made to the text to address this comment.
10	Page 3-1,	Note somewhere in the document that a lot of the past	Watermaster Engineer concurs that since the

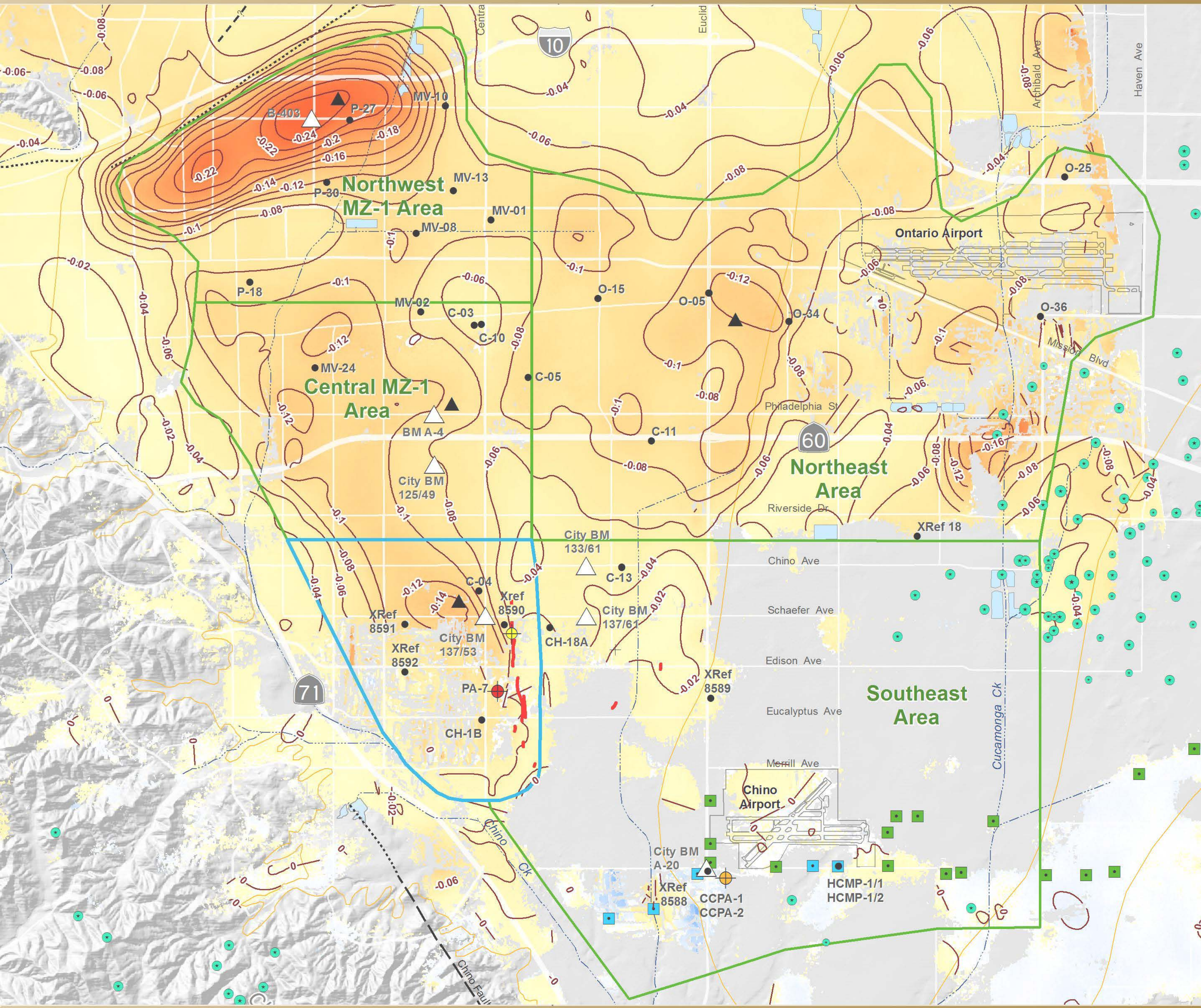
Comment Number	Reference	Comment	Response
	Section 3-1	data, pumping tests and compaction etc., have not been reproducible as far as trying to establish a subsidence threshold level for the southern MZ-1 managed area based on a maximum pumping rate time and vertical and spatial area. Until it can be established that there can be a definitive "cause and effect" relationship with reproducible results (i.e. pumping this much and for this long will cause a permanent lowering of the land surface), then we are still in the investigation phase of applying the scientific method.	development of the Guidance Criteria during the IMP, the piezometric levels in the deep aquifer system at the PA-7 piezometer have not been lowered to or past the Guidance Level to test whether the results of pumping tests conducted during the IMP are reproducible. The Engineer and the Committee have continued to recommend analyzing ongoing monitoring data and conducting the Long-Term Pumping Test to evaluate the Guidance Level. No changes have been made to the text to address this comment.
11	Page 3-1, Section 3-1	I also think that the GLMC should discuss the fact that if there definitely is non-recoverable compaction due to pumping, then a threshold subsidence limit should be established. For example, Santa Clara Water District operates their basin on a subsidence threshold of one ft/100 years (0.01 ft/yr). However, they have the advantage of being able to show more of a cause and effect between pumping and land lowering--we have yet to establish that in my opinion.	This comment and recommendation can be discussed at future Committee meetings.
12	Page 3-2, Section 3.1.2.2	I still think we are splitting hairs on interpretation of this data. One needs to look at all of the pumping that has been done and all of the hysteresis loops to see if they are "reproducible".	The Ayala Park Extensometer is the key monitoring facility in the Managed Area. The data, and interpretations of the data, were used to develop the Guidance Criteria. It is appropriate to continue to interpret the Ayala Park Extensometer data to evaluate the effectiveness of the Guidance Criteria. No changes have been made to the text to address this

Comment Number	Reference	Comment	Response
			comment.
13	Page 4-1, Section 4.1	Since Francis Riley is not available, maybe we should think about occasionally having a subsidence expert from the USGS give an independent opinion on what all of the past data showed (or didn't show) and if the GLMC is on the right track in general.	Committee members have technical experts attend and participate in the Committee activities. That said, this suggestion can be discussed at future Committee meetings.
14	Page 4-1, Section 4.1	Not 100% convinced if the +/- on the data measured is significant. Can we do statistical analyses to help us with the support we need to make statements like this? For example, what is the error on extensometer measurements, water level measurements etc. I think everything we are doing is good, I just don't have the confidence yet that it is reproducible.	We are unclear on what is being proposed in this comment. The comment can be discussed at future Committee meetings. No changes to the report text were made to address this comment.
15	Page 4-2, Section 4.2	Unless I missed it, I didn't see any task for conducting a 1-D subsidence model of all of the data we have collected to date from the Ayala Park extensometers. I think this would be very instructive to see if we could predict if what we are seeing (at least in part), may be from residual subsidence from lowering of water levels long ago. You have the data from the years of measurements and I think this task should be done as soon as possible. I would recommend that the Don Helms model be used as it is simple and easy to implement.	Watermaster has constructed and calibrated a 1D compaction model at the Ayala Park location. That said, there is no task in the FY 2016-17 scope of work to update and run this 1D model. This suggestion can be discussed at future Committee meetings. No changes to the report text were made to address this comment.
16	Page 5-3, Glossary	For purposes of this report, subsidence will be the permanent lowering of the land surface due to non-recoverable compaction of fine-grained materials in the aquifer sections caused by withdrawal of groundwater.	In this document, the word “subsidence” does not indicate cause. It describes the permanent (non-recoverable) sinking of the land surface.

B-5 City of Chino

Comment Number	Reference	Comment	Response
1		We did not see that the results of the horizontal measurements by the Daniels horizontal extensometer and EDM measurements were described in the report. We believe these results should be included for completeness.	Added language to Section 3.1.2.4: "In April 2016, the DHX was decommissioned because the property was sold for development. During FY 2016-17, the DHX and EDM data collected in the Managed Area to date will be analyzed with respect to local groundwater levels and vertical ground motion to assess the usefulness of the horizontal extensometer as a tool to measure ground motion and, if deemed useful, to determine a potential location for the re-installation of the DHX in the Managed Area."
2	Section 3.6	Additionally, Section 3.6 (Seismicity) does not mention the 1988 and 1990 EQs on the San Jose fault.	The 1988 and 1990 earthquakes occurred prior to the beginning of the available InSAR record for the Northwest MZ-1 Area and prior to the implementation of the Ground-Level Monitoring Program. Because the vertical ground motion record is not available for the period of the earthquakes, an analysis of ground-level data verses earthquake events is not possible. No changes to the report text were made to address this comment.

WILDERMUTH ENVIRONMENTAL, INC.



Corporate Office
23692 Birtcher Drive
Lake Forest, California 92630
T: 949.420.3030
F: 949.420.4040

www.weiwater.com