The exhibits in this section show the state of ground-level subsidence in the Chino Basin, using data from the Chino Basin ground-level monitoring program that was designed to minimize and/or abate land subsidence.

One of the earliest indications of land subsidence in Chino Basin was the appearance of ground fissures 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.

In 1999, the OBMP Phase I Report (WEI, 1999) identified pumping-induced drawdown and subsequent aquifer-system compaction as the most likely cause of land subsidence and ground fissuring observed in MZ1. Program Element 1 – *Develop and Implement a Comprehensive Monitoring Program*, called for basin-wide analysis of land subsidence via ground-level surveys and remote sensing (InSAR), and ongoing monitoring based on the analysis of the subsidence data. 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 MZ1 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.

In 2000, the Implementation Plan in the Peace Agreement called for an aquifer system and land subsidence investigation in the southwestern region of MZ1 to support the development of a management plan for MZ1 (second and third bullets above). This investigation was titled the MZ1 Interim Monitoring Program (IMP). From 2001-2005, Watermaster developed, coordinated, and conducted the IMP under the guidance of the MZ1 Technical Committee, which was composed of representatives from all major producers in MZ1 and their technical consultants. The investigation methods, results, and conclusions are described in detail in the MZ1 Summary Report (WEI, 2006). The investigation provided enough information for Watermaster to develop Guidance Criteria for MZ1 producers in the investigation area that, if followed, would minimize the potential for subsidence and fissuring. The Guidance Criteria also formed the basis for the MZ1 Subsidence Management Plan (WEI, 2007b).

The Subsidence Management Plan was developed by the MZ1 Technical Committee and approved by Watermaster in October 2007. In November 2007, the California Superior Court, which retains continuing jurisdiction over the Chino Basin Adjudication, approved the Subsidence Management Plan and ordered its implementation. The Subsidence Management Plan calls for (1) the continued scope and frequency of monitoring implemented during the IMP within the MZ1 Managed Area (see Exhibit 52) 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.

Watermaster's current ground-level monitoring program includes:

- *Piezometric Levels.* Piezometric levels are an important part of the ground-level monitoring program because piezometric changes are the mechanism for aquifer-system deformation and land subsidence. Watermaster monitors piezometric levels at about 33 wells in MZ1. Currently, a pressure-transducer/data-logger is installed at each of these wells and records one water-level reading every 15 minutes. Watermaster also records depth-specific water levels at the piezometers located at the Ayala Park Extensometer Facility every 15 minutes.
- *Aquifer-System Deformation.* Watermaster records aquifer-system deformation at the Ayala Park Extensometer Facility (see Exhibit 52). At this facility, two extensometers, completed at 550 ft-bgs (Shallow Extensometer) and 1,400 ft-bgs (Deep Extensometer), record the vertical component of aquifer-system compression and/or expansion once every 15 minutes (synchronized with the piezometric measurements).
- *Vertical Ground-Surface Deformation.* Watermaster monitors vertical ground-surface deformation via the ground-level surveying and InSAR techniques established during the IMP. Currently, ground-level surveys are being conducted in the MZ1 Managed Area once per year. InSAR is the only monitoring technique being employed outside the MZ1 Managed Area, and InSAR data is analyzed once per year.
- *Horizontal Ground-Surface Deformation.* Watermaster monitors horizontal ground-surface displacement across the eastern side of the subsidence trough and the adjacent area east of the barrier/fissure zone. These data, obtained by electronic distance measurements (EDMs), are used to characterize the horizontal component of land surface displacement caused by groundwater production on either side of the fissure zone.

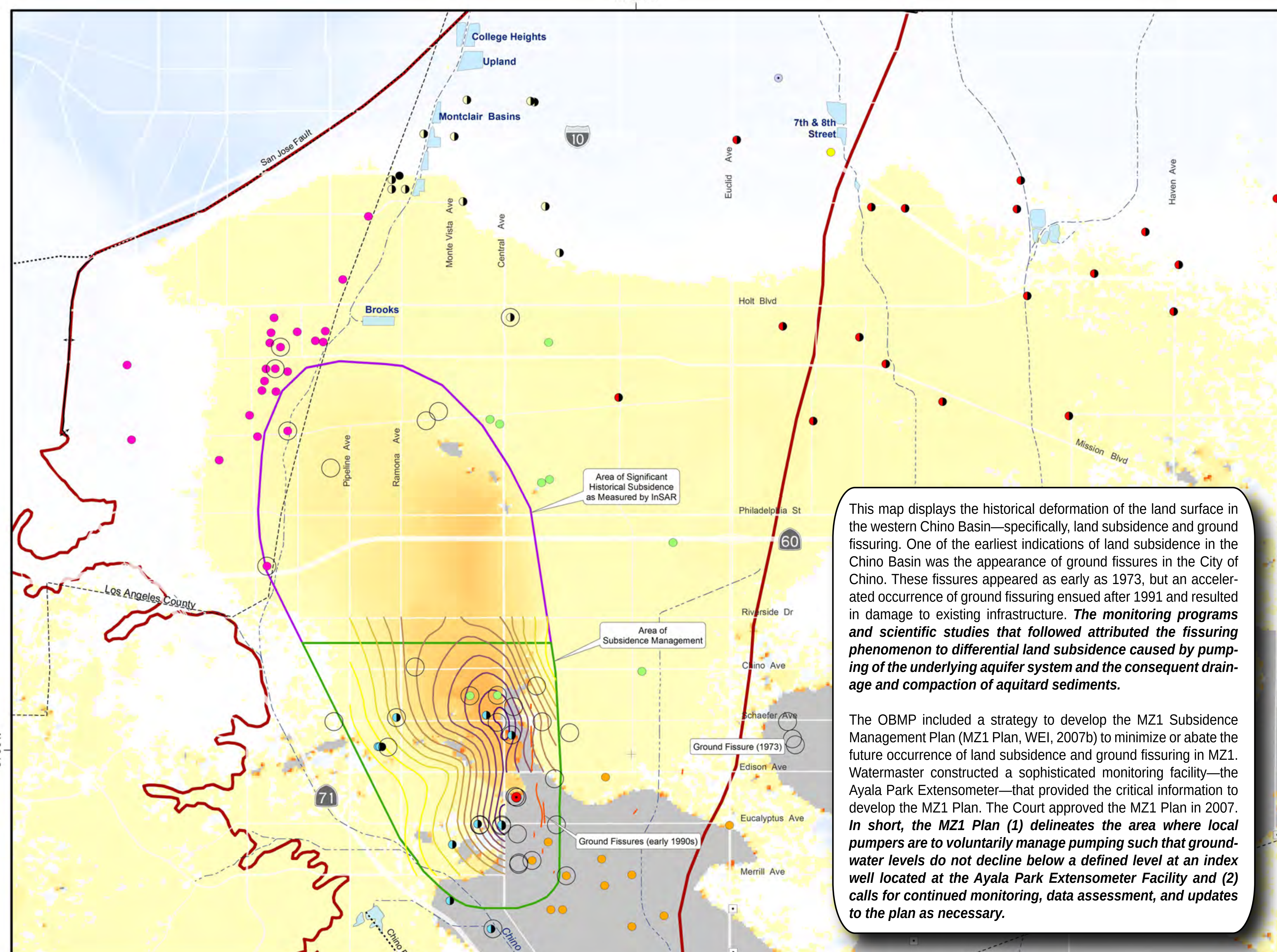
  Currently, Watermaster is collecting EDMs between east/west aligned benchmarks on Eucalyptus, Edison, Schaefer, and Philadelphia Avenues at a semiannual frequency (Spring/Fall).

Exhibits 52 through 54 show historical and recent ground surface motion information collected from InSAR and ground-level surveys in MZ1 and across the Chino Basin.

Historical ground motion data (shown in Exhibit 52) and recent ground motion data (shown in Exhibits 53 and 54) indicate that land subsidence concerns in the Chino Basin are confined to certain portions of MZ1 and MZ2. These "areas of subsidence concern" are delineated and labeled in Exhibits 53 and 54. Besides the MZ1 Managed Area, Watermaster has designated four additional areas of subsidence concern: the Central MZ1 Area, the Pomona Area, the Ontario Area, and the Southeast Area.

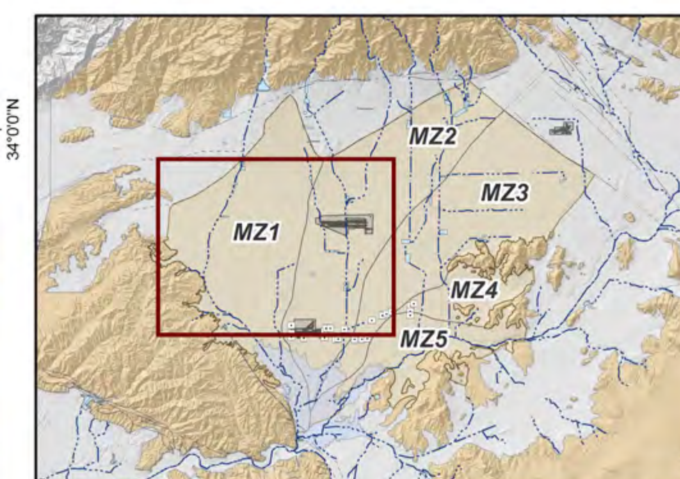
The recent land subsidence that has occurred in each of these areas is mainly controlled by recent and/or historical changes in groundwater levels, which, in turn, are mainly controlled by pumping and recharge. Exhibits 55 through 62 show the relationships between groundwater pumping, aquifer recharge, groundwater levels, and ground motion. These graphics reveal cause and effect relationships, the current state of ground motion, and the nature of current land subsidence (i.e. elastic and/or inelastic, differential, etc.). For each area of concern, if applicable, two time history charts are included to display 1) the long-term history of the data beginning in 1930, and 2) the recent, higher resolution data beginning in 1990. Discussions of these data are included on the first exhibit for each area of subsidence concern. Only one time history chart combining the historical and recent data is shown for the MZ1 Managed Area (Exhibit 55), and the Southeast Area (Exhibit 62), because the historical data only goes back to 1974, and 1987, respectively.

Watermaster convenes a Land Subsidence Committee to review the data from the ground-level monitoring program. This committee evaluates the appropriateness of the guidance criteria in the MZ1 Plan annually and recommends changes if necessary. The committee also recommends changes to the ground-level monitoring program if needed. Watermaster's Subsidence Management Plan is a prime example of adaptive management based on current technical information.




This map displays the historical deformation of the land surface in the western Chino Basin—specifically, land subsidence and ground fissuring. One of the earliest indications of land subsidence in the Chino Basin was the appearance of ground fissures 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. ***The monitoring programs and scientific studies that followed 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.***

The OBMP included a strategy to develop the MZ1 Subsidence Management Plan (MZ1 Plan, WEI, 2007b) to minimize or abate the future occurrence of land subsidence and ground fissuring in MZ1. Watermaster constructed a sophisticated monitoring facility—the Ayala Park Extensometer—that provided the critical information to develop the MZ1 Plan. The Court approved the MZ1 Plan in 2007. ***In short, the MZ1 Plan (1) delineates the area where local pumpers are to voluntarily manage pumping such that groundwater levels do not decline below a defined level at an index well located at the Ayala Park Extensometer Facility and (2) calls for continued monitoring, data assessment, and updates to the plan as necessary.***

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Date: 20110906
File: Exhibit_52.mxd

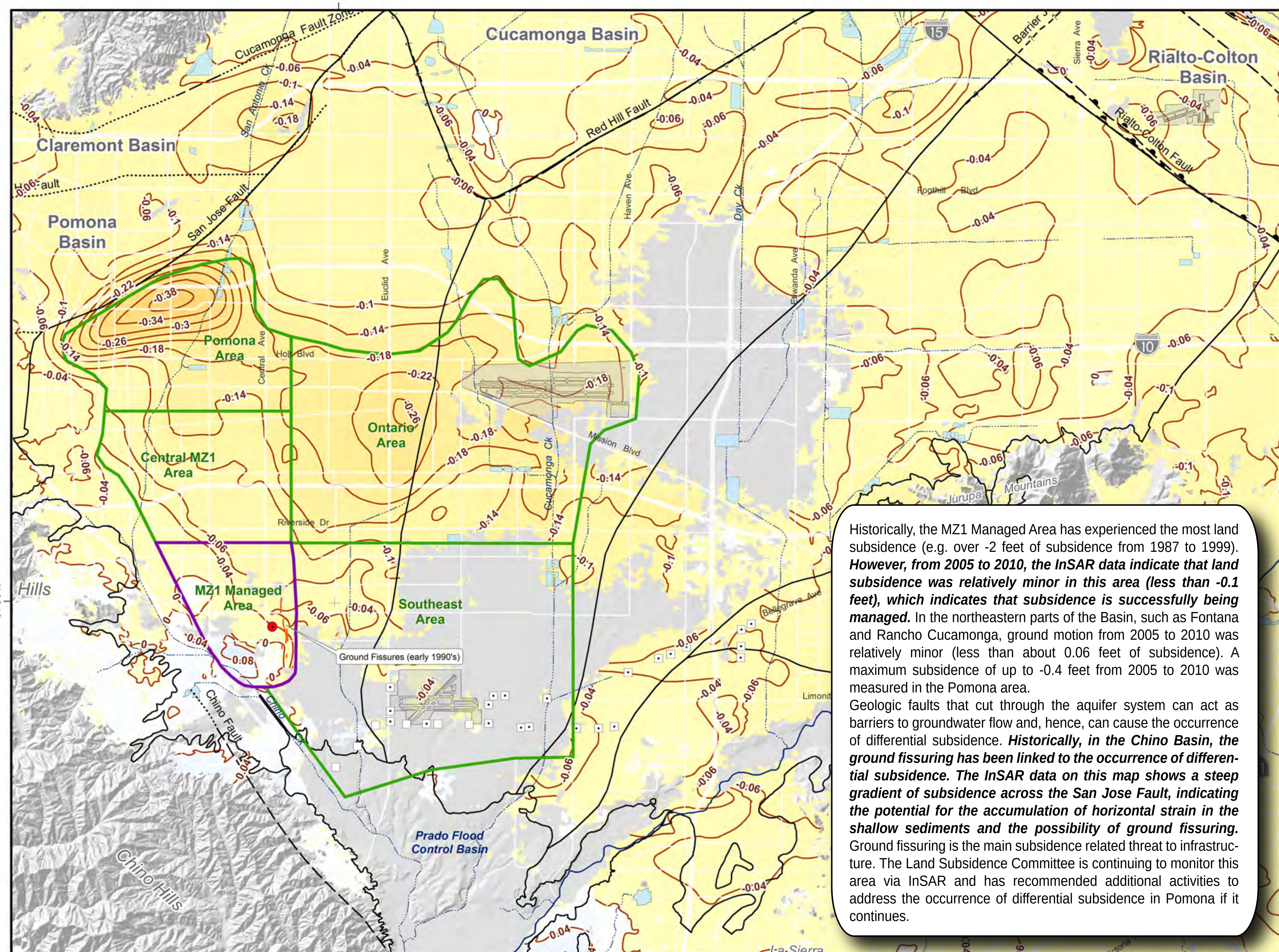
0 1 2 3 Miles
0 1 2 3 4 KM

**2010 State of the Basin**
*Ground-Level Monitoring*

## Historical Land Surface Deformation in Management Zone 1

*Leveling Surveys (1987 to 1999) and InSAR (1993 to 1995)*

**Exhibit 52**




Historically, the MZ1 Managed Area has experienced the most land subsidence (e.g. over -2 feet of subsidence from 1987 to 1999). ***However, from 2005 to 2010, the InSAR data indicate that land subsidence was relatively minor in this area (less than -0.1 feet), which indicates that subsidence is successfully being managed.*** In the northeastern parts of the Basin, such as Fontana and Rancho Cucamonga, ground motion from 2005 to 2010 was relatively minor (less than about 0.06 feet of subsidence). A maximum subsidence of up to -0.4 feet from 2005 to 2010 was measured in the Pomona area.

Geologic faults that cut through the aquifer system can act as barriers to groundwater flow and, hence, can cause the occurrence of differential subsidence. ***Historically, in the Chino Basin, the ground fissuring has been linked to the occurrence of differential subsidence. The InSAR data on this map shows a steep gradient of subsidence across the San Jose Fault, indicating the potential for the accumulation of horizontal strain in the shallow sediments and the possibility of ground fissuring.*** Ground fissuring is the main subsidence related threat to infrastructure. The Land Subsidence Committee is continuing to monitor this area via InSAR and has recommended additional activities to address the occurrence of differential subsidence in Pomona if it continues.

Relative Change in Land Surface Altitude as Measured by InSAR June 2005 to September 2010 (feet)

+1 / 0 / -0.50 / -1

InSAR data absent (incoherent)

- Ayala Park Extensometer
- Ground Fissures (early 1990's)
- Proposed Chino Creek Desalter Well
- Existing Chino Desalter Well
- Chino Basin OBMP Management Zones
- MZ1 Managed Area
- Other Areas of Subsidence Concern
- Streams & Flood Control Channels
- Flood Control & Conservation Basins

*Faults*

- Location Certain
- Location Approximate
- Approximate Location of Groundwater Barrier
- Location Concealed
- Location Uncertain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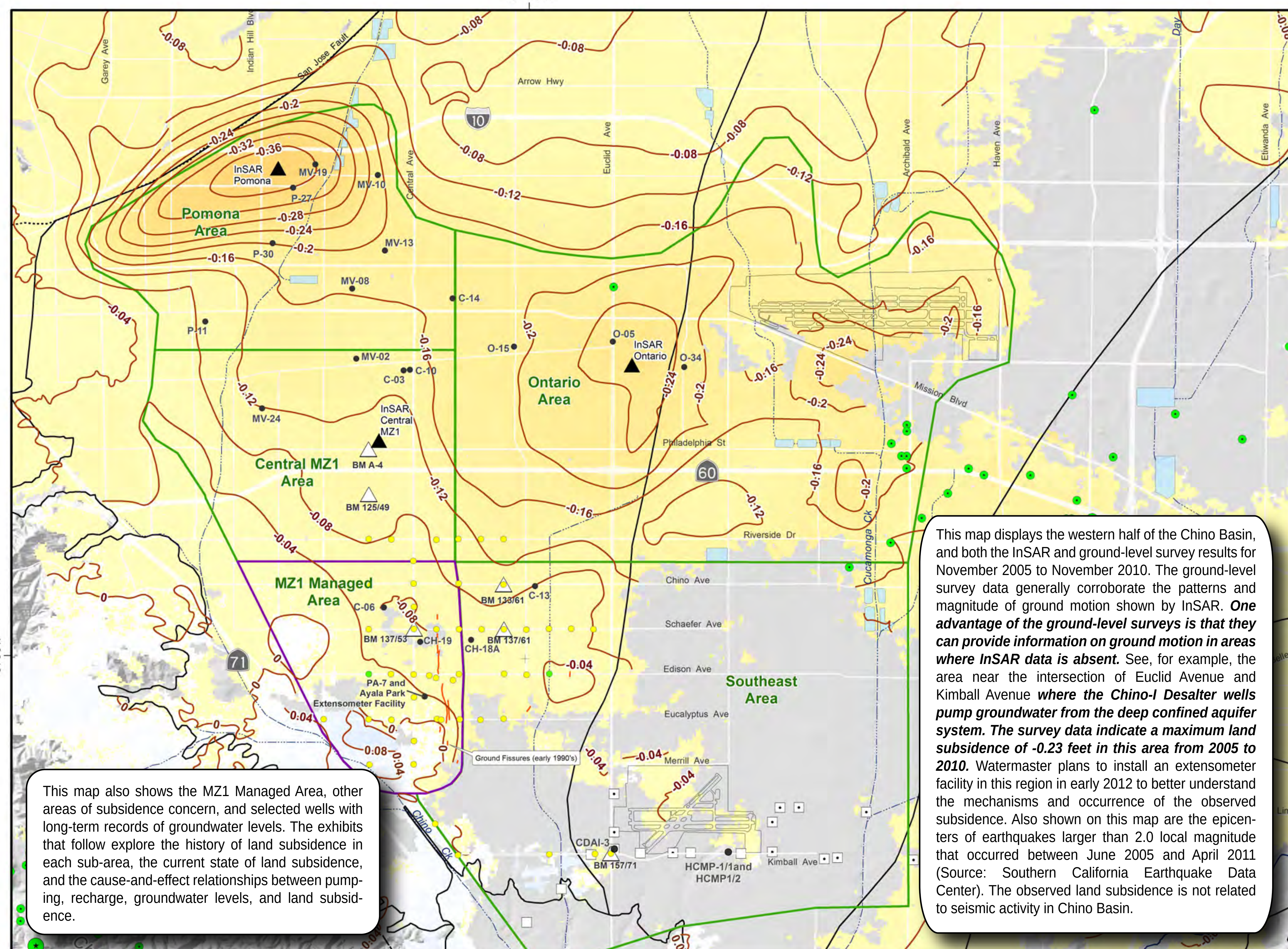
0 1 2 3 4 Miles
0 1 2 3 4 5 6 KM

2010 State of the Basin
*Ground-Level Monitoring*

## Vertical Ground Motion (2005 to 2010)

*as Measured by InSAR in the Chino Basin Area*

**Exhibit 53**




This map also shows the MZ1 Managed Area, other areas of subsidence concern, and selected wells with long-term records of groundwater levels. The exhibits that follow explore the history of land subsidence in each sub-area, the current state of land subsidence, and the cause-and-effect relationships between pumping, recharge, groundwater levels, and land subsidence.

This map displays the western half of the Chino Basin, and both the InSAR and ground-level survey results for November 2005 to November 2010. The ground-level survey data generally corroborate the patterns and magnitude of ground motion shown by InSAR. ***One advantage of the ground-level surveys is that they can provide information on ground motion in areas where InSAR data is absent.*** See, for example, 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 survey data indicate a maximum land subsidence of -0.23 feet in this area from 2005 to 2010.*** Watermaster plans to install an extensometer facility in this region in early 2012 to better understand the mechanisms and occurrence of the observed subsidence. Also shown on this map are the epicenters of earthquakes larger than 2.0 local magnitude that occurred between June 2005 and April 2011 (Source: Southern California Earthquake Data Center). The observed land subsidence is not related to seismic activity in Chino Basin.

**Relative Change in Land Surface Altitudes Measured by Leveling Surveys November 2005 to November 2010 (feet)**

- Insufficient Data
- 0.75 - 1
- 0.50 - 0.75
- 0.25 - 0.50
- 0.01 - 0.25
- 0.00
- -0.01 - -0.25
- -0.25 - -0.50
- -0.50 - -0.75
- -0.75 - -1

**Relative Change in Land Surface Altitude as Measured by InSAR June 2005 to September 2010 (feet)**

+1, 0, -0.50, -1

InSAR data absent (incoherent)

- Water Level Wells (Exhibits 55 to 62)
- Chino Basin Desalter Well
- Proposed Chino Creek Desalter Well
- Survey Measurement Stations (Exhibits 55 to 62)
- Selected InSAR Measurement Point (Exhibits 56 to 62)
- Chino Basin OBMP Management Zones
- MZ1 Managed Area
- Other Areas of Subsidence Concern
- Ground Fissures (early 1990's)

**Earthquake Epicenters June 2005 to April 2011 (Local Magnitude)**

- 2
- 2 - 3
- 3 - 4
- 4 - 5
- < 5

**Faults**

- Location Certain
- Location Approximate
- Approximate Location of Groundwater Barrier
- Location Concealed
- Location Uncertain



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0 1 2 3 Miles
0 1 2 3 4 KM

**2010 State of the Basin**
*Ground-Level Monitoring*

## Vertical Ground Motion (2005 to 2010)

*Leveling Surveys and InSAR in Western Chino*

**Exhibit 54**

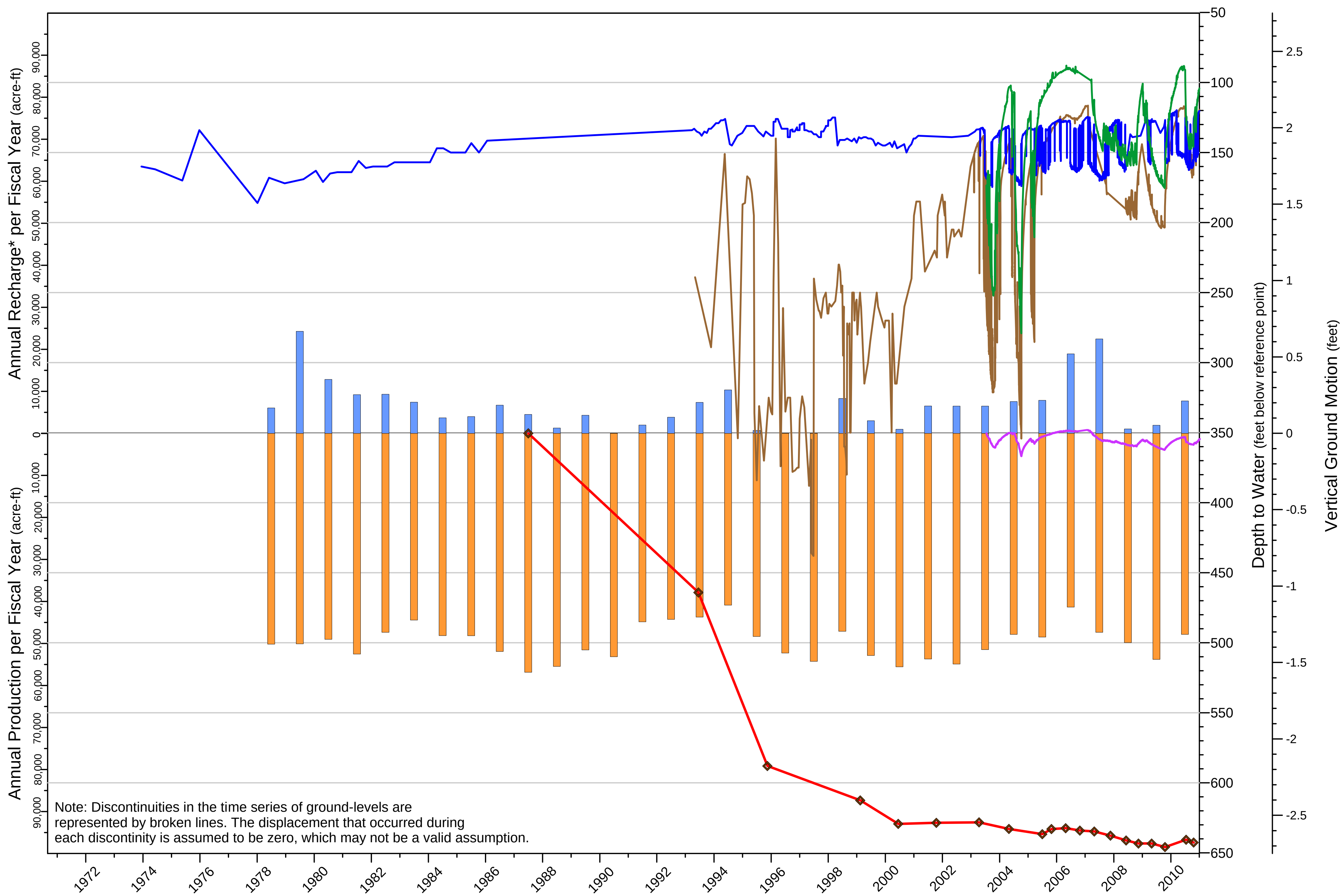


Exhibit 55 is a time series chart that displays annual pumping and recharge in MZ1, along with groundwater levels at wells and ground-level survey data at measurement stations within the MZ1 Managed Area (see Exhibit 54). The observations and conclusions described below were largely derived during the testing and monitoring that was performed by Watermaster during the development of the MZ1 Plan during 2000 to 2006.

Artificial recharge in the northern portions of MZ1 has no immediate impact on groundwater levels in the deep aquifer system. ***Pumping of the deep aquifer system is the main cause of groundwater-level changes and ground motion in the MZ1 Managed Area.***

Wells CH-19 and PA-7 are perforated within the deep aquifer system. Well C-06 is perforated in the shallow aquifer system. Pumping of the deep confined aquifer system causes groundwater- level drawdowns that are much greater in magnitude and lateral extent than drawdowns caused by pumping of the shallow aquifer system. Groundwater-level drawdowns due to pumping of the deep aquifer system can cause inelastic (permanent) compaction of the aquifer-system sediments, which results in permanent land subsidence. During controlled pumping tests in 2004 and 2005, the initiation of inelastic compaction within the aquifer system began to happen when groundwater-levels were drawdown about 250 feet below reference point (ft-brp) in the PA-7 piezometer at Ayala Park. I***n order to avoid inelastic compaction a guidance level of 245 feet in the PA-7 piezometer was established and is the primary criteria for the management of subsidence in the MZ1 Plan.***

This exhibit also shows the history of vertical ground motion measured at the Deep Extensometer at Ayala Park and at a benchmark monument (137/53) at the corner of Schaefer Avenue and Central Avenue. About -2.5 ft of subsidence occurred in portions of the ***MZ1 Managed Area from 1987 to 2000, but very little inelastic subsidence has occurred since 2000, and no additional ground fissuring has been observed.*** From 2006 to 2010, groundwater levels at PA-7 did not decline below 250 ft-brp, and very little, if any, inelastic compaction was recorded in the MZ1 Managed Area.

* Recharge includes imported water and recycled water delivered to recharge basins, and does not include in-lieu replenishment water.


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**Groundwater Levels at Wells (top-bottom of well screen)**
- PA-7 (438-448 ft-bgs)
- CH-19 (340-1000 ft-bgs)
- C-06 (200-375 ft-bgs)

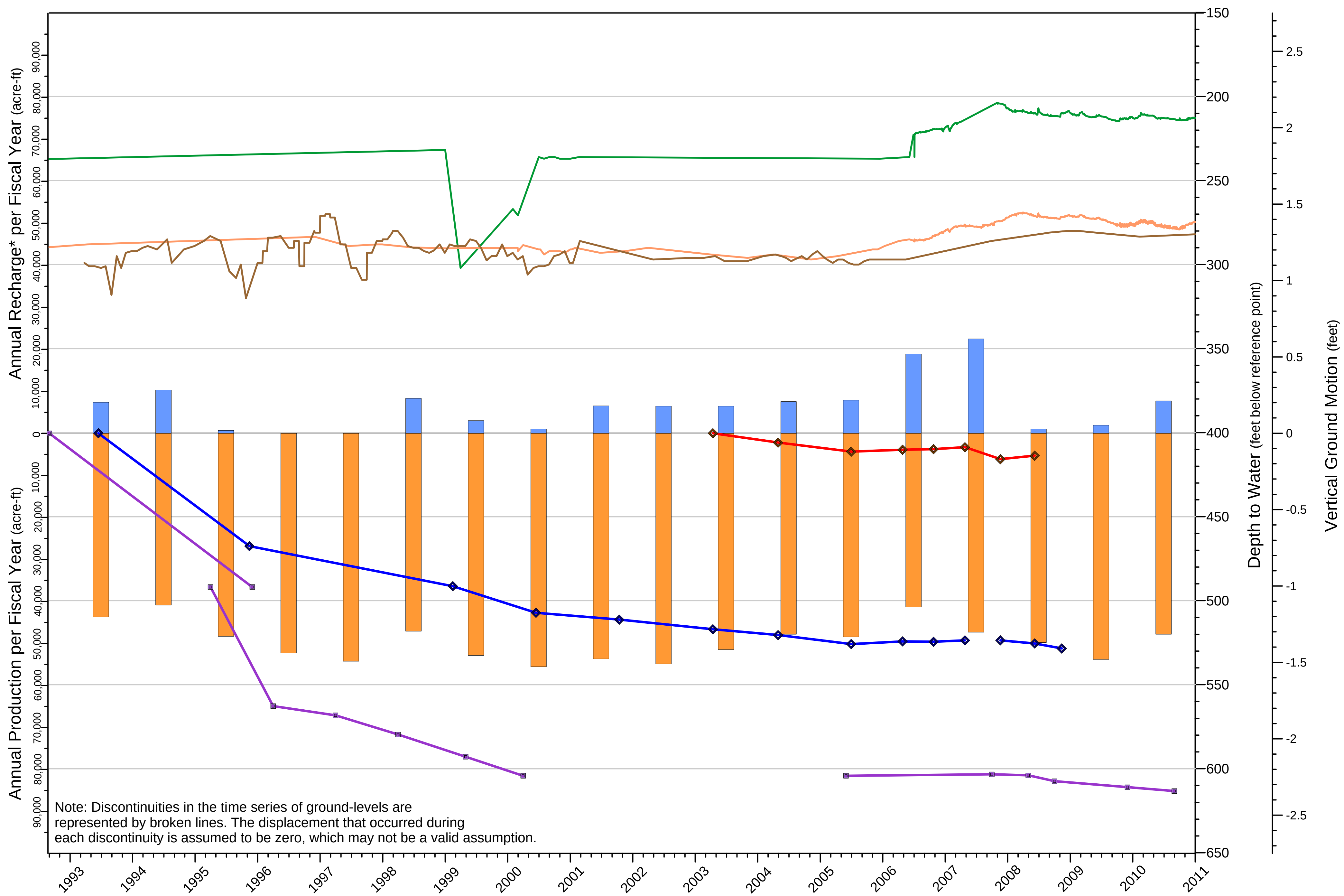
**Production & Recharge in MZ1**
- Recharge*
- Groundwater Production

**Ground-Levels**
- BM 137/53 Survey Measurements
- Deep Extensometer at Ayala Park (1,400 ft-bgs)

**2010 State of the Basin**
Ground-Level Monitoring

## Groundwater Levels versus Ground-Levels in the MZ1 Managed Area
*1970 to 2010*

**Exhibit 55**




The Central MZ1 subsidence area is located directly north of the MZ1 Managed Area. Exhibits 56 and 57 are time series charts that display annual production and recharge in MZ1, along with groundwater levels at wells and ground-level survey data at measurement stations within the Central MZ1 Area (see Exhibit 54).

The vertical ground motion time histories for Central MZ1 subsidence area are similar to those of the MZ1 Managed Area: ***as much as -2.2 feet of inelastic subsidence occurred at the corner of Philadelphia and Monte Vista Avenue from 1993-2000, but very little inelastic subsidence has occurred since 2000.*** This similarity suggests a relationship to the causes of land subsidence in the MZ1 Managed Area; however, there is very little historical groundwater-level data in this area to confirm this relationship.

Most of the wells with historical groundwater level records are in the northern part of the Central MZ1 subsidence area (see Exhibit 54), where historical subsidence was not as pronounced. From about 1935 to 1978, groundwater levels in these wells declined by about 150 feet. Groundwater levels increase by about 50 feet during the 1980s and remained relatively stable until 2005. From 2005 to 2008, groundwater levels increased by about 25 feet, which was likely due to decreased pumping and increased recharge in MZ1. Since 2008, recharge in MZ1 has decreased, production has increased, and water levels have remained relatively stable

* Recharge includes imported water and recycled water delivered to recharge basins, and does not include in-lieu replenishment water.

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Groundwater Levels at Wells (top-bottom of well screen)
- C-10 (355-1090 ft-bgs)
- MVWD-24 (244-420 ft-bgs)
- MVWD-02 (397-962 ft-bgs)

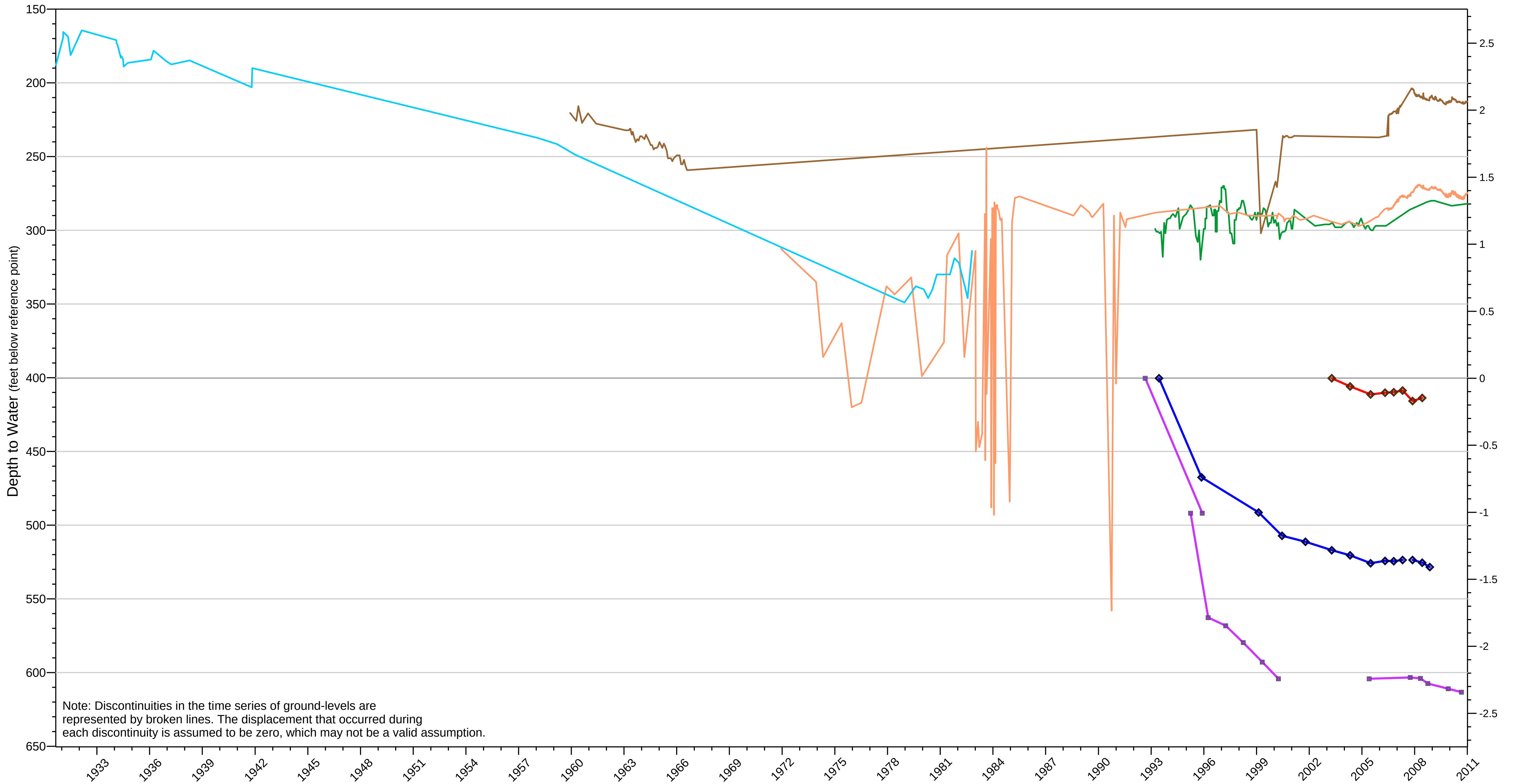
Production & Recharge in MZ1
- Recharge*
- Groundwater Production

Ground-Levels
- BM 125/49 Survey Measurements
- BM A-4 Survey Measurements
- Central-MZ1 InSAR Measurements

**2010 State of the Basin**
Ground-Level Monitoring

## Groundwater Levels versus Ground-Levels in the Central MZ1 Area
*1993 to 2010*

**Exhibit 56**

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Groundwater Levels at Wells (top-bottom of well screen)

- C-03 (230-450 ft-bgs)
- C-10 (355-1090 ft-bgs)
- MVWD-02 (397-962 ft-bgs)
- MVWD-24 (244-420 ft-bgs)

Ground-Levels

- Central-MZ1 InSAR Measurements
- BM A-4 Survey Measurements
- City BM 125/49 Survey Measurements

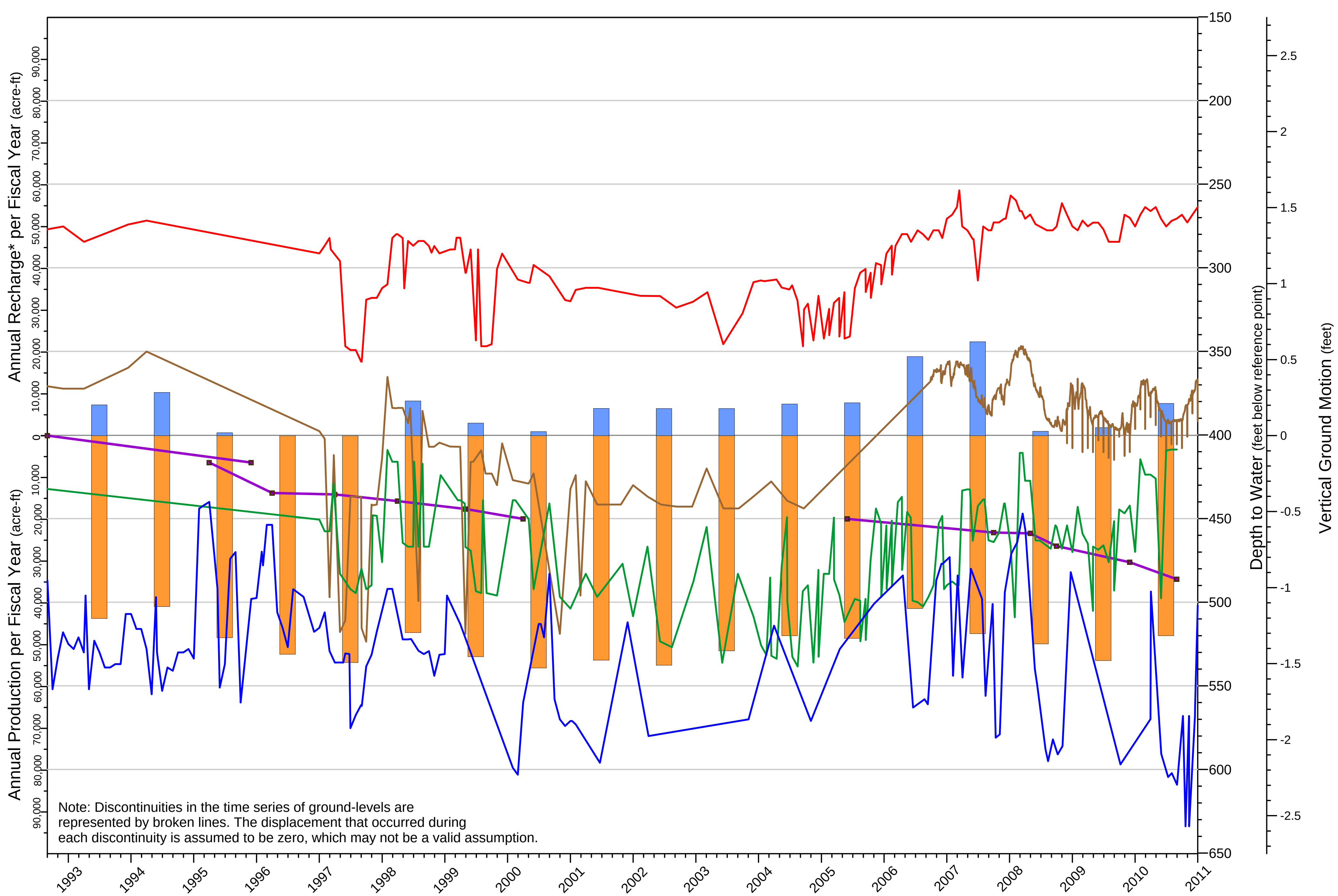
CHINO BASIN WATERMASTER

**2010 State of the Basin**
Ground-Level Monitoring

**Groundwater Levels versus Ground-Levels in the Central MZ1 Area**

*1930 to 2010*

**Exhibit 57**




The Pomona subsidence area is located directly north of the Central MZ1 subsidence area. Exhibits 58 and 59 are time series charts that display annual production and recharge within MZ1, along with groundwater levels at wells and ground-level survey data at measurement stations within the Pomona Area (see Exhibit 54).

The history of vertical ground motion in the Pomona subsidence area is based solely on InSAR data from 1992 to 1995, 1995 to 2000, and 2005 to 2010. ***These data indicate that land subsidence has occurred continuously in this area, generally at a rate of about 0.07 feet per year (ft/yr).***

From about 1935 to 1978, groundwater levels in the Pomona Area declined by about 175 feet or more. Groundwater levels increased by about 50 to 100 feet during the 1980s. From about 1990 to 2004, groundwater levels declined again by about 25 to 50 feet. From 2004 to 2008, groundwater levels increased by about 50 to over 100 feet. And, from 2008 to 2010, groundwater levels remained stable or declined slightly. ***The groundwater level changes from 1990 to 2010 appear to be closely related to pumping and recharge in MZ1.***

The observed, continuous land subsidence cannot be explained entirely by the corresponding changes in groundwater levels. A plausible explanation for the subsidence is that thick, slowly-draining aquitards are compacting in response to the historical drawdowns that occurred from 1935 to 1978 (see Exhibit 59).

* Recharge includes imported water and recycled water delivered to recharge basins, and does not include in-lieu replenishment water.

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Groundwater Levels at Wells (top-bottom of well screen)
- MVWD-19 (620-1230 ft-bgs)
- P-11 (168-550 ft-bgs)
- P-27 (472-849 ft-bgs)
- P-30 (565-875 ft-bgs)

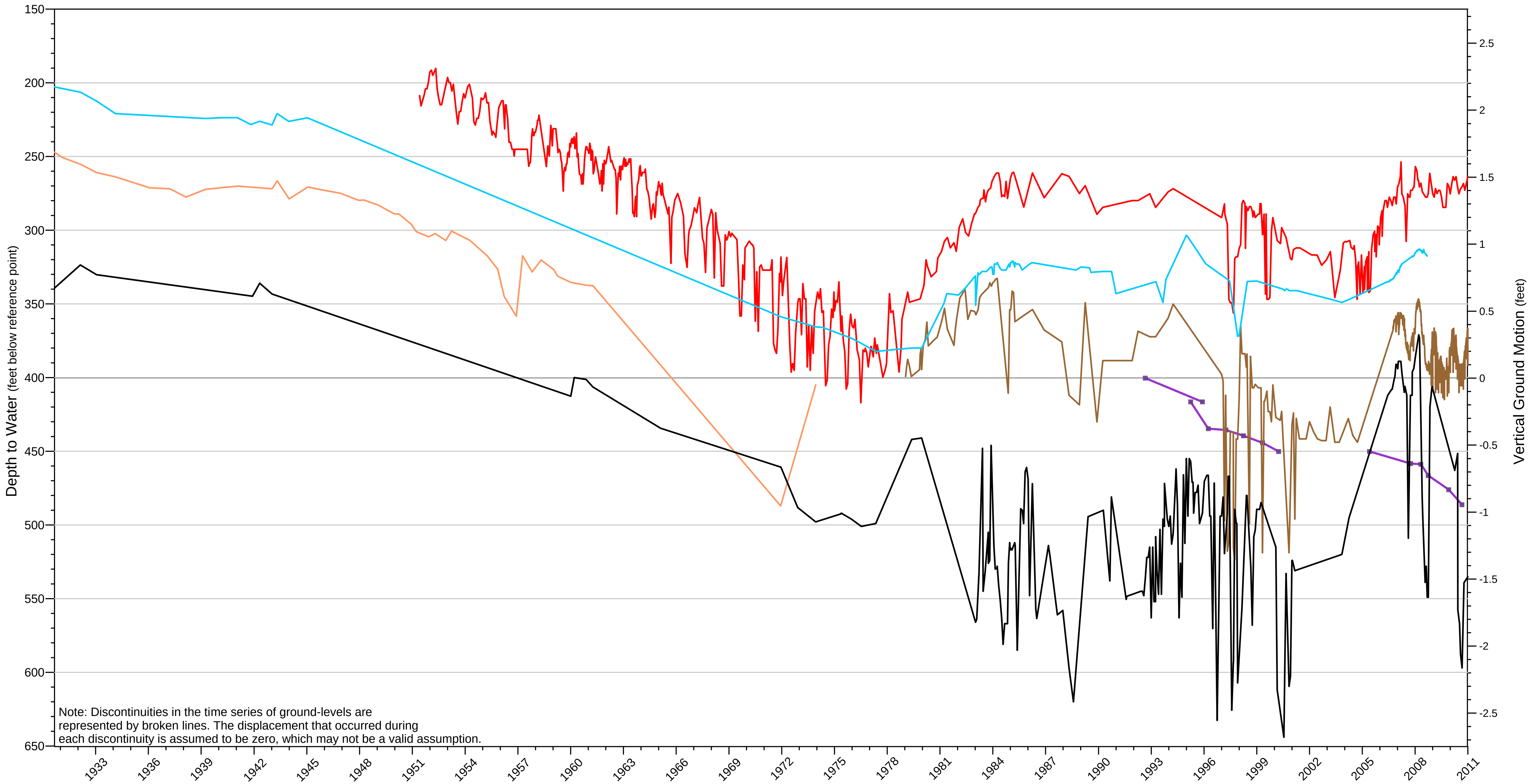
Production & Recharge in MZ1
- Recharge*
- Groundwater Production

Ground-Levels
- Pomona InSAR Measurements

**2010 State of the Basin**
Ground-Level Monitoring

## Groundwater Levels versus Ground-Levels in the Pomona Area
*1993 to 2010*

**Exhibit 58**

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Groundwater Levels at Wells
(top-bottom of well screen)

- MVWD-08 (225-447 ft-bgs)
- MVWD-10 (520-1084 ft-bgs)
- MVWD-13 (203-475 ft-bgs)
- P-11 (168-550 ft-bgs)
- P-30 (565-875 ft-bgs)

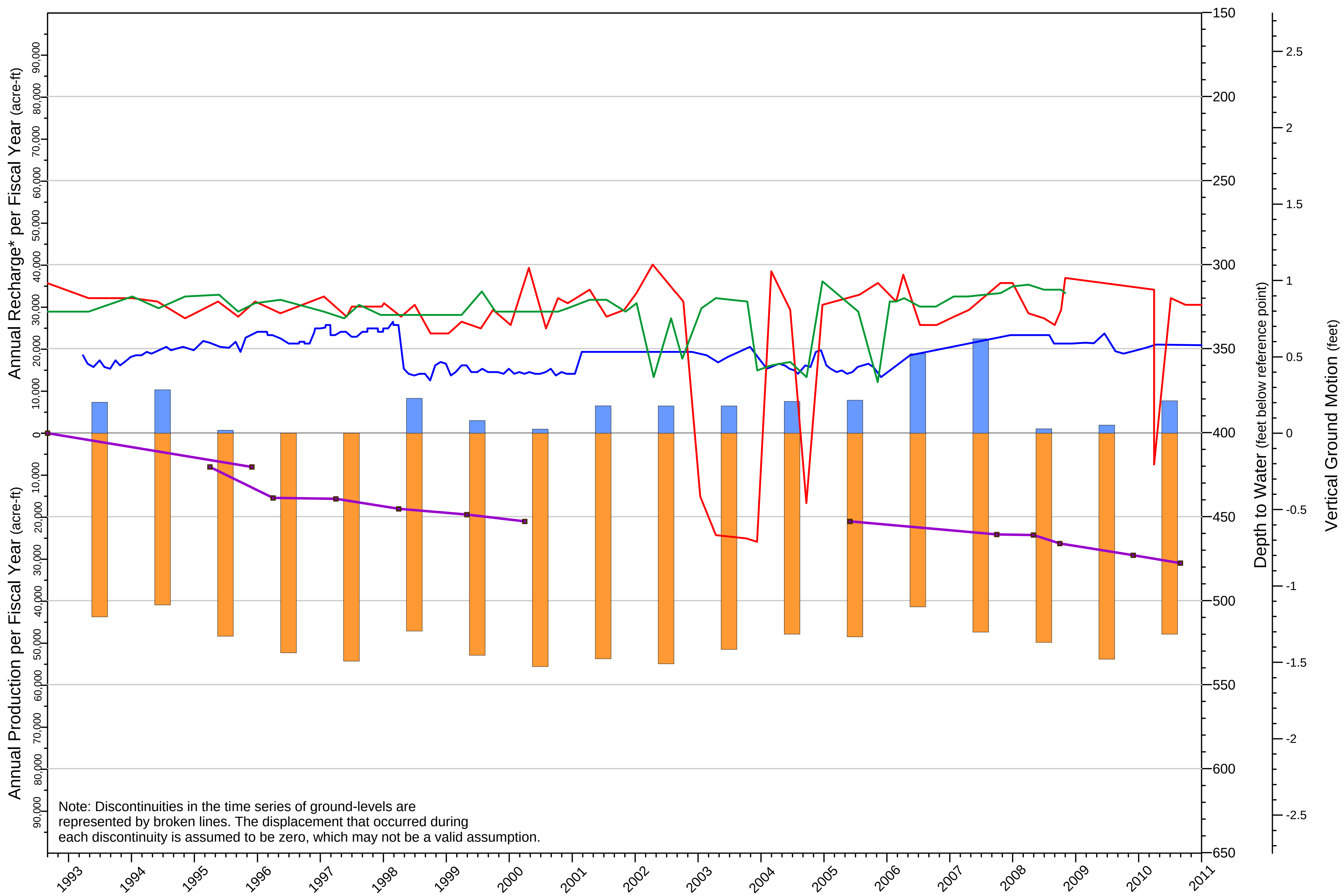
Ground-Levels

- Pomona InSAR Measurements

**2010 State of the Basin**
Ground-Level Monitoring

**Groundwater Levels versus Ground-Levels in the Pomona Area**
*1930 to 2010*

**Exhibit 59**




The Ontario subsidence area is located east of the Central MZ1 and the Pomona subsidence areas. Exhibits 60 and 61 are time series charts that display MZ1 annual production and recharge, along with groundwater levels at wells and ground-level survey data at measurement stations within the Ontario Area (see Exhibit 54).

The history of vertical ground motion in the Ontario Area is based solely on InSAR data from 1992 to 1995, 1995 to 2000, and 2005 to 2010. ***These data indicate that land subsidence has occurred continuously in this area, generally at a rate of about 0.07 ft/yr.***

From about 1935 to 1978, groundwater levels in the Ontario Area declined by about 125 feet. Groundwater levels increased by about 10 to 20 feet during the early 1980s and have remained relatively stable since then.

***The observed, continuous land subsidence from 1992 to 2010 is not explained by the relatively stable groundwater levels. A plausible explanation for the subsidence is that thick, slowly draining aquitards are compacting in response to the historical draw-downs that occurred from 1935 to 1978*** (see Exhibit 61).

* Recharge includes imported water and recycled water delivered to recharge basins, and does not include in-lieu replenishment water.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Groundwater Levels at Wells (top-bottom of well screen)

- C-14 (480-1200 ft-bgs)
- O-15 (474-966 ft-bgs)
- O-34 (522-1092 ft-bgs)

Production & Recharge in MZ1

- Recharge*
- Groundwater Production

Ground-Levels

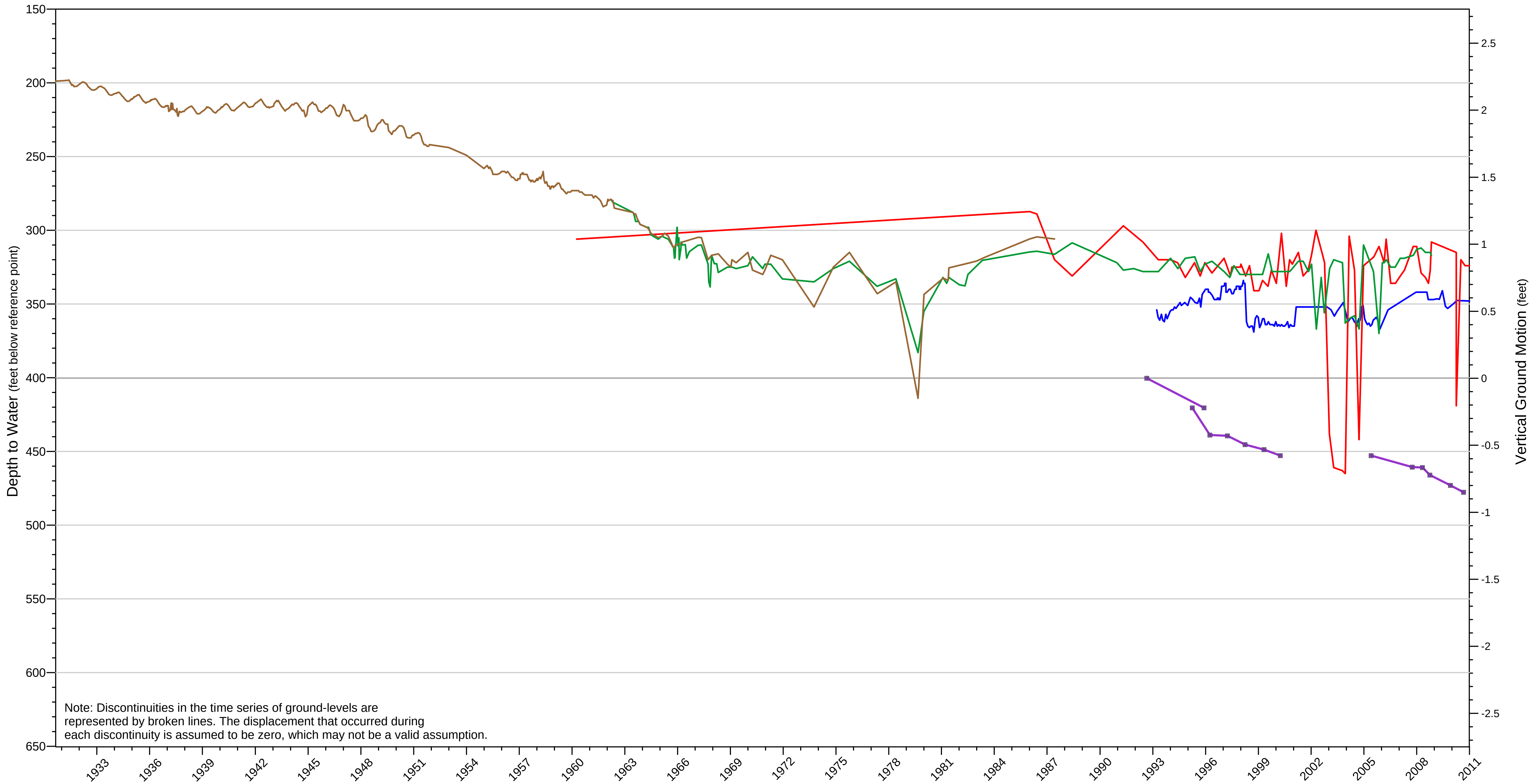
- Ontario InSAR Measurements

**2010 State of the Basin**
Ground-Level Monitoring

## Groundwater Levels versus Ground-Levels in the Ontario Area

*1993 to 2010*

**Exhibit 60**

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Groundwater Levels at Wells
(top-bottom of well screen)

O-05 (360-470 ft-bgs)
O-15 (474-966 ft-bgs)
O-34 (522-1092 ft-bgs)
C-14 (480-1200 ft-bgs)

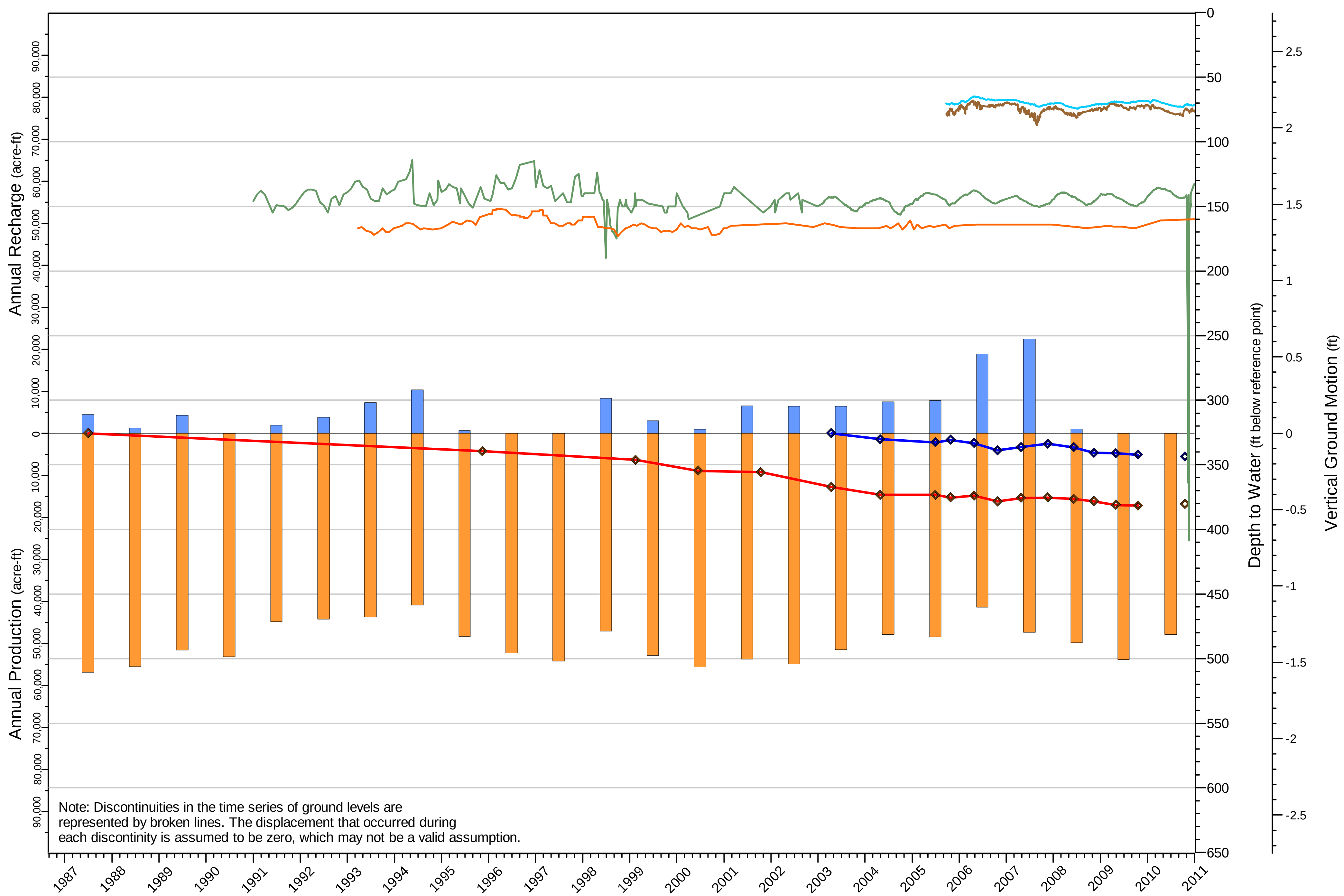
Ground-Levels

Ontario InSAR Measurements

**2010 State of the Basin**
Ground-Level Monitoring

**Groundwater Levels versus Ground-Levels in the Ontario Area**
*1930 to 2010*

**Exhibit 61**




The Southeast subsidence area is located east of the MZ1 Managed Area. This exhibit is a time series chart that displays annual production and recharge within MZ1, along with groundwater levels at wells and ground-level survey data at measurement stations within the Southeast Area. The history of vertical ground motion in the Southeast Area is based solely on ground-level surveys performed from 1987 to 2010.

In the northern portion of the Southeast Area, the ground-level survey data indicate that land subsidence has occurred continuously and slowly in this area, generally at a rate of about 0.02 ft/yr. There is very little historical groundwater-level data for this area prior to about 1990. ***The data since 1990 indicate relatively stable groundwater levels. The observed slow but continuous land subsidence from 1987 to 2010 is not explained by the relatively stable groundwater levels. A plausible explanation for the subsidence in this area is that thick, slowly-draining aquitards are compacting in response to the historical drawdowns 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 indicate land subsidence of about -0.23 feet in this area from 2005 to 2010. ***The desalter wells have been pumping since 2000, and have been causing drawdown within the deep aquifer system that is likely the cause of the observed land subsidence.*** Watermaster plans to install an extensometer facility in this region in early 2012 to better understand the mechanisms and occurrence of the subsidence in the vicinity of the Chino I-Desalter well field.

The first ground fissures documented in the Chino Basin occurred in the Southeast Area in the early 1970s, but ground fissuring has not been observed in the area since.

* Recharge includes imported water and recycled water delivered to basins, and does not include in-lieu replenishment water.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Groundwater Levels at Wells (top-bottom of well screen)
- 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)

Production & Recharge in MZ1
- Recharge*
- Groundwater Production

Ground Levels
- BM 137/61 Survey Measurements
- BM 133/61 Survey Measurements

**2010 State of the Basin**
Ground-Level Monitoring

## Groundwater Levels versus Ground-Levels in the Southeast Area

*1987 to 2010*

**Figure 62**