WEST YOST
Water. Engineered.

Ground-Level Monitoring Committee

October 3, 2024

Agenda

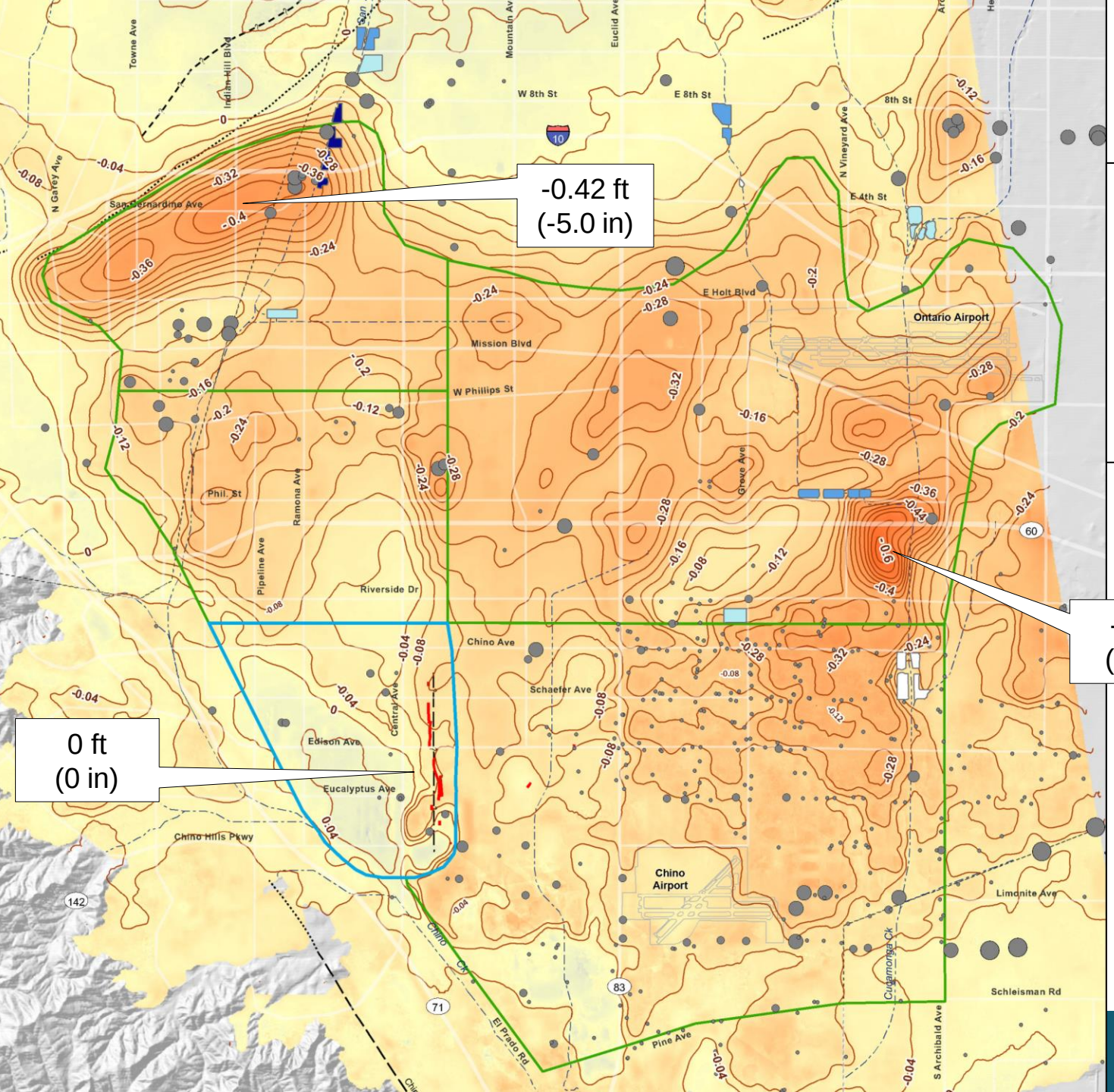
- **Review of Draft 2023/24 Annual Report of the Ground-Level Monitoring Committee**

Main Findings

2023/24 Annual Report for the GLMP

- InSAR has become an increasingly reliable and accurate method for monitoring of vertical ground motion across the Chino Basin.
- During 2023/24, subsidence has been minor across most Areas of Subsidence Concern. This is mainly due to decreased pumping and increased recharge associated with the recent relatively wet conditions and DYYP "puts." Exceptions were the eastern portions of the Southeast and Northeast areas, where maximum rates of recent subsidence have ranged from 0.02-0.04 ft/yr.
- The spatial extent of the Whispering Lakes Subsidence Feature closely aligns with the spatial extent of the Whispering Lakes Golf Course → Shallow soil consolidation is the likely cause of the ongoing subsidence.
- Future declines in hydraulic heads, caused by increases in pumping and/or decreases in recharge, could cause aquitard compaction and rates of land subsidence to increase.
- Pomona Extensometer is not recording logical (and therefore, accurate) data.

Vertical Ground Motion March 2011–March 2024



Relative Change in Land Surface Elevation as Estimated by InSAR (March 2011 to March 2024)

- High : 0.6
- 0 ft
- Low : -0.6
- InSAR absent or incoherent

Average Annual Groundwater Pumping April 1, 2011 to March 31, 2024 (afy)

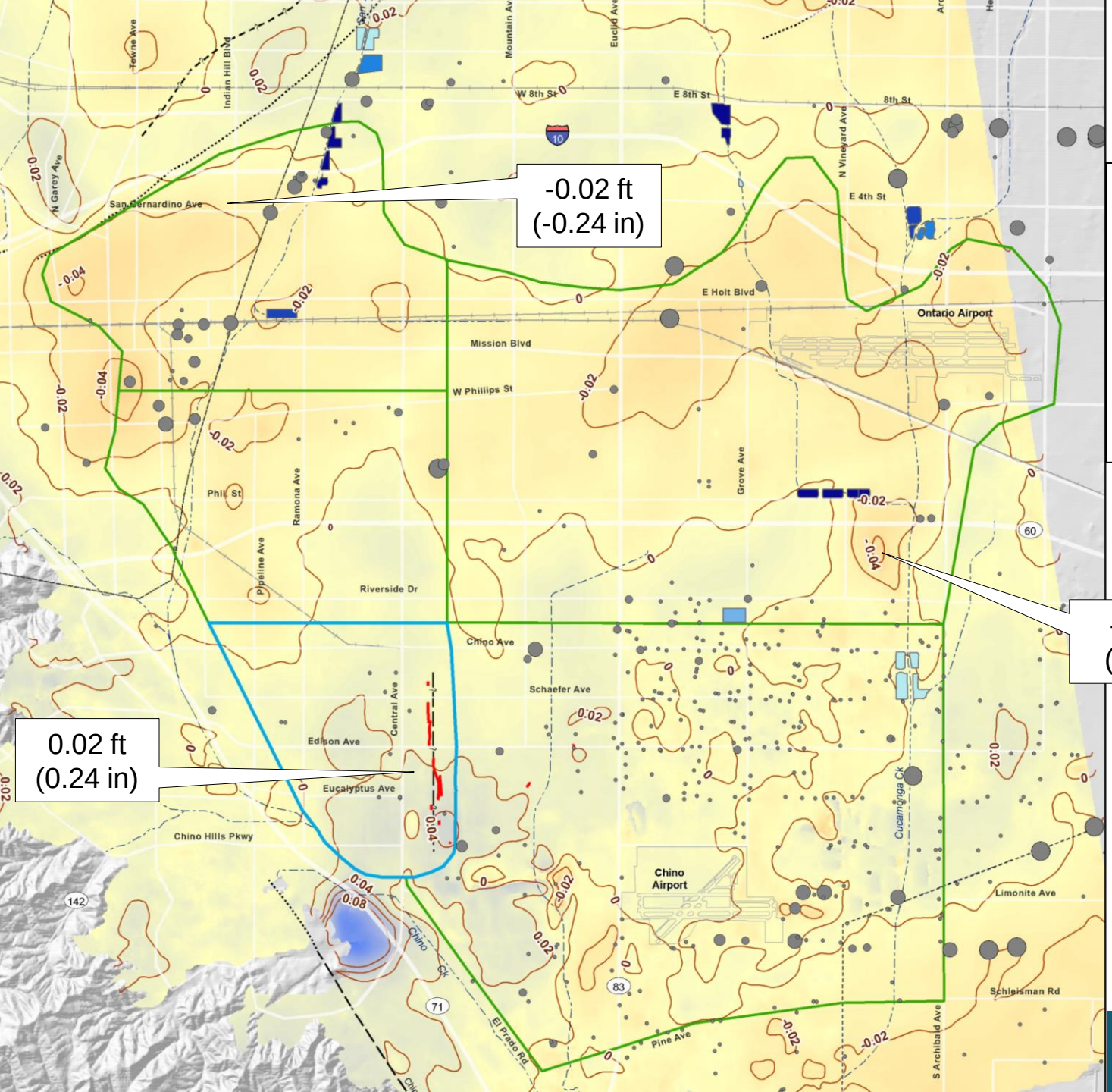
- 0 - 100
- 101 - 500
- 501 - 1,000
- 1,001 - 2,000
- > 2,000

Average Annual Basin Recharge April 1, 2011 to March 31, 2024 (afy)

- 0
- 1- 1500
- 1500 - 2500
- 2500 - 3500

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

Vertical Ground Motion March 2022–March 2023



Relative Change in Land Surface Elevation as Estimated by InSAR (March 2022 to May 2023)

- +0.2 ft
- 0 ft
- -0.2 ft
- InSAR absent or incoherent

Average Annual Groundwater Pumping April 1, 2022 to March 31, 2023 (afy)

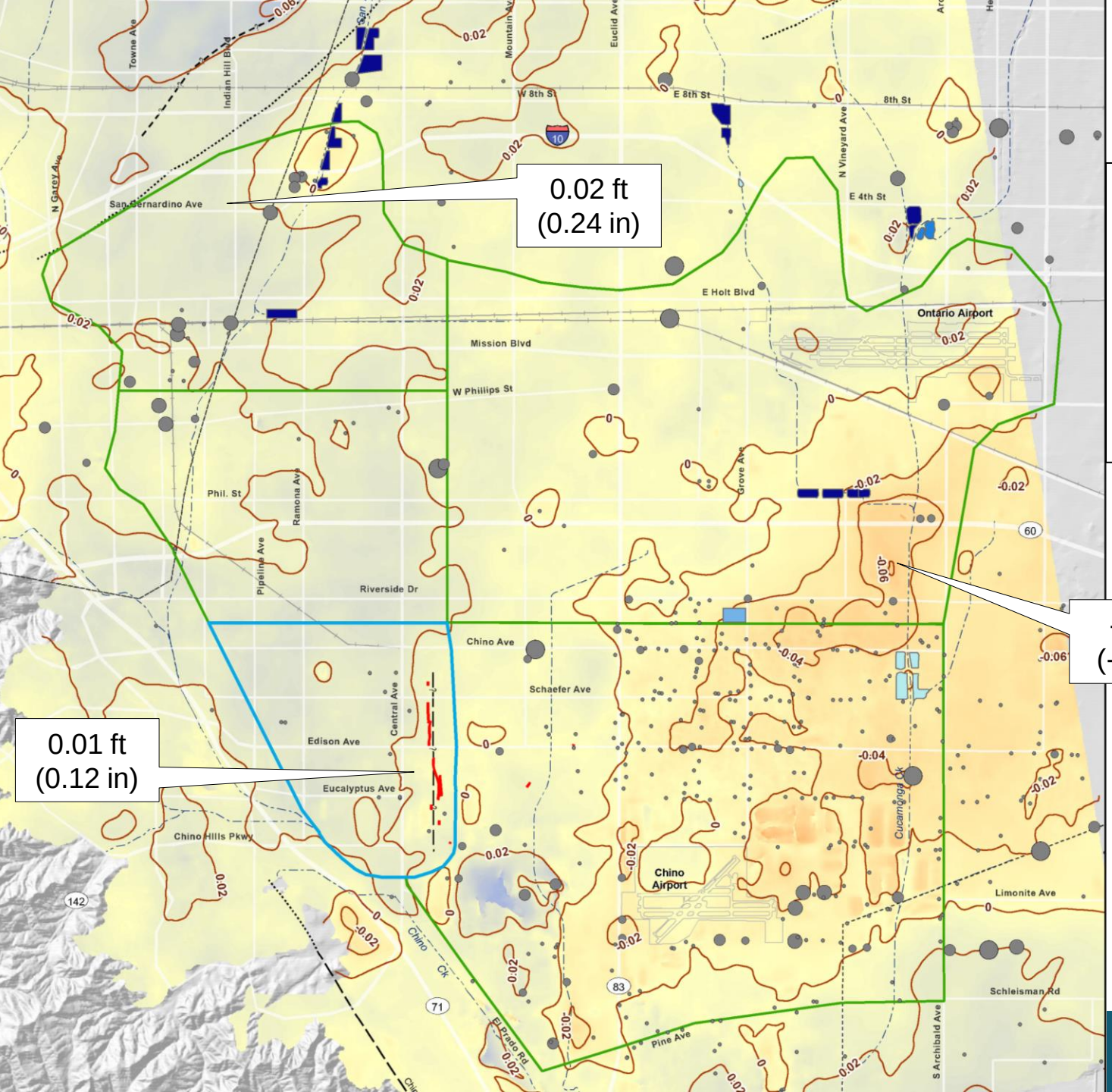
- 0 - 100
- 101 - 500
- 501 - 1,000
- 1,001 - 2,000
- > 2,000

Average Annual Basin Recharge April 1, 2022 to March 31, 2023 (afy)

- 0 - 250
- 250 - 500
- 500 - 750
- 750 - 1,250
- > 1,250

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

Vertical Ground Motion March 2023–March 2024



Relative Change in Land Surface Elevation as Estimated by InSAR (May 2023 to March 2024)

- +0.2 ft
- 0 ft
- -0.2 ft
- InSAR absent or incoherent

Average Annual Groundwater Pumping April 1, 2023 to March 31, 2024 (afy)

- 0 - 100
- 101 - 500
- 501 - 1,000
- 1,001 - 2,000
- > 2,000

Average Annual Basin Recharge April 1, 2023 to March 31, 2024 (afy)

- 0 - 250
- 250 - 500
- 500 - 750
- 750 - 1,250
- > 1,250

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

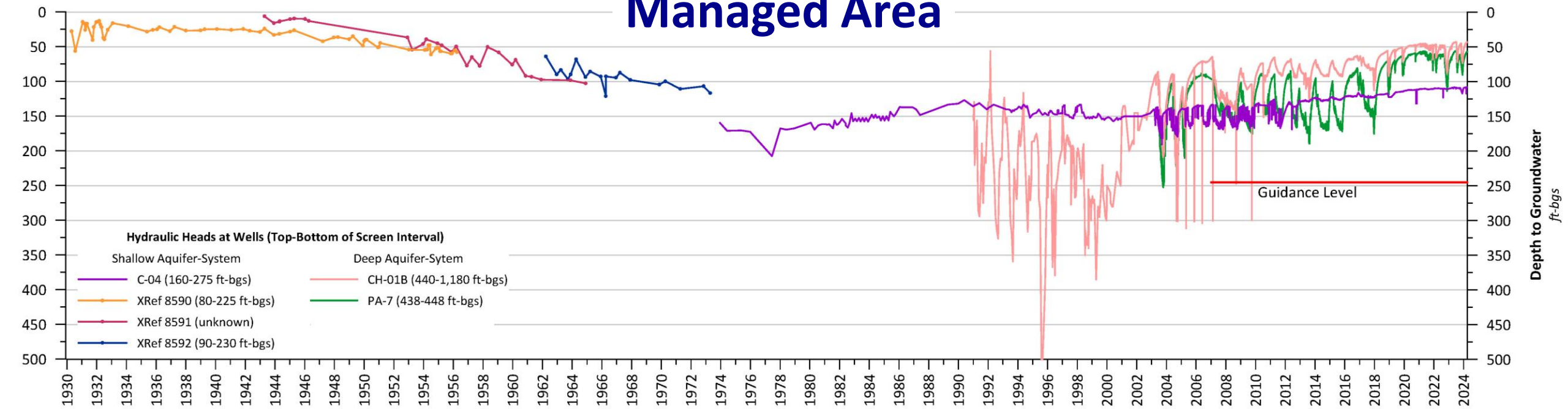
Conclusions and Recommendations: *InSAR Monitoring*

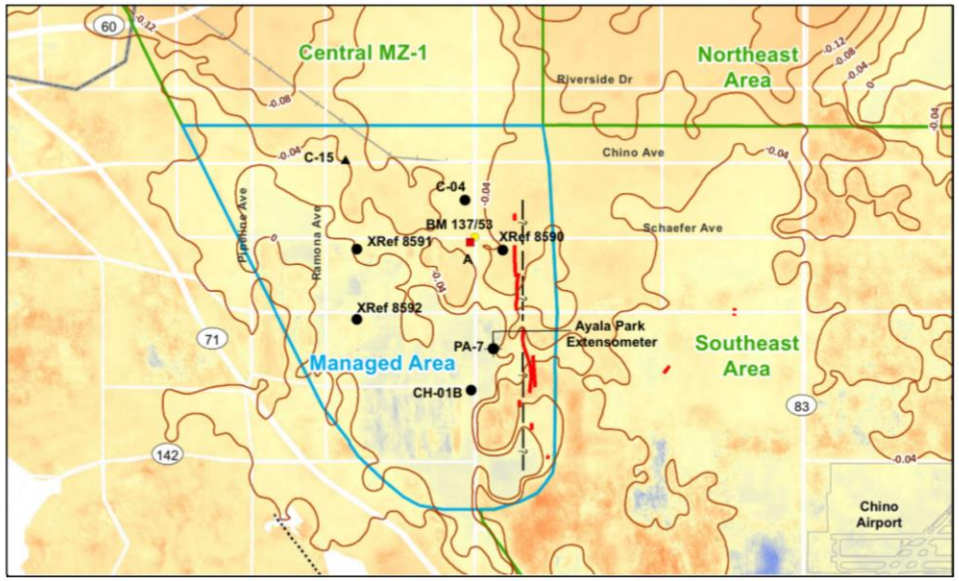
InSAR has become an increasingly reliable and accurate method for monitoring of vertical ground motion across the Chino Basin:

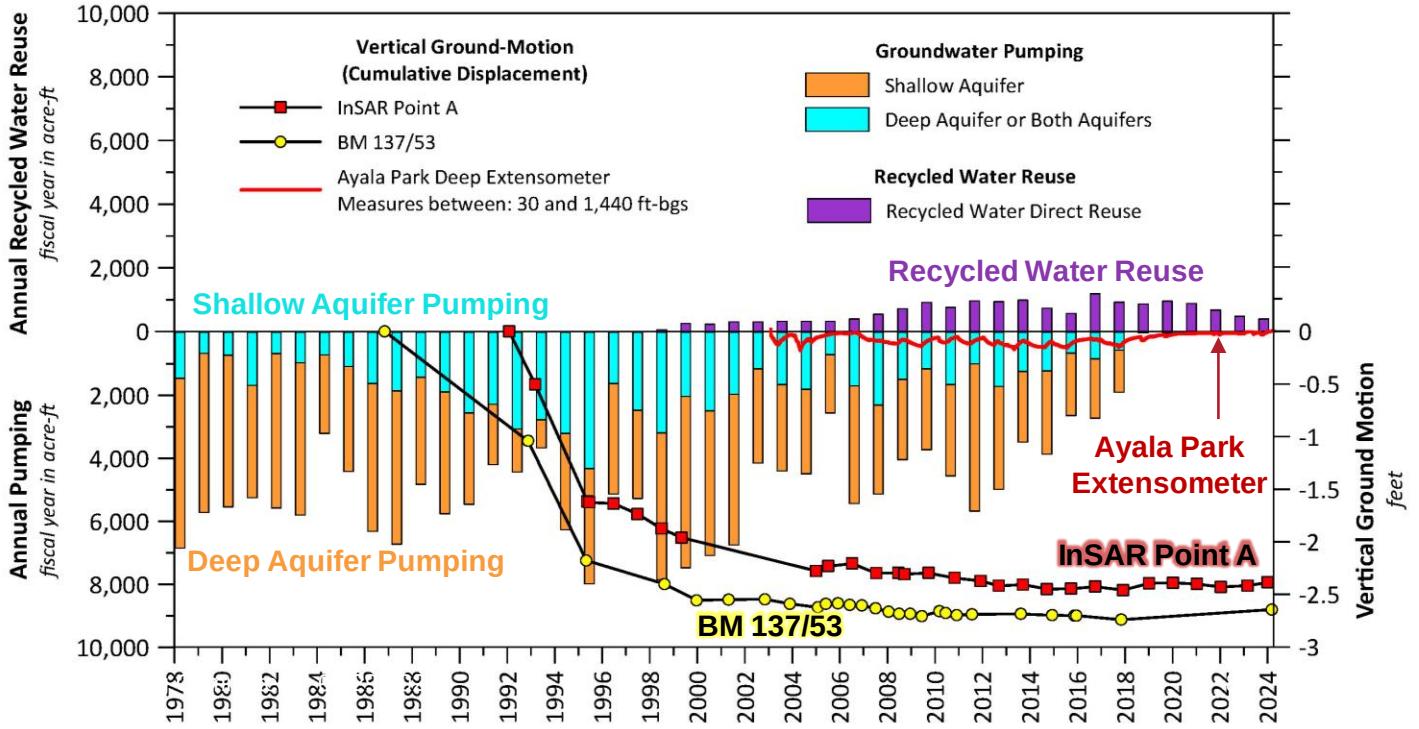
- TerraSAR-X satellite has relatively high spatial/temporal resolution and accuracy for InSAR monitoring.
- The original analysis team stays abreast of the newest InSAR products and processing techniques → GLMC receives InSAR of high accuracy, resolution, and coherence.
- Extensometer, InSAR, and ground-leveling show similar spatial pattern and magnitude of ground motion.
- Errors inherent in InSAR and traditional ground-level methods are similar.
- Land-use changes from ag to urban have added hard, consistent radar wave reflectors.

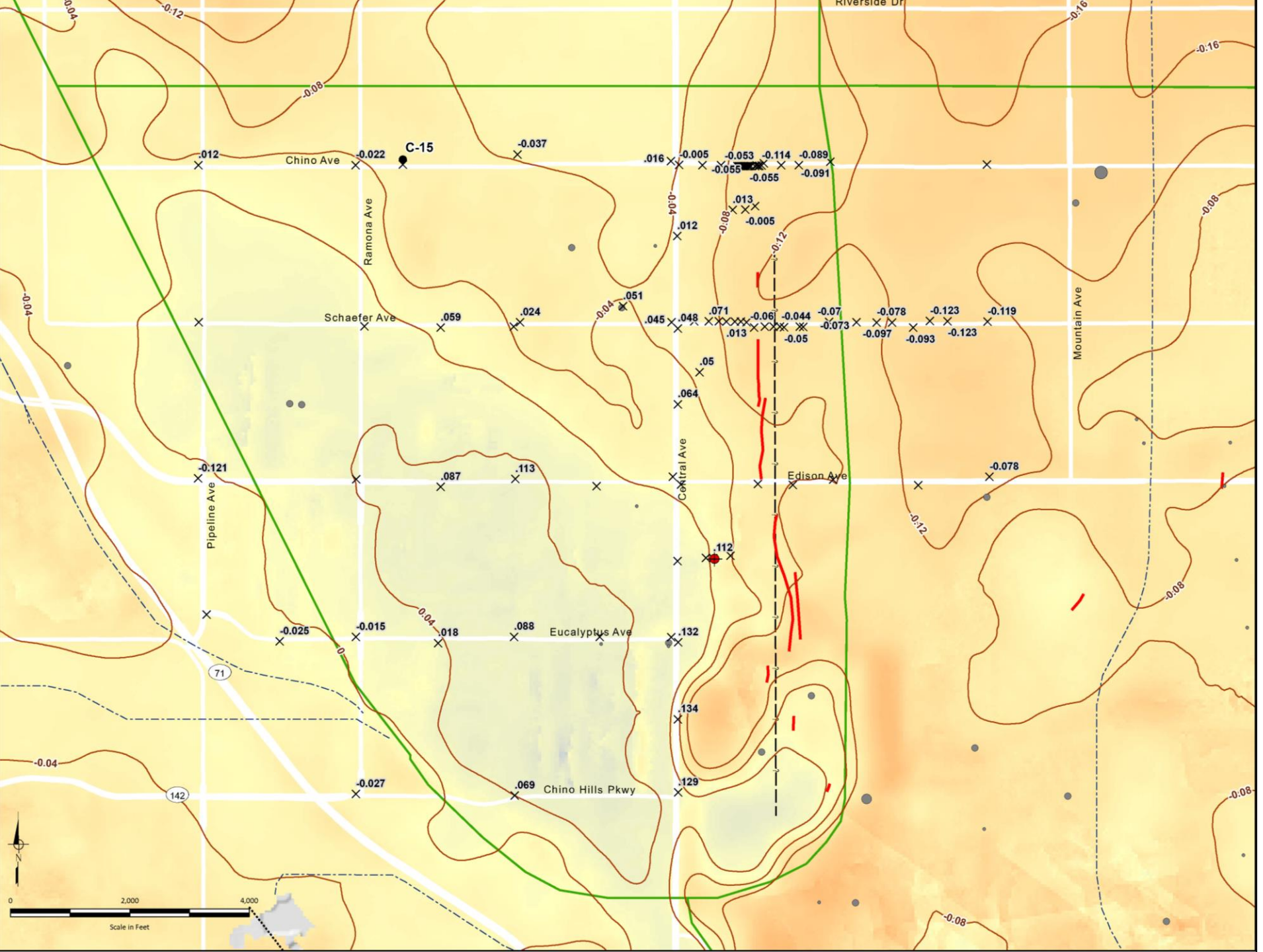
RECOMMENDATION: Watermaster should continue to prepare high-quality, high-resolution InSAR deliverables (using TerraSAR-X) to estimate vertical ground motion and reduce the frequency of performing ground-level surveys.

Managed Area









InSAR vs Surveys

Managed Area

Relative Change in Land Surface Elevation
as Estimated by InSAR
(March 2011 to March 2024)

High : 0.6

0

-0.3 ft

Low : -0.6

InSAR absent or incoherent

Ground-Level Survey Benchmark
(Measured May 3, 2024) Labeled
by Vertical Ground Motion
(in feet from November 2011 to
May 2024)

Average Annual Groundwater Pumping
April 1, 2011 to March 31, 2024
(afy)

- 0 - 100
- 101 - 500
- 501 - 1,000
- 1,001 - 2,000
- > 2,000

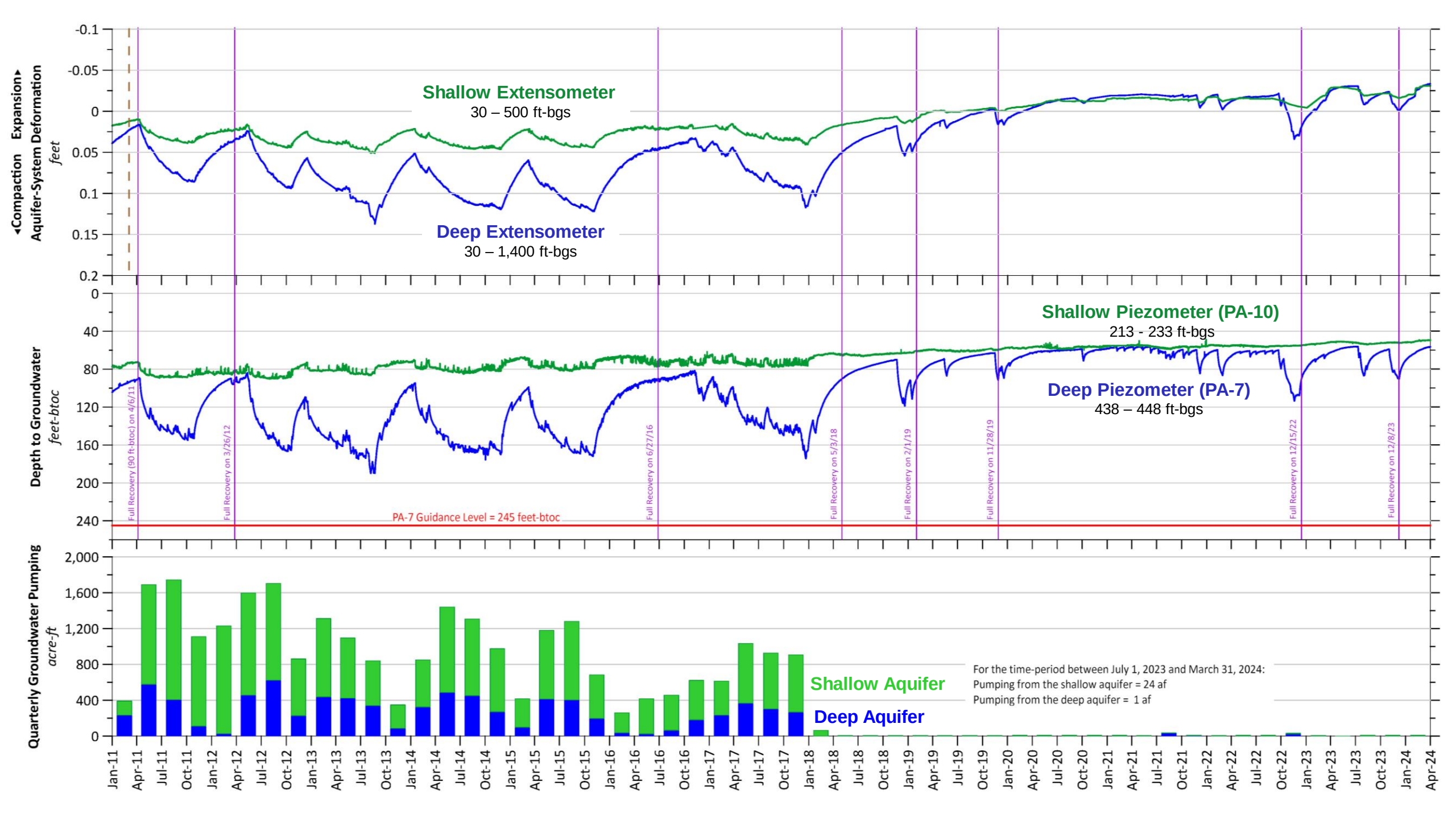
Ayala Park Extensometer

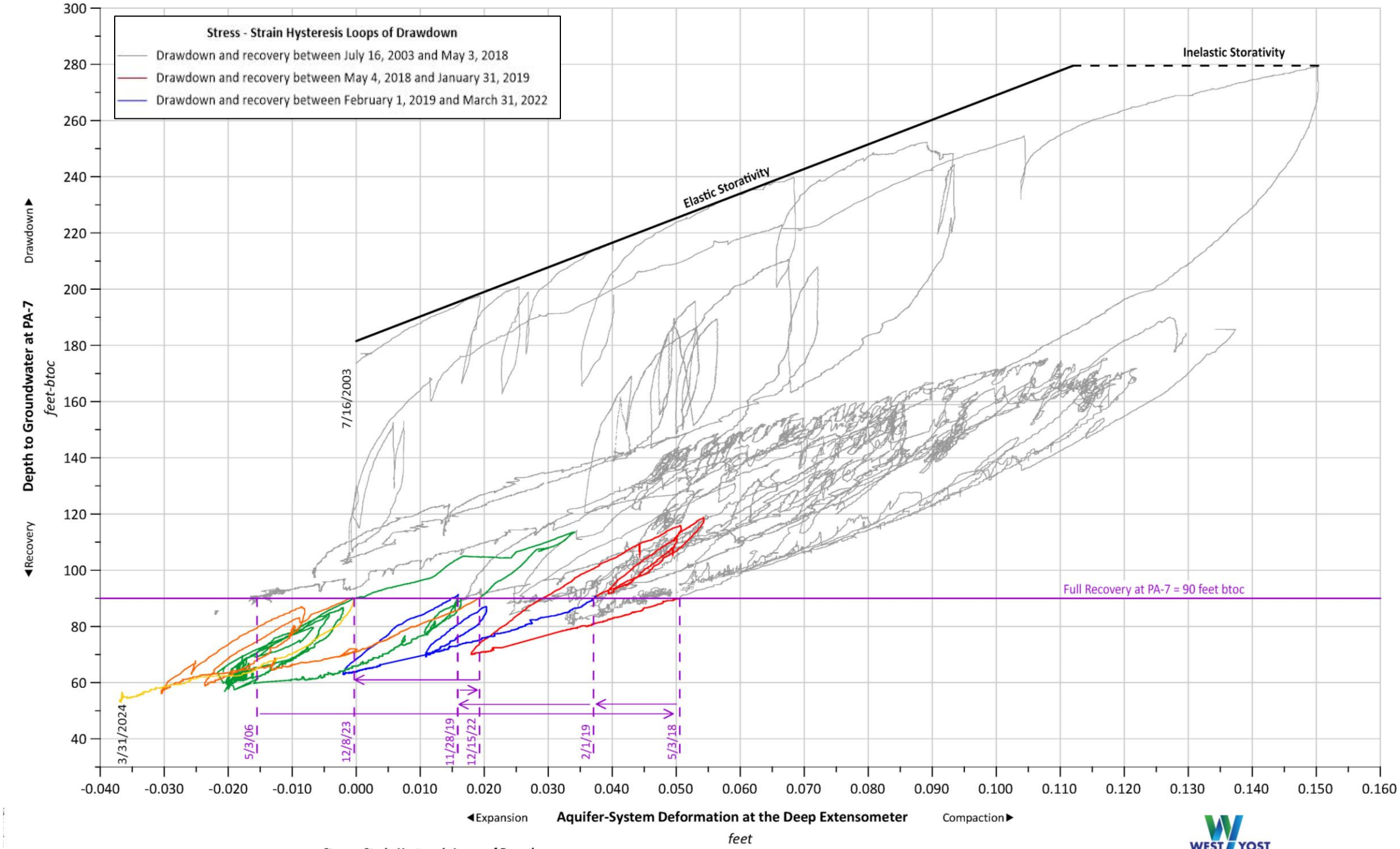
Groundwater Well (C-15)

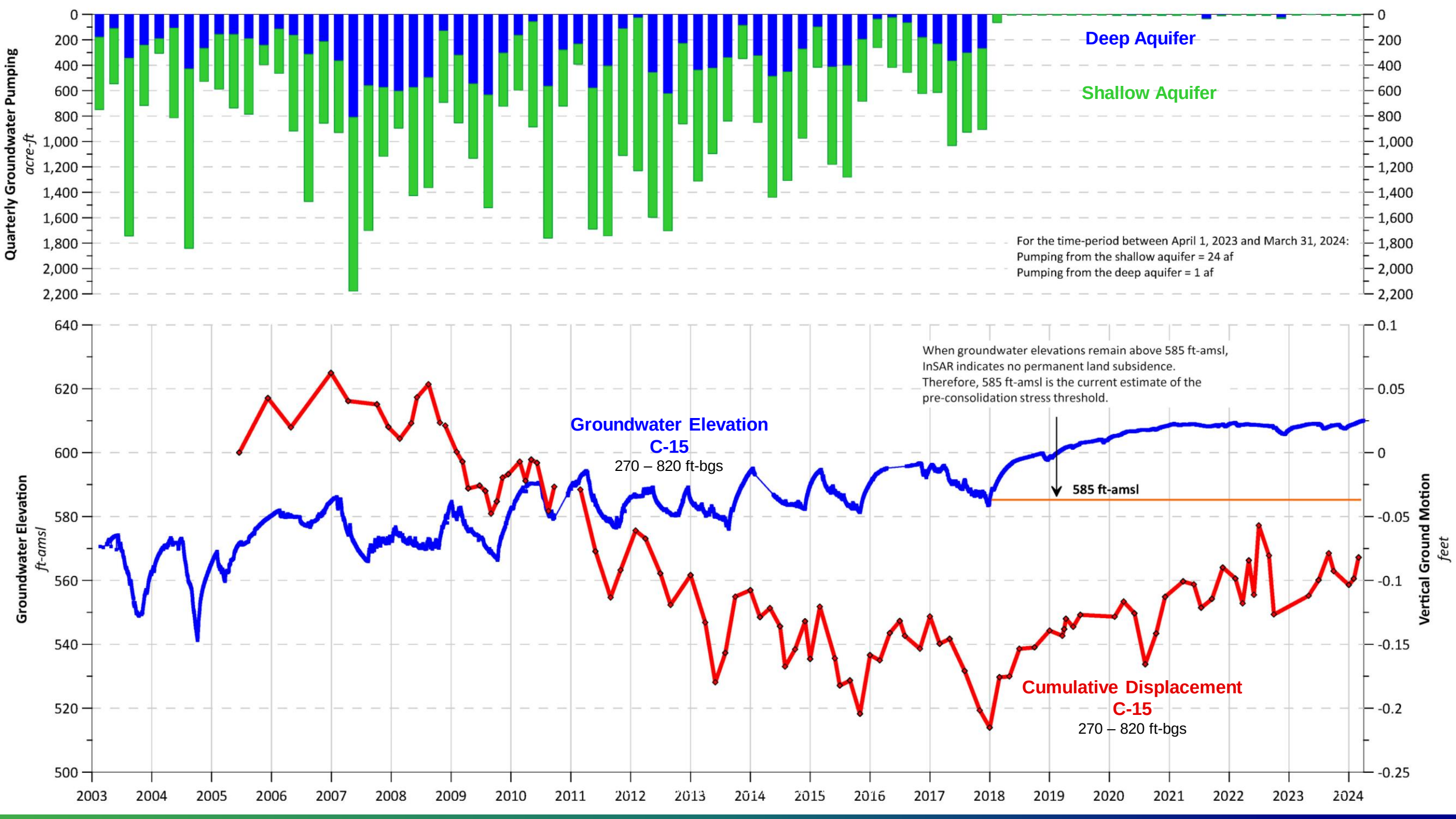
Areas of Subsidence Concern

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

Historical Ground Fissures


◂Compaction Expansion▸
Aquifer-System Deformation
feet
-0.1
-0.05
0
0.05
0.1
0.15
0.2
Shallow Extensometer
30 – 500 ft-bgs
Deep Extensometer
30 – 1,400 ft-bgs
Depth to Groundwater
feet-btoc
0
40
80
120
160
200
240
Shallow Piezometer (PA-10)
213 - 233 ft-bgs
Deep Piezometer (PA-7)
438 – 448 ft-bgs
Full Recovery (90 ft-btoc) on 4/6/11
Full Recovery on 3/26/12
Full Recovery on 6/27/16
Full Recovery on 5/3/18
Full Recovery on 2/1/19
Full Recovery on 11/28/19
Full Recovery on 12/15/22
Full Recovery on 12/8/23
PA-7 Guidance Level = 245 feet-btoc
Quarterly Groundwater Pumping
acre-ft
2,000
1,600
1,200
800
400
0
Shallow Aquifer
Deep Aquifer
For the time-period between July 1, 2023 and March 31, 2024:
Pumping from the shallow aquifer = 24 af
Pumping from the deep aquifer = 1 af
Jan-11
Apr-11
Jul-11
Oct-11
Jan-12
Apr-12
Jul-12
Oct-12
Jan-13
Apr-13
Jul-13
Oct-13
Jan-14
Apr-14
Jul-14
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Apr-20
Jul-20
Oct-20
Jan-21
Apr-21
Jul-21
Oct-21
Jan-22
Apr-22
Jul-22
Oct-22
Jan-23
Apr-23
Jul-23
Oct-23
Jan-24
Apr-24


Stress - Strain Hysteresis Loops of Drawdown
Drawdown and recovery between July 16, 2003 and May 3, 2018
Drawdown and recovery between May 4, 2018 and January 31, 2019
Drawdown and recovery between February 1, 2019 and March 31, 2022
Inelastic Storativity
Elastic Storativity
7/16/2003
3/31/2024
5/3/06
12/8/23
11/28/19
12/15/22
2/1/19
5/3/18
Full Recovery at PA-7 = 90 feet btoc
Depth to Groundwater at PA-7
feet-btoc
Drawdown▶
◀Recovery
◀Expansion
Aquifer-System Deformation at the Deep Extensometer
Compaction▶
feet
300
280
260
240
220
200
180
160
140
120
100
80
60
40
-0.040
-0.030
-0.020
-0.010
0.000
0.010
0.020
0.030
0.040
0.050
0.060
0.070
0.080
0.090
0.100
0.110
0.120
0.130
0.140
0.150
0.160

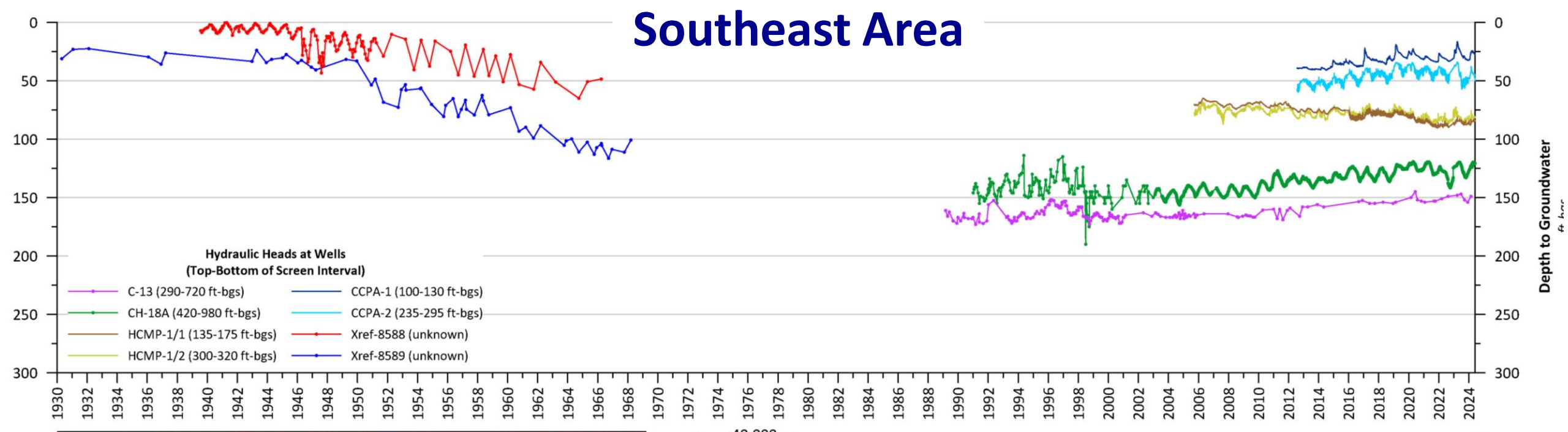

Quarterly Groundwater Pumping
acre-ft
Deep Aquifer
Shallow Aquifer
For the time-period between April 1, 2023 and March 31, 2024:
Pumping from the shallow aquifer = 24 af
Pumping from the deep aquifer = 1 af
When groundwater elevations remain above 585 ft-amsl,
InSAR indicates no permanent land subsidence.
Therefore, 585 ft-amsl is the current estimate of the
pre-consolidation stress threshold.
Groundwater Elevation
C-15
270 – 820 ft-bgs
585 ft-amsl
Cumulative Displacement
C-15
270 – 820 ft-bgs
Groundwater Elevation
ft-amsl
Vertical Ground Motion
feet

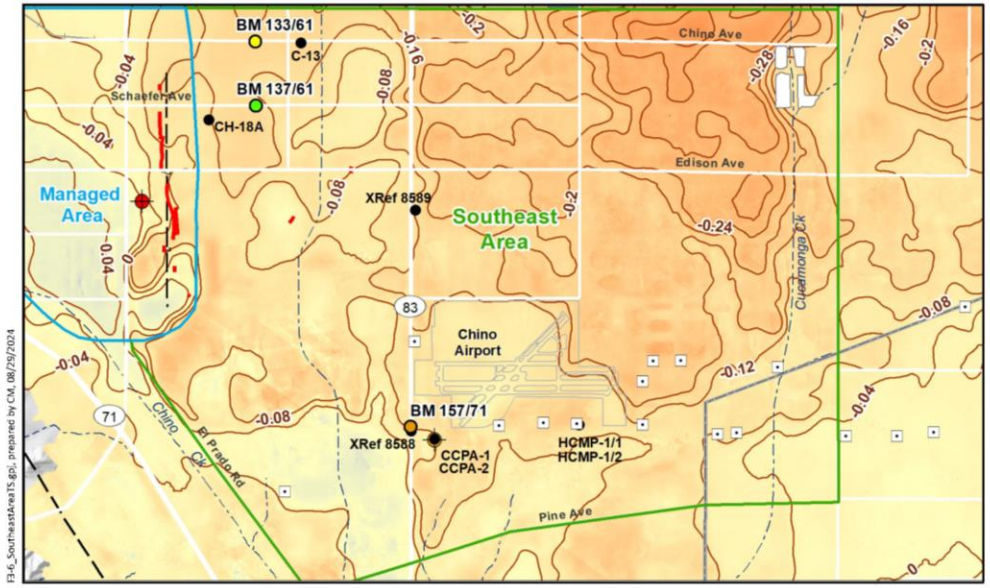
Conclusions and Recommendations: *Managed Area*

- Hydraulic heads within the shallow and deep aquifer-systems are at or near their highest levels since the inception of the GLMP in 2003, and the Ayala Park Extensometers recorded elastic compaction and expansion of the aquifer-system.
- Both InSAR and the leveling surveys indicate very little, if any, subsidence across the Managed Area.
- The increases in hydraulic head were due to the virtual cessation of pumping in the Managed Area, largely due to the presence of water-quality contaminants in groundwater that constrain its use as drinking water.
- Hydraulic heads in the deep aquifer-system remain well above the Guidance Level, and the Ayala Park Extensometers recorded no inelastic compaction of the aquifer-system.

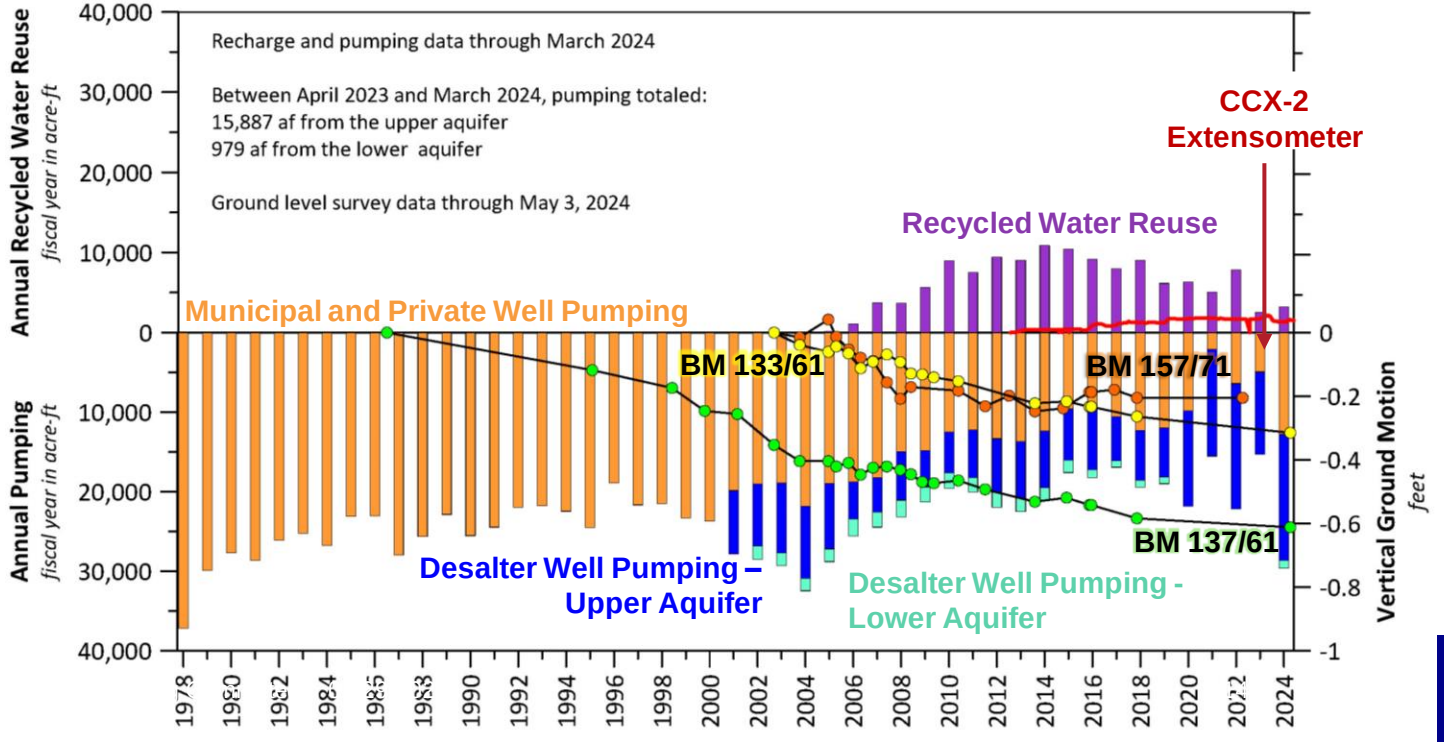
- RECOMMENDATION: Continue the monitoring/reporting program.

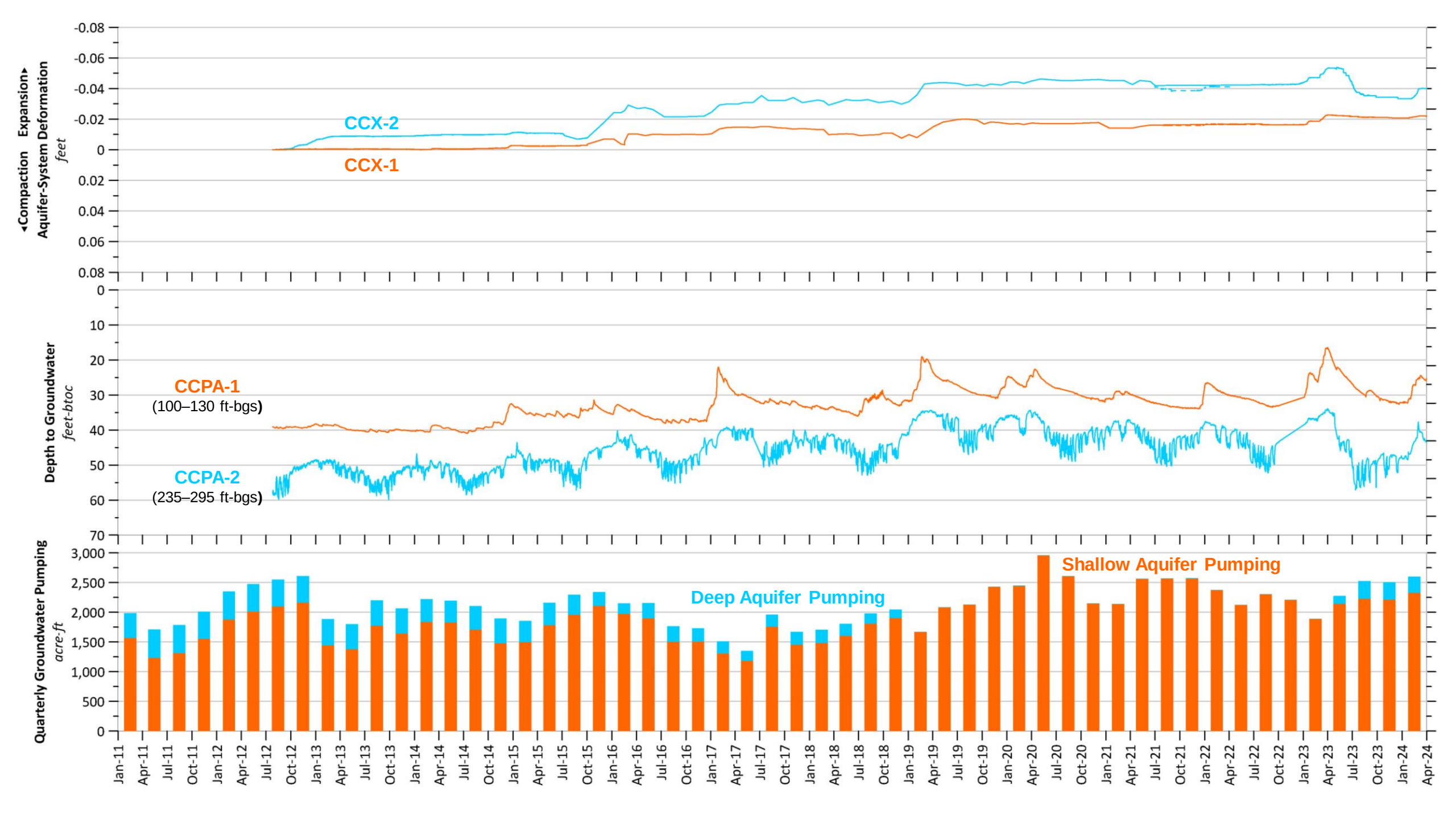
Southeast Area





InSAR from March 2011 to March 2024 (see Figure 3-1a)



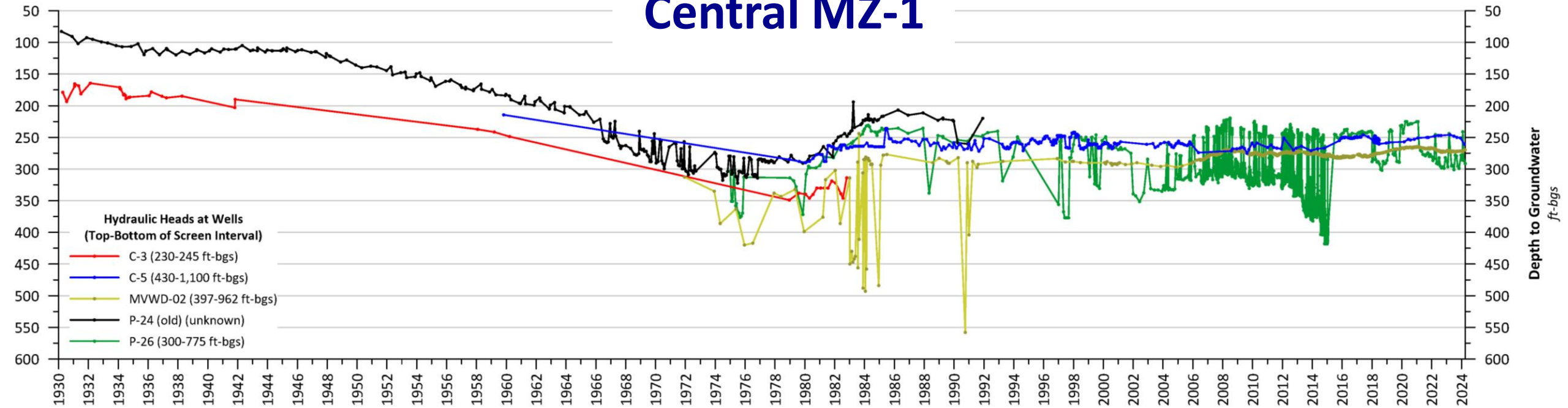

◂Compaction Expansion▸
Aquifer-System Deformation
feet
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08
CCX-2
CCX-1
Depth to Groundwater
feet-btoc
0
10
20
30
40
50
60
70
CCPA-1
(100–130 ft-bgs)
CCPA-2
(235–295 ft-bgs)
Quarterly Groundwater Pumping
acre-ft
3,000
2,500
2,000
1,500
1,000
500
0
Deep Aquifer Pumping
Shallow Aquifer Pumping
Jan-11
Apr-11
Jul-11
Oct-11
Jan-12
Apr-12
Jul-12
Oct-12
Jan-13
Apr-13
Jul-13
Oct-13
Jan-14
Apr-14
Jul-14
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Apr-20
Jul-20
Oct-20
Jan-21
Apr-21
Jul-21
Oct-21
Jan-22
Apr-22
Jul-22
Oct-22
Jan-23
Apr-23
Jul-23
Oct-23
Jan-24
Apr-24

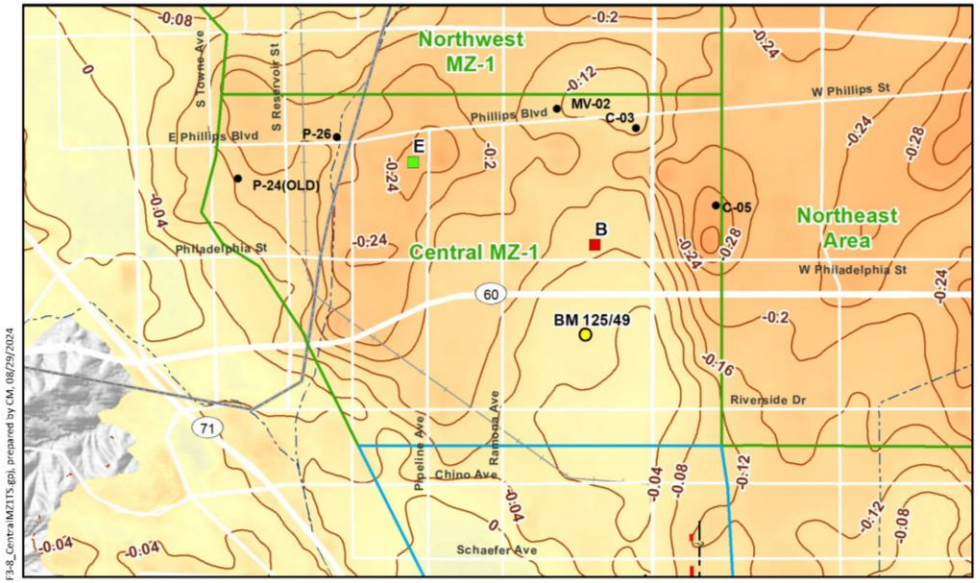
Conclusions and Recommendations: *Southeast Area*

- In the western portion of the area, hydraulic heads have gradually increased since 2012 → In general, the aquifer-system deformation has been minor and elastic.
- In the eastern portion of the area, CDA pumping is greater, and hydraulic heads have gradually decreased since 2012 → Maximum subsidence of about -0.34 ft was measured by InSAR. However, there are no obvious areas of differential subsidence that could be a threat for ground fissuring.

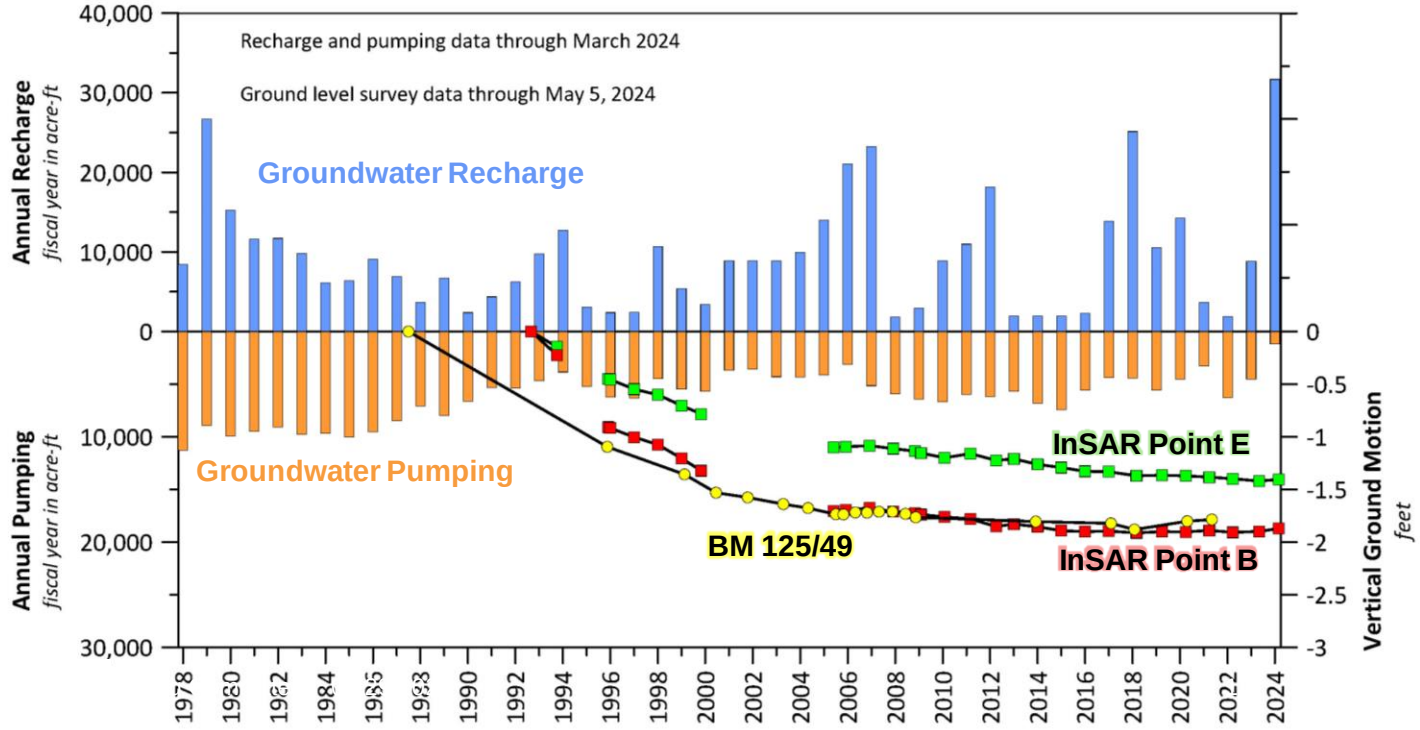
RECOMMENDATION: Continue the monitoring/reporting program.

Central MZ-1

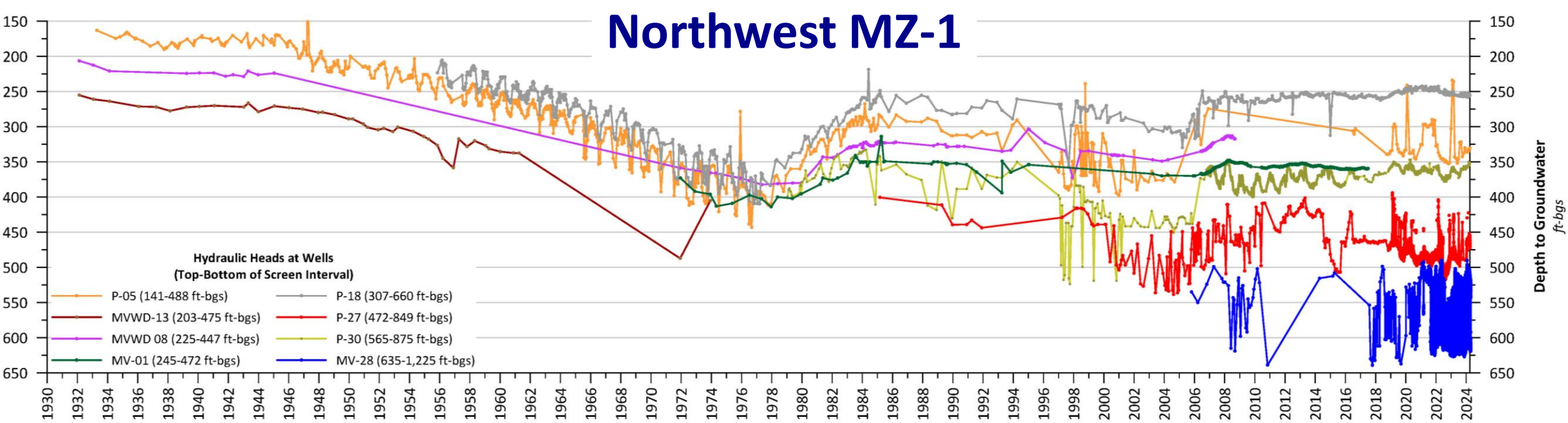


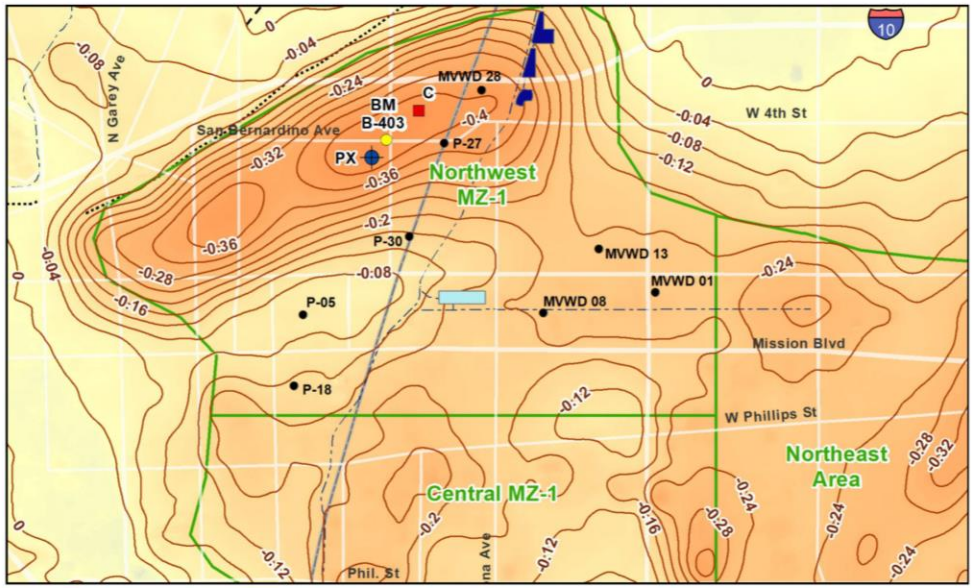


InSAR from March 2011 to March 2024 (see Figure 3-1a)

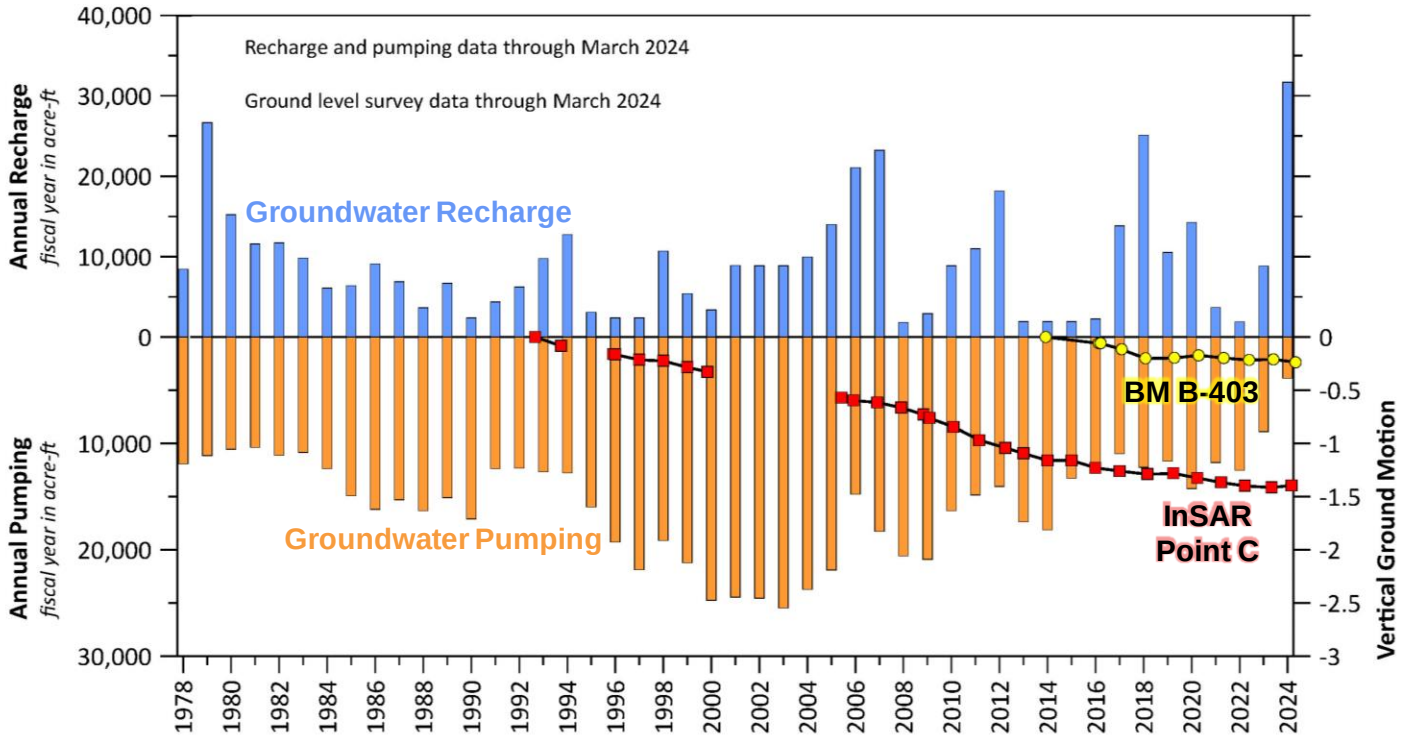


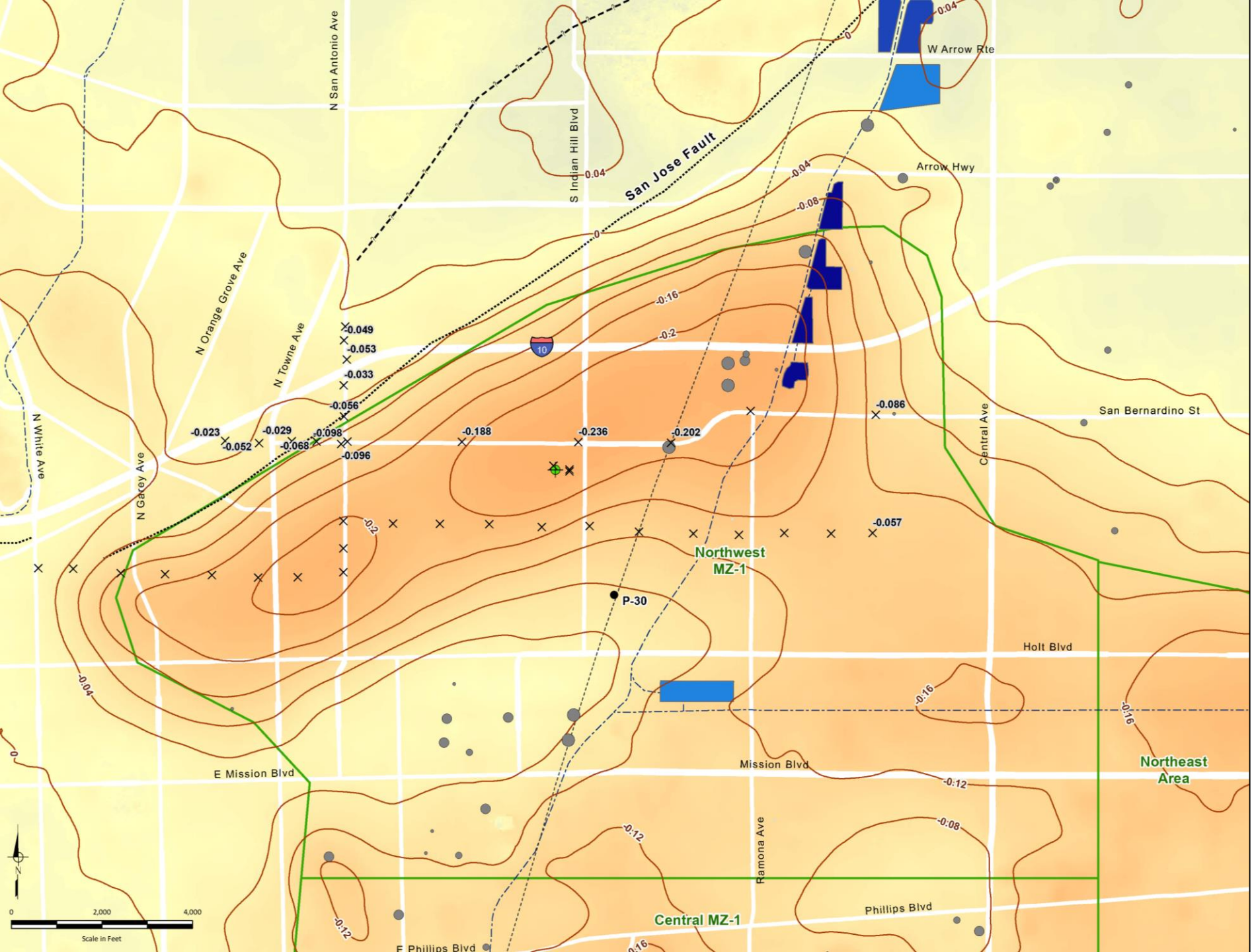
Northwest MZ-1





InSAR from March 2011 to March 2024 (see Figure 3-1a)





InSAR vs. Surveys

Northwest MZ-1

Relative Change in Land Surface Elevation
as Estimated by InSAR
(April 2014 to March 2024)

+0.45 ft
0 ft
- 0.25 ft
-0.45 ft

InSAR absent or incoherent

Ground-Level Survey Benchmark
(Measured May 3, 2024) Labeled by Vertical Ground Motion (in feet from November 2014 to May 2024)

Average Annual Groundwater Pumping
April 1, 2014 to March 31, 2024
(afy)

- 0 - 100
- 101 - 500
- 501 - 1,000
- 1,000 - 2,000
- > 2,000

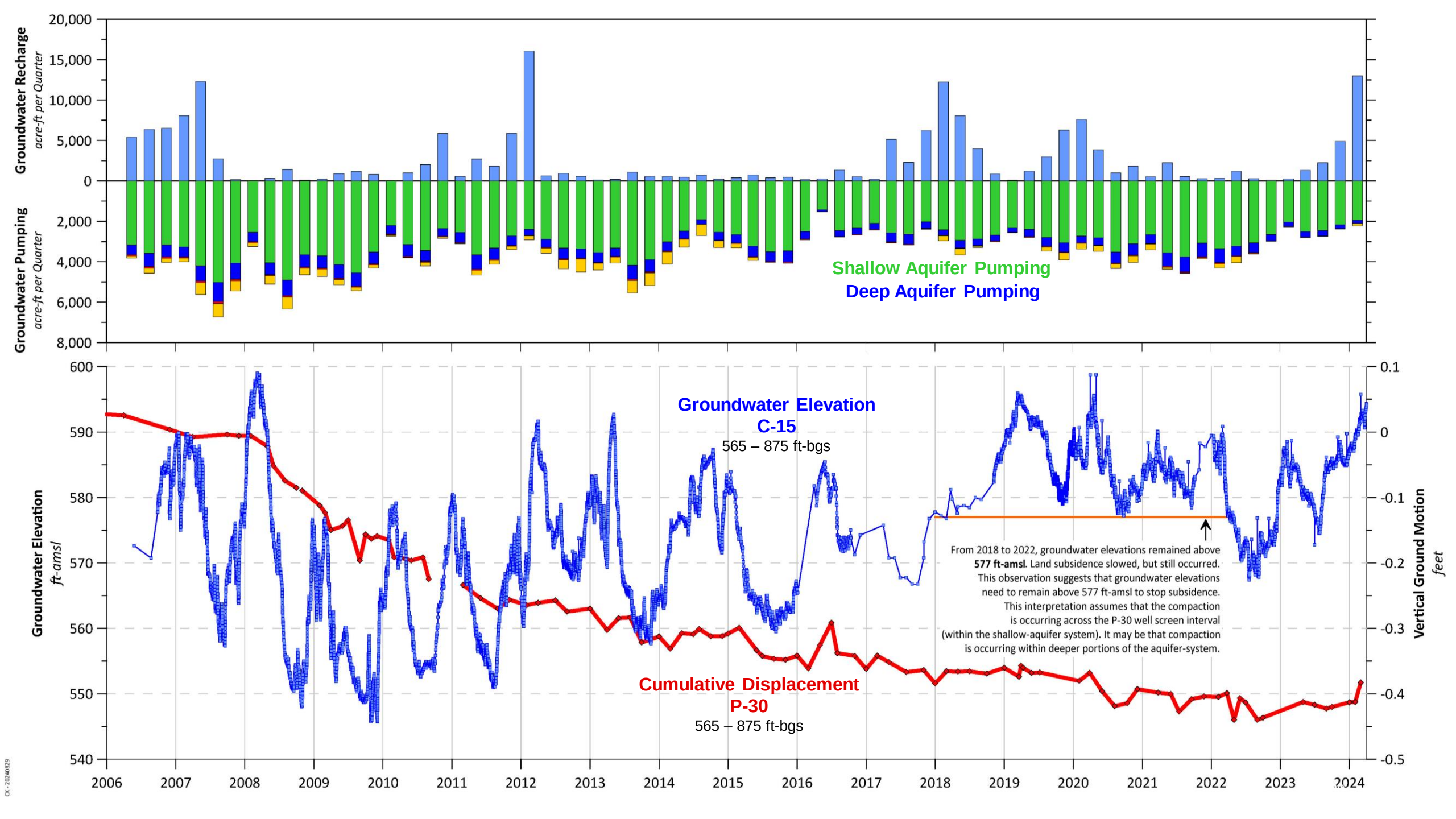
Average Annual Basin Recharge
April 1, 2014 to March 31, 2024
(afy)

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

Pomona Extensometer Facility

Groundwater Well (P-30)

Areas of Subsidence Concern


Groundwater Recharge
acre-ft per Quarter
20,000
15,000
10,000
5,000
0
Groundwater Pumping
acre-ft per Quarter
2,000
4,000
6,000
8,000
Shallow Aquifer Pumping
Deep Aquifer Pumping
Groundwater Elevation
ft-amsl
600
590
580
570
560
550
540
Groundwater Elevation
C-15
565 – 875 ft-bgs
Cumulative Displacement
P-30
565 – 875 ft-bgs
From 2018 to 2022, groundwater elevations remained above
577 ft-amsl. Land subsidence slowed, but still occurred.
This observation suggests that groundwater elevations
need to remain above 577 ft-amsl to stop subsidence.
This interpretation assumes that the compaction
is occurring across the P-30 well screen interval
(within the shallow-aquifer system). It may be that compaction
is occurring within deeper portions of the aquifer-system.
Vertical Ground Motion
feet
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024

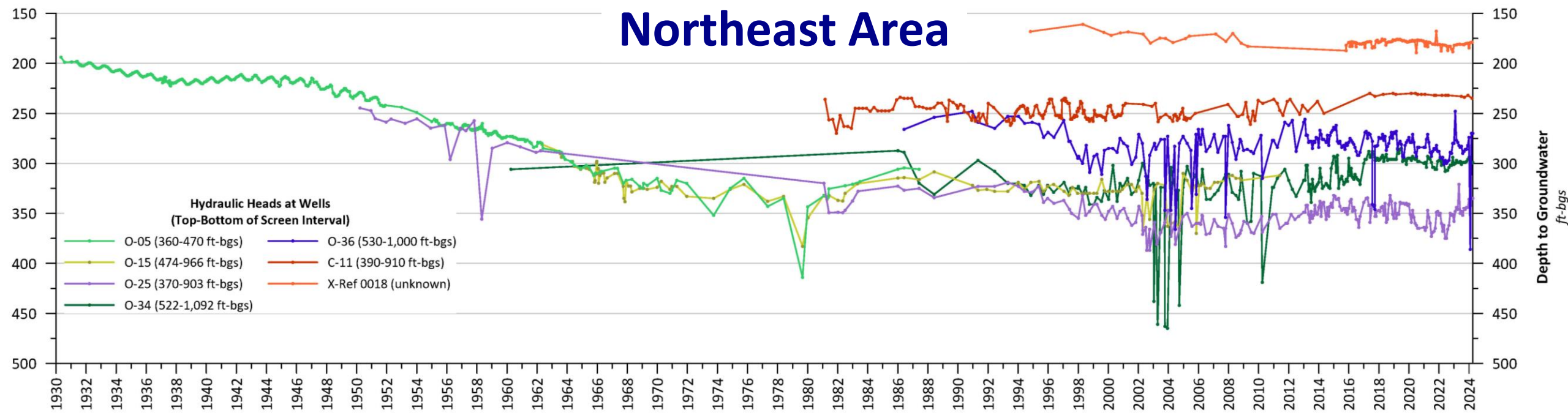
Conclusions and Recommendations: *Northwest MZ-1*

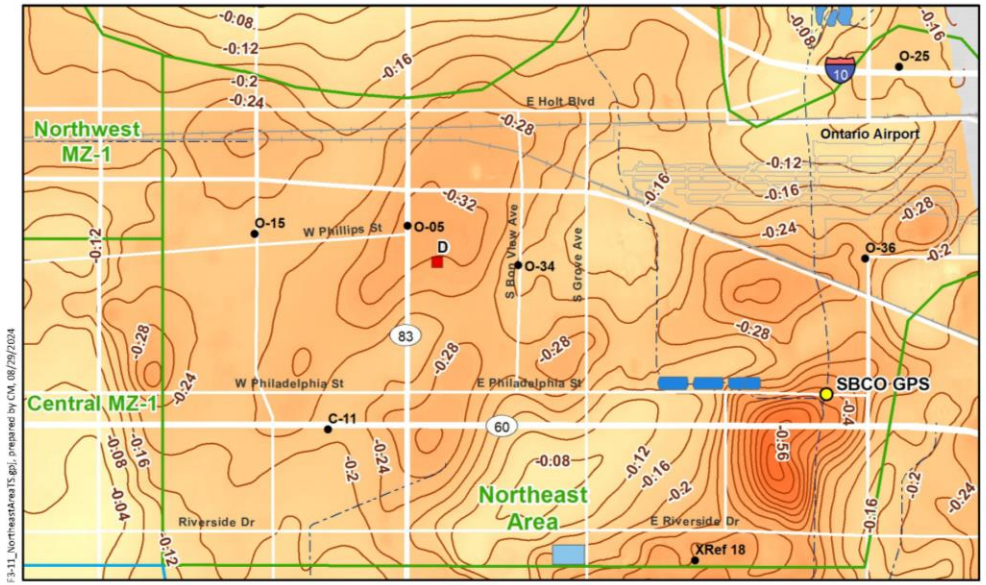
- Pumping has decreased and recharge has increased, which caused heads to stabilize or increase.
- InSAR estimates of ground motion have shown that the trends of land subsidence have slowed.
- Hydraulic heads in the aquitards and aquifers are likely beginning to equilibrate, which is slowing the delayed drainage and compaction of the aquitards.
- Future declines in hydraulic heads, caused by increases in pumping and/or decreases in recharge, may cause aquitard compaction and rates of land subsidence to increase.

RECOMMENDATION: Continue developing a *Subsidence-Management Plan for Northwest MZ-1*:

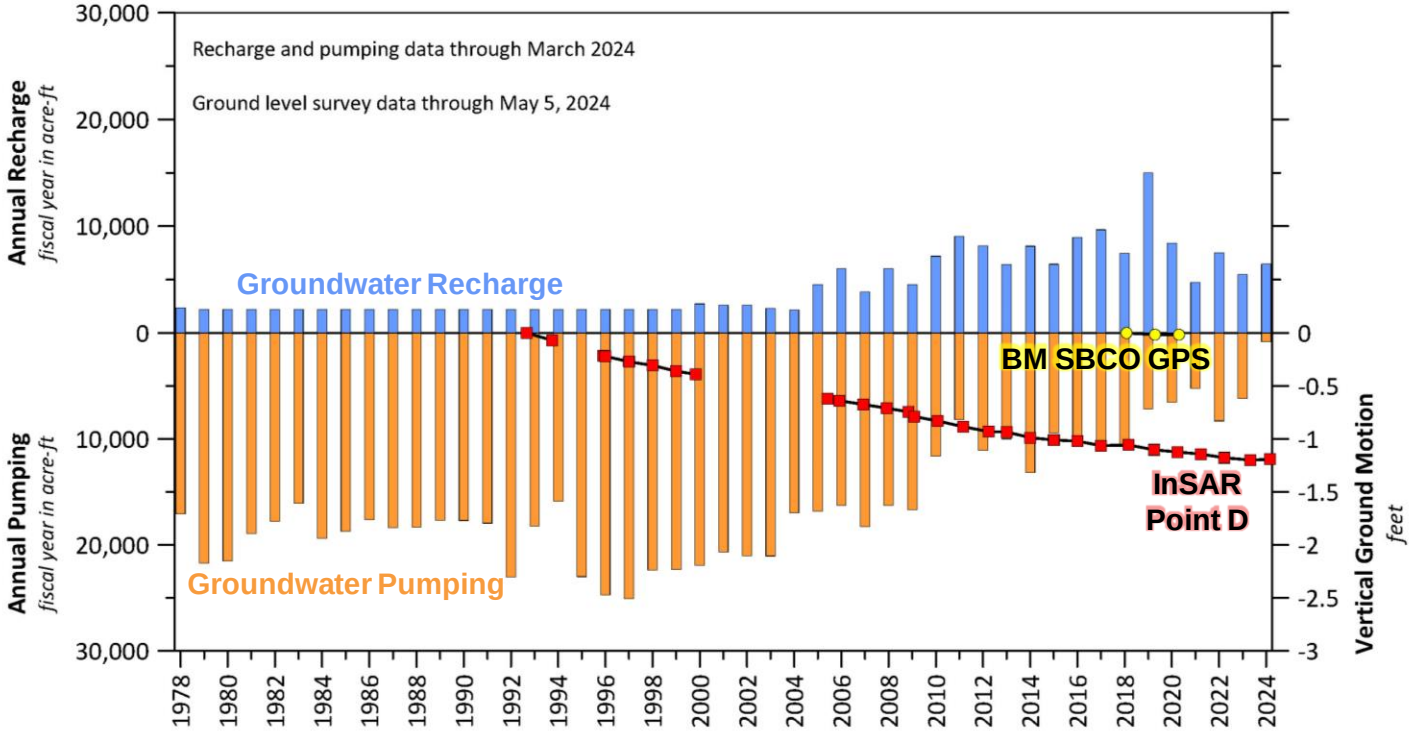
- Continue aquifer-system monitoring and data analysis in Northwest MZ-1.
- Use the 1D compaction models at the MVWD-28 and PX locations to estimate the future occurrence of subsidence in Northwest MZ-1 under the 2025 SYR.
- Develop and evaluate additional subsidence-management alternatives in FY 2025/26 if the 2025 SYR alternatives are unsuccessful at abating future subsidence in Northwest MZ-1.

Northeast Area



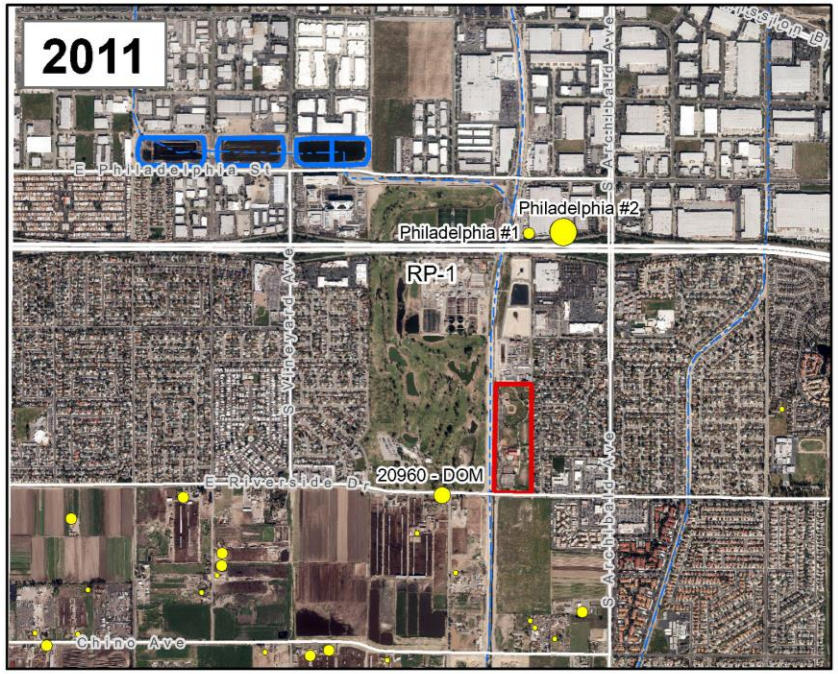


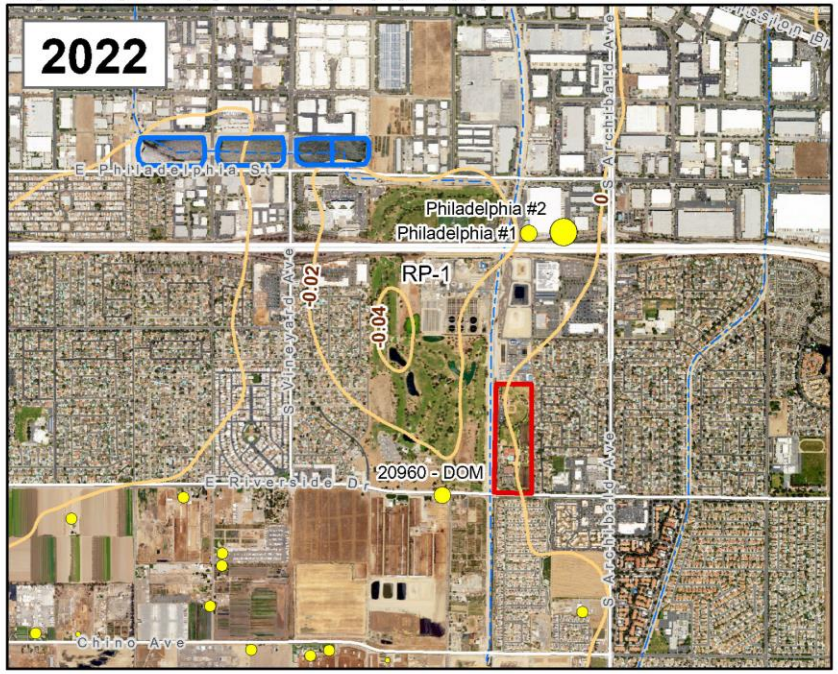
InSAR from March 2011 to March 2024 (see Figure 3-1a)



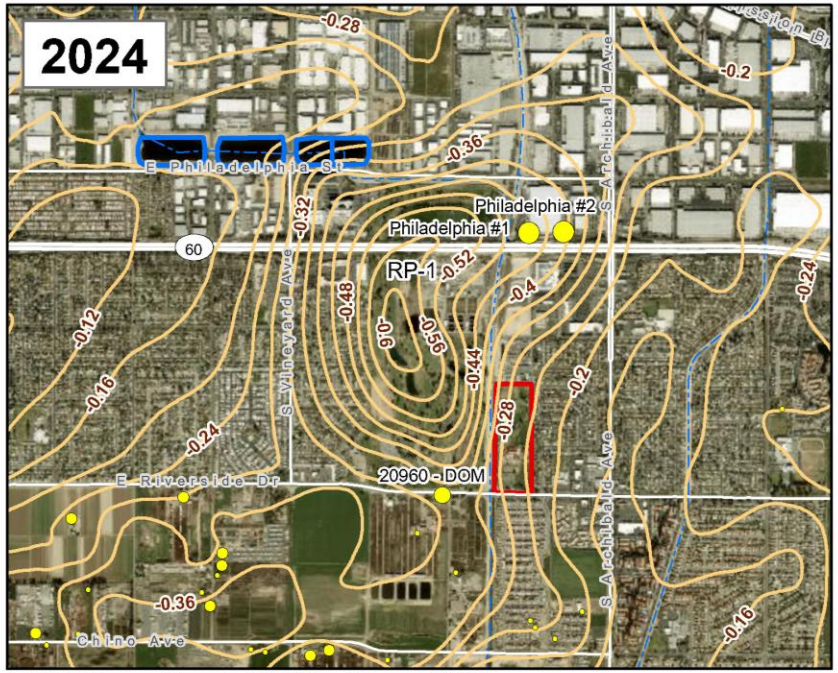
Whispering Lakes Subsidence Feature

InSAR from March 2022 to March 2023





InSAR from March 2023 to March 2024



InSAR from March 2011 to March 2024

Contours of the Relative Change in Land Surface Elevation as Estimated by InSAR (ft)

Annual Groundwater Production (af)
(reported by fiscal year)

- < 10
- 10 - 100
- 101 - 250
- 250 - 500
- 500 - 730

*Pumping records unavailable prior 1978 and the Stipulated Judgement
**Pumping for FY 2024 is limited to data from Q1 through Q3

Other Features

- Location of Historic Sewage Disposal Ponds
- Ely Recharge Basins

Conclusions and Recommendations: *Whispering Lake Subsidence Feature*

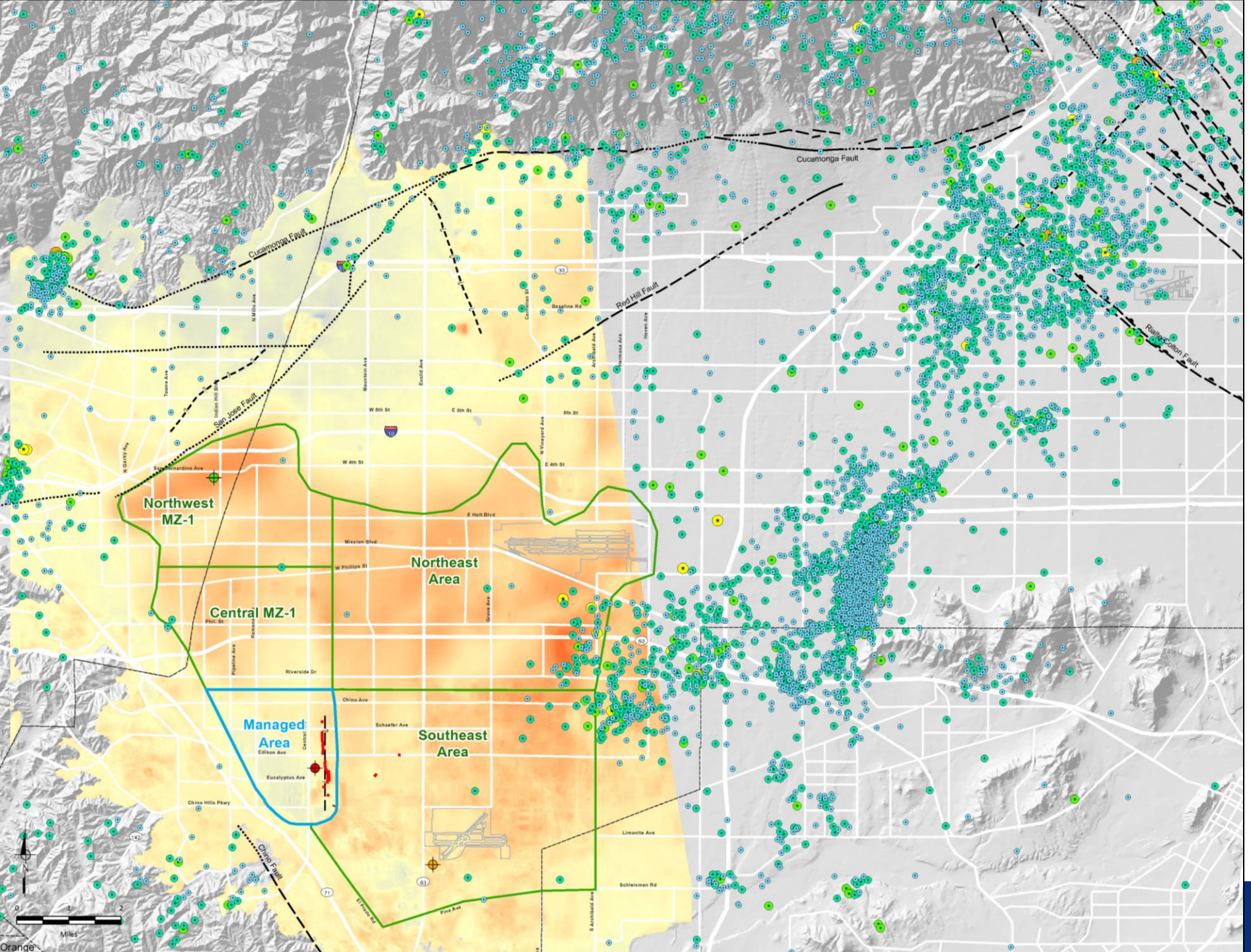
- The spatial extent of the subsidence feature closely aligns with the spatial extent of the Whispering Lakes Golf Course.
- Shallow soil consolidation is the likely cause of the ongoing subsidence in this area.
- Other potential causes, such as aquitard drainage, cannot be ruled out.

RECOMMENDATION: Continue a limited monitoring program to rule out aquitard drainage as a cause:

- Continue monitoring vertical ground motion by high-resolution InSAR.
- Continue monitoring pumping at wells within the Study Area.
- Install transducers in wells within the Study Area to measure and record hydraulic heads at high temporal frequency.
- Analyze and report on the monitoring data in GLMP annual reports.

Seismicity in the Chino Basin

2011-2024



Seismicity in the Chino Basin
March 1, 2011 to March 31, 2024
(Magnitude)

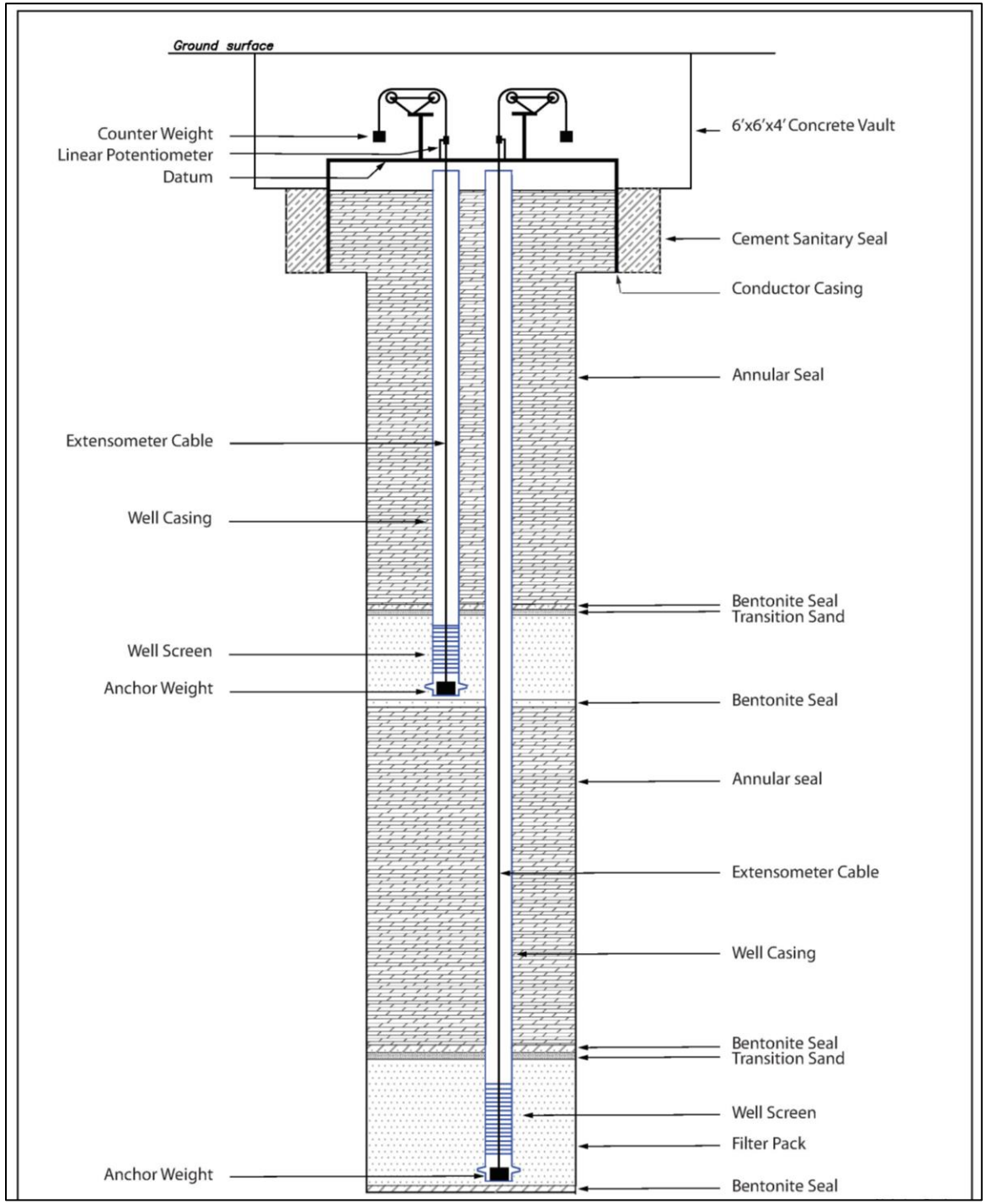
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6

Relative Change in Land Surface Elevation
as Estimated by InSAR
(March 2011 to March 2024)

- High : 0.6
- 0 ft
- Low : -0.6

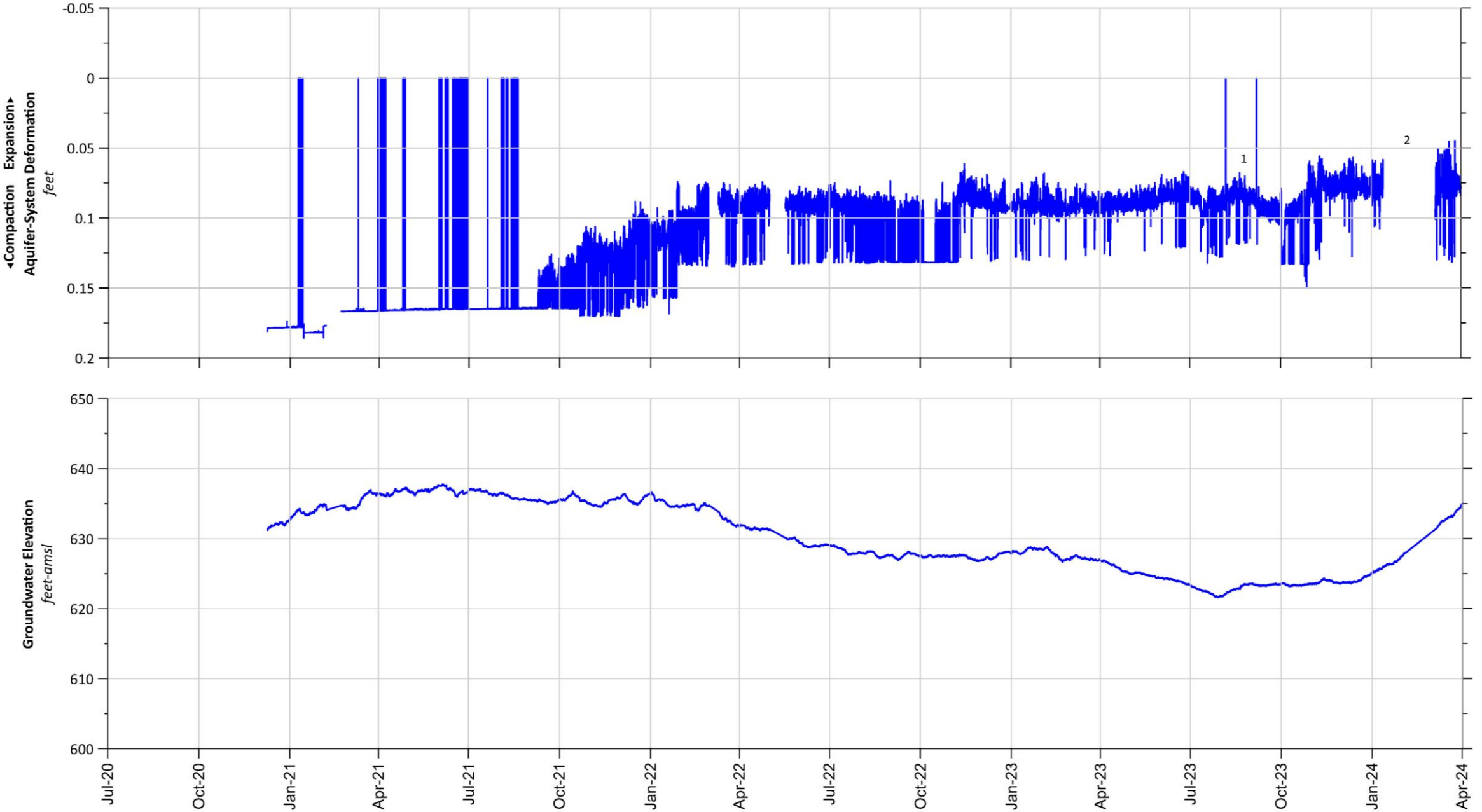
Pomona Extensometer (PX) Monitoring

- PX is an experimental monitoring facility located in Northwest MZ-1 that monitors:
  - Depth-specific head changes
  - Vertical compression/expansion of the aquifer-system
- PX should monitor a correlated relationship between head changes and extensometer displacement but does not, which indicates that: (i) the extensometers are malfunctioning, (ii) the monitoring/recording equipment is malfunctioning, or (iii) both are malfunctioning.
- To improve the functionality of the PX, Watermaster Engineer has been making incremental adjustments to each extensometer by: (i) adding/subtracting counterweights, (ii) adjusting the position of the cable extensometer within the well casing, and/or (iii) making adjustments to the monitoring/recording equipment.
- Each adjustment is followed by an extended period of data collection and evaluation.



Conceptual Dual-Nested Cable Extensometer

PX-1



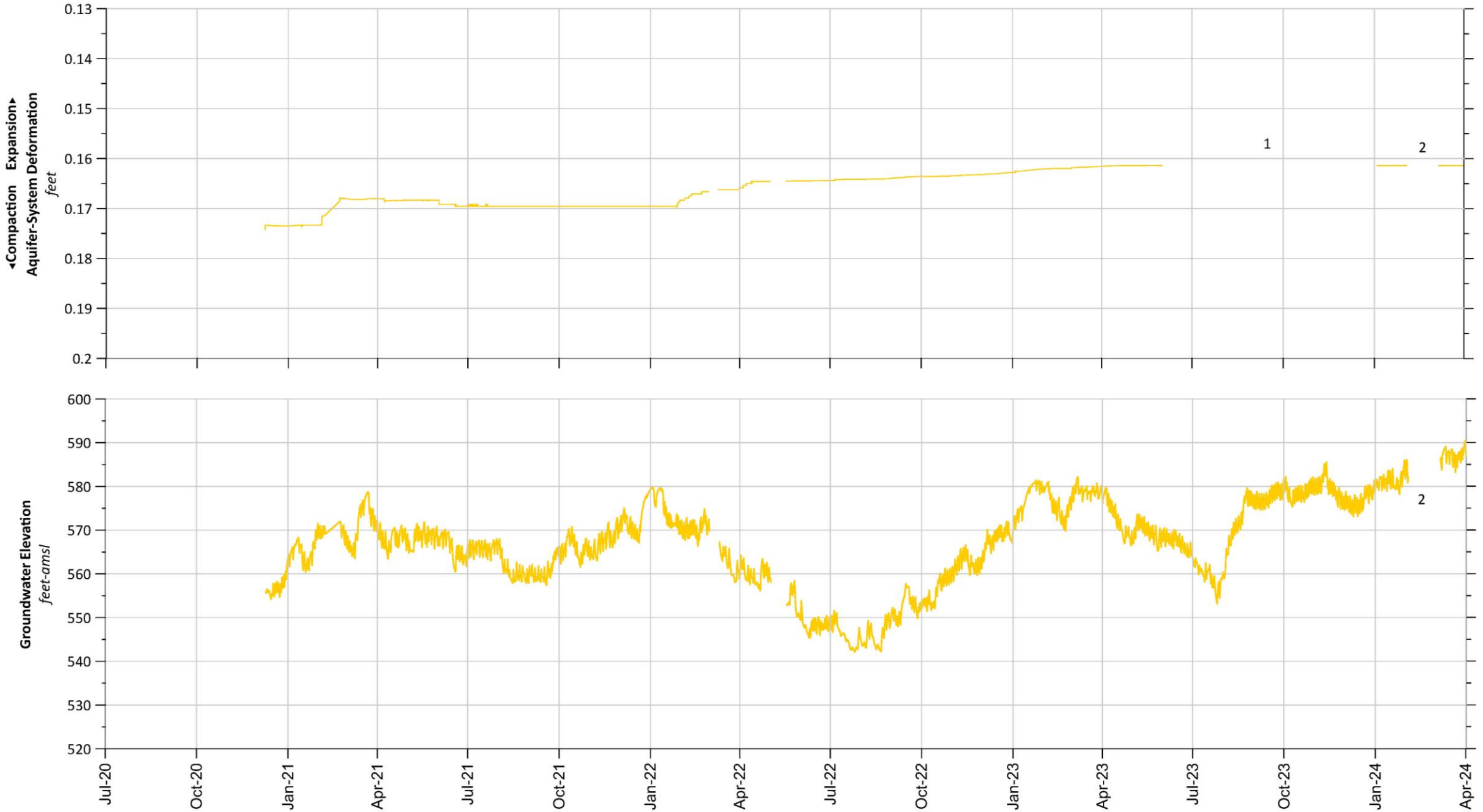
1 Added counterweight sleeve approximately 10 lbs.
2 Battery voltage too low

WEST YOST

Chino Basin Water Master
2023/24 Annual Report for the
Ground-Level Monitoring Program

Figure 2-4a

PX-2



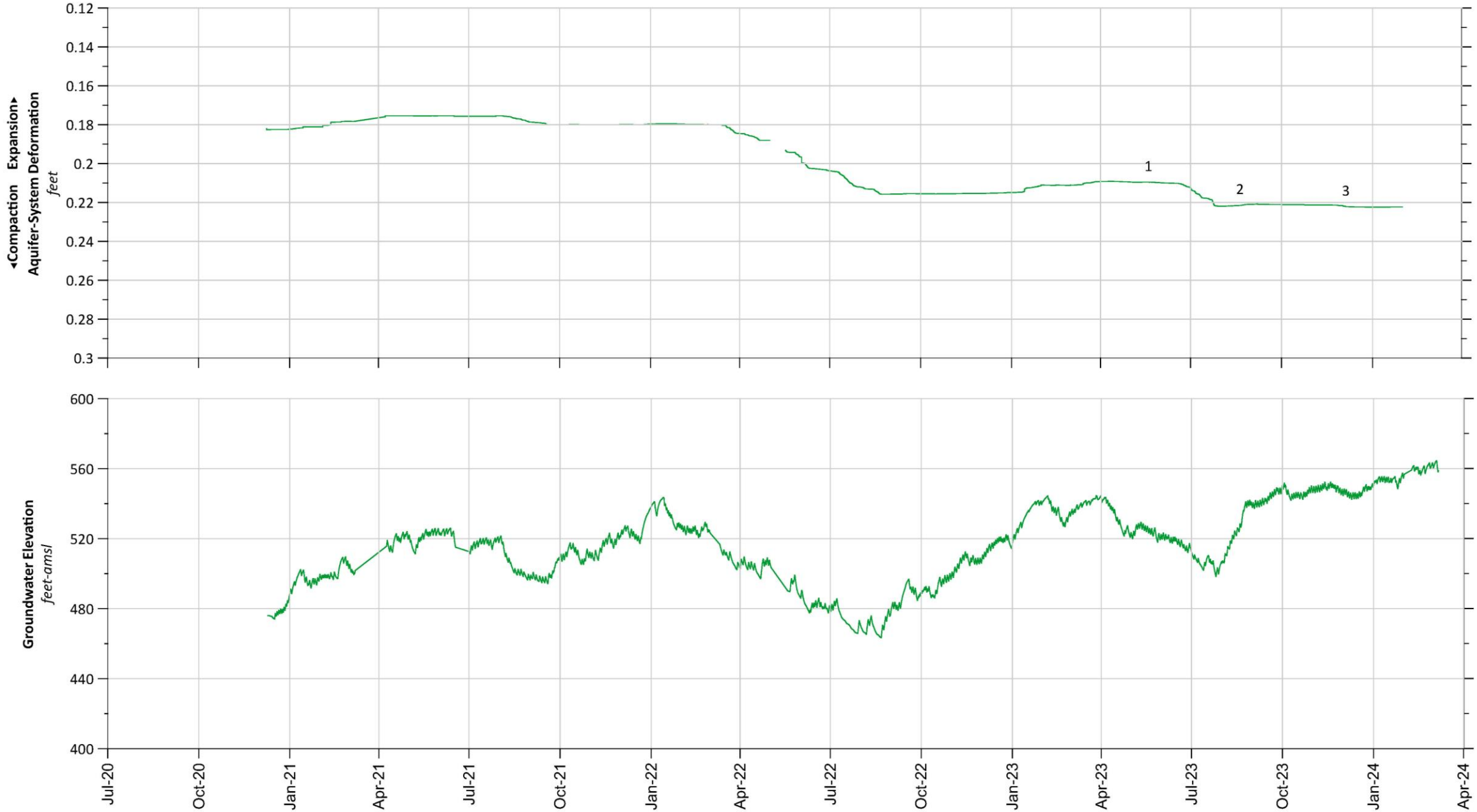
1 Removed Linear Potentiometer to test in office
2 Battery source low

WEST YOST

Chino Basin Water Master
2023/24 Annual Report for the
Ground-Level Monitoring Program

Figure 2-4b

PX-3



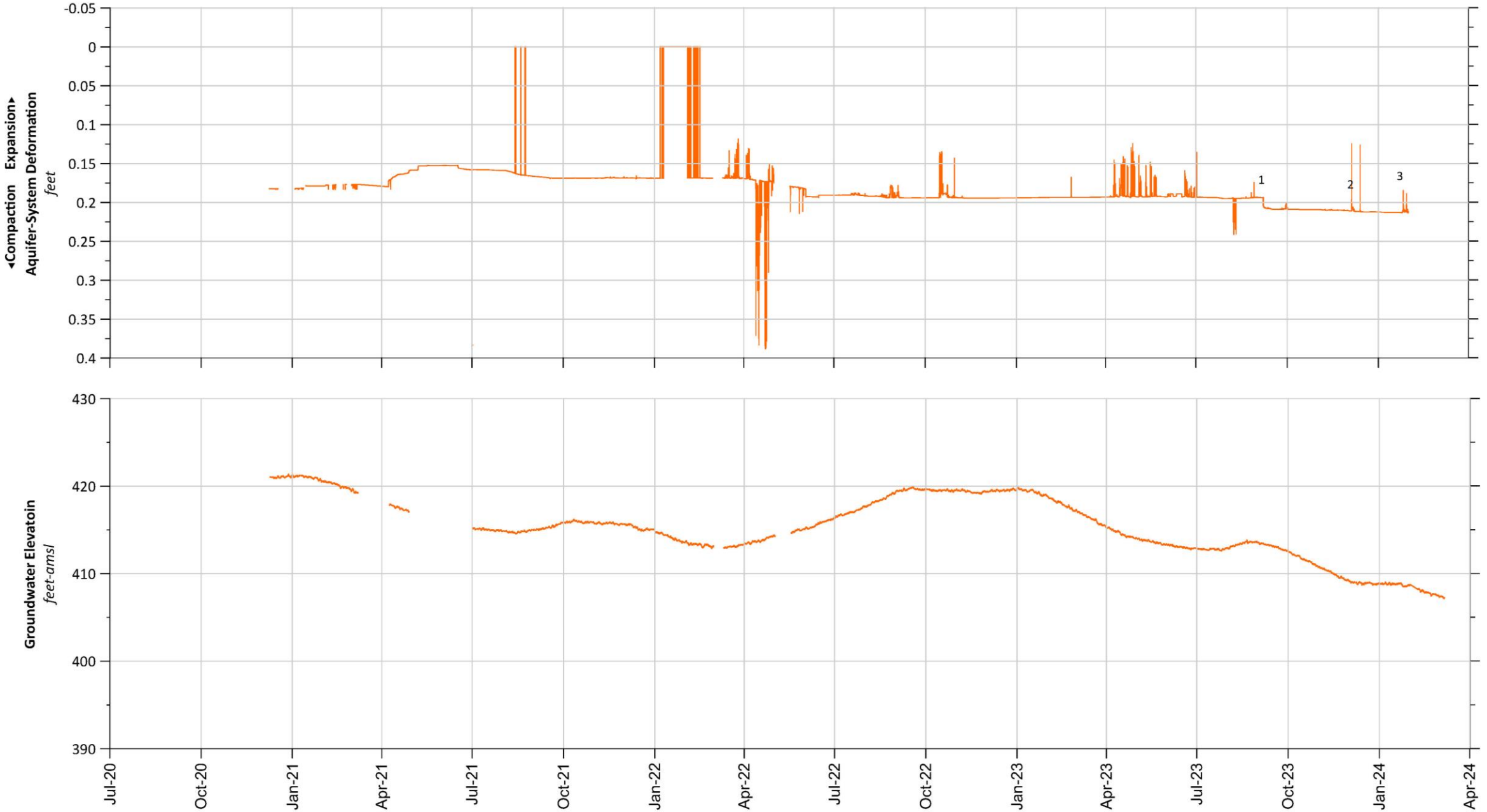
1 Adjusted linear potentiometer parallel to wire; added counterweight sleeve approximately 10 lbs.
2 Added one weight sleeve approximately 10lbs.
3 Removed one weidght sleeve approximately 10lbs.

WEST YOST

Chino Basin Water Master
2023/24 Annual Report for the
Ground-Level Monitoring Program

Figure 2-4c

PX-4



1 Adjusted linear potentiometer parallel to wire; added counterweight sleeve approximately 10 lbs.
2 Added one weight sleeve approximately 10lbs.
3 Removed one weidght sleeve approximately 10lbs.

WEST YOST

Chino Basin Water Master
2023/24 Annual Report for the
Ground-Level Monitoring Program

Figure 2-4d

Pomona Extensometer (PX) Monitoring

RECOMMENDATIONS:

- Continue to make incremental adjustments to the extensometers followed by extended periods of data collection and evaluation.
- Reinstall the extensometer cables, counterweights, and monitoring/recording equipment and equip the facility with telemetry to analyze and evaluate the collected data more quickly.

With input from GLMC, Watermaster Engineer with include recommendation in FY 2025/26 scope and budget memo (~March 2025).

Next Steps: Annual Report

- **October 23, 2024**
  - GLMC submits comments and suggested revisions on the draft annual report to Watermaster and Watermaster Engineer.

    etellezfoster@cbwm.org; amalone@westyost.com

- **November 1, 2024**
  - Watermaster Engineer prepares the final *2023/24 Annual Report.*
  - The *Annual Report* will be included in the agenda packet for the November Watermaster meetings for receive and file.

THANK YOU

WESTYOST.COM