# SUMMARY OF OPERATIONS

# MONTEREY PENINSULA ASR PROJECT

# WATER YEAR 2015

Prepared for:

Monterey Peninsula Water Management District

JUNE 2016

**DRAFT**

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June 30, 2016
Project No. 12-0043

Monterey Peninsula Water Management District
Post Office Box 85
Monterey, California 93942-0085

Attention: Mr. Joe Oliver, Water Resources Manager

Subject: Monterey Peninsula ASR Project; Draft Water Year 2015 Summary of Operations Report

Dear Joe:

We are transmitting one digital image (PDF) of the subject draft report documenting operations of the Monterey Peninsula ASR Project during Water Year 2015 (WY 2015) for your review and comments. WY 2015 was a Dry Water Year on the on the Monterey Peninsula, and as a result a commensurately modest volume totaling 215 acre-feet (af) of water was able to be diverted from the Carmel River system for recharge in the Seaside Groundwater Basin (SGB) via the ASR-1, -2, -3 and -4 wells. This contrasts with the over 1,100 af injected via ASR-1 and -2 in both WY 2010 and WY 2011, which were Above Normal Water Years. To date, a total volume of approximately 4,390 af of excess Carmel River system water has been successfully injected, stored, and recovered in the SBG since the ASR project was initiated in 2001.

We appreciate the opportunity to provide ongoing assistance to the District on this important community water-supply project. Please contact us with any questions.

Sincerely,

PUEBLO WATER RESOURCES, INC.

Robert C. Marks, P.G., C.Hg.
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Copies submitted: 1 digital (PDF)

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# INTRODUCTION

## GENERAL STATEMENT

Presented in this report is a summary of operations of the Monterey Peninsula Aquifer Storage and Recovery (ASR) Project during Water Year 2015 (WY 2015)[1]. During WY 2015, approximately 215 acre-feet (af) of excess flows were diverted from the Carmel River system for recharge, storage, and subsequent recovery in the Seaside Groundwater Basin (SGB). This report presents a summary of the project operations during WY 2015, an assessment of ASR well performance, aquifer response and water-quality data, and provides recommendations for ongoing operation of the project.

## BACKGROUND

The Monterey Peninsula ASR Project is cooperatively implemented by the Monterey Peninsula Water Management District (MPWMD or District) and California American Water (CAW) and involves the diversion of excess winter and spring time flows from the Carmel River system for recharge and storage in the Seaside Groundwater Basin (SGB). The excess water is captured by CAW wells in the Carmel Valley during periods when flows in the Carmel River exceed fisheries bypass flow requirements, treated to potable drinking water standards, and then conveyed through CAW's distribution system to ASR facilities in the SGB. Recharge is accomplished via injection of these excess flows into specially designed ASR wells drilled in the SGB. The locations of the ASR wells and associated project monitoring wells in the SGB are shown on **Figure 1**. The recharged water is temporarily stored underground utilizing the available storage space within the aquifer system. During periods of high demand, other existing CAW production wells in the SGB and/or the ASR wells can be used to recover the previously recharged water, which in turn allows for reduced extractions from the Carmel River system during seasonal dry periods.

The District and CAW have been cooperatively developing an ASR project on the Monterey Peninsula since 1996. These efforts have evolved over time, from the performance of various technical feasibility investigations, leading to the construction and testing of pilot- and then full-scale ASR test wells to demonstrate the viability and operational parameters for ASR wells in the SGB. Based on the success of the ASR demonstration testing program, MPWMD and CAW are in the process of implementing a full-scale permanent ASR Project.

The Phase 1 ASR Project (a.k.a. Water Project 1) includes two ASR wells (SM ASR-1 and SM ASR-2) located at the Santa Margarita ASR Facility at 1910 General Jim Moore Blvd. in Seaside. The Phase 1 Project is capable of recharging up to the State Water Resources Control Board (SWRCB) water right[2] maximum annual diversion limit of 2,426 acre-feet per year (afy) at a combined permitted injection rate of approximately 3,000 gallons per minute ([gpm]

[1] Water Year 2015 is the period of October 1, 2014 through September 30, 2015.
[2] SWRCB water right 20808A for the Phase 1 ASR Project is held jointly by MPWMD and CAW.

maximum diversion rate of 6.7 cubic feet per second [cfs]), with an average annual yield of approximately 920 afy. SM ASR-1 is designed for an injection capacity of 1,000 to 1,250 gpm and SM ASR-2 is designed for an injection capacity of 1,500 to 1,750 gpm. As-built schematics of SM ASR-1 and SM ASR-2 are presented on **Figures 2 and 3**, respectively.

The Phase 2 ASR Project (a.k.a. Water Project 2) includes two ASR wells (SMS ASR-3 and SMS ASR-4) located at the Seaside Middle School (SMS) ASR Facility at 2111 General Jim Moore Blvd. in Seaside. The Phase 2 Project is designed to be capable of recharging up to the SWRCB water right[3] maximum annual diversion limit of 2,900 afy at a combined permitted injection rate of approximately 3,600 gpm (maximum diversion rate of 8.0 cfs), with an average annual yield of approximately 1,000 afy. SMS ASR-3 and SMS ASR-4 are both designed for injection capacities of 1,500 to 1,750 gpm. SMS ASR-3 was constructed in 2010, and WY 2012 was the first time injection occurred at this well. As-built schematics of SMS ASR-3 and SMS ASR-4 are presented on **Figures 4 and 5**, respectively.

A graphical summary of historical ASR operations in the SGB is shown on **Figure 6**. Shown are the annual injection and recovery volumes since the inception of injection operations at the Santa Margarita ASR Facility in WY 2001 through the current period of WY 2015. Also presented is a delineation of the various phases of project implementation, starting with the Santa Margarita Test Injection Well (SMTIW) in 2001, which became SM ASR-1 as the project transitioned from a testing program to a permanent project in WY 2008 (Phase 1 ASR Project), through construction and operation of the second well (SM ASR-2) at the facility in 2010. As shown, having the Santa Margarita Facility in full operation with two ASR wells injecting simultaneously since 2010 (combined with above normal rainfall and Carmel River flows during WY 2010 and WY 2011) resulted in significant increases in the volume injected annually. As the two additional Phase 2 Project ASR wells (ASR-3 and ASR-4) come on line in full operation, commensurate increases in annual injection volumes are expected to occur (depending on hydrologic conditions in any given year).

**PURPOSE AND SCOPE**

The overall purpose of the ongoing ASR program is to recharge the SGB with excess treated Carmel River system water when it is available during wet periods for storage and later extraction (recovery) during dry periods. ASR benefits the resources of both systems by raising water levels in the SGB during the recharge and storage periods and reducing extractions from the Carmel River System during dry periods.

The scope of the ongoing data collection, analysis, and reporting program for the ASR program can be categorized into issues generally associated with:

1) ASR well hydraulics and performance;
2) Aquifer response to injection, and;

[3] The SWRCB water right 20808C for the Phase 2 ASR Project is held jointly by MPWMD and CAW.

3) Water-quality issues associated with geochemical interaction and mixing of injected and native groundwaters.

The ongoing data collection and reporting program is intended to monitor and track ASR well performance and aquifer response to injection (both hydraulic and water quality) and to comply with the requirements of the Central Coast Regional Water Quality Control Board (RWQCB) for submitting annual technical reports for the project pursuant to Section 13267 of the California Water Code[4] and the existing General Waiver for Specific Types of Discharges (Resolution R3-2008-0010).

## FINDINGS

## WY 2015 ASR OPERATIONS

### General Recharge Procedures

Recharge of the SGB occurs via injection of diverted flows from the CAW distribution system into ASR wells during periods of available excess Carmel River system flows. The ASR recharge source water is potable (treated) water provided from the CAW distribution system. The water is currently diverted by various production well sources in Carmel Valley and (after treatment and disinfection to potable standards) then conveyed through the Segunda-Crest pipeline network to the ASR Pipeline in General Jim Moore Blvd and then to the Santa Margarita and Seaside Middle School ASR facilities.

Injection water is introduced into the ASR wells via the pump columns. Injection rates are controlled primarily by downhole flow control valves (FCV's) installed on the pump columns, and secondarily by modulating the automatic flow control valves (i.e., Cla-Vals) installed on the ASR wellhead piping. Injection flow rates and total injected volumes are measured with rate and totalizing meters at each of the wellheads. Positive gauge pressures are maintained at the wellheads during injection to prevent cascading of water into the wells (which can lead to air-binding). Continuous water-level data at each of the ASR wells are collected with submersible pressure transducer data loggers.

Injection generally occurs at each of the ASR wells on a continuous basis when flows are available, interrupted only for periodic backflushing, which typically occurs on an approximate weekly basis. Most sources of injection water contain trace amounts of solids that slowly accumulate in the pore spaces in the well's gravel pack and adjacent aquifer materials, and the CAW source water is no exception. Periodic backflushing of the ASR wells is therefore necessary to maintain well performance by removing materials deposited/accumulated around the well bore during injection. The procedure is similar to backwashing a media filter to remove accumulated material deposited during filtration.

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[4] Letter from Roger W. Briggs, Executive Officer of the Central Coast RWQCB, to Joseph Oliver, Water Resources Manager for MPWMD, dated April 29, 2009.

The trigger for backflushing is when the amount of water-level drawup during injection equals the available drawdown (as measured from the static water level to the top of the pump bowls) in the well for backflushing, or one week of continuous injection, whichever occurs first. This helps to avoid over-pressurization and compression of plugging materials, thereby maximizing the efficiency of backflushing and limiting the amount of residual plugging. This factor is the basis for the maximum recommended drawup levels referenced in the following section.

The general procedure consists of temporarily stopping injection and then pumping the wells at a rates of approximately 2,000 to 3,000 gpm (i.e., at least twice the rate of injection) for a period of approximately 15 to 20 minutes, and repeated as necessary to effectively remove particulates from the well screen / gravel pack / aquifer matrix. Backflush water is discharged to the Santa Margarita ASR Facility backflush pit, where it percolates back into the groundwater basin.

**Injection Operations Summary**

A summary of injection operations at the four ASR wells is presented in **Table 1** below. Field data collected during injection operations are presented in **Appendix A** (not included in draft).

**Table 1. WY 2015 Injection Operations Summary**

| | Injection Season | | Active | Injection Rate (gpm) | | | Total Vol |
|---|---|---|---|---|---|---|---|
| Well | Start | End | Days | Min | Max | Avg | (af) |
| ASR-1 | 12/15/2014 | 2/17/2015 | 12 | 870 | 1,610 | 1,274 | 38.6 |
| ASR-2 | 12/12/2014 | 2/17/2015 | 23 | 340 | 1,775 | 1,404 | 130.9 |
| ASR-3 | 12/15/2014 | 2/15/2015 | 12 | 655 | 1,066 | 942 | 45.2 |
| ASR-4 | 2/11/2015 | 2/13/2015 | 3 | 247 | 1,073 | 550 | 0.5 |
| | | | | | | **Total** | **215.2** |

As shown in **Table 1**, recharge operations were performed intermittently in WY 2015 during the period of December 12, 2014 through February 17, 2015. WY 2015 was classified as a Dry Water Year[5] on the Carmel River with only 23 days of active injection and a commensurately modest total volume of approximately 215 acre-feet (af) of water was available for diversion from the CAW system for recharge in the SGB. The recharge water was injected at all four ASR wells into the Santa Margarita Sandstone aquifer with per-well average injection rates ranging from approximately 550 to 1,400 gpm (approximately 2.43 to 6.20 acre-feet per day [afd]). The combined total volume of injection during WY 2015 was approximately 215 af.

It is noted that the variability in injection rates at the ASR wells during the injection season is controlled by various factors, including the number of active sources to the CAW

[5] Based on 22,209 af of unimpaired Carmel River flow at the San Clemente Dam site in WY 2015.

system, customer demands on the CAW system, and the ability of CAW's distribution system to maintain piping pressure at the ASR wellheads.

Water-level data collected at SM ASR-1, SM ASR-2, SMS ASR-3 and SMS ASR-4 during WY 2015 are presented in **Figures 7 through 10**, respectively. The water-level data show the response of both SM ASR-1 and ASR-2 to injection, with maximum water-level drawups of approximately 51 and 95 feet, which were well below the maximum recommended drawup levels of approximately 100 and 130 feet, respectively. At SMS ASR-3 the maximum water-level drawup was approximately 113 feet, which was also well below its maximum recommended drawup level of approximately 170 feet. At ASR-4, the water-level transducer/datalogger malfunctioned and no data are available for WY 2015.

### Recovery Operations Summary

As WY 2015 was the fourth consecutive Dry or Critically Dry Year on the Monterey Peninsula, a decision was made by the resource management agencies to not recover the water injected during this year, so that this water could be held over for recovery if needed in the following year, should dry conditions persist. Accordingly, as shown on **Figure 6**, no WY 2015 recharged water was recovered by CAW wells during WY 2015.

When the injected water is recovered via delivery through the CAW system, the recovered water is offset by reduced pumping by CAW from the Carmel River system during the low-flow, high demand periods of the year. It is noted that in this context, ASR recovery is essentially an accounting / allocation of CAW's various water rights and pumping from the SGB, and does not represent a "molecule-for-molecule" recovery of the injected water. Rather, the volume recharged increases the operational yield of the SGB by the same amount and can be "recovered" by any of CAW's wells in the SGB and / or the ASR wells themselves. It is anticipated, however, that recovery operations via the ASR wells will occur more extensively in the future, once all of the wells are permitted for production into the CAW distribution system.

## WELL PERFORMANCE

Well performance is generally measured by specific capacity (pumping) and / or specific injectivity (injection), which is the ratio of flow rate (pumping or injection) to water-level change in the well (drawdown or drawup) over a specific elapsed time. The value is typically expressed as gallons per minute per foot of water level change (gpm/ft). The value normalizes well performance by taking into account differing static water levels and flow rates. As such, specific capacity / injectivity data are useful for comparing well performance over time and at differing flow rates. Decreases in specific capacity / injectivity are indicative of decreases in the hydraulic efficiency of a well due to the effects of plugging and/or particle rearrangement.

### Injection Performance

Injection performance has been tracked at ASR-1 since the inception of the ASR program in WY 2002 by measurement and comparison of 24-hour injection specific injectivities (a.k.a. injection specific capacity).

**SM ASR-1.** A summary of 24-hour specific injectivity for ASR-1 for WY 2002 through 2015 is presented in **Table 2** below:

**Table 2. Injection Performance Summary - ASR-1**

| Water Year | Injection Rate (gpm) | 24-hour DUP (feet) | Specific Injectivity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| **WY2002** | | | | | |
| Beginning Period | 1,570 | 81.7 | **19.2** | | FCV not installed yet in WY2002. No recovery pumping performed. |
| Ending Period | 1,164 | 199.8 | **6.4** | **-67%** | |
| **WY2003** | | | | | |
| Beginning Period | 1,070 | 70.0 | **15.5** | | Recovery pumping performed following WY2003 Injection |
| Ending Period | 1,007 | 49.7 | **20.3** | **+31%** | |
| **WY2004** | | | | | |
| Beginning Period | 1,383 | 183.4 | **7.5** | | Recovery pumping performed following WY2004 Injection |
| Ending Period | 1,072 | 67.4 | **15.9** | **+112%** | |
| **WY2005** | | | | | |
| Beginning Period | 1,045 | 46.6 | **22.4** | | Injectate dechlorinated in WY2005. No recovery pumping performed. |
| Ending Period | 976 | 94.1 | **10.4** | **-54%** | |
| **WY2006** | | | | | |
| Beginning Period | 1,039 | 71.5 | **15.0** | | Injection procedures consistent and performance stable in WY2006. No recovery pumping performed. |
| Ending Period | 1,008 | 62.2 | **17.5** | **+17%** | |
| **WY2007** | | | | | |
| Beginning Period | 1,098 | 92.4 | **11.9** | | Only one injection period in WY2007. No recovery pumping performed. |
| Ending Period | -- | -- | **--** | **--** | |
| **WY2008** | | | | | |
| Beginning Period | 979 | 25.5 | **38.4** | | Formal rehabilitation performed prior to WY2008 injection |
| Ending Period | 1,063 | 33.4 | **31.8** | **-17%** | |
| **WY 2009** | | | | | |
| Beginning Period | 1,119 | 56.1 | **19.9** | | Beginning period low specific injectivity due to high plugging rate during initial injection period. No recovery pumping performed. |
| Ending Period | 1,069 | 34.3 | **31.1** | **+56%** | |
| **WY 2010** | | | | | |
| Beginning Period | 1,080 | 35.6 | **30.3** | | Observed decline in performance due to residual plugging. |
| Ending Period | 1,326 | 54.0 | **24.6** | **-19%** | |

| Water Year | Injection Rate (gpm) | 24-hour DUP (feet) | Specific Injectivity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| **WY 2011** | | | | | |
| Beginning Period | 1,367 | 53.0 | **25.8** | | Observed decline in performance due to residual plugging. |
| Ending Period | 1,454 | 63.7 | **22.8** | **-10%** | |
| **WY 2012** | | | | | |
| Beginning Period | NA | NA | NA | | No injection at this well this year. |
| Ending Period | NA | NA | NA | **NA** | |
| **WY 2013** | | | | | |
| Beginning Period | NA | NA | NA | | No injection at this well this year. |
| Ending Period | NA | NA | NA | **NA** | |
| **WY 2014** | | | | | |
| Beginning Period | NA | NA | NA | | No injection at this well this year. |
| Ending Period | NA | NA | NA | **NA** | |
| **WY 2015** | | | | | |
| Beginning Period | NA | NA | NA | | See discussion below. |
| Ending Period | 1,018 | 40.7 | **25.0** | **NA** | |

As shown in **Table 2**, there are no beginning period data for ASR-1 during WY 2015 because the water-level transducer / datalogger was non-operational; however, the ending period specific injectivity was 25.0 gpm/ft, which is slightly greater than the ending specific injectivity in WY 2011 (the last time data are available) of 22.8 gpm/ft, suggesting that little residual plugging likely occurred at this well during WY 2015.

**ASR-2.** A summary of the beginning and ending injection performance at ASR-2 for WY 2010 through WY 2015 is presented in **Table 3** below:

**Table 3. Injection Performance Summary - ASR-2**

| Water Year | Injection Rate (gpm) | 24-hour DUP (feet) | Specific Injectivity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| **WY 2010** | | | | | |
| Beginning Period | 1,017 | 156.5 | **6.5** | | Significant residual plugging. |
| Ending Period | 237 | 85.0 | **2.8** | **-57%** | |
| **WY 2011** | | | | | |
| Beginning Period | 1,497 | 39.5 | **37.9** | | Significant improvement as a result of well rehabilitation. No residual plugging during year. |
| Ending Period | 1,292 | 34.3 | **37.7** | **-0.5%** | |

| Water Year | Injection Rate (gpm) | 24-hour DUP (feet) | Specific Injectivity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| **WY 2012** | | | | | |
| Beginning Period | 1,830 | 56.1 | **32.6** | | Observed decline in performance due to residual plugging. |
| Ending Period | 1,817 | 63.4 | **28.7** | **-12%** | |
| **WY 2013** | | | | | |
| Beginning Period | 1,087 | 32.7 | **33.2** | | No residual plugging during year. |
| Ending Period | 1,508 | 44.2 | **34.1** | **+3%** | |
| **WY 2014** | | | | | |
| Beginning Period | NA | NA | NA | | No injection at this well this year. |
| Ending Period | NA | NA | NA | **NA** | |
| **WY 2015** | | | | | |
| Beginning Period | 1,456 | 38.9 | **37.4** | | See discussion below. |
| Ending Period | 1,574 | 49.1 | **32.1** | **-14%** | |

As shown in **Table 3**, the 24-hour specific injectivity at the beginning of WY 2015 was 37.4 gpm/ft and at the end of WY 2015 it was 32.1 gpm/ft, representing a decrease of approximately 14 percent, indicating that slight residual plugging occurred at ASR-2 over the course of the WY 2015 injection season; however, the WY 2015 ending specific injectivity is only slightly lower than the value at the end of WY 2013 of 34.1 gpm/ft, suggesting that little residual plugging has occurred over the long-term at this well since it was rehabilitated in WY 2011.

**ASR-3.** A summary of the beginning and ending injection performance at ASR-3 for WY 2013 through WY 2015 is presented in **Table 4** below:

**Table 4. Injection Performance Summary – ASR-3**

| Water Year | Injection Rate (gpm) | 24-hour DUP (feet) | Specific Injectivity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| **WY 2013** | | | | | |
| Beginning Period | 1,044 | 87.0 | **12.0** | | See discussion below. |
| Ending Period | 822 | 99.6 | **8.3** | **-31%** | |
| **WY 2014** | | | | | |
| Beginning Period | NA | NA | NA | | No injection at this well this year. |
| Ending Period | NA | NA | NA | **NA** | |
| **WY 2015** | | | | | |
| Beginning Period | NA | NA | NA | | See discussion below. |
| Ending Period | 892 | 90.3 | **9.9** | **NA** | |

As shown in **Table 4**, there are no beginning period data for ASR-3 during WY 2015 because the water-level transducer / datalogger was non-operational; however, the ending period specific injectivity was 9.9 gpm/ft, which is slightly greater than the ending specific injectivity in WY 2013[6] of 9.9 gpm/ft; this suggests that little residual plugging likely occurred at this well during WY 2015.

**ASR-4.** Injection at ASR-4 during WY 2015 was limited to three days of well "conditioning" (0.49 af). This conditioning consisted of numerous injection and backflushing cycles at relatively low rates and durations, being incrementally increased upon confirmation that well performance was being maintained. The conditioning was performed in an effort to limit the performance decline that has historically been observed at all three ASR wells following their initial injection operations.

Initial injection was performed at a rate of approximately 280 gpm for 5 minutes, followed by backflushing. The injection rate and duration were incrementally increased over the course of three days, up to an injection rate of approximately 1,070 gpm for a maximum duration of 30 minutes, followed by backflushing. The specific injectivity during these operations was consistently approximately 50 gpm/ft (plus or minus 10 percent), indicating that no measureable residual plugging occurred. Additional well conditioning is planned for WY 2016 to achieve the design injection rate of 1,500 gpm.

### Pumping Performance

Pumping performance has also been tracked at ASR-1 since the inception of the SMTIW testing program by measurement and comparison of specific capacity. Following routine backflushing operations and periods of water-level recovery, controlled 10-minute specific-capacity tests are typically performed to track well pumping performance, similar to the tracking of injection performance from 24-hour specific injectivity discussed above.

**ASR-1.** A summary of injection season beginning and ending 10-minute specific capacities at ASR-1 for WY 2002 through 2015 is presented below in **Table 5**:

**Table 5. Pumping Performance Summary - ASR-1**

| Water Year | Pumping Rate (gpm) | 10-min DDN (feet) | Specific Capacity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| **WY2002** | | | | | |
| Pre-Injection | 2,825 | 45.1 | **62.6** | | FCV not installed yet in WY2002 |
| Post- Injection | 2,800 | 95.3 | **29.4** | **-53%** | |

[6] The last time data are available.

| Water Year | Pumping Rate (gpm) | 10-min DDN (feet) | Specific Capacity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| **WY2003** | | | | | |
| Pre-Injection | 2,775 | 81.9 | **33.9** | **-16%** | Recovery pumping performed following WY2003 Injection |
| Post- Injection | 2,600 | 91.7 | **28.4** | | |
| **WY2004** | | | | | |
| Pre-Injection | 2,000 | 51.8 | **38.6** | **-46%** | Recovery pumping performed following WY2004 Injection |
| Post- Injection | 1,700 | 81.2 | **20.9** | | |
| **WY2005** | | | | | |
| Pre-Injection | 1,900 | 49.8 | **38.1** | **-55%** | Injectate dechlorinated in WY2005. No recovery pumping performed. |
| Post- Injection | 1,500 | 87.1 | **17.2** | | |
| **WY2006** | | | | | |
| Pre-Injection | 1,500 | 82.4 | **18.2** | **+19%** | Injection procedures consistent and performance stable in WY2006. No recovery pumping performed. |
| Post- Injection | 1,600 | 74.1 | **21.6** | | |
| **WY2007** | | | | | |
| Pre-Injection | 1,500 | 81.7 | **18.4** | **+3%** | Only one injection period in WY2007. No recovery pumping performed. |
| Post- Injection | 1,500 | 79.4 | **18.9** | | |
| **WY2008** | | | | | |
| Pre-Injection | 1,980 | 31.0 | **63.8** | **-44%** | Formal rehabilitation performed prior to WY2008 injection. No recovery pumping performed. |
| Post- Injection | 2,000 | 55.6 | **36.0** | | |
| **WY 2009** | | | | | |
| Pre-Injection | 2,000 | 52.0 | **38.5** | **-21%** | No recovery pumping performed. |
| Post- Injection | 1,900 | 62.7 | **30.3** | | |
| **WY 2010** | | | | | |
| Pre-Injection | 1,900 | 62.5 | **30.4** | **+2%** | Performance essentially stable. |
| Post- Injection | 2,000 | 64.2 | **31.1** | | |
| **WY 2011** | | | | | |
| Pre-Injection | 2,000 | 64.2 | **31.1** | **-3%** | Performance essentially stable. |
| Post- Injection | 2,000 | 64.6 | **30.1** | | |
| **WY 2012** | | | | | |
| Pre-Injection | 2,400 | 74.7 | **32.1** | NA | No injection during WY 2012. Datalogger damaged in June 2012. |
| Post-Injection | NA | NA | NA | | |

| Water Year | Pumping Rate (gpm) | 10-min DDN (feet) | Specific Capacity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| **WY 2013** | | | | | |
| Pre-Injection | NA | NA | NA | | No injection during WY 2013. Pump non-operational |
| Post- Injection | NA | NA | NA | NA | |
| **WY 2014** | | | | | |
| Pre-Injection | NA | NA | NA | | No injection during WY 2014. |
| Post-Injection | NA | NA | NA | NA | |
| **WY 2015** | | | | | |
| Pre-Injection | 3,300 | 73.6 | **44.8** | | See discussion below. |
| Post- Injection | 3,600 | 84.8 | **42.5** | **-5%** | |

As shown in **Table 5**, the pumping performance of ASR-1 declined significantly following initial injection in WY 2002. Performance improved significantly in WY 2008 compared to WY 2007 as a result of rehabilitation of the well prior to the WY 2008 injection season. During WY 2015, pumping performance declined slightly by approximately 5 percent.

**ASR-2.** A summary of injection season beginning and ending 10-minute specific capacities for ASR-2 is presented below in **Table 6**:

**Table 6. Pumping Performance Summary - ASR-2**

| Water Year | Pumping Rate (gpm) | 10-min DDN (feet) | Specific Capacity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| **WY 2009** | | | | | |
| Pre-Injection | 3,200 | 72.3 | **44.3** | | Injection testing performed with source water from MCWD. |
| Post- Injection | 2,200 | 117.7 | **18.7** | **-58%** | |
| **WY 2010** | | | | | |
| Pre-Injection | 2,200 | 117.7 | **18.7** | | Pre-injection is after MCWD testing (refer to WY 2009 Summary of Operation report) |
| Post- Injection | 2,300 | 136.9 | **16.8** | **-10%** | |
| **WY 2011** | | | | | |
| Pre-Injection | 3,100 | 83.9 | **36.9** | | Formal rehabilitation performed prior to WY 2011 injection season. Relatively stable during season. |
| Post- Injection | 3,100 | 93.5 | **33.2** | **-10%** | |
| **WY 2012** | | | | | |
| Pre-Injection | 2,800 | 84.5 | **33.1** | | Minor residual plugging occurred. |
| Post- Injection | 2,700 | 92.3 | **29.3** | **-11%** | |

| Water Year | Pumping Rate (gpm) | 10-min DDN (feet) | Specific Capacity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| **WY 2013** | | | | | |
| Pre-Injection | 2,700 | 92.3 | **29.3** | | Performance improved. |
| Post- Injection | 3,000 | 87.7 | **34.2** | **+17%** | |
| **WY 2014** | | | | | |
| Pre-Injection | NA | NA | NA | | No injection during WY 2014. |
| Post- Injection | NA | NA | NA | NA | |
| **WY 2015** | | | | | |
| Pre-Injection | 3,300 | 67.4 | **48.9** | | See discussion below. |
| Post- Injection | 2,800 | 86.7 | **32.3** | **-34%** | |

As shown in **Table 6**, the pumping performance of ASR-2 declined significantly following initial injection in WY 2009, similar to the initial decline experienced at ASR-1. ASR-2 performance improved significantly in WY 2011 compared to WY 2010 as a result of rehabilitation of the well prior to the WY 2011 injection season. During WY 2015, pumping performance declined by approximately 34 percent. This compares with the injection performance results, which showed an approximate 14 percent decline in performance over the course of WY 2015. However, the WY 2015 ending specific capacity is only slightly lower than the value at the end of WY 2013 of 34.2 gpm/ft, again indicating that little residual plugging has occurred over the long-term at this well since it was rehabilitated in WY 2011.

**ASR-3.** A summary of injection season beginning and ending 10-minute specific capacities for ASR-3 is presented below in **Table 7**:

**Table 7. Pumping Performance Summary - ASR-3**

| Water Year | Pumping Rate (gpm) | 10-min DDN (feet) | Specific Capacity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| **WY 2012** | | | | | |
| Pre-Injection | 3,200 | 107.1 | **29.9** | | Significant residual plugging occurred. |
| Post- Injection | 2,400 | 186.4 | **12.9** | **-57%** | |
| **WY 2013** | | | | | |
| Pre-Injection | 2,400 | 186.4 | **12.9** | | Slight decline in performance |
| Post- Injection | 2,000 | 174.3 | **11.5** | **-11%** | |
| **WY 2014** | | | | | |
| Pre-Injection | NA | NA | NA | | No injection during WY 2014. |
| Post- Injection | NA | NA | NA | NA | |

| Water Year | Pumping Rate (gpm) | 10-min DDN (feet) | Specific Capacity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| **WY 2015** | | | | | |
| Pre-Injection | 1,600 | 119.6 | **13.4** | | See discussion below. |
| Post- Injection | 2,100 | 149.8 | **14.0** | **+4%** | |

As shown in **Table 7**, the pumping performance of ASR-3 declined significantly following initial injection in WY 2012, similar to the declines experienced at both SM ASR-1 and SM ASR-2 following initial injection. During WY 2015, performance was relatively stable, increasing very slightly by 4 percent.

The above results indicate a pattern in ASR well performance, with all three ASR wells having experienced comparably significant declines in performance following initial injection, followed by a period of relative stability in performance. It is hypothesized that the observed loss in performance is due to particle rearrangement (mechanical jamming) and/or chemical precipitation, as opposed to the normal and relatively slow plugging caused by particulates. This phenomenon is the reason for the well "conditioning" effort performed at ASR-4 during WY 2015 (discussed previously in the Pumping Performance section on page 9). It is also noted that while ASR-3 has experienced a significant decline in performance following initial injection, (which limits its injection capacity to approximately 1,000 gpm,) it is expected that rehabilitation will result in significantly improved performance as has been observed at both ASR-1 and ASR-2.

## Residual Plugging

Experience at injection well sites around the world shows that all injection wells are subject to some amount of plugging, because no water source is completely free of particulates, bionutrients, or oxidants, all of which can contribute to well plugging; the CAW source water is no exception. During injection, trace amounts of suspended solids are continually being deposited in the gravel pack and aquifer pore spaces, much as a media filter captures particulates in the filter bed. The effect of plugging is to impede the flow of water from the injection well into the aquifer, causing increased injection heads in the well to maintain a given injection rate, or reduced injection rates at a given head level. Well plugging reduces injection and extraction capacity, and can result in decreased useful well life if not mitigated.

Relative measurements of the particulate matter in the injectate have historically been made at the Santa Margarita site through silt density index (SDI) testing during injection. The SDI was originally developed to quantitatively assess particulate concentrations in reverse-osmosis feed waters. The SDI test involves pressure filtration of source water through a 0.45-micron membrane, and observation of the decrease in flow rate through the membrane over time; the resulting (dimensionless) value of SDI is used as a comparative value for tracking relative declines in well plugging rates associated with particulate plugging during an injection season (i.e., plugging rates tend to increase directly with SDI). During WY 2015 injection operations, SDI values at the beginning of the injection season were less than 3.0 and fell to approximately 1.0 after the first week of injection.

*Residual plugging* is the plugging that remains following backflush pumping. Residual plugging increases drawdown during pumping and drawup during injection, and is manifested as declining specific capacity / injectivity. The presence of residual plugging is indicative of incomplete removal of plugging particulates during backflushing and has the cumulative effect of reducing well performance and capacity over time.

As discussed previously, routine 10-minute specific capacity tests were performed at the ASR wells as part of backflushing events during WY 2015. Presented in **Table 8** below is a summary of the residual plugging calculations for the ASR wells during WY 2015.

**Table 8. Residual Plugging Summary**

| Well | Test | Pumping Rate (gpm) | 10-min Drawdown (ft) | 10-min Q/s[1] (gpm/ft) | Normalize-ation Ratio[2] | Normalized Drawdown[2] (ft) | Residual Plugging (ft) |
|---|---|---|---|---|---|---|---|
| ASR-1 | Pre-Injection | 3,300 | 73.6 | 44.8 | 0.91 | 66.9 | -- |
| | Post-Injection | 3,600 | 84.8 | 42.5 | 0.83 | 70.7 | 3.8 |
| ASR-2 | Pre-Injection | 3,300 | 67.4 | 49.0 | 0.91 | 61.3 | -- |
| | Post-Injection | 2,800 | 86.7 | 32.3 | 1.07 | 92.9 | 31.6 |
| ASR-3 | Pre-Injection | 1,600 | 119.6 | 13.4 | 1.25 | 149.5 | -- |
| | Post-Injection | 2,100 | 149.8 | 14.0 | 0.95 | 142.7 | -6.8 |
| ASR-4 | Pre-Injection | 2,900 | 105.8 | 27.4 | 1.03 | 109.4 | -- |
| | Post-Injection | 3,000 | 103.5 | 29.0 | 1.00 | 103.5 | -5.9 |

**Notes:**
1 - Specific Capacity. Ratio of pumping rate to drawdown.
2 - Normalized based on ratio of 3,000 gpm to actual test pumping rate for ASR-1, -2 and -4. Based on 2,000 gpm for ASR-3.

As shown on **Figures 7 through 9**, injection water levels were maintained significantly below the recommended maximum available drawups at all three ASR wells during WY 2015. As shown in **Table 8**, the bulk the observed residual plugging during WY 2015 occurred at ASR-2 with 31.6 feet of residual plugging. The other three wells observed little to no residual plugging. The specific reason that ASR-2 experienced a relatively higher level of residual plugging compared to the other wells is unknown, but these results indicate that more intensive backflushing (e.g., multiple backflush cycles as opposed to a single cycle) should be implemented at ASR-2 during WY 2016 to limit residual plugging and maintain performance.

## AQUIFER RESPONSE TO INJECTION

The response of the regional aquifer system to injection has been monitored since the SMTIW project was initiated in WY 2002. Submersible water-level transducer/data logger units have been installed at seven offsite monitoring well locations in the SGB as well as three onsite monitoring wells. The locations of each offsite monitoring well are shown on **Figure 1**, and water-level hydrographs for the monitoring wells during WY 2015 are graphically presented on **Figures 11 through 19**. A summary of the regional water-level observations during the WY 2015 injection season is presented in **Table 9** below.

**Table 9. Aquifer Response Summary**

| Well ID | Distance from Nearest Active ASR Well (feet) | Aquifer Monitored | Fig. No. | Pre-Injection DTW (ft. btoc) | Shallowest Injection DTW (ft. btoc) | Maximum Drawup Response (ft.) |
|---|---|---|---|---|---|---|
| SMS (Shallow) | 25 (SMS ASR-3) | QTp | **11** | No Discernable Response | | |
| SMS (Deep) | | Tsm | | 363.7 | 321.9 | **41.8** |
| SM MW-1 | 190 (SM ASR-2) | Tsm | **12** | 354.1 | 330.7 | **23.4** |
| Paralta Test | 650 (SM ASR-2) | QTp & Tsm | **13** | 365.3 | 356.8 | **8.5** |
| Ord Grove Test | 1,820 (SM ASR-2) | QTp & Tsm | **14** | No Discernable Response | | |
| Ord Terrace (Shallow) | 2,550 (SM ASR-2) | Tsm | **15** | No Discernable Response | | |
| FO-7 (Shallow) | 3,700 (SMS ASR-3) | QTp | **16** | No Discernable Response | | |
| FO-7 (Deep) | | Tsm | | 491.9 | 485.3 | **6.6** |
| FO-9 (Deep) | 6,130 (SMS ASR-3) | Tsm | **17** | 135.8 | 131.4 | **4.4** |
| PCA East (Shallow) | 6,200 (SMS ASR-3) | QTp | **18** | No Discernable Response | | |
| PCA East (Deep) | | Tsm | | 88.6 | 82.9 | **5.7** |
| FO-8 (Deep) | 6,450 (SMS ASR-3) | Tsm | **19** | 398.2 | 393.1 | **5.1** |

**Notes**:
QTp – Quaternary / Tertiary-age Paso Robles Formation aquifer
Tsm – Tertiary-age Santa Margarita Sandstone aquifer
DTW – Depth to Water

As shown on the water-level hydrographs, water levels in the Santa Margarita Sandstone (Tsm) aquifer at the start of the WY 2015 recharge season ranged between approximately 15 to 65 feet below sea level. Positive response to injection during WY 2015 was observed at 7 of the 9 monitoring wells completed in the Santa Margarita Sandstone aquifer, with apparent water-level responses ranging between approximately 4 to 42 feet, decreasing with distance from the ASR wells, which is the typical and expected aquifer response to hydraulic stresses (i.e., injection or pumping). The WY 2015 responses are comparable to those observed in previous water years.

The available water-level data also continue to show that at the Tsm-only monitoring wells, water levels consistently remained below sea level throughout the injection season. Under these water-level conditions, little to no offshore groundwater flow from the Tsm aquifer would be expected to occur and any “losses” associated with ASR project operations from water potentially migrating offshore are highly unlikely.

The limited available data for wells completed in the Paso Robles Formation (QTp) also continue to show no discernible response to injection and water levels in this aquifer remained above the water levels in the underlying Tsm aquifer during WY 2015. Under these water-level conditions, little to no flow of water from the Tsm to the QTp aquifer would be expected to occur.

It is further noted that the Ord Grove Test and Ord Terrace monitoring wells (refer to **Figures 14 and 15**) continue to show no discernible response to injection operations, as has been observed during previous injection seasons. Most project monitoring wells show no discernible response to the pumping of CAW's Ord Grove production well. These observations suggest that the Ord Terrace Fault or a parallel branch of the fault may represent a hydraulic barrier in the Tsm aquifer.

## WATER QUALITY

### General

Source water for injection is supplied from the CAW municipal water system, primarily from Carmel River system wells which are treated at the CAW Begonia Iron Removal Plant (BIRP) for iron and manganese removal. The BIRP water is also disinfected and maintains a free chlorine residual. A phosphate-based corrosion inhibitor (Zinc Orthophosphate) is also added to the filtered water before entering the CAW distribution system. The finished product water meets all California Department of Public Health (CADPH) Primary and Secondary water quality standards.

As in previous years, water quality was routinely monitored at the ASR well sites during WY 2015 injection and aquifer storage operations. Far-field water quality was also monitored at the CAW Paralta production well and at the PCE-East Deep monitoring well (PCA-E Deep). Summaries of the collected water-quality data during WY 2015 are presented in **Tables 10 through 18** below. Analytic laboratory reports are presented in **Appendix B** (not included in draft). A discussion of the water-quality data collected during WY 2015 is presented below.

### Mixing and Dilution

To track the general mixing, dilution, and interaction between injected and native groundwaters, chloride ion ($Cl^-$) has historically been used for the SGB ASR project as a natural tracer. Chloride ion is very stable, highly soluble and is present in both injected and native ground waters; albeit at a 400 percent concentration differential. The historical "native" $Cl^-$ concentration of the groundwaters within the Tsm has averaged approximately 120 - 130 milligrams per liter (mg/L) in this area of the basin. Presented in **Table 10** below is a summary of the relative percentages of injection water at each of the monitored wells before WY 2015 injection operations and at the end of the WY 2015 storage period. Calculation of the injected versus native groundwater (NGW) contribution in a given sample is based on the historical NGW and injected water $Cl^-$ concentrations.

**Table 10. Percent Injectate at Wells**

| Well | Pre-Injection Conditions | | | End-Storage Conditions | | | WY 2015 |
|---|---|---|---|---|---|---|---|
| | Sample Date | Cl (mg/l) | % Injectate in Water | Sample Date | Cl (mg/l) | % Injectate in Water | Change (%) |
| ASR Wells | | | | | | | |
| ASR-1 | 12/4/14 | 142 | 0 | 9/22/15 | 141 | 0 | 0 |
| ASR-2 | 12/4/14 | 107 | 14 | 9/22/15 | 110 | 11 | -2 |
| ASR-3 | 12/5/14 | 95 | 27 | 9/23/15 | 79 | 47 | 20 |
| ASR-4 | 12/5/14 | 118 | 2 | No Data | | | |
| Monitoring Wells | | | | | | | |
| SM MW-1 | 12/4/14 | 109 | 12 | 9/23/15 | 110 | 11 | 0 |
| SMS Deep | 12/5/15 | 92 | 30 | 9/23/15 | 124 | 0 | -30 |
| Paralta | 7/28/14 | 76 | 47 | 7/14/15 | 112 | 9 | -38 |
| PCA-E Deep | 12/10/14 | 80 | 43 | 7/23/15 | 82 | 43 | 1 |

**Notes:**

Based on 2001 Tsm NGW $Cl^-$ content vs 2015 CAW Injectate $Cl^-$

As shown in **Table 10**, prior to the WY 2015 injection season, all of the wells had different percentage mixes of injectate and native groundwater (NGW) and water from the multiple previous injection and recovery seasons. These results range from an estimated 0 percent injected water at ASR-1 to 47 percent at Paralta. By the end of the WY 2015 storage period, the concentrations of injected water at most wells were back to pre-injection levels, with the exception of ASR-3, which observed a net increase in the concentration of injected water of approximately 20 percent. Interestingly, SMS Deep, located approximately 25 feet from ASR-3, and Paralta both observed a net decrease of approximately 30 percent compared to pre-injection conditions (i.e., higher NGW influence) suggesting that the pool of injected water drifted away from the area during WY 2015 operations.

### Injection Water Quality

Injection water quality from the CAW system during WY 2015 is presented in **Table 11** below; the data show injection water quality was typical of recent years. Levels of Trihalomethanes (THM) and Haloacetic Acid (HAA) compounds, as well as bionutrients (oxygen, nitrogen, phosphorous, and organic carbon), were all present at levels similar to previous years.

## Table 11. Summary of WY 2015 Water Quality Data – Injectate

| Parameter | Unit | PQL | MCL | Results CAW Injectate 12/13/14 | 2/11/15 |
|---|---|---|---|---|---|
| | | Sample Description | | Injectate | |
| **Major Cations** | | | | | |
| Calcium | mg/L | *0.5* | | 45 | 42 |
| Magnesium | mg/L | *0.5* | | 15 | 13 |
| Potasium | mg/L | *0.5* | | 2.9 | 2.9 |
| Sodium | mg/L | *0.5* | | 46 | 46 |
| **Major Anions** | | | | | |
| Alkalinity, Total (as CaCO3) | mg/L | *2* | | 153 | 135 |
| Chloride | mg/L | *1* | *250* | 35 | 30 |
| Sulfate | mg/L | *1* | *250* | 90 | 89 |
| Nitrate (as NO3) | mg/L | *1* | *45* | 1 | ND |
| Nitrite (as Nitrogen) | mg/L | *1* | *1* | 0.6 | 0.1 |
| **General Physical** | | | | | |
| pH | Std Units | | | 7.5 | 7.5 |
| Specific Conductance (EC) | uS | *1* | *900* | 611 | 542 |
| Total Dissolved Solids | mg/L | *10* | *500* | 374 | 331 |
| **Metals** | | | | | |
| Arsenic (Total) | ug/L | *1* | *10* | ND | ND |
| Barium (Total) | ug/L | *10* | *1000* | 78 | 61 |
| Iron (Dissolved) | ug/L | *10* | | ND | ND |
| Iron (Total) | ug/L | *10* | *300* | 11 | ND |
| Lithium | ug/L | *1* | | 6 | 5 |
| Manganese (Dissolved) | ug/L | *10* | | ND | ND |
| Manganese (Total) | ug/L | *10* | *50* | 1 | ND |
| Molybdenum | ug/L | *1* | *1000* | 2 | 3 |
| Nickel | ug/L | *10* | *100* | ND | ND |
| Selenium | ug/L | *2* | *50* | 2 | 3 |
| Strontium (Total) | ug/L | *5* | | 259 | 223 |
| Uranium (by ICP/MS) | ug/L | *1* | *30* | 1 | ND |
| Vanadium (Total) | ug/L | *1* | *1000* | ND | ND |
| Zinc (Total) | ug/L | *10* | *5000* | 284 | 271 |
| **Miscellaneous** | | | | | |
| Ammonia-N | mg/L | *0.05* | | ND | ND |
| Boron | mg/L | *0.05* | | ND | ND |
| Chloramines | mg/L | *0.05* | | ND | 0.06 |
| Gross Alpha | pCi/L | | *15* | 1.87 +/- 0.74 | 6.50 +/- 1.39 |
| Kjehldahl Nitrogen (Total) | mg/L | *0.5* | | 0.7 | ND |
| Methane | ug/L | *0.1* | | 0.53 | 0.66 |
| Nitrogen (Total) | mg/L | *0.5* | | 1.5 | ND |
| o-Phosphate-P | mg/L | *0.05* | | 0.2 | 0.4 |
| Phosphorous (Total) | mg/L | *0.03* | | 0.39 | 0.44 |
| Radium 226 | pCi/L | | *3* | 0.56 +/- 0.5 | **5.41 +/- 0.69** |
| **Organic Analyses** | | | | | |
| Haloacetic Acids (Total) | ug/L | *1.0* | *60.0* | 9.2 | 12.2 |
| *Dibromoacetic Acid* | *ug/L* | *1.0* | | *3.3* | *2.5* |
| *Dichloroacetic Acid* | *ug/L* | *1.0* | | *3.4* | *5.7* |
| *Monobromoacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* |
| *Monochloroacetic Acid* | *ug/L* | *2.0* | | *ND* | *ND* |
| *Trichloroacetic Acid* | *ug/L* | *1.0* | | *2.5* | *4.0* |
| Organic Carbon (Dissolved) | mg/L | *0.2* | | 1.0 | 1.7 |
| Organic Carbon (Total) | mg/L | *0.2* | | 1.0 | 1.4 |
| Trihalomethanes (Total) | ug/L | *1.0* | *80.0* | 24.8 | 25.9 |
| *Bromodichloromethane* | *ug/L* | *0.5* | | *8.6* | *9.2* |
| *Bromoform* | *ug/L* | *0.5* | | *1.7* | *0.9* |
| *Chloroform* | *ug/L* | *0.5* | | *6.4* | *9.4* |
| *Dibromochloromethane* | *ug/L* | *0.5* | | *8.1* | *6.4* |
| **Field Parameters** | | | | | |
| Temperature | $^0$ C | *0.1* | | 15.9 | 18.1 |
| Specific Conductance (EC) | uS | *1.0* | *900* | 352 | 463 |
| pH | Std Units | *0.1* | *6.5 - 8.5* | 7.2 | 7.6 |
| ORP | mV | *1.0* | | 573 | 608 |
| Free Chlorine Residual | mg/L | *0.1* | *2 - 5* | 1.3 | 0.5 |
| Dissolved Oxygen | mg/L | *0.01* | | | |
| Silt Density Index | Std Units | *0.1* | | 2.4 | 1.3 |
| Gas Volume | mL | *2.0* | | | |
| $H_2S$ | mg/L | *0.1* | | | |

**Notes:**
Constituents exceeding MCLs denoted in **BOLD** type

**Water Quality During Aquifer Storage**

**Tables 12 through 15** present summaries of water-quality data collected at the four ASR wells. **Tables 16 and 17** present similar data collected at the on-site monitoring wells SM MW-1 and SMS Deep, respectively; and **Table 18** presents the water-quality data collected at the off-site monitoring wells (PCA-E Deep and Paralta). Data for the ASR wells include baseline water quality taken prior to WY 2015 injection (end of WY 2013 Storage) and stored water quality (WY 2015 Storage) collected periodically from the aquifer after WY 2015 injection operations were terminated.

Review of water-quality parameters gathered at the ASR wells, including major anions and cations, redox potential (ORP), and conductivity all showed similar effects of dilution / intermixing of injected water with native groundwater during aquifer storage. As found in previous ASR operations at the site, the most significant water-quality changes observed during aquifer storage other than simple dilution/mixing were redox-related (and likely biologically mediated) reactions; these were primarily evidenced by the degradation of HAA and THM compounds and absence of hydrogen sulfide even in mixed NGW and injected waters.

Disinfection Byproducts (DBPs) parameters at the on-site wells during WY 2015 are graphically presented on **Figures 20 through 24**. As shown, THMs at the ASR wells showed their typical initial and significant ingrowth during the storage period, which results from the presence of free chlorine and trace levels of organic carbon in the injected water. THM ingrowth generally peaks in concentration approximately 30-90 days after the cessation of injection, followed by a gradual decline during the storage period. After approximately 150 to 210 days of storage, THMs typically degraded to below the initial injection levels. The decline in THMs observed at the ASR and on-site monitoring wells followed the characteristic process: rapid degradation of Bromoform and the highly brominated species with much slower decline in Chloroform.

It is noted that THMs were below the Maximum Contaminant Level (MCL) of 80 ug/L throughout WY 2015, with the exception of transiently elevated levels up to 95 and 94 ug/L at ASR-2 and ASR-3, respectively during the peak in-growth periods. These THM levels dropped to 13 and 38 ug/L, respectively, by the end of the storage season.

## Table 12. Summary of WY 2015 Water-Quality Data - ASR-1

| | | | | Results | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | SM ASR-1 | | | | |
| Parameter | Unit | PQL | MCL | 3/21/01 | 12/4/14 | 3/24/15 | 6/17/15 | 9/22/15 |
| | | Sample Description | | NGW | WY 2013 Storage | WY 2015 Storage | | |
| Elapsed Storage Time | Days | | | -- | 686 | 35 | 120 | 217 |
| Volume Purged at Sampling | 1,000 gals | | | -- | | | | |
| **Major Cations** | | | | | | | | |
| Calcium | mg/L | 0.5 | | 85 | 96 | 39 | 64 | 96 |
| Magnesium | mg/L | 0.5 | | 19 | 23 | 13 | 20 | 23 |
| Potasium | mg/L | 0.5 | | 5.3 | 5.5 | 2.9 | 3.7 | 5.7 |
| Sodium | mg/L | 0.5 | | 88 | 105 | 42 | 63 | 101 |
| **Major Anions** | | | | | | | | |
| Alkalinity, Total (as CaCO3) | mg/L | 2 | | 224 | 250 | 133 | 180 | 237 |
| Chloride | mg/L | 1 | 250 | 120 | 142 | 30 | 77 | 141 |
| Sulfate | mg/L | 1 | 250 | 95 | 106 | 83 | 85 | 118 |
| Nitrate (as NO3) | mg/L | 1 | 45 | ND | ND | ND | 1 | ND |
| Nitrite (as Nitrogen) | mg/L | 1 | 1 | | 0.6 | 0.3 | 0.3 | 0.3 |
| **General Physical** | | | | | | | | |
| pH | Std Units | | | 7.1 | 7.2 | 7.1 | 7.4 | 7.1 |
| Specific Conductance (EC) | uS | 1 | 900 | **1015** | **1186** | 516 | 753 | **1141** |
| Total Dissolved Solids | mg/L | 10 | 500 | **618** | **720** | 308 | 463 | **677** |
| **Metals** | | | | | | | | |
| Arsenic (Total) | ug/L | 1 | 10 | ND | 2 | 1 | 1 | 1 |
| Barium (Total) | ug/L | 10 | 1000 | 52 | 80 | 59 | 85 | 84 |
| Iron (Dissolved) | ug/L | 10 | | | 30 | ND | ND | 10 |
| Iron (Total) | ug/L | 10 | 300 | 120 | **324** | 27 | 21 | 59 |
| Lithium | ug/L | 1 | | | 38 | 6 | 20 | 41 |
| Manganese (Dissolved) | ug/L | 10 | | | 41 | ND | ND | 20 |
| Manganese (Total) | ug/L | 10 | 50 | 40 | 40 | ND | ND | 23 |
| Molybdenum | ug/L | 1 | 1000 | | 10 | 3 | 7 | 10 |
| Nickel | ug/L | 10 | 100 | | ND | ND | ND | ND |
| Selenium | ug/L | 2 | 50 | ND | 2 | 4 | 2 | 2 |
| Strontium (Total) | ug/L | 5 | | | 454 | 218 | 322 | 472 |
| Uranium (by ICP/MS) | ug/L | 1 | 30 | | 1 | ND | 1 | 1 |
| Vanadium (Total) | ug/L | 1 | 1000 | | ND | ND | ND | ND |
| Zinc (Total) | ug/L | 10 | 5000 | 10 | 108 | 210 | 250 | 118 |
| **Miscellaneous** | | | | | | | | |
| Ammonia-N | mg/L | 0.05 | | 0.33 | 0.23 | ND | ND | 0.19 |
| Boron | mg/L | 0.05 | | 0.14 | 0.12 | ND | 0.06 | 0.13 |
| Chloramines | mg/L | 0.05 | | | 0.06 | ND | ND | ND |
| Gross Alpha | pCi/L | | 15 | | 3.35 +/- 1.68 | 2.91 +/- 1.19 | 3.46 +/- 1.82 | 4.70 +/- 2.00 |
| Kjehldahl Nitrogen (Total) | mg/L | 0.5 | | | 0.6 | ND | ND | ND |
| Methane | ug/L | 0.1 | | | 3.3 | 0.34 | 2.1 | 0.4 |
| Nitrogen (Total) | mg/L | 0.5 | | | 1.3 | ND | ND | ND |
| o-Phosphate-P | mg/L | 0.05 | | 0.46 | 0.2 | 0.3 | 0.2 | 0.2 |
| Phosphorous (Total) | mg/L | 0.03 | | | 0.15 | 0.3 | 0.3 | 0.17 |
| Radium 226 | pCi/L | | 3 | | 2.82 +/- 1.26 | 0.26 +/- 0.40 | 0.71 +/- 0.48 | 1.28 +/- 0.34 |
| **Organic Analyses** | | | | | | | | |
| Haloacetic Acids (Total) | ug/L | 1.0 | 60.0 | | 0.0 | 11.1 | 0.0 | 0.0 |
| *Dibromoacetic Acid* | *ug/L* | 1.0 | | | *ND* | *ND* | *ND* | *ND* |
| *Dichloroacetic Acid* | *ug/L* | 1.0 | | | *ND* | *2.2* | *ND* | *ND* |
| *Monobromoacetic Acid* | *ug/L* | 1.0 | | | *ND* | *ND* | *ND* | *ND* |
| *Monochloroacetic Acid* | *ug/L* | 2.0 | | | *ND* | *ND* | *ND* | *ND* |
| *Trichloroacetic Acid* | *ug/L* | 1.0 | | | *ND* | *8.9* | *ND* | *ND* |
| Organic Carbon (Dissolved) | mg/L | 0.2 | | | 0.7 | 1.2 | 1.5 | 1.5 |
| Organic Carbon (Total) | mg/L | 0.2 | | 6.3 | 0.8 | 1.2 | 1.1 | 1.3 |
| Trihalomethanes (Total) | ug/L | 1.0 | 80.0 | | 0.0 | 53.0 | 40.6 | 0.6 |
| *Bromodichloromethane* | *ug/L* | 0.5 | | | *ND* | *17* | *12* | *ND* |
| *Bromoform* | *ug/L* | 0.5 | | | *ND* | *0.79* | *0.75* | *ND* |
| *Chloroform* | *ug/L* | 0.5 | | | *ND* | *27* | *22* | *0.6* |
| *Dibromochloromethane* | *ug/L* | 0.5 | | | *ND* | *8.2* | *5.8* | *ND* |
| **Field Parameters** | | | | | | | | |
| Temperature | $^0$C | 0.1 | | | 23.6 | 16.8 | 16.8 | 20.4 |
| Specific Conductance (EC) | uS | 1.0 | 900 | 1015 | 560 | 476 | 789 | 1211 |
| pH | Std Units | 0.1 | 6.5 - 8.5 | 7.1 | 7.1 | 7.8 | 7.2 | 7.3 |
| ORP | mV | 1.0 | | | -203 | -63 | -72 | -147 |
| Free Chlorine Residual | mg/L | 0.1 | 2 - 5 | | 0.02 | 0.04 | 0.11 | ND |
| Dissolved Oxygen | mg/L | 0.01 | | | | | 0.09 | ND |
| Silt Density Index | Std Units | 0.1 | | | | | | |
| Gas Volume | mL | 2.0 | | | | | | |
| $H_2S$ | mg/L | 0.1 | | 1.5 | | ND | 0.04 | 0.07 |

**Notes:**
Constituents exceeding MCLs denoted in **BOLD** type

# Table 13. Summary of WY 2015 Water Quality Data – ASR-2

| Parameter | Unit | PQL | MCL | Results: SM ASR-2 12/4/14 | 3/27/15 | 6/24/15 | 9/22/15 |
|---|---|---|---|---|---|---|---|
| | | Sample Description | | WY 2013 Storage | WY 2015 Storage | | |
| Elapsed Storage Time | Days | | | **686** | **38** | **127** | **217** |
| Volume Purged at Sampling | 1,000 gals | | | | | | |
| **Major Cations** | | | | | | | |
| Calcium | mg/L | *0.5* | | 77 | 43 | 43 | 72 |
| Magnesium | mg/L | *0.5* | | 19 | 14 | 14 | 22 |
| Potasium | mg/L | *0.5* | | 5.3 | 2.9 | 2.8 | 4.6 |
| Sodium | mg/L | *0.5* | | 93 | 44 | 44 | 82 |
| **Major Anions** | | | | | | | |
| Alkalinity, Total (as CaCO3) | mg/L | *2* | | 245 | 132 | 139 | 225 |
| Chloride | mg/L | *1* | *250* | 107 | 30 | 32 | 110 |
| Sulfate | mg/L | *1* | *250* | 72 | 82 | 86 | 74 |
| Nitrate (as NO3) | mg/L | *1* | *45* | 1.0 | ND | ND | ND |
| Nitrite (as Nitrogen) | mg/L | *1* | *1* | 0.9 | 0.4 | 0.4 | 0.3 |
| **General Physical** | | | | | | | |
| pH | Std Units | | | 7.8 | 7.5 | 7.5 | 7.3 |
| Specific Conductance (EC) | uS | *1* | *900* | **990** | 566 | 550 | **950** |
| Total Dissolved Solids | mg/L | *10* | *500* | **597** | 337 | 340 | **540** |
| **Metals** | | | | | | | |
| Arsenic (Total) | ug/L | *1* | *10* | 2 | 1 | 1 | 1 |
| Barium (Total) | ug/L | *10* | *1000* | 100 | 60 | 66 | 108 |
| Iron (Dissolved) | ug/L | *10* | | ND | ND | ND | ND |
| Iron (Total) | ug/L | *10* | *300* | 91 | 113 | 35 | 145 |
| Lithium | ug/L | *1* | | 34 | 6 | 12 | 31 |
| Manganese (Dissolved) | ug/L | *10* | | 39 | ND | ND | ND |
| Manganese (Total) | ug/L | *10* | *50* | 38 | ND | ND | ND |
| Molybdenum | ug/L | *1* | *1000* | 10 | 3 | 4 | 10 |
| Nickel | ug/L | *10* | *100* | ND | ND | ND | ND |
| Selenium | ug/L | *2* | *50* | 2 | 5 | 5 | 2 |
| Strontium (Total) | ug/L | *5* | | 390 | 213 | 248 | 386 |
| Uranium (by ICP/MS) | ug/L | *1* | *30* | 2 | ND | ND | 1 |
| Vanadium (Total) | ug/L | *1* | *1000* | ND | ND | ND | ND |
| Zinc (Total) | ug/L | *10* | *5000* | 206 | 208 | 250 | 396 |
| **Miscellaneous** | | | | | | | |
| Ammonia-N | mg/L | *0.05* | | 0.28 | ND | ND | ND |
| Boron | mg/L | *0.05* | | 0.09 | ND | 0.05 | 0.09 |
| Chloramines | mg/L | *0.05* | | ND | ND | ND | ND |
| Gross Alpha | pCi/L | | *15* | 2.62 +/- 1.46 | 3.48 +/- 2.19 | 0.273+/- 1.08 | 1.16 +/- 0.76 |
| Kjehldahl Nitrogen (Total) | mg/L | *0.5* | | 0.6 | ND | ND | ND |
| Methane | ug/L | *0.1* | | 3.6 | 0.47 | 0.54 | 0.23 |
| Nitrogen (Total) | mg/L | *0.5* | | 1.5 | ND | ND | ND |
| o-Phosphate-P | mg/L | *0.05* | | 0.3 | 0.3 | 0.3 | 0.1 |
| Phosphorous (Total) | mg/L | *0.03* | | 0.22 | 0.37 | 0.26 | 0.27 |
| Radium 226 | pCi/L | | *3* | 2.18 +/- 1.23 | 0.61 +/- 0.45 | 0.054+/-0.106 | 0.189+/-0.16 |
| **Organic Analyses** | | | | | | | |
| Haloacetic Acids (Total) | ug/L | *1.0* | *60.0* | 0.0 | 16.7 | 1.1 | 0.0 |
| *Dibromoacetic Acid* | *ug/L* | *1.0* | | *ND* | *1.0* | *ND* | *ND* |
| *Dichloroacetic Acid* | *ug/L* | *1.0* | | *ND* | *2.7* | *1.1* | *ND* |
| *Monobromoacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | *ND* | *ND* |
| *Monochloroacetic Acid* | *ug/L* | *2.0* | | *ND* | *ND* | *ND* | *ND* |
| *Trichloroacetic Acid* | *ug/L* | *1.0* | | *ND* | 13.0 | ND | *ND* |
| Organic Carbon (Dissolved) | mg/L | *0.2* | | 0.6 | 1.3 | 1.4 | 1.20 |
| Organic Carbon (Total) | mg/L | *0.2* | | 0.7 | 1.1 | 1.5 | 1.30 |
| Trihalomethanes (Total) | ug/L | *1.0* | *80.0* | 0.0 | **84.3** | **95.1** | 13.0 |
| *Bromodichloromethane* | *ug/L* | *0.5* | | *ND* | 26.0 | 27.0 | *3.6* |
| *Bromoform* | *ug/L* | *0.5* | | *ND* | 1.3 | 2.1 | ND |
| *Chloroform* | *ug/L* | *0.5* | | *ND* | 44.0 | 52.0 | 7.4 |
| *Dibromochloromethane* | *ug/L* | *0.5* | | *ND* | 13.0 | 14.0 | 2.0 |
| **Field Parameters** | | | | | | | |
| Temperature | $^0$ C | *0.1* | | 24.3 | 16.5 | 17.6 | 19.8 |
| Specific Conductance (EC) | uS | *1.0* | *900* | 550 | 512 | 550 | 971.0 |
| pH | Std Units | *0.1* | *6.5 - 8.5* | 7.0 | 7.2 | 7.0 | 7.3 |
| ORP | mV | *1.0* | | -73 | -73 | -57 | -104 |
| Free Chlorine Residual | mg/L | *0.1* | *2 - 5* | ND | 0.23 | 0.06 | ND |
| Dissolved Oxygen | mg/L | *0.01* | | | ND | 0.05 | ND |
| Silt Density Index | Std Units | *0.1* | | | | | |
| Gas Volume | mL | *2.0* | | | | | |
| $H_2S$ | mg/L | *0.1* | | | ND | ND | 0.06 |

**Notes:**
Constituents exceeding MCLs denoted in **BOLD** type

# Table 14. Summary of WY 2015 Water Quality Data – ASR-3

| Parameter | Unit | PQL | MCL | Results | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | SMS ASR-3 | | | | |
| | | | | 10/22/2010 | 12/5/14 | 3/25/15 | 6/25/15 | 9/23/15 |
| | | Sample Description | | NGW | WY 2013 Storage | WY 2015 Storage | | |
| Elapsed Storage Time | Days | | | | 687 | 36 | 128 | 218 |
| Volume Purged at Sampling | 1,000 gals | | | | | | | |
| **Major Cations** | | | | | | | | |
| Calcium | mg/L | 0.5 | | 76 | 74 | 41 | 50 | 61 |
| Magnesium | mg/L | 0.5 | | 18 | 21 | 13 | 17 | 18 |
| Potasium | mg/L | 0.5 | | 5 | 5 | 3 | 3 | 4 |
| Sodium | mg/L | 0.5 | | 102 | 98 | 45 | 52 | 73 |
| **Major Anions** | | | | | | | | |
| Alkalinity, Total (as CaCO3) | mg/L | 2 | | 304 | 228 | 133 | 166 | 200 |
| Chloride | mg/L | 1 | 250 | 107 | 95 | 31 | 55 | 79 |
| Sulfate | mg/L | 1 | 250 | 56 | 63 | 83 | 82 | 79 |
| Nitrate (as NO3) | mg/L | 1 | 45 | 1 | 1.0 | ND | ND | ND |
| Nitrite (as Nitrogen) | mg/L | 1 | 1 | ND | 0.3 | 0.2 | 0.4 | 0.3 |
| **General Physical** | | | | | | | | |
| pH | Std Units | | | 7.7 | 7.3 | 7.1 | 7.4 | 7.3 |
| Specific Conductance (EC) | uS | 1 | 900 | **954** | 886 | 543 | 645 | 810 |
| Total Dissolved Solids | mg/L | 10 | 500 | **575** | **546** | 334 | 388 | 477 |
| **Metals** | | | | | | | | |
| Arsenic (Total) | ug/L | 1 | 10 | 4 | 4 | 3 | 4 | 5 |
| Barium (Total) | ug/L | 10 | 1000 | 50 | 84 | 63 | 75 | 85 |
| Iron (Dissolved) | ug/L | 10 | | 21 | 47 | ND | ND | ND |
| Iron (Total) | ug/L | 10 | 300 | 21 | 167 | ND | 156 | 116 |
| Lithium | ug/L | 1 | | 36 | 29 | 5 | 18 | 27 |
| Manganese (Dissolved) | ug/L | 10 | | 27 | 32 | ND | 21 | 12 |
| Manganese (Total) | ug/L | 10 | 50 | 27 | 32 | ND | 22 | 12 |
| Molybdenum | ug/L | 1 | 1000 | -- | 8 | 14 | 20 | 9 |
| Nickel | ug/L | 10 | 100 | ND | ND | ND | 11 | ND |
| Selenium | ug/L | 2 | 50 | ND | 2 | 8 | 4 | 2 |
| Strontium (Total) | ug/L | 5 | | 403 | 360 | 235 | 281 | 330 |
| Uranium (by ICP/MS) | ug/L | 1 | 30 | -- | 2 | 1 | 2 | 2 |
| Vanadium (Total) | ug/L | 1 | 1000 | -- | ND | ND | ND | ND |
| Zinc (Total) | ug/L | 10 | 5000 | -- | 128 | 202 | 227 | 194 |
| **Miscellaneous** | | | | | | | | |
| Ammonia-N | mg/L | 0.05 | | 249 | 0.1 | ND | ND | 0.06 |
| Boron | mg/L | 0.05 | | ND | 0.09 | ND | 0.05 | 0.08 |
| Chloramines | mg/L | 0.05 | | 0.08 | ND | ND | ND | ND |
| Gross Alpha | pCi/L | | 15 | -- | 2.20 +/- 0.76 | 3.03 +/- 1.24 | 1.33 +/- 1.52 | 3.11 +/- 1.41 |
| Kjehldahl Nitrogen (Total) | mg/L | 0.5 | | ND | ND | 0.6 | ND | ND |
| Methane | ug/L | 0.1 | | ND | 1.20 | 0.47 | 1.10 | 0.22 |
| Nitrogen (Total) | mg/L | 0.5 | | ND | 0.5 | 0.8 | 0.5 | ND |
| o-Phosphate-P | mg/L | 0.05 | | ND | 0.2 | 0.2 | 0.2 | ND |
| Phosphorous (Total) | mg/L | 0.03 | | 0.03 | 0.14 | 0.27 | 0.21 | 0.21 |
| Radium 226 | pCi/L | | 3 | -- | 0.80 +/- 0.65 | 0.07 +/- 0.27 | 0.081 +/- 0.119 | 0.288 +/- 0.181 |
| **Organic Analyses** | | | | | | | | |
| Haloacetic Acids (Total) | ug/L | 1.0 | 60.0 | ND | 0.0 | 19.9 | 8.7 | 3.2 |
| *Dibromoacetic Acid* | *ug/L* | 1.0 | | *ND* | *ND* | *1.8* | *ND* | *ND* |
| *Dichloroacetic Acid* | *ug/L* | 1.0 | | *ND* | *ND* | *7.1* | *3.8* | *1.1* |
| *Monobromoacetic Acid* | *ug/L* | 1.0 | | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Monochloroacetic Acid* | *ug/L* | 2.0 | | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Trichloroacetic Acid* | *ug/L* | 1.0 | | *ND* | *ND* | *11* | *4.9* | *2.1* |
| Organic Carbon (Dissolved) | mg/L | 0.2 | | 0.71 | 0.5 | 1.4 | 1.4 | 1.3 |
| Organic Carbon (Total) | mg/L | 0.2 | | 0.70 | 0.7 | 1.2 | 1.2 | 1.3 |
| Trihalomethanes (Total) | ug/L | 1.0 | 80.0 | ND | 5.9 | **94.0** | 70.7 | 37.5 |
| *Bromodichloromethane* | *ug/L* | 0.5 | | *ND* | *1.8* | *27.0* | *20.0* | *11.0* |
| *Bromoform* | *ug/L* | 0.5 | | *ND* | *ND* | *0.98* | *1.7* | *1.0* |
| *Chloroform* | *ug/L* | 0.5 | | *ND* | *3.0* | *54.0* | *38.0* | *19.0* |
| *Dibromochloromethane* | *ug/L* | 0.5 | | *ND* | *1.1* | *12.0* | *11.0* | *6.5* |
| **Field Parameters** | | | | | | | | |
| Temperature | $^{0}$ C | 0.1 | | 26.2 | | 17.2 | 16.9 | 20.4 |
| Specific Conductance (EC) | uS | 1.0 | 900 | 991 | | 509 | 516 | 749 |
| pH | Std Units | 0.1 | 6.5 - 8.5 | 7.0 | | 7.3 | 7.2 | 7.4 |
| ORP | mV | 1.0 | | -82 | | -62 | -65 | -65 |
| Free Chlorine Residual | mg/L | 0.1 | 2 - 5 | ND | | 0.03 | ND | ND |
| Dissolved Oxygen | mg/L | 0.01 | | -- | | ND | 0.02 | 0.04 |
| Silt Density Index | Std Units | 0.1 | | -- | | | | |
| Gas Volume | mL | 2.0 | | -- | | | | |
| $H_2S$ | mg/L | 0.1 | | 0.60 | | ND | ND | 0.05 |

**Notes:**
Constituents exceeding MCLs denoted in **BOLD** type

## Table 15. Summary of WY 2015 Water Quality Data – ASR-4

| Parameter | Unit | PQL | MCL | Results SMS ASR-4 11/19/14 |
|---|---|---|---|---|
| | | Sample Description | | Pre-Injection |
| Elapsed Storage Time | Days | | | **671** |
| Volume Purged at Sampling | 1,000 gals | | | |
| **Major Cations** | | | | |
| Calcium | mg/L | *0.5* | | 68 |
| Magnesium | mg/L | *0.5* | | 15 |
| Potasium | mg/L | *0.5* | | 4 |
| Sodium | mg/L | *0.5* | | 94 |
| **Major Anions** | | | | |
| Alkalinity, Total (as CaCO3) | mg/L | *2* | | 226 |
| Chloride | mg/L | *1* | *250* | 118 |
| Sulfate | mg/L | *1* | *250* | 55 |
| Nitrate (as NO3) | mg/L | *1* | *45* | 1.0 |
| Nitrite (as Nitrogen) | mg/L | *1* | *1* | 0.3 |
| **General Physical** | | | | |
| pH | Std Units | | | 7.4 |
| Specific Conductance (EC) | uS | *1* | *900* | **911** |
| Total Dissolved Solids | mg/L | *10* | *500* | **517** |
| **Metals** | | | | |
| Arsenic (Total) | ug/L | *1* | *10* | 4 |
| Barium (Total) | ug/L | *10* | *1000* | 55 |
| Iron (Dissolved) | ug/L | *10* | | 37 |
| Iron (Total) | ug/L | *10* | *300* | 71 |
| Lithium | ug/L | *1* | | 29 |
| Manganese (Dissolved) | ug/L | *10* | | 28 |
| Manganese (Total) | ug/L | *10* | *50* | 34 |
| Molybdenum | ug/L | *1* | *1000* | 7 |
| Nickel | ug/L | *10* | *100* | 93 |
| Selenium | ug/L | *2* | *50* | 2 |
| Strontium (Total) | ug/L | *5* | | 482 |
| Uranium (by ICP/MS) | ug/L | *1* | *30* | 1 |
| Vanadium (Total) | ug/L | *1* | *1000* | ND |
| Zinc (Total) | ug/L | *10* | *5000* | ND |
| **Miscellaneous** | | | | |
| Ammonia-N | mg/L | *0.05* | | ND |
| Boron | mg/L | *0.05* | | 0.1 |
| Chloramines | mg/L | *0.05* | | ND |
| Gross Alpha | pCi/L | | *15* | 3.41 +/- 1.68 |
| Kjehldahl Nitrogen (Total) | mg/L | *0.5* | | ND |
| Methane | ug/L | *0.1* | | 1.30 |
| Nitrogen (Total) | mg/L | *0.5* | | 0.5 |
| o-Phosphate-P | mg/L | *0.05* | | ND |
| Phosphorous (Total) | mg/L | *0.03* | | 0.04 |
| Radium 226 | pCi/L | | *3* | 2.25 +/- 0.95 |
| **Organic Analyses** | | | | |
| Haloacetic Acids (Total) | ug/L | *1.0* | *60.0* | 0.0 |
| *Dibromoacetic Acid* | *ug/L* | *1.0* | | *ND* |
| *Dichloroacetic Acid* | *ug/L* | *1.0* | | *ND* |
| *Monobromoacetic Acid* | *ug/L* | *1.0* | | *ND* |
| *Monochloroacetic Acid* | *ug/L* | *2.0* | | *ND* |
| *Trichloroacetic Acid* | *ug/L* | *1.0* | | *ND* |
| Organic Carbon (Dissolved) | mg/L | *0.2* | | 0.4 |
| Organic Carbon (Total) | mg/L | *0.2* | | 0.6 |
| Trihalomethanes (Total) | ug/L | *1.0* | *80.0* | 0.0 |
| *Bromodichloromethane* | *ug/L* | *0.5* | | *ND* |
| *Bromoform* | *ug/L* | *0.5* | | *ND* |
| *Chloroform* | *ug/L* | *0.5* | | *ND* |
| *Dibromochloromethane* | *ug/L* | *0.5* | | *ND* |
| **Field Parameters** | | | | |
| Temperature | $^0$ C | *0.1* | | 23.3 |
| Specific Conductance (EC) | uS | *1.0* | *900* | 960 |
| pH | Std Units | *0.1* | *6.5 - 8.5* | 7.1 |
| ORP | mV | *1.0* | | -188 |
| Free Chlorine Residual | mg/L | *0.1* | *2 - 5* | |
| Dissolved Oxygen | mg/L | *0.01* | | |
| Silt Density Index | Std Units | *0.1* | | |
| Gas Volume | mL | *2.0* | | |
| $H_2S$ | mg/L | *0.1* | | |

**Notes:**
Constituents exceeding MCLs denoted in **BOLD** type

# Table 16. Summary of WY 2015 Water Quality Data – SM MW-1

| Parameter | Unit | PQL | MCL | Results SM MW-1 12/4/14 | 12/23/14 | 3/27/15 | 6/24/15 | 9/23/15 |
|---|---|---|---|---|---|---|---|---|
| | | Sample Description | | WY 2013 Storage | WY 2015 Injection | WY 2015 Storage | | |
| Elapsed Storage Time | Days | | | **686** | **0** | **38** | **127** | **218** |
| Volume Purged at Sampling | 1,000 gals | | | | | | | |
| **Major Cations** | | | | | | | | |
| Calcium | mg/L | *0.5* | | 68 | | | 50 | 81 |
| Magnesium | mg/L | *0.5* | | 20 | | | 13 | 22 |
| Potasium | mg/L | *0.5* | | 5 | | | 3.7 | 4.6 |
| Sodium | mg/L | *0.5* | | 84 | | | 52 | 78 |
| **Major Anions** | | | | | | | | |
| Alkalinity, Total (as CaCO3) | mg/L | *2* | | 229 | | | 153 | 210 |
| Chloride | mg/L | *1* | *250* | 109 | | | 42 | 110 |
| Sulfate | mg/L | *1* | *250* | 61 | | | 88 | 83 |
| Nitrate (as NO3) | mg/L | *1* | *45* | ND | | | ND | ND |
| Nitrite (as Nitrogen) | mg/L | *1* | *1* | 0.7 | | | 0.3 | 0.3 |
| **General Physical** | | | | | | | | |
| pH | Std Units | | | 7.3 | | | 7.5 | 7.1 |
| Specific Conductance (EC) | uS | *1* | *900* | 948 | | | 610 | **935** |
| Total Dissolved Solids | mg/L | *10* | *500* | 557 | | | 394 | **540** |
| **Metals** | | | | | | | | |
| Arsenic (Total) | ug/L | *1* | *10* | 2 | | | 2 | 2 |
| Barium (Total) | ug/L | *10* | *1000* | 63 | | | 33 | 59 |
| Iron (Dissolved) | ug/L | *10* | | ND | | | ND | ND |
| Iron (Total) | ug/L | *10* | *300* | ND | | | ND | 62 |
| Lithium | ug/L | *1* | | 30 | | | 24 | 24 |
| Manganese (Dissolved) | ug/L | *10* | | 24 | | | ND | 14 |
| Manganese (Total) | ug/L | *10* | *50* | 22 | | | ND | 15 |
| Molybdenum | ug/L | *1* | *1000* | 15 | | | 6 | 10 |
| Nickel | ug/L | *10* | *100* | ND | | | ND | ND |
| Selenium | ug/L | *2* | *50* | 2 | | | 5 | ND |
| Strontium (Total) | ug/L | *5* | | 376 | | | 256 | 402 |
| Uranium (by ICP/MS) | ug/L | *1* | *30* | 1 | | | 1 | 2 |
| Vanadium (Total) | ug/L | *1* | *1000* | ND | | | ND | ND |
| Zinc (Total) | ug/L | *10* | *5000* | 43 | | | ND | ND |
| **Miscellaneous** | | | | | | | | |
| Ammonia-N | mg/L | *0.05* | | ND | | | ND | ND |
| Boron | mg/L | *0.05* | | 0.08 | | | 0.05 | 0.08 |
| Chloramines | mg/L | *0.05* | | ND | | | ND | ND |
| Gross Alpha | pCi/L | | *15* | 2.16 +/- 0.67 | | | 2.81 +/- 1.27 | 4.82 +/- 1.81 |
| Kjehldahl Nitrogen (Total) | mg/L | *0.5* | | ND | | | ND | ND |
| Methane | ug/L | *0.1* | | 0.67 | | | 3.0 | 3.20 |
| Nitrogen (Total) | mg/L | *0.5* | | 0.8 | | | ND | ND |
| o-Phosphate-P | mg/L | *0.05* | | 0.2 | | | ND | ND |
| Phosphorous (Total) | mg/L | *0.03* | | 0.12 | | | 0.08 | 0.08 |
| Radium 226 | pCi/L | | *3* | 1.70 +/- 1.01 | | | 0.514 +/- 0.243 | 0.762 +/- 0.265 |
| **Organic Analyses** | | | | | | | | |
| Haloacetic Acids (Total) | ug/L | *1.0* | *60.0* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Dibromoacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Dichloroacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Monobromoacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Monochloroacetic Acid* | *ug/L* | *2.0* | | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Trichloroacetic Acid* | *ug/L* | *1.0* | | ND | ND | ND | ND | ND |
| Organic Carbon (Dissolved) | mg/L | *0.2* | | 0.6 | | | 1.2 | 1.2 |
| Organic Carbon (Total) | mg/L | *0.2* | | 0.7 | | | 1.3 | 1.20 |
| Trihalomethanes (Total) | ug/L | *1.0* | *80.0* | 0.0 | 46.2 | 13.5 | 44.2 | 4.9 |
| *Bromodichloromethane* | *ug/L* | *0.5* | | *ND* | *13.0* | *4.9* | *10.0* | *1.0* |
| *Bromoform* | *ug/L* | *0.5* | | *ND* | *0.9* | *ND* | *0.7* | *ND* |
| *Chloroform* | *ug/L* | *0.5* | | *ND* | *27.0* | *7.2* | *29.0* | *3.4* |
| *Dibromochloromethane* | *ug/L* | *0.5* | | *ND* | *5.3* | *1.4* | *4.5* | *0.5* |
| **Field Parameters** | | | | | | | | |
| Temperature | $^0$C | *0.1* | | 23.3 | 22.7 | 16.1 | 17.1 | |
| Specific Conductance (EC) | uS | *1.0* | *900* | 520 | 510 | 536 | 545 | |
| pH | Std Units | *0.1* | *6.5 - 8.5* | 6.8 | 7.1 | 7.2 | 7.1 | |
| ORP | mV | *1.0* | | -143 | -37 | -64 | -84 | |
| Free Chlorine Residual | mg/L | *0.1* | *2 - 5* | ND | ND | ND | 0.08 | |
| Dissolved Oxygen | mg/L | *0.01* | | | | 0.23 | 0.04 | |
| Silt Density Index | Std Units | *0.1* | | | | | | |
| Gas Volume | mL | *2.0* | | | | | | |
| $H_2S$ | mg/L | *0.1* | | | | 0.08 | ND | |

**Notes:**
Constituents exceeding MCLs denoted in **BOLD** type

# Table 17. Summary of WY 2015 Water Quality Data – SMS Deep

| Parameter | Unit | PQL | MCL | Results | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | SMS Deep | | | | |
| | | | | 12/5/14 | 12/23/14 | 3/25/15 | 6/25/15 | 9/23/15 |
| | | Sample Description | | WY 2013 Storage | WY 2015 Injection | WY 2015 Storage | | |
| Elapsed Storage Time | Days | | | 687 | | 36 | 128 | 218 |
| Volume Purged at Sampling | 1,000 gals | | | | | | | |
| **Major Cations** | | | | | | | | |
| Calcium | mg/L | *0.5* | | 69 | | | 56 | 84 |
| Magnesium | mg/L | *0.5* | | 15 | | | 13 | 19 |
| Potasium | mg/L | *0.5* | | 4.3 | | | 3 | 4.7 |
| Sodium | mg/L | *0.5* | | 93 | | | 53 | 98 |
| **Major Anions** | | | | | | | | |
| Alkalinity, Total (as CaCO3) | mg/L | *2* | | 225 | | | 172 | 260 |
| Chloride | mg/L | *1* | *250* | 92 | | | 55 | 124 |
| Sulfate | mg/L | *1* | *250* | 50 | | | 80 | 73 |
| Nitrate (as NO3) | mg/L | *1* | *45* | 1.0 | | | ND | ND |
| Nitrite (as Nitrogen) | mg/L | *1* | *1* | 0.3 | | | 0.4 | 0.3 |
| **General Physical** | | | | | | | | |
| pH | Std Units | | | 7.4 | | | 7.6 | 7.3 |
| Specific Conductance (EC) | uS | *1* | *900* | 850 | | | 656 | **1032** |
| Total Dissolved Solids | mg/L | *10* | *500* | 497 | | | 397 | **611** |
| **Metals** | | | | | | | | |
| Arsenic (Total) | ug/L | *1* | *10* | 5 | | | 6 | 9 |
| Barium (Total) | ug/L | *10* | *1000* | 52 | | | 34 | 65 |
| Iron (Dissolved) | ug/L | *10* | | ND | | | ND | ND |
| Iron (Total) | ug/L | *10* | *300* | 20 | | | ND | 32 |
| Lithium | ug/L | *1* | | 23 | | | 19 | 41 |
| Manganese (Dissolved) | ug/L | *10* | | 23 | | | ND | 14 |
| Manganese (Total) | ug/L | *10* | *50* | 23 | | | ND | 14 |
| Molybdenum | ug/L | *1* | *1000* | 7 | | | 10 | 8 |
| Nickel | ug/L | *10* | *100* | ND | | | ND | ND |
| Selenium | ug/L | *2* | *50* | 2 | | | 4 | ND |
| Strontium (Total) | ug/L | *5* | | 421 | | | 383 | 552 |
| Uranium (by ICP/MS) | ug/L | *1* | *30* | 2 | | | 3 | 2 |
| Vanadium (Total) | ug/L | *1* | *1000* | ND | | | ND | ND |
| Zinc (Total) | ug/L | *10* | *5000* | 28 | | | ND | ND |
| **Miscellaneous** | | | | | | | | |
| Ammonia-N | mg/L | *0.05* | | 0.06 | | | ND | 0.06 |
| Boron | mg/L | *0.05* | | 0.08 | | | 0.06 | 0.1 |
| Chloramines | mg/L | *0.05* | | ND | | ND | ND | ND |
| Gross Alpha | pCi/L | | *15* | 1.95 +/- 0.72 | | | 3.17 +/- 1.29 | 1.24 +/- 1.42 |
| Kjehldahl Nitrogen (Total) | mg/L | *0.5* | | ND | | | ND | ND |
| Methane | ug/L | *0.1* | | 1.2 | | | 0.8 | 0.27 |
| Nitrogen (Total) | mg/L | *0.5* | | 0.5 | | | 0.5 | ND |
| o-Phosphate-P | mg/L | *0.05* | | ND | | | ND | ND |
| Phosphorous (Total) | mg/L | *0.03* | | 0.05 | | | 0.1 | 0.13 |
| Radium 226 | pCi/L | | *3* | 1.19 +/- 0.77 | | | 0.244 +/- 0.176 | 0.268 +/- 0.176 |
| **Organic Analyses** | | | | | | | | |
| Haloacetic Acids (Total) | ug/L | *1.0* | *60.0* | 0.0 | 21.1 | 17.5 | 6.9 | 0.0 |
| *Dibromoacetic Acid* | *ug/L* | *1.0* | | *ND* | *3.6* | *1.2* | *ND* | *ND* |
| *Dichloroacetic Acid* | *ug/L* | *1.0* | | *ND* | *9.8* | *4.3* | *2.3* | *ND* |
| *Monobromoacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Monochloroacetic Acid* | *ug/L* | *2.0* | | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Trichloroacetic Acid* | *ug/L* | *1.0* | | ND | 7.7 | 12 | 4.6 | ND |
| Organic Carbon (Dissolved) | mg/L | *0.2* | | 0.4 | | | 1.2 | 1.2 |
| Organic Carbon (Total) | mg/L | *0.2* | | 0.60 | | | 1.2 | 1.2 |
| Trihalomethanes (Total) | ug/L | *1.0* | *80.0* | 4.1 | 67.5 | 74.1 | 62.7 | 3.3 |
| *Bromodichloromethane* | *ug/L* | *0.5* | | *1.2* | *22.0* | *22.0* | *18.0* | *0.7* |
| *Bromoform* | *ug/L* | *0.5* | | *ND* | *2.5* | *1.1* | *1.7* | *ND* |
| *Chloroform* | *ug/L* | *0.5* | | *2.3* | *29.0* | *40.0* | *33.0* | *2.6* |
| *Dibromochloromethane* | *ug/L* | *0.5* | | *0.6* | *14.0* | *11.0* | *10.0* | *ND* |
| **Field Parameters** | | | | | | | | |
| Temperature | $^0$ C | *0.1* | | | 18.4 | 17.7 | 17.5 | 19.8 |
| Specific Conductance (EC) | uS | *1.0* | *900* | | 560 | 354 | 445 | 752 |
| pH | Std Units | *0.1* | *6.5 - 8.5* | | 7.5 | 7.3 | 7.3 | 7.2 |
| ORP | mV | *1.0* | | | 16.2 | -67 | -68 | |
| Free Chlorine Residual | mg/L | *0.1* | *2 - 5* | | ND | 0.08 | ND | ND |
| Dissolved Oxygen | mg/L | *0.01* | | | | ND | 0.05 | 0.01 |
| Silt Density Index | Std Units | *0.1* | | | | | | |
| Gas Volume | mL | *2.0* | | | | | | |
| $H_2S$ | mg/L | *0.1* | | | | ND | ND | 0.04 |

**Notes:**
Constituents exceeding MCLs denoted in **BOLD** type

## Table 18. Summary of WY 2015 Water Quality Data – Off-Site Monitoring Wells

| Parameter | Unit | PQL | MCL | Results | | | |
|---|---|---|---|---|---|---|---|
| | | | | PCA-E Deep | | Paralta | |
| | | | | 12/10/14 | 7/23/15 | 11/13/14 | 7/14/15 |
| | | | Sample Description | WY 2013 Storage | WY 2015 Storage | WY 2013 Storage | WY 2015 Storage |
| Volume Pumped at Sampling | 1,000 gals | | | | | | |
| **Major Cations** | | | | | | | |
| Calcium | mg/L | *0.5* | | 44 | 43 | | 77 |
| Magnesium | mg/L | *0.5* | | 9 | 8 | | 20 |
| Potasium | mg/L | *0.5* | | 3.5 | 3.5 | | 5 |
| Sodium | mg/L | *0.5* | | 81 | 80 | | 103 |
| **Major Anions** | | | | | | | |
| Alkalinity, Total (as CaCO3) | mg/L | *2* | | 168 | 163 | | 225 |
| Chloride | mg/L | *1* | *250* | 80 | 82 | | 112 |
| Sulfate | mg/L | *1* | *250* | 25 | 24 | | 70 |
| Nitrate (as NO3) | mg/L | *1* | *45* | ND | ND | | ND |
| Nitrite (as Nitrogen) | mg/L | *1* | *1* | 0.7 | 0.3 | | |
| **General Physical** | | | | | | | |
| pH | Std Units | | | 7.6 | 7.5 | | 7.2 |
| Specific Conductance (EC) | uS | *1* | *900* | 664 | 628 | | **909** |
| Total Dissolved Solids | mg/L | *10* | *500* | 388 | 394 | | **502** |
| **Metals** | | | | | | | |
| Arsenic (Total) | ug/L | *1* | *10* | 7 | 7 | | ND |
| Barium (Total) | ug/L | *10* | *1000* | 69 | 68 | | ND |
| Iron (Dissolved) | ug/L | *10* | | ND | ND | | |
| Iron (Total) | ug/L | *10* | *300* | ND | ND | | ND |
| Lithium | ug/L | *1* | | 23 | 34 | | |
| Manganese (Dissolved) | ug/L | *10* | | ND | ND | | |
| Manganese (Total) | ug/L | *10* | *50* | ND | ND | | 24 |
| Molybdenum | ug/L | *1* | *1000* | 10 | 11 | | |
| Nickel | ug/L | *10* | *100* | ND | ND | | |
| Selenium | ug/L | *2* | *50* | ND | ND | | |
| Strontium (Total) | ug/L | *5* | | 239 | 228 | | |
| Uranium (by ICP/MS) | ug/L | *1* | *30* | ND | ND | | |
| Vanadium (Total) | ug/L | *1* | *1000* | ND | ND | | |
| Zinc (Total) | ug/L | *10* | *5000* | 15 | ND | | |
| **Miscellaneous** | | | | | | | |
| Ammonia-N | mg/L | *0.05* | | ND | ND | | 0.14 |
| Boron | mg/L | *0.05* | | 0.08 | 0.08 | | 103 |
| Chloramines | mg/L | *0.05* | | ND | ND | | |
| Gross Alpha | pCi/L | | *15* | 0.79 +/- 0.78 | 2.04 +/- 1.86 | | |
| Kjehldahl Nitrogen (Total) | mg/L | *0.5* | | ND | ND | | |
| Methane | ug/L | *0.1* | | ND | 0.21 | | |
| Nitrogen (Total) | mg/L | *0.5* | | 0.8 | ND | | |
| o-Phosphate-P | mg/L | *0.05* | | ND | ND | | ND |
| Phosphorous (Total) | mg/L | *0.03* | | 0.06 | 0.05 | | |
| Radium 226 | pCi/L | | *3* | 0.29 +/- 0.55 | 0.150 +/ - 0.227 | | |
| **Organic Analyses** | | | | | | | |
| Haloacetic Acids (Total) | ug/L | *1.0* | *60.0* | 0.0 | 0.0 | | |
| *Dibromoacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | | |
| *Dichloroacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | | |
| *Monobromoacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | | |
| *Monochloroacetic Acid* | *ug/L* | *2.0* | | *ND* | *ND* | | |
| *Trichloroacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | | |
| Organic Carbon (Dissolved) | mg/L | *0.2* | | 0.2 | 0.8 | | |
| Organic Carbon (Total) | mg/L | *0.2* | | 0.4 | 0.6 | | 0.68 |
| Trihalomethanes (Total) | ug/L | *1.0* | *80.0* | 0.0 | 0.0 | 1.5 | 2.2 |
| *Bromodichloromethane* | *ug/L* | *0.5* | | *ND* | *ND* | *ND* | *ND* |
| *Bromoform* | *ug/L* | *0.5* | | *ND* | *ND* | *ND* | *ND* |
| *Chloroform* | *ug/L* | *0.5* | | *ND* | *ND* | *1.5* | *2.2* |
| *Dibromochloromethane* | *ug/L* | *0.5* | | *ND* | *ND* | *ND* | *ND* |
| **Field Parameters** | | | | | | | |
| Temperature | $^0$ C | *0.1* | | | 23.9 | | 24.6 |
| Specific Conductance (EC) | uS | *1.0* | *900* | | 552 | | |
| pH | Std Units | *0.1* | *6.5 - 8.5* | | 7.6 | | 7.2 |
| ORP | mV | *1.0* | | | -122 | | |
| Free Chlorine Residual | mg/L | *0.1* | *2 - 5* | | ND | | ND |
| Dissolved Oxygen | mg/L | *0.01* | | | 0.02 | | |
| Silt Density Index | Std Units | *0.1* | | | | | |
| Gas Volume | mL | *2.0* | | | | | |
| $H_2S$ | mg/L | *0.1* | | | 0.06 | | |

**Notes:**
Constituents exceeding MCLs denoted in **BOLD** type

## Water Quality at Off-Site Monitor Wells

Water-quality data collected from off-site wells in WY 2015 data are presented in **Table 18**. Samples from PCA-E Deep were collected prior to and following the WY 2015 injection season. As discussed previously and as shown in **Table 10**, evaluation of chloride ion concentrations indicates that some previously injected water appears to have reached this well prior to the WY 2013 injection season. The well showed a slightly lower-than-historical chloride concentration; however, the absence of DBP's and the presence of hydrogen sulfide gas suggest that the influence of recharge operations is negligible to date at this location.

Data from the nearest CAW production well to the ASR wells (i.e., Paralta) show a trend similar to the SMS Deep MW, i.e., an increasing contribution of NGW water quality over the WY 2015 storage season.

## Additional Water Quality Observations

At the commencement of WY 2013 recovery pumping of ASR-1, a sample collected by CAW[7] had a Mercury (Hg) concentration of 4 µg/L, exceeding the State MCL of 2 µg/L. Although the occurrence of Hg in surface water and groundwater has been documented elsewhere in the Monterey Bay region, the detection of Hg in SGB water was unusual; further investigation of the actual sampling conditions and protocols for that sample were also nonstandard. The results were nonetheless followed up with additional sampling to verify the presence of Hg; the subsequent sampling identified detectable levels of Hg, although below the MCL. The fact that detectable Hg was identified, and at levels above historical NGW and Injectate concentrations led to the development of an in-depth investigation of Hg occurrence at the ASR wells. The origin of the detected Hg could be the result one or more sources, including the following:

- Naturally occurring Hg present in the Santa Margarita Sandstone (Tsm) aquifer mineralogy, which solubilized into the groundwater under natural NGW / Tsm geochemical interaction conditions.
- Hg present in the Carmel River System injection source water that accumulated in the well bore area, similar to the accumulation of other particulate matter present in the Carmel River injectate and CAW conveyance system.
- Solubilization of naturally occurring Hg present in the Tsm minerals, which is the result of geochemical interactions between the injection source water, NGW and aquifer minerals.
- Other anthropogenic sources of Hg in well components or other off-site sources.

During WY 2015, a Supplemental Sampling and Analysis Plan (SSAP) was developed for additional investigation of the Hg occurrence. In addition to the collection of Hg samples

[7] Collected on October 24, 2013.

utilizing a variety of EPA-approved laboratory methods and detections limits, the suite of analytes included a variety of constituents that are known to affect (or directly react with) Hg and/or Hg compounds. As of this writing, the investigation is ongoing; however, the results of SSAP during WY 2015 provided several initial findings:

- Samples of drill cuttings from ASR-1 (as well as nearby ASR-2) confirmed the low-level presence of Total Hg within the Tsm mineralogy. Methyl-Hg was essentially absent, confirming that inorganic Hg was the primary form of occurrence.
- Total Hg content of the samples collected is largely composed of insoluble (i.e., particulate) Hg as evidenced by the significantly lower Hg levels measured in the sub-micron filtered samples vs the unfiltered samples.
- Elevated Hg levels correlated strongly with turbidity levels, and both parameters dropped precipitously soon after the initiation of backflush pumping to the pit.
- Hg occurrence was found to be highly transient, and extended pumping of the well consistently showed Hg levels to be below MCL's under normal operational conditions for CAW recovery pumping.
- In all cases, Hg levels that did exceed MCL's occurred only within the first few minutes of turbid flush water discharges when the stagnant well casing water was discharged to the on-site percolation pit. Hg levels dropped to below the MCL and/or non-detect levels within the first 10-20 minutes of well flushing operations.

These findings suggested that the issue of sporadic elevated Hg occurrences was potentially a result of particulate Hg released from near-wellbore sediment accumulations when the well was initially started and well casing turbulence and velocity changes result in the release of fine particulate matter.

Additional samples were collected of sediments from the Backflush Pit at the Santa Margarita ASR Facility. Relevant findings from these sediment samples included the following:

- Confirmation that a significant portion of the total Hg content from the wells is insoluble / particulate Hg.
- The particulate Hg does not appear to be migrating beneath the surface of the pit to any measurable extent, but is rather sequestered with the surficial deposits from well backflushing operations.
- The concentration level of Hg in the accumulated surficial sediments is well below the California TTLC limit of 20 mg/kg.

**Next Steps in the Investigation.** The Hg investigation during WY 2015 has not yet conclusively established the origin of Hg detected at ASR-1; however, issues that will be investigated further in WY 2016 include the following:

- Determination of the origin of the suspected naturally-occurring, predominantly particulate Hg detected at the well as observed during initial well purging (i.e., from native aquifer minerals within the Santa Margarita Sandstone formation and/or from the produced recharge waters in the Carmel Valley Aquifer System).

- Assessment of the character and cumulative long-term fate of sediments with Hg-detections within the Backflush Pit. This investigation will include further assessment of the Hg particulate matter and its physical and chemical mobility over time.
- Further assessment of the other ASR wells to determine if similar Hg occurrences and mechanisms exist at all ASR facilities.

As the Hg investigation continues, additional findings, conclusions, and recommendations will be documented in the WY 2016 Summary of Operations Report to facilitate ongoing operation of the ASR project.

**Water Quality Summary**

Overall, water-quality data from WY 2015 showed no significant deviations from previous years. The only deviation from the norm for the ASR program was the anomalous and transient occurrence of Hg detections as described for the ASR-1 well; however, as discussed above, additional investigation in WY 2016 will be implemented to further investigate the origin of the detected Hg. The most important factors regarding ASR operations to date are that:

1. No evidence of adverse geochemical reactions has been observed during aquifer storage (with the exception of near-bore Hg accumulation possibly related to Hg dissolution), and;
2. Injection has shown direct and measurable benefit to the basin water quality vis-à-vis reductions in salinity, dissolved solids, hardness, and aesthetic parameters such as manganese and sulfide ion, which impart color and odor to the consumers' drinking water.

These improvements are likely to prevail as ASR operations continue and expand in the future.

# CONCLUSIONS

Based on the findings developed from operation of Monterey Peninsula ASR Project during WY 2015, we conclude the following:

## WY 2015 Recharge Operations

WY 2015 was classified as a Dry Water Year on the Monterey Peninsula and as a result, a commensurately modest total volume of 215 af of water was recharged into the Seaside Groundwater Basin at the Santa Margarita and Seaside Middle Schools ASR Facilities during the WY 2015 injection season.

## ASR Well Performance

**ASR-1.** Pertinent well performance conclusions for ASR-1 during WY 2015 are summarized below:

- Injection Rates: Ranged between approximately 870 to 1,610 gpm, averaging approximately 1,275 gpm.

- Water Levels: Generally maintained greater than 300 ft. bgs with 45 ft. of available “freeboard” remaining below the maximum recommended drawup level.

- Specific Injectivity: Although there are no initial specific injectivity data for WY 2015, the ending specific injectivity was approximately 25 gpm/ft, which is slightly great than the ending value in WY 2011 of approximately 23 gpm/ft.

- Residual Plugging: No residual plugging was observed.

- General Conclusions: ASR-1 performed very well during WY 2015 with no evidence of residual plugging. The positive trend in performance and available “freeboard” at injection rates ranging between 870 to 1,610 gpm suggests the design injection rate of 1,500 gpm can be maintained in WY 2016 without adversely affecting the well’s performance.

**ASR-2.** Pertinent well performance conclusions for ASR-2 during WY 2015 are summarized below:

- Injection Rates: Ranged between approximately 340 to 1,775 gpm, averaging approximately 1,400 gpm.

- Water Levels: Generally maintained greater than 280 ft. bgs with 30 ft. of available “freeboard” remaining below the maximum recommended drawup level.

- Specific Injectivity: Ranged between approximately 32 to 37 gpm/ft and overall trend in 24-hr specific injectivity slightly negative.

- Residual Plugging: Approximately 32 feet of residual plugging occurred.

- General Conclusions: ASR-2 performed well during WY 2015; however, the well did experience a moderate level residual plugging. The negative trend in performance at injection rates ranging up to 1,775 gpm suggests the injection rate at this well should be maintained at or below the design rate of 1,500 gpm in WY 2016.

**ASR-3.** Pertinent well performance conclusions for ASR-3 during WY 2015 are summarized below:

- Injection Rates: Ranged between approximately 655 to 1,070 gpm, averaging approximately 940 gpm.

- Water Levels: Generally maintained greater than 240 ft bgs with 50 ft of available “freeboard” remaining below the maximum recommended drawup level.

- Specific Injectivity: Although there are no initial specific injectivity data for WY 2015, the ending specific injectivity was approximately 10 gpm/ft, which is slightly great than the ending value in WY 2013 of approximately 8 gpm/ft.

- Residual Plugging: No residual plugging was observed.

- General Conclusions: ASR-3 performance appeared to be relatively stable compared to the significant declines observed in WY 2012. The pattern of relative performance stabilization followed by the initial significant decline in well performance observed at ASR-3 is very similar to the pattern observed at both ASR-1 and ASR-2 when they were initially brought on-line. The stable performance at injection rates ranging between 655 to 1,070 gpm suggests the injection rate should be maintained at or below 1,000 gpm to maintain performance.

**ASR-4.** Injection at ASR-4 during WY 2015 was limited to three days of well “conditioning”. This conditioning consisted of initial injection at relatively low rates and durations, being incrementally increased following thorough backflushing and upon confirmation that well performance was being maintained. The conditioning was performed in an effort to limit the amount of residual plugging that has historically been observed at all three previous ASR wells following their initial injection operations. Injection rates ranging between approximately 250 to 1,075 gpm for durations up to 30 minutes were achieved during WY 2015 without a measurable loss in performance. Further conditioning is planned for WY 2016 until the design injection rate of 1,500 gpm has been achieved.

## Water Quality

Significant conclusions regarding the water-quality investigation during WY 2015 include the following:

- Consistent with previous observations, no significant ion exchange, acid-base, or precipitation reactions were observed at the ASR sites.
- THMs at the ASR sites showed characteristic and significant initial “ingrowth” that peaked at approximately 30 to 90 days after the cessation of injection, followed by a gradual decline over the next 120 to 150 days of storage.
- HAAs showed little “ingrowth” following the cessation of injection and degraded completely during aquifer storage.
- Hg exceedances of the MCL observed in WY 2015 samples are considered anomalous and will be subject to additional investigation in WY 2016.

## RECOMMENDATIONS

Based on the WY 2015 ASR program results and our experience with similar ASR projects, we offer the following recommendations for continued and future operations of the Monterey Peninsula ASR Project wells:

### ASR-1 Well Operational Parameters

- Injection Rate: Based on the lack of observed residual plugging during WY 2015, ASR-1 can be operated at an injection rate up to approximately **1,500 gpm** (6.6 afd) to avoid excessive plugging during injection. This represents a 50 percent increase in the design injection rate of 1,000 gpm.
- Water-Level Drawup: Under the present local water-level conditions, the amount of water-level drawup should be limited to approximately 100 feet. This amount of water-level drawup during injection equals the typical available drawdown in the well for backflushing. This helps to avoid over-pressurization and compression of plugging materials, thereby maximizing the efficiency of backflushing and limiting the amount of residual plugging.
- Backflushing Frequency: During the recharge season, routine backflushing should continue to be performed on an approximate weekly basis, or when the amount of water-level drawup in the casing reaches approximately 100 feet, whichever occurs first.

### ASR-2 Well Operational Parameters

- Injection Rate: Based on the amount of residual plugging that occurred during WY 2015 with the well injecting up to 1,775 gpm, we recommend the injection rate be limited to the design rate of approximately **1,500 gpm** in order to limit residual plugging and maintain long-term performance.
- Water-Level Drawup: Under the present local water-level conditions, the amount of water-level drawup should be limited to approximately 130 feet, which is equal to the typical amount of available drawdown in the well for backflushing. Again, this helps to avoid over-pressurization and compression of plugging materials and limiting the amount of residual plugging.
- Backflushing Frequency: During the recharge season, routine backflushing should continue to be performed on an approximate weekly basis, or when the amount of water-level drawup in the casing reaches approximately 130 feet, whichever occurs first.

### ASR-3 Well Operational Parameters

- Injection Rate: Based on the lack of apparent residual plugging that occurred during WY 2015 with the well injecting up to 1,070 gpm, we recommend the injection rate continue to be limited to **1,000 gpm** in order to limit residual plugging and maintain long-term performance.

- Water-Level Drawup: Under the present local water-level conditions, the amount of water-level drawup should be limited to approximately 170 feet, which is equal to the typical amount of available drawdown in the well for backflushing. Again, this helps to avoid over-pressurization and compression of plugging materials and limiting the amount of residual plugging.
- Backflushing Frequency: During the recharge season, routine backflushing should continue to be performed on an approximate weekly basis, or when the amount of water-level drawup in the casing reaches approximately 170 feet, whichever occurs first.

ASR-3 should undergo formal rehabilitation to improve well performance and injection capacity, similar to that performed at SM ASR-1 and SM ASR-2. It is believed that following rehabilitation, the well will be able to operate at its design injection rate of 1,500 gpm (i.e., 50 percent greater than the current capacity of 1,000 gpm).

**SMS ASR-4 Well Startup Conditioning and Baseline Injection Testing**

"Conditioning" of ASR-4 should continue in WY 2016 in an effort to limit the amount of apparent residual plugging that has historically been observed at all three of the existing ASR wells following their initial injection operations. Once the design injection rate of 1,500 gpm has been achieved, a baseline injection testing program should be implemented that includes the following tests:

1. 8-hr variable rate injection test (combined with downhole velocity surveys);
2. 24-hr constant rate injection test;
3. 7-day constant rate injection test;
4. Backflushing between each of the above injection tests, and;
5. Post-injection production performance testing.

At the conclusion of the baseline injection testing program, recommendations for the long-term injection operations of ASR-4 can then be provided.

## CLOSURE

This report has been prepared exclusively for the Monterey Peninsula Water Management District for the specific application to the ASR Project on the Monterey Peninsula. The findings and conclusions presented herein were prepared in accordance with generally accepted hydrogeologic and engineering practices. No other warranty, express or implied, is made.

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**FIGURES**

June 2016
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PUEBLO water resources

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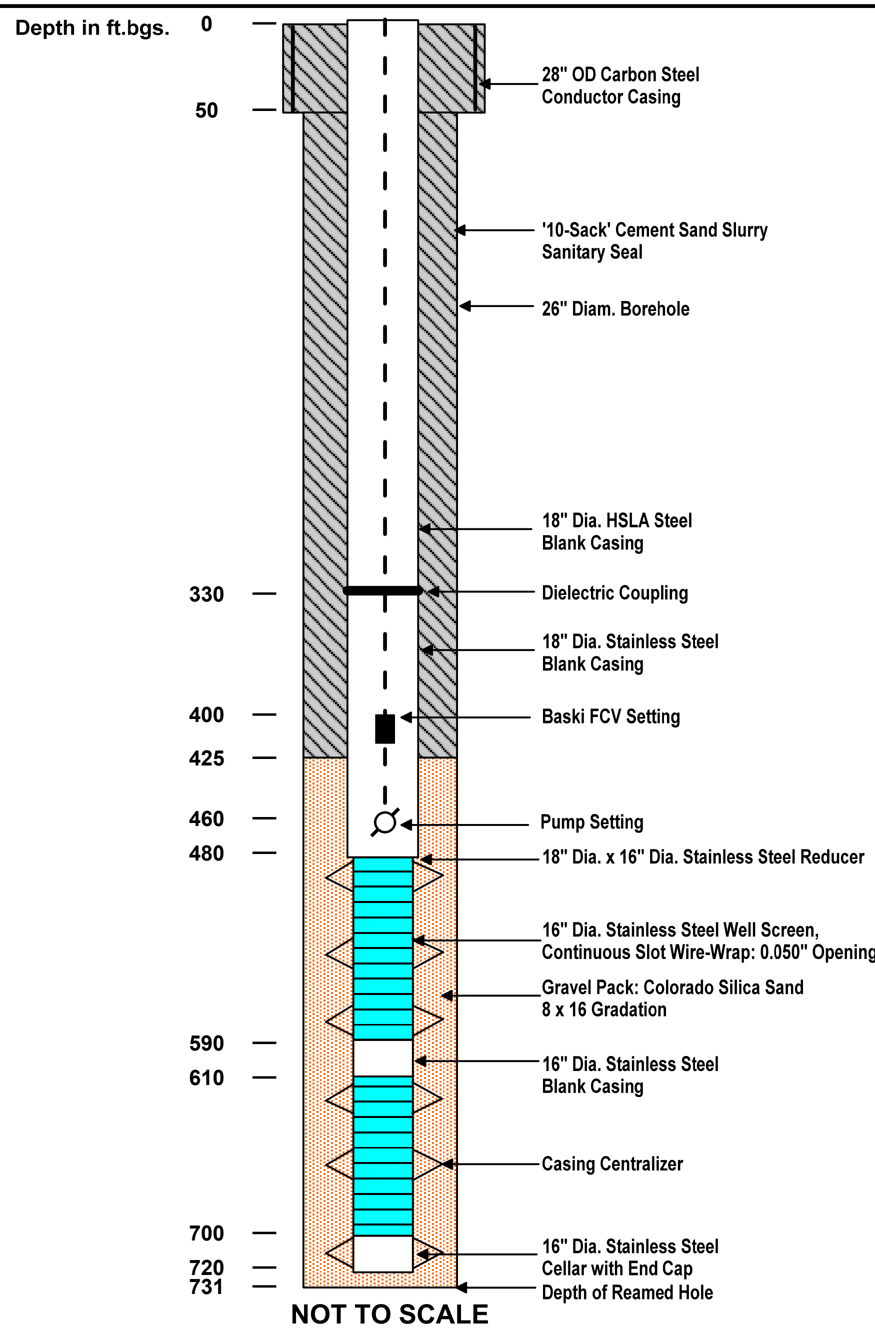
**FIGURE 1. SITE LOCATION MAP**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

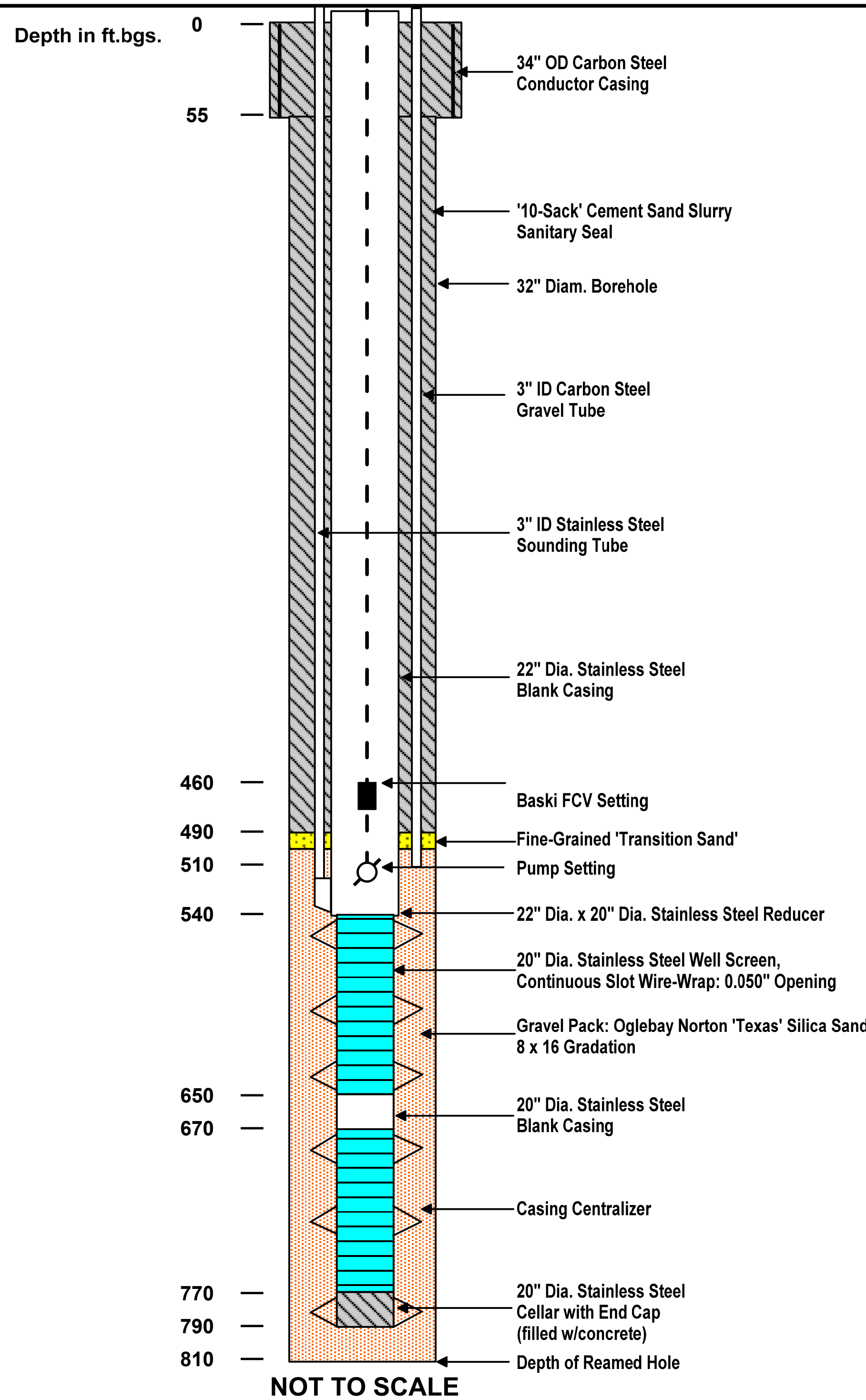
June 2016
Project No. 12-0043




Pump Assembly Notes:
Hp: 600
Bowls: 16ENL, 7 stage
Col. Pipe Dia: 12"
Col. Pipe Length: 20'
Assy. Type: Water Lube/Open Shaft
Baski FCV Setting: 400' - 410'
Top of Bowls: 460'
Bowl Length: 10.5'
Suction Length: 10'
Intake: 480.5'

PUEBLO water resources

**FIGURE 2. ASR-1 AS-BUILT SCHEMATIC**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

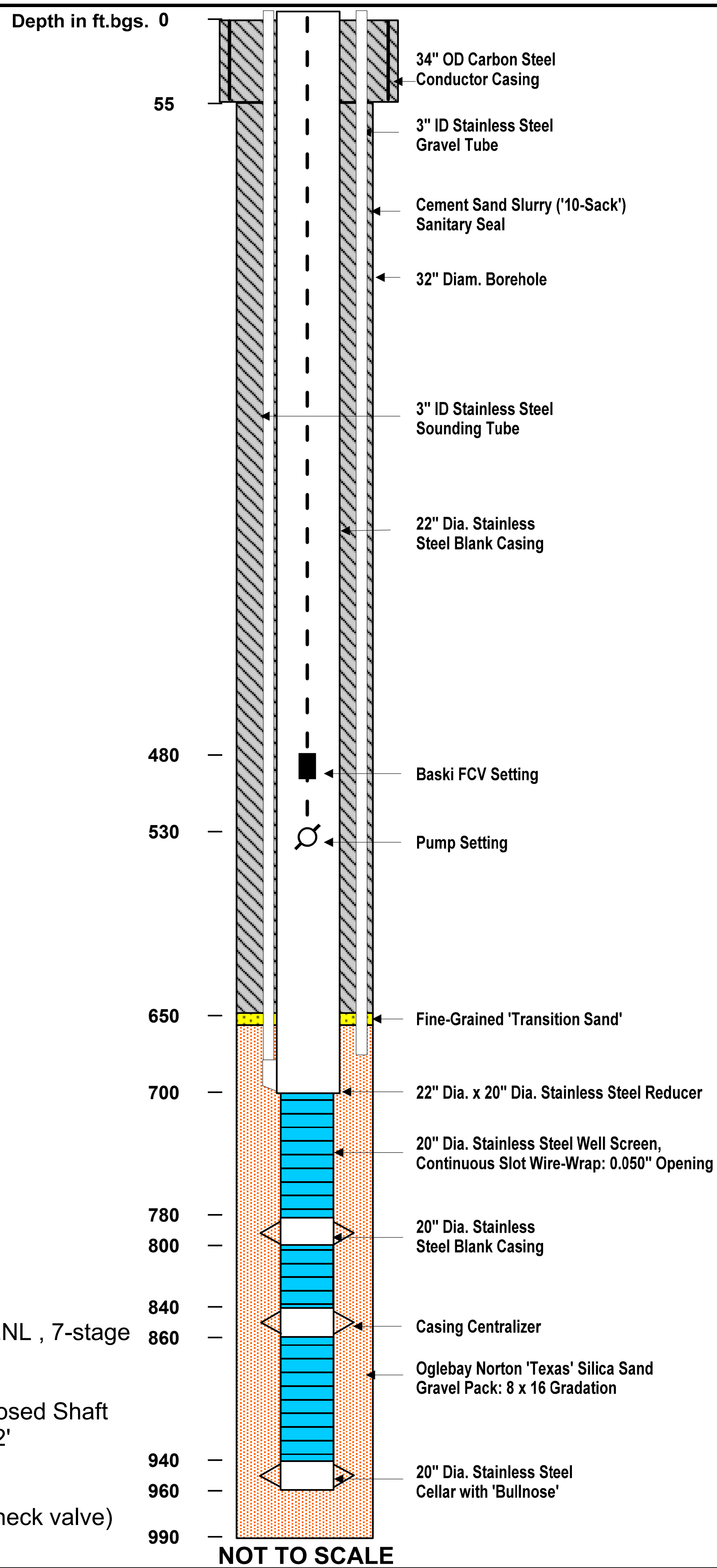



Pump Assembly Notes:
Hp: 600
Bowls: 16ENL, 7 stage
Col. Pipe Dia: 12"
Col. Pipe Length: 20'
Assy. Type: Water Flush/Enclosed Shaft
Baski FCV Setting: 460' - 470'
Top of Bowls: 510'
Bowl Length: 10.5'
Suction Length: 10'
Intake: 530.5'

PUEBLO water resources

**FIGURE 3. ASR-2 AS-BUILT SCHEMATIC**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

June 2016
Project No. 12-0043

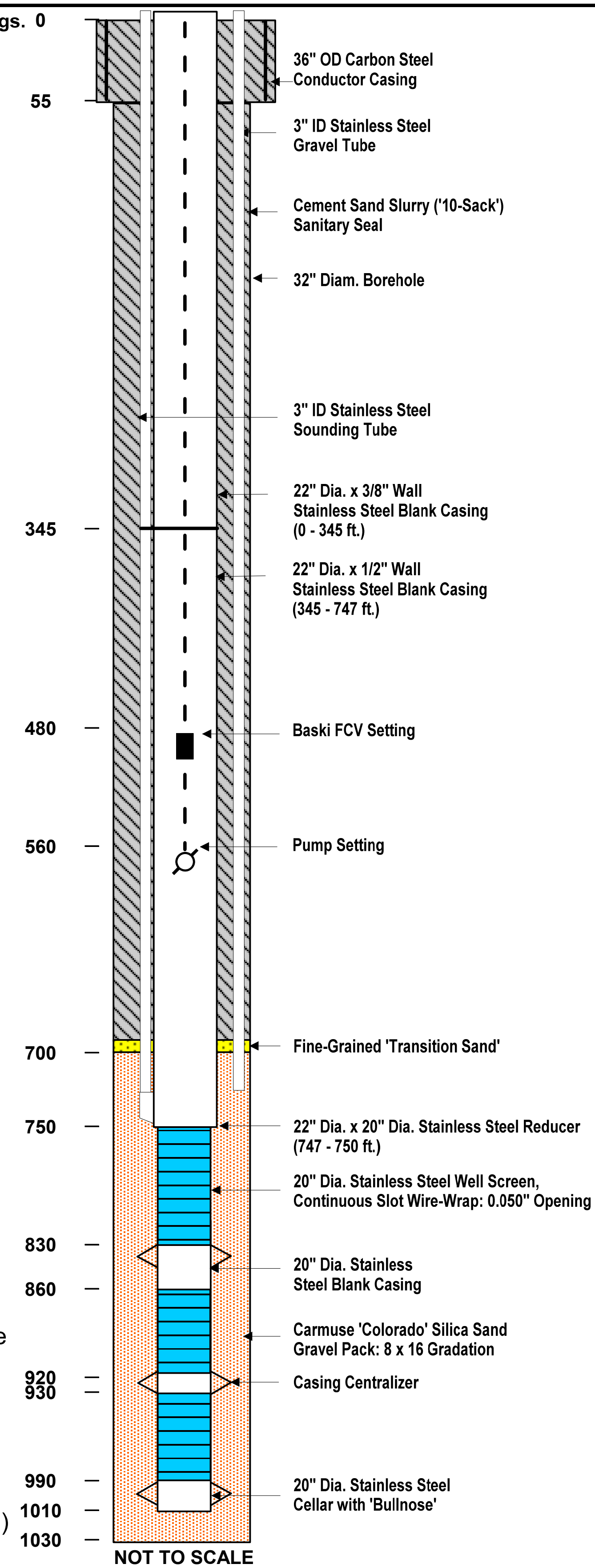



Pump Assembly Notes:
Hp: 600
Bowls: Flowserve Model 16 ENL , 7-stage
Col. Pipe Dia: 12"
Col. Pipe Length: 20'
Assy. Type: Water Flush/Enclosed Shaft
Baski FCV Setting: 482' to 492'
Top of Bowls: 532'
Bowl Length: 10.5'
Suction Length: 8'(including check valve)
Intake: 550.5'

PUEBLO water resources

**FIGURE 4. ASR-3 AS-BUILT SCHEMATIC**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

June 2016
Project No. 12-0043




Pump Assembly Notes:
Hp: 600
Bowls: Flowserve Model 16 ENL , 7-stage
Col. Pipe Dia: 12"
Col. Pipe Length: 20'
Assy. Type: Water Flush/Enclosed Shaft
Baski FCV Setting: 480' to 490'
Top of Bowls: 562'
Bowl Length: 10.4'
Suction Length: 10' (including check valve)
Intake: 582.4'

PUEBLO water resources

**FIGURE 5. ASR-4 AS-BUILT SCHEMATIC**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

June 2016
Project No. 12-0043

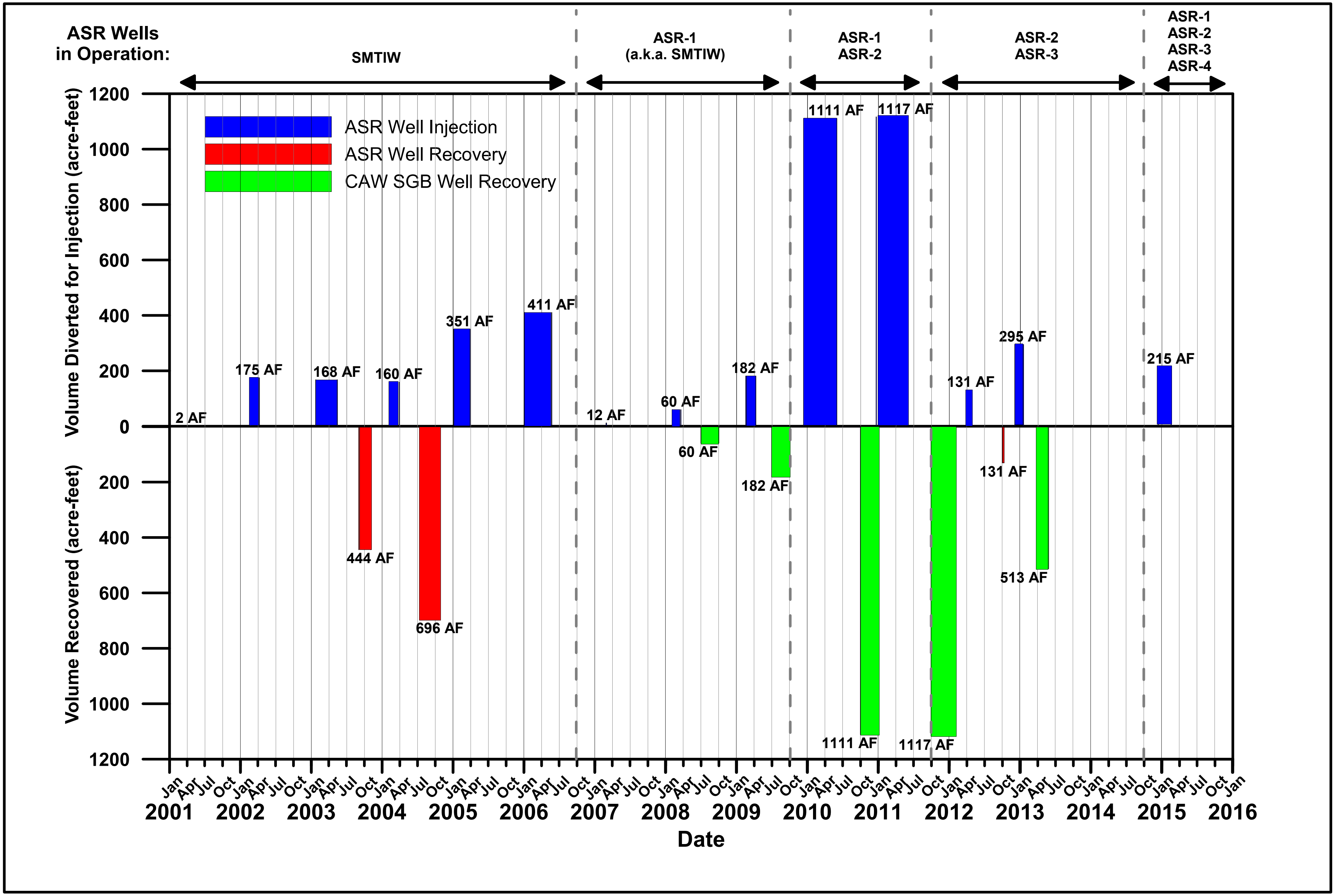



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**FIGURE 6. SUMMARY OF ASR OPERATIONS (WY 2001 - WY 2015)**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

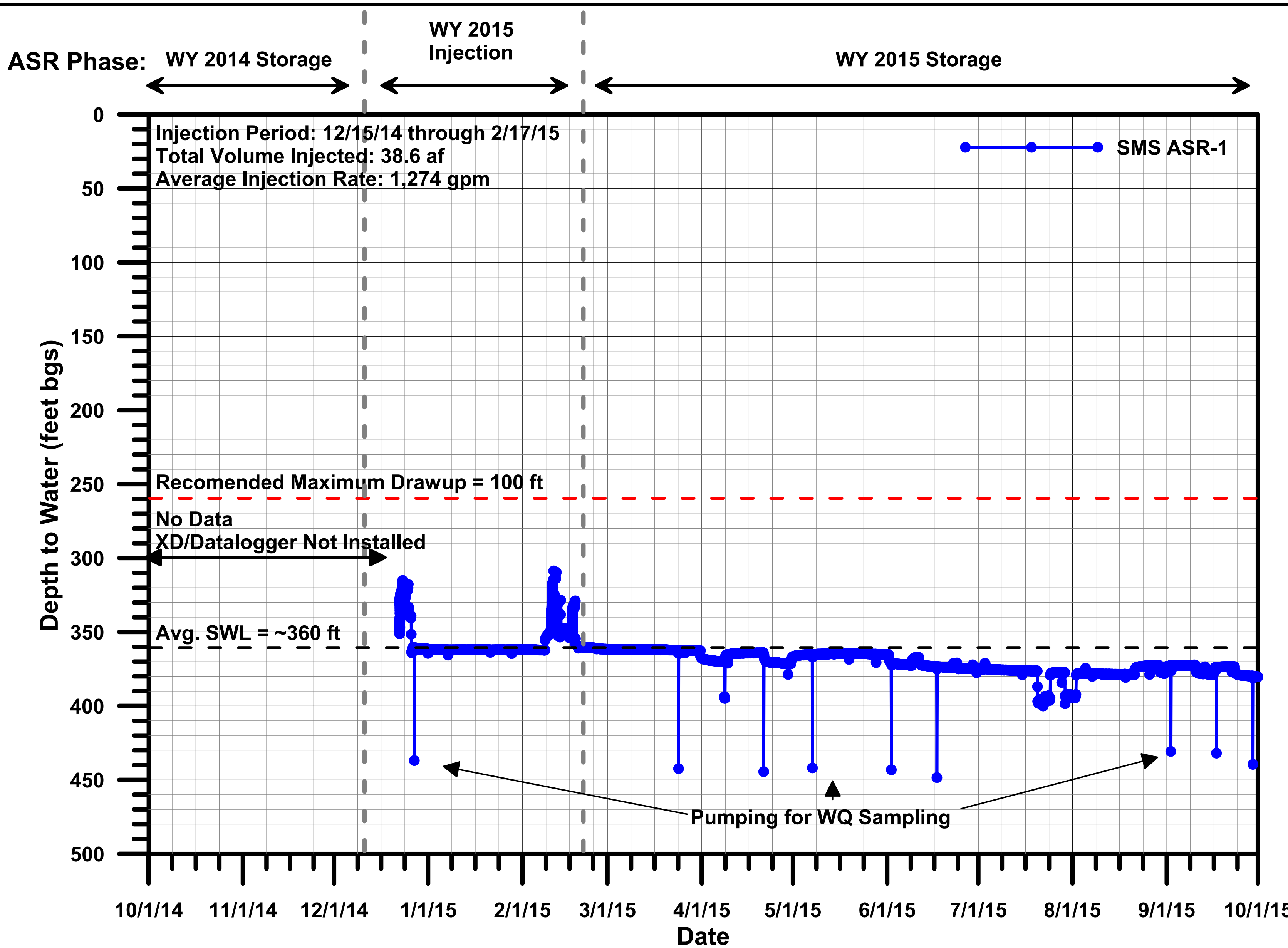


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**FIGURE 7. ASR-1 WATER-LEVEL DATA**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

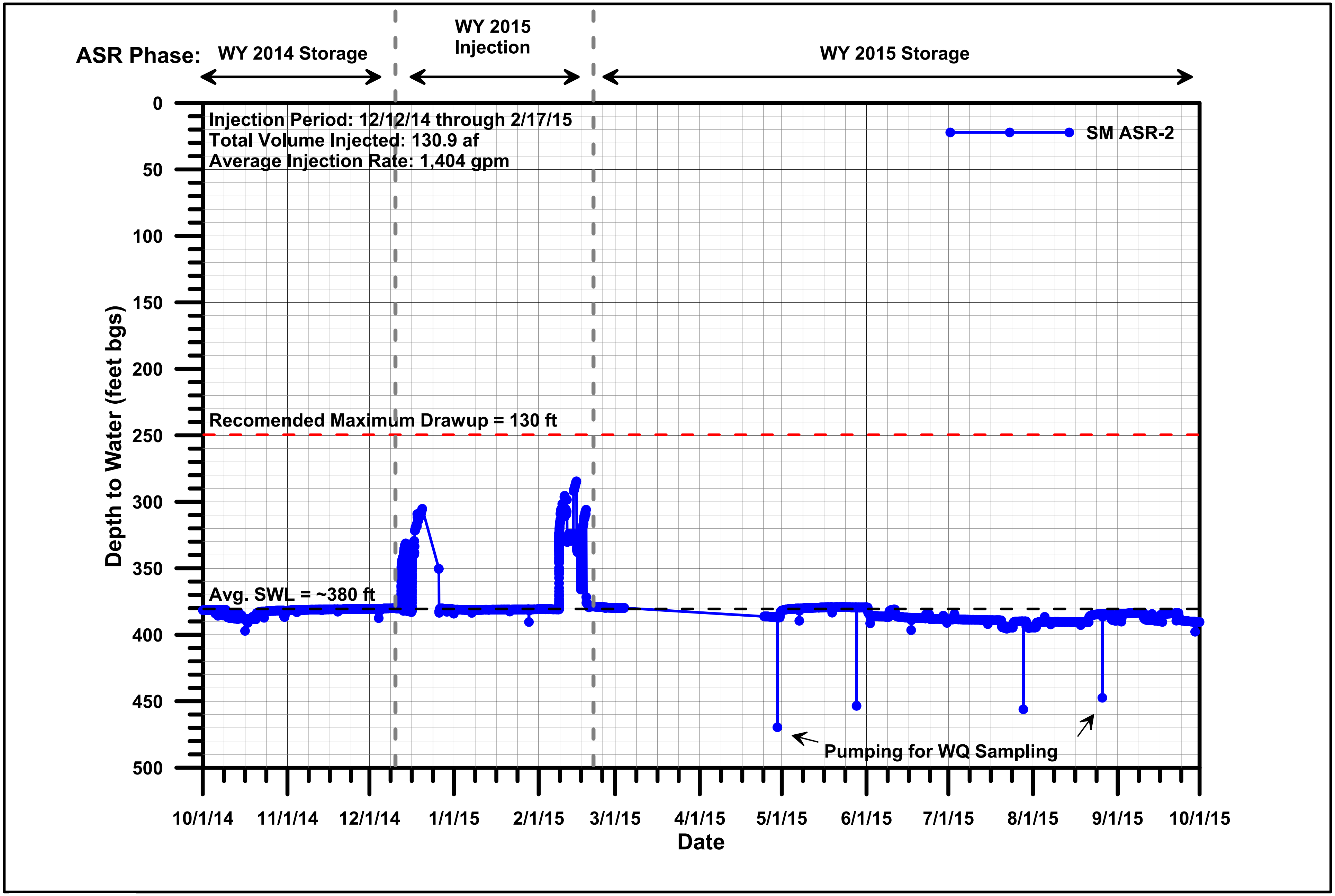


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**FIGURE 8. ASR-2 WATER-LEVEL DATA**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

June 2016
Project No. 12-0043

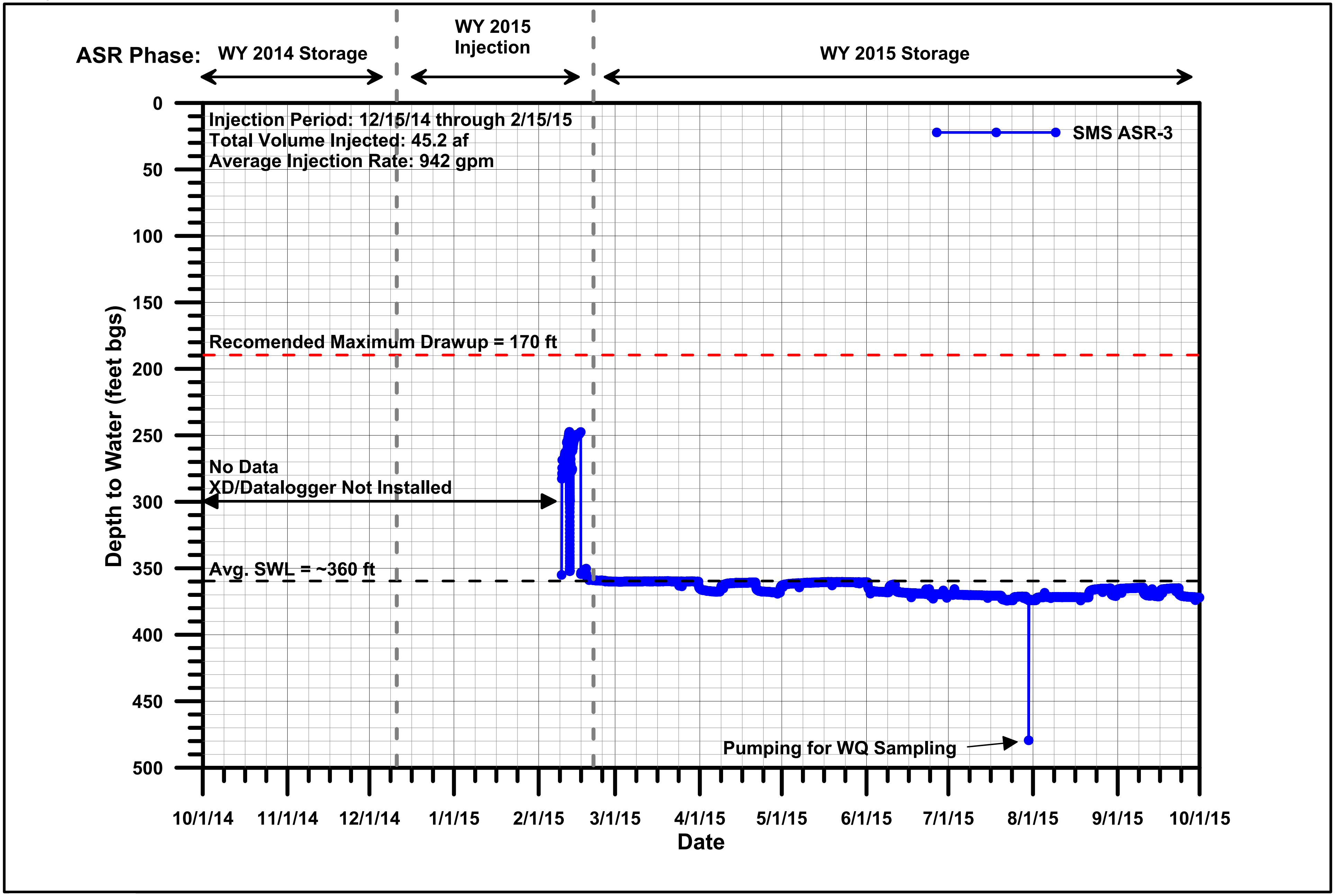


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**FIGURE 9. ASR-3 WATER-LEVEL DATA**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

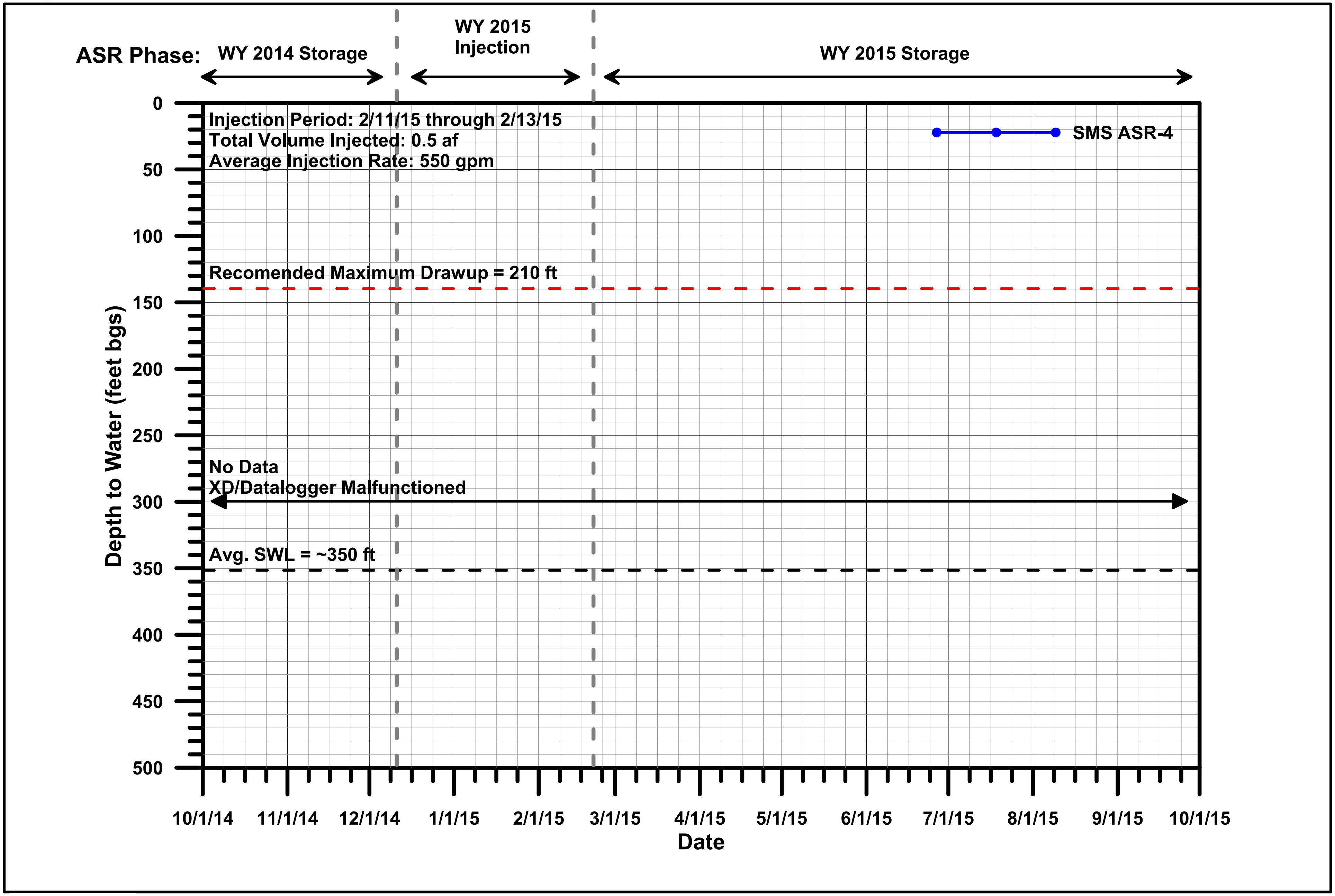


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**FIGURE 10. ASR-4 WATER-LEVEL DATA**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

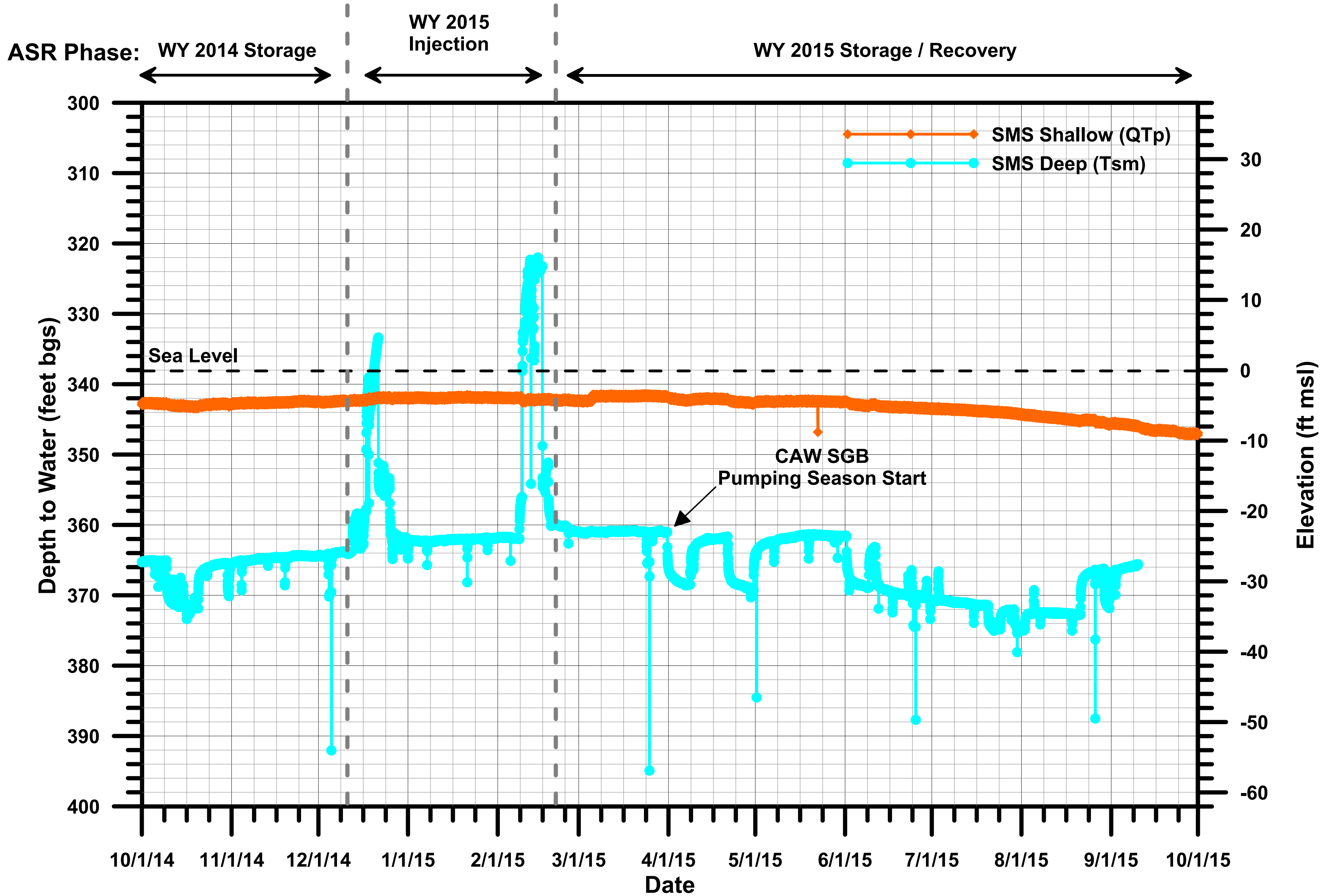


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**FIGURE 11. SMS MW WATER-LEVEL DATA**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

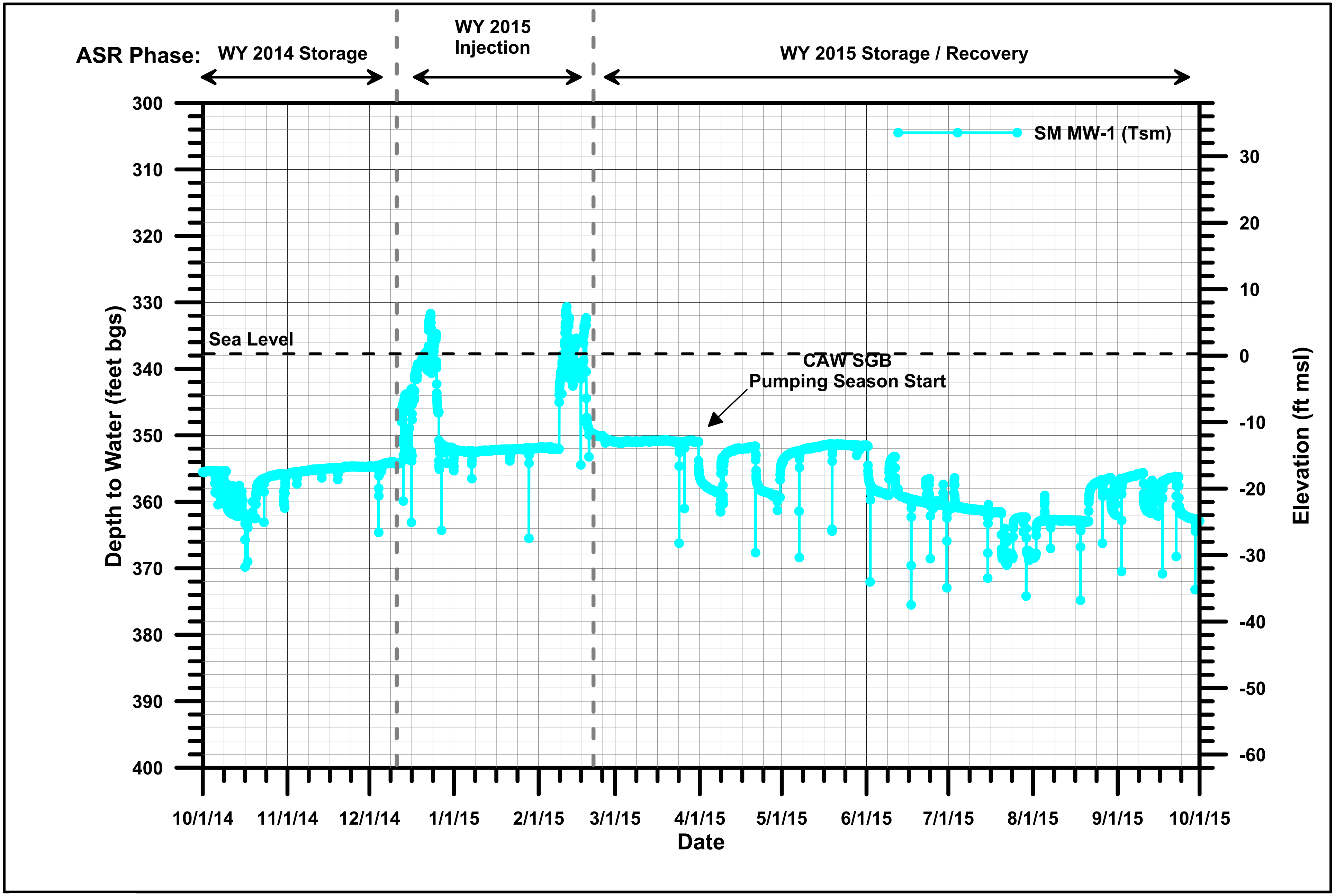


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**FIGURE 12. SM MW-1 WATER-LEVEL DATA**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

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Project No. 12-0043

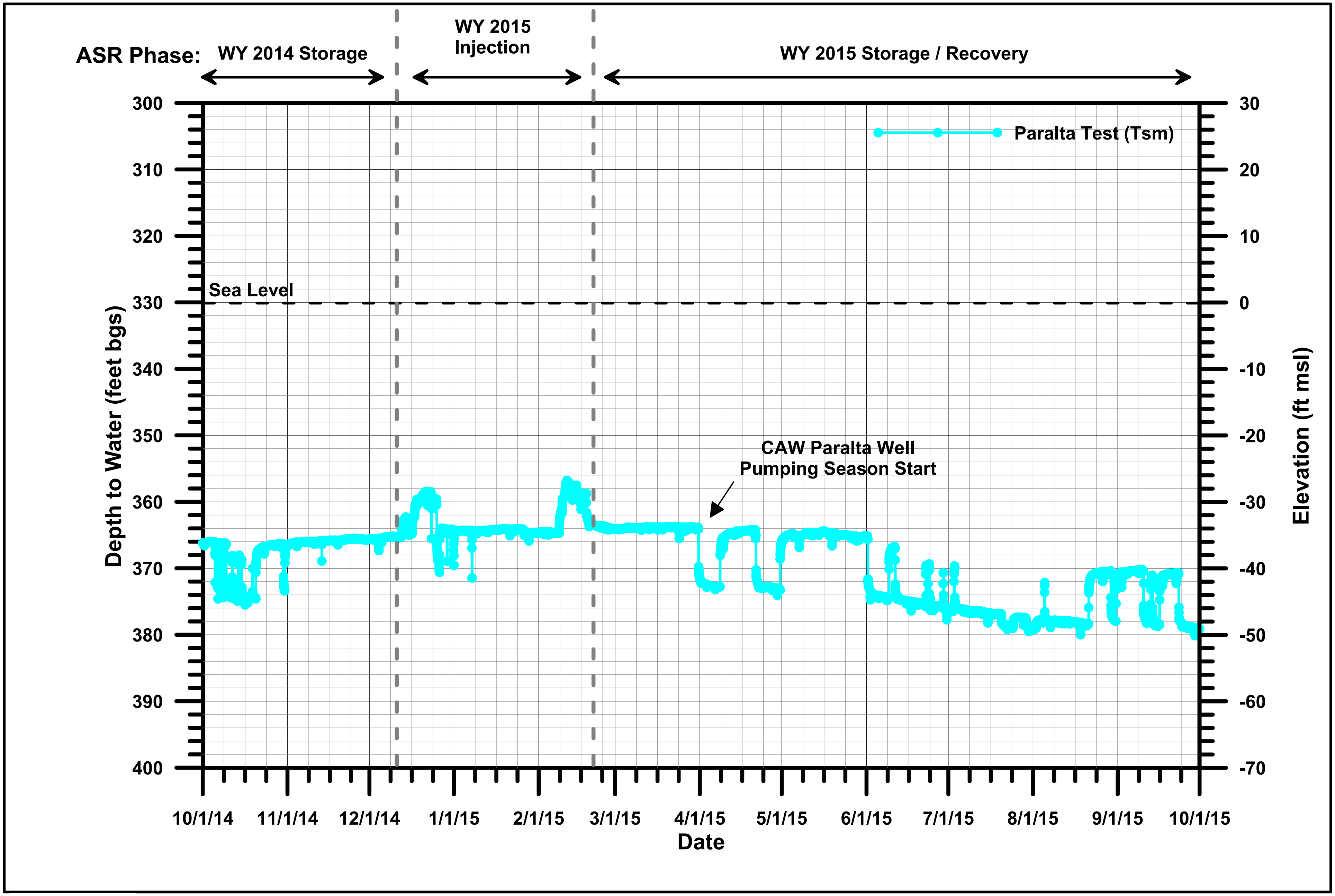


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**FIGURE 13. PARALTA TEST WATER-LEVEL DATA**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

June 2016
Project No. 12-0043

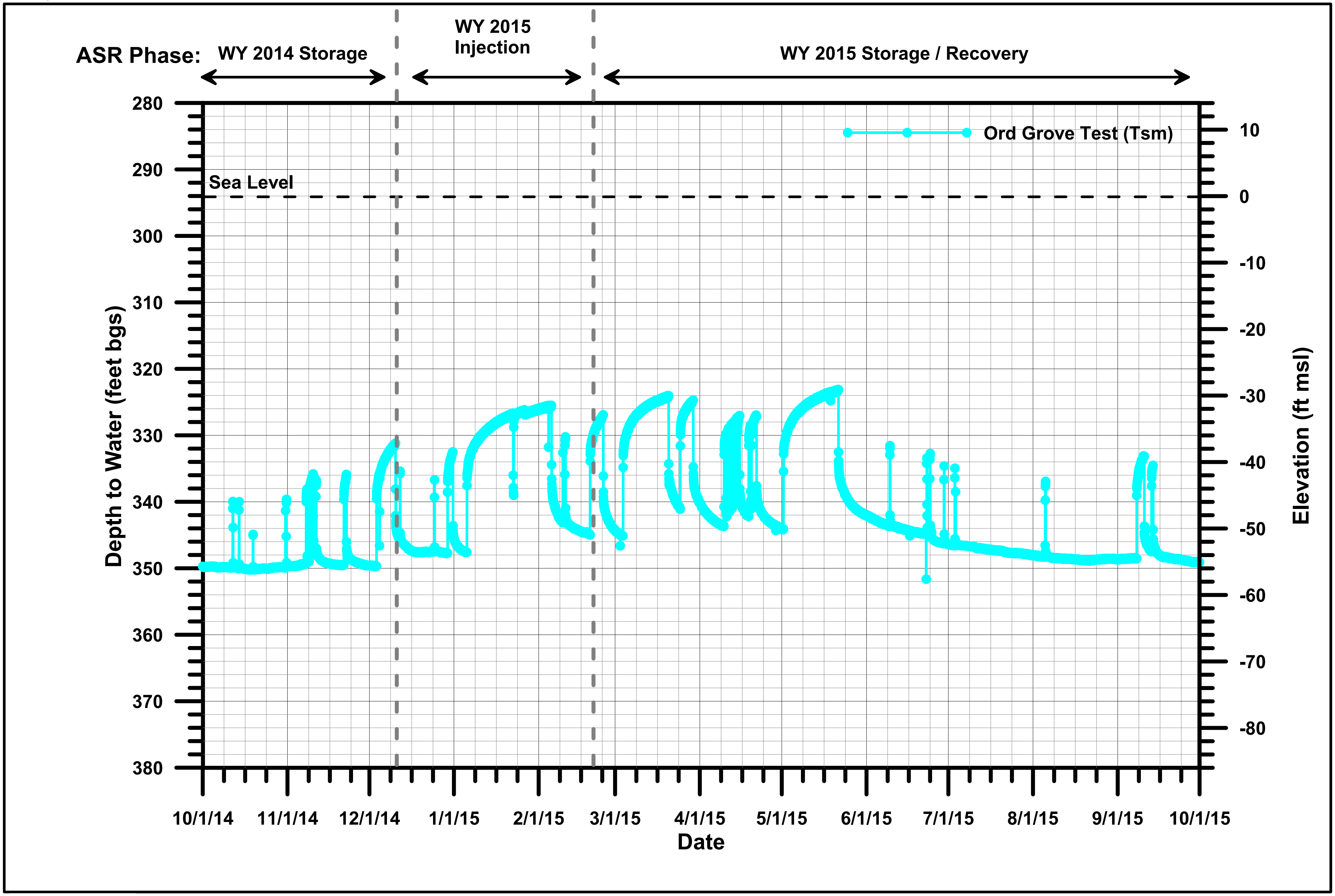


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**FIGURE 14. ORD GROVE TEST WATER-LEVEL DATA**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

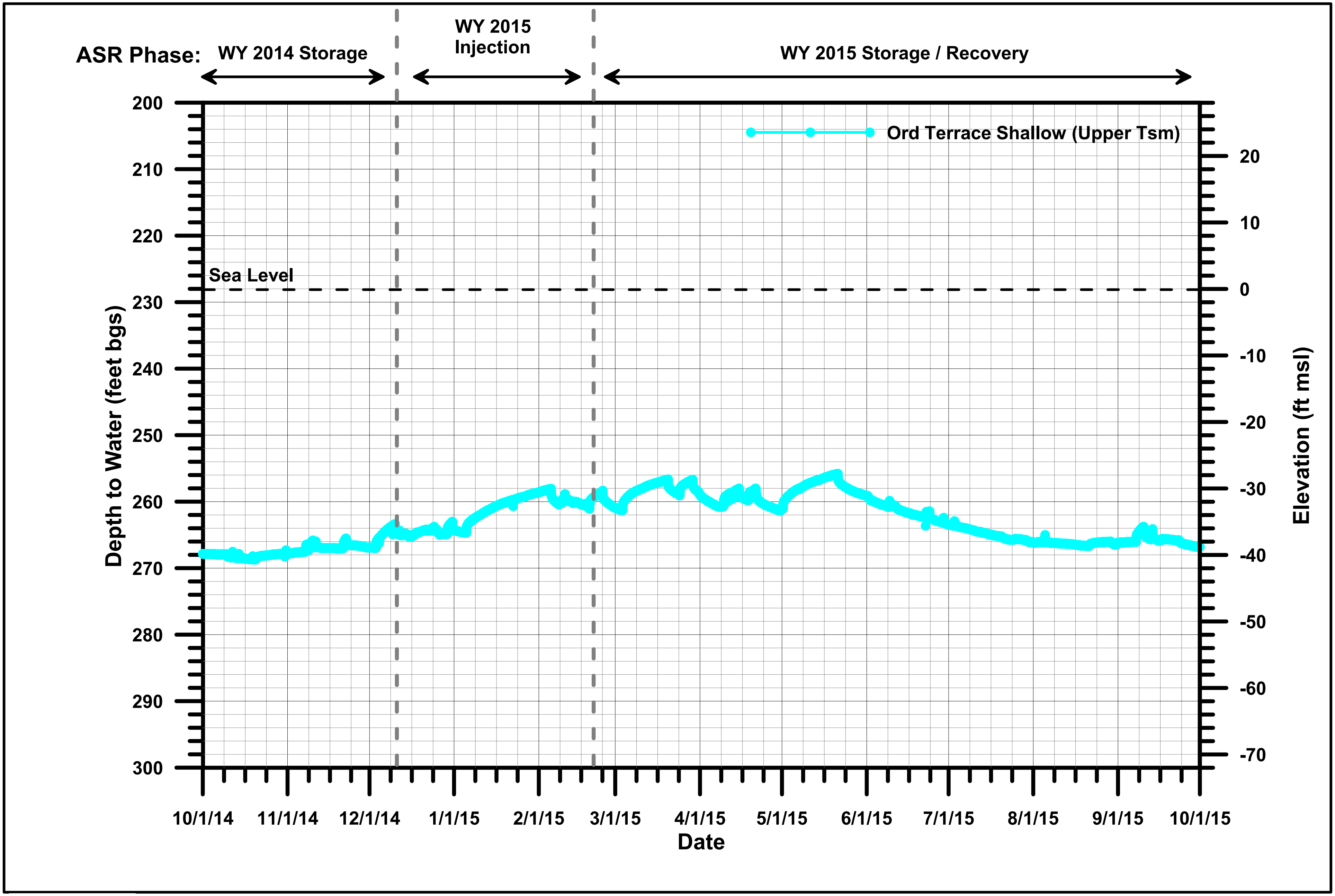


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**FIGURE 15. ORD TERRACE WATER-LEVEL DATA**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

June 2016
Project No. 12-0043

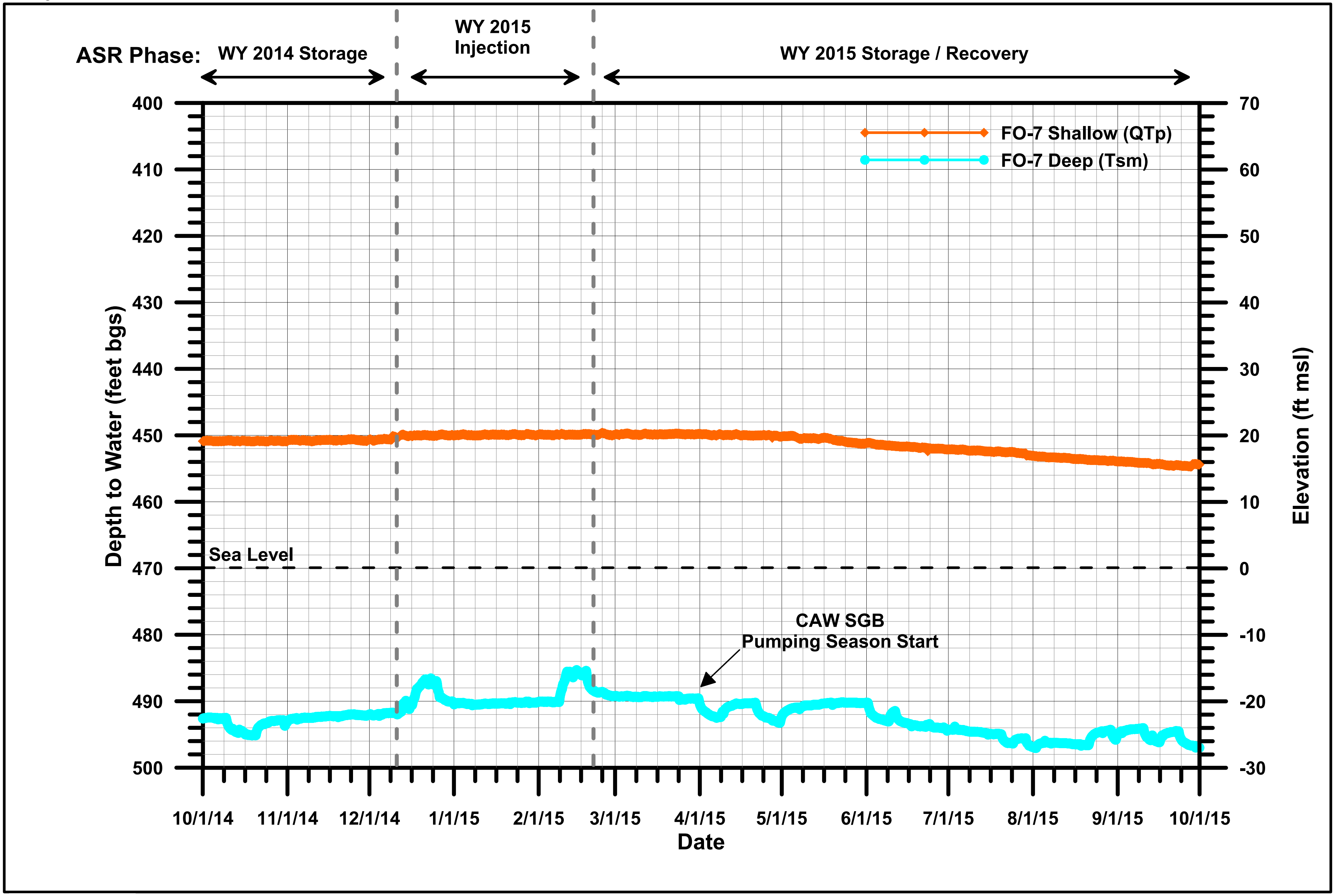


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**FIGURE 16. FO-7 WATER-LEVEL DATA**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

June 2016
Project No. 12-0043

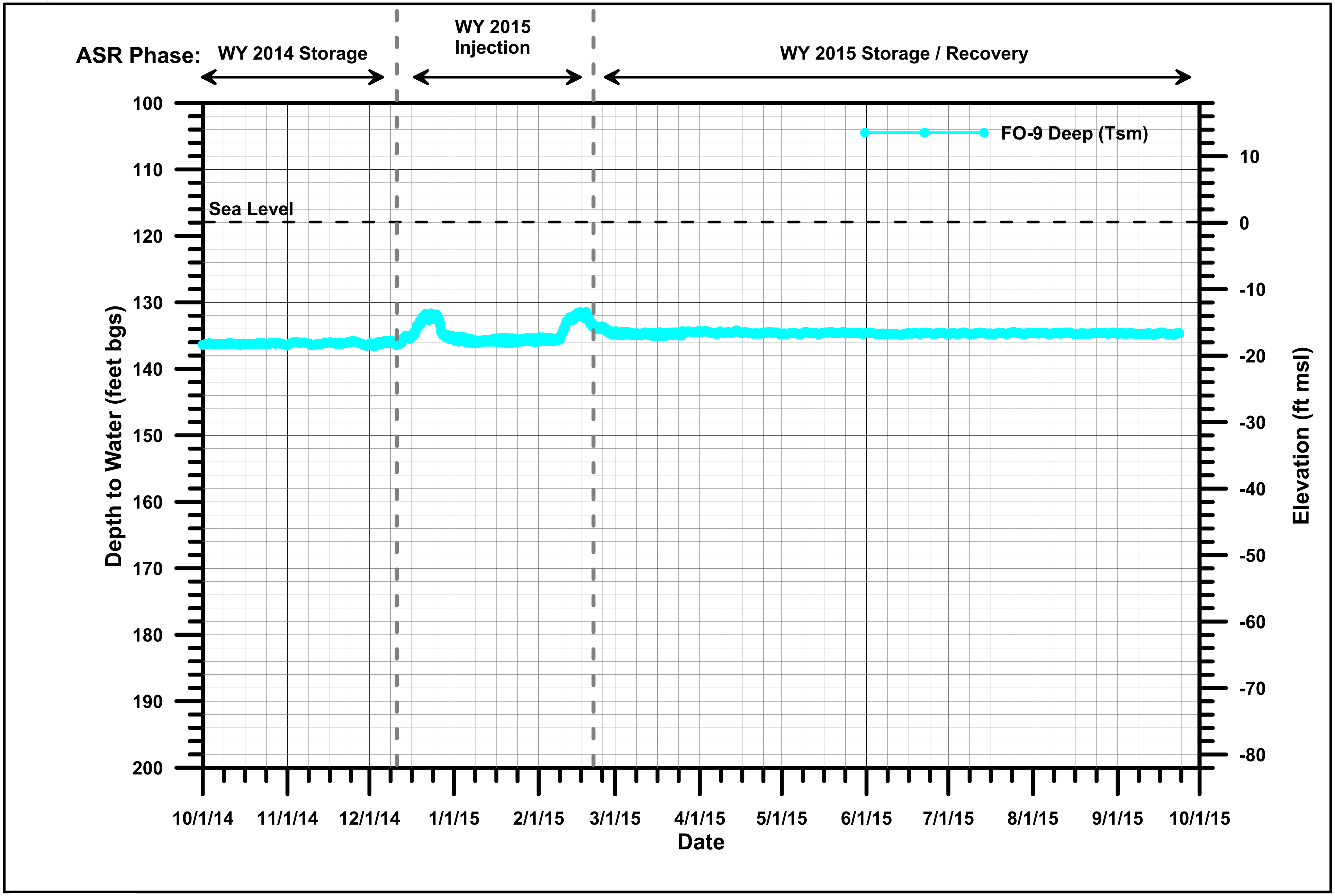


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**FIGURE 17. FO-9 WATER-LEVEL DATA**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

June 2016
Project No. 12-0043

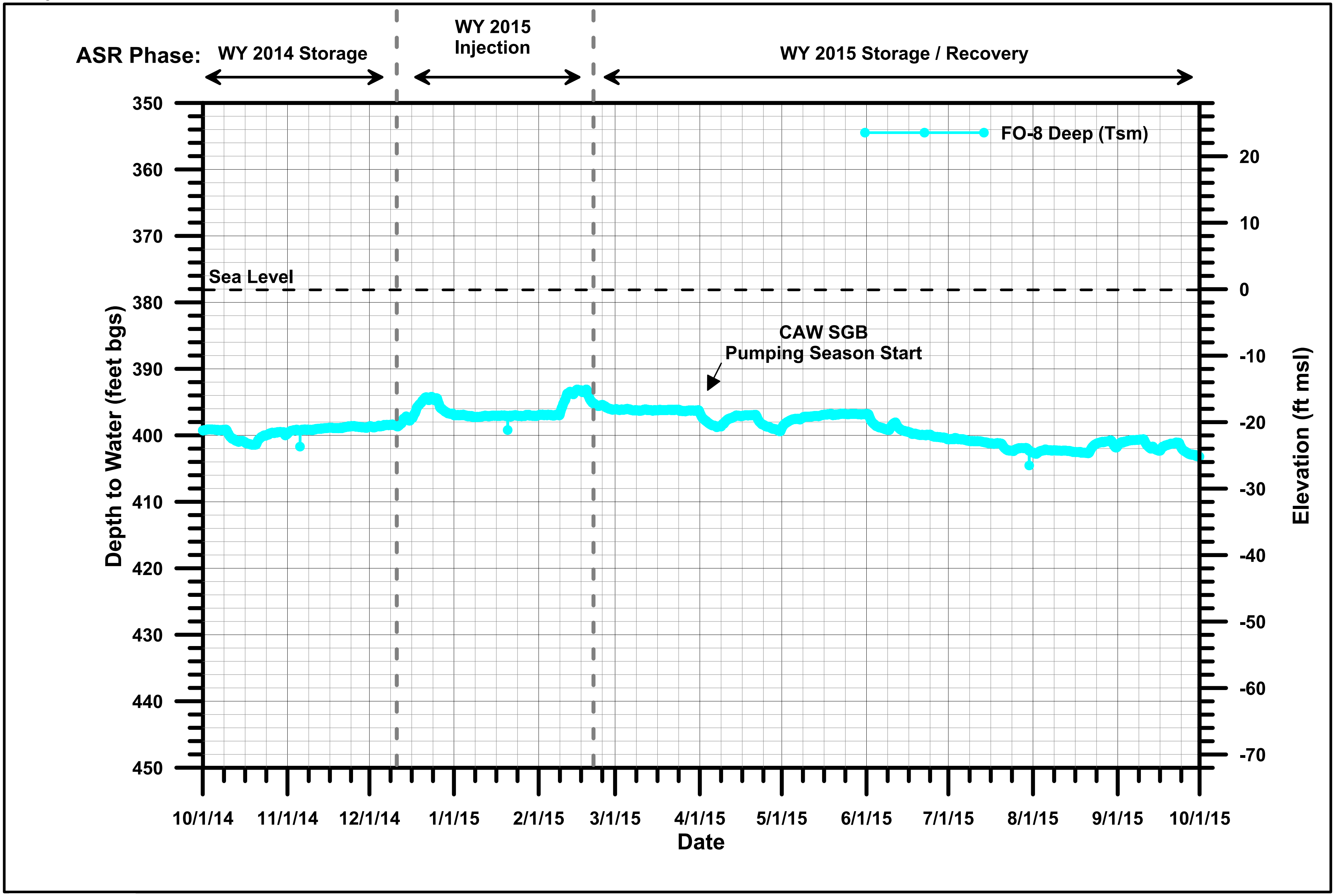


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**FIGURE 18. FO-8 WATER-LEVEL DATA**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

June 2016
Project No. 12-0043

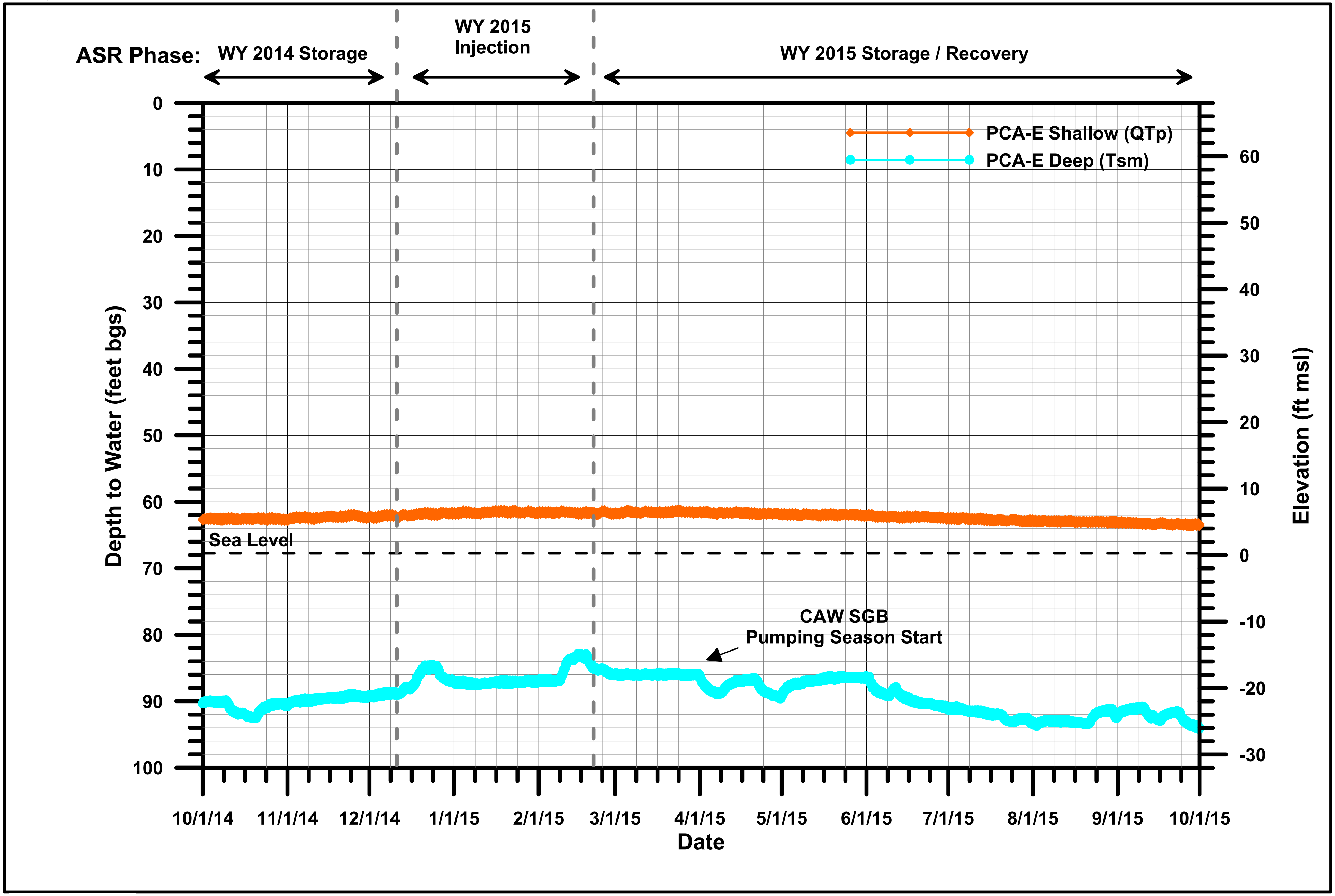


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FIGURE 19. PCA-EAST WATER-LEVEL DATA
WY 2015 ASR Program
Monterey Peninsula Water Management District

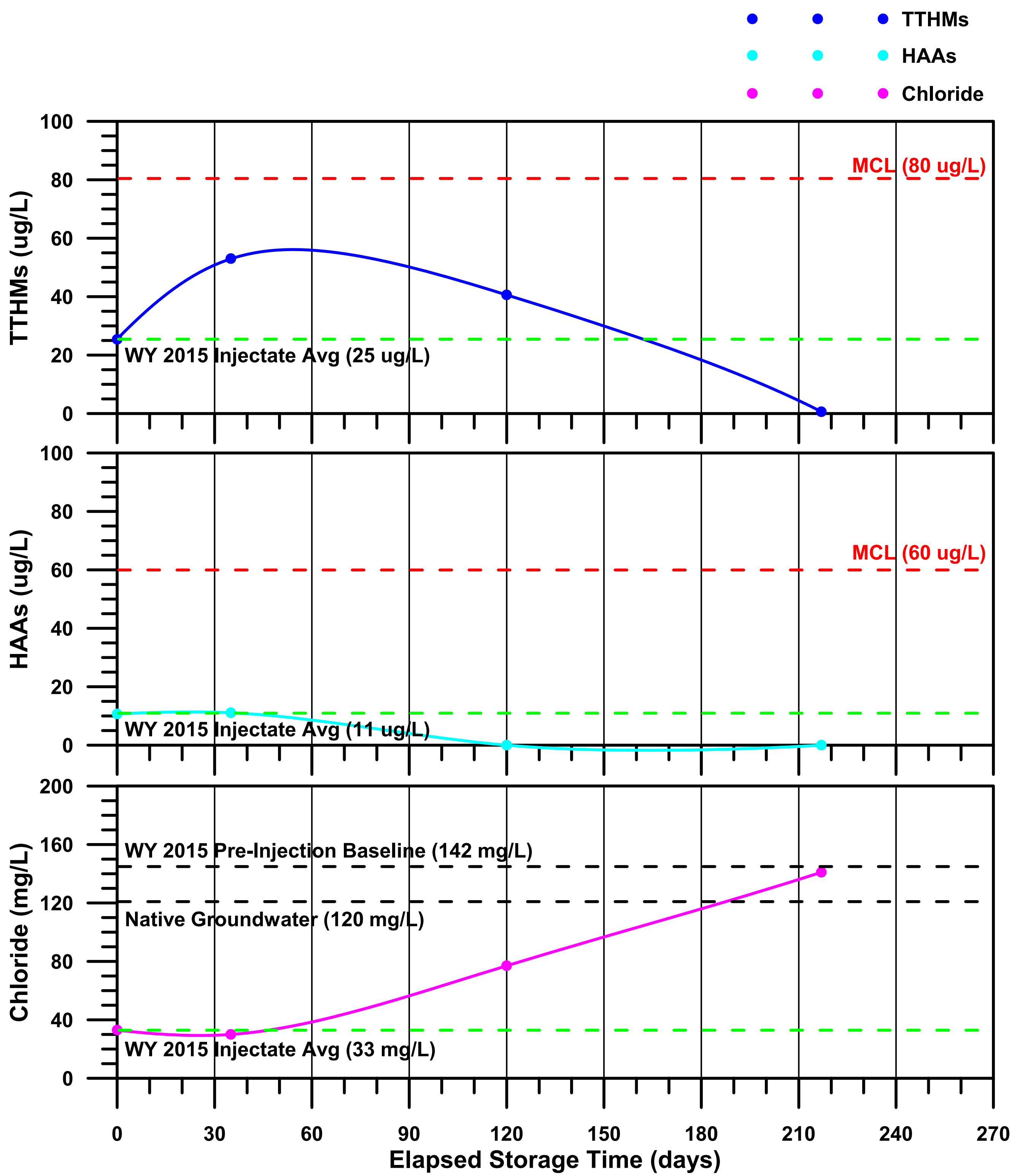


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FIGURE 20. ASR-1 DISINFECTION BYPRODUCTS PARAMETERS
WY 2015 ASR Program
Monterey Peninsula Water Management District

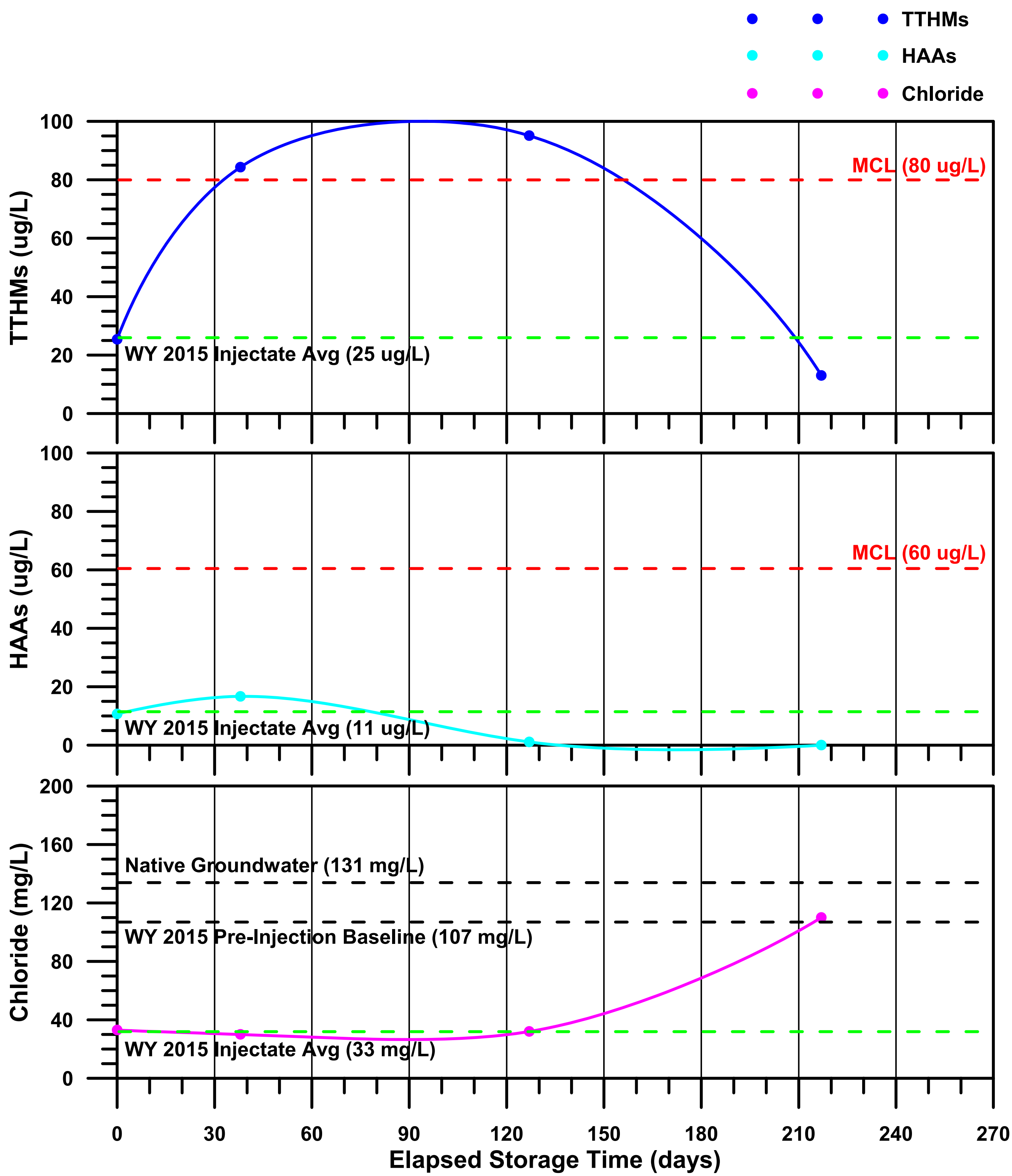


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**FIGURE 21. ASR-2 DISINFECTION BYPRODUCTS PARAMETERS**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

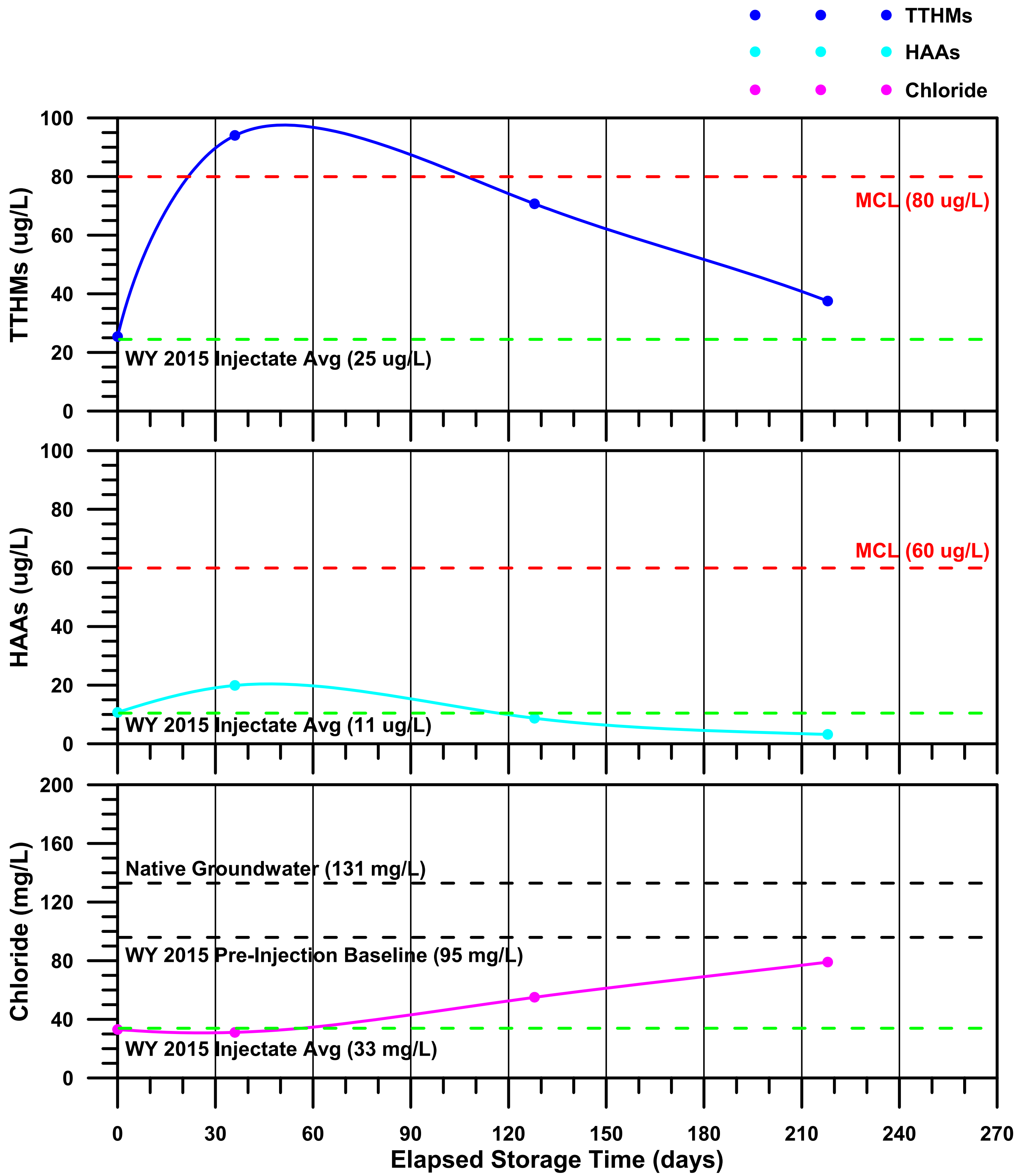


**FIGURE 22. ASR-3 DISINFECTION BYPRODUCTS PARAMETERS**
**WY 2015 ASR Program**
**Monterey Peninsula Water Management District**

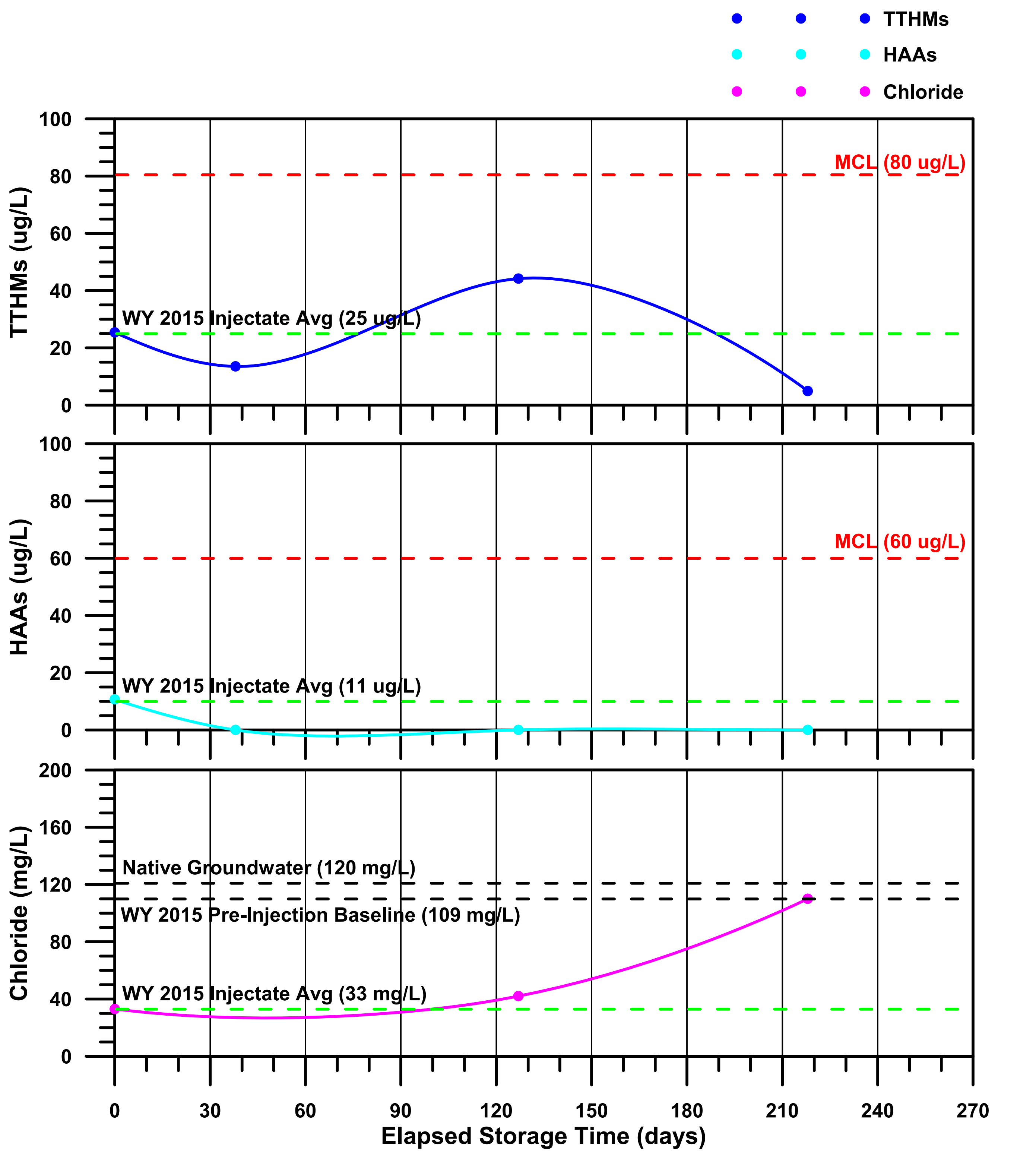


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FIGURE 23. SM MW-1 DISINFECTION BYPRODUCTS PARAMETERS
WY 2015 ASR Program
Monterey Peninsula Water Management District

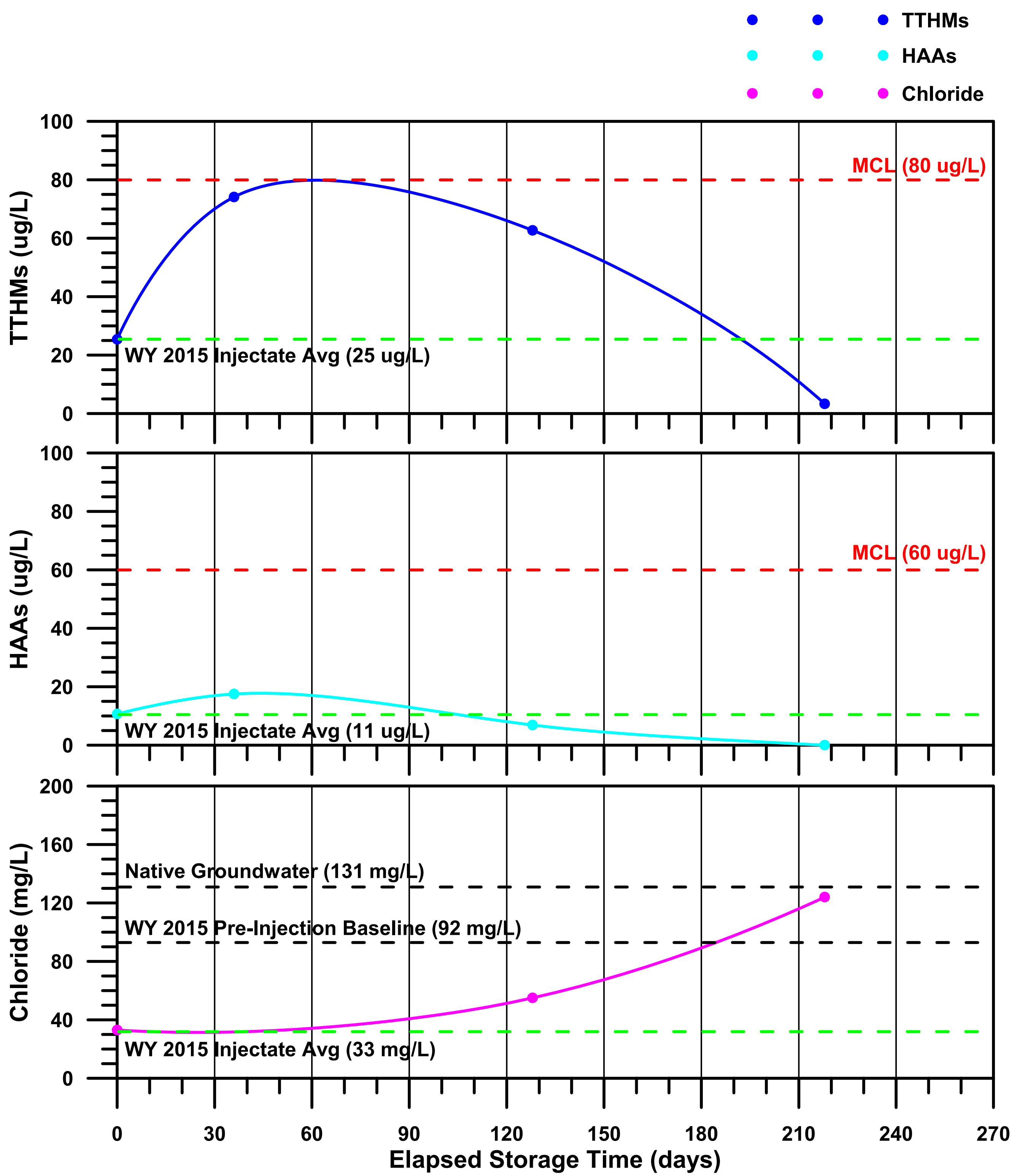


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FIGURE 24. SMS DEEP DISINFECTION BYPRODUCTS PARAMETERS
WY 2015 ASR Program
Monterey Peninsula Water Management District

# APPENDIX A - FIELD DATA
(not included in draft)

## APPENDIX B – WATER-QUALITY LABORATORY REPORTS
## (not included in draft)