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Seaside Groundwater Basin
2022 Seawater Intrusion Analysis Report

Prepared for:

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ACRONYMS & ABBREVIATIONS

ASR................aquifer storage and recovery
Ca...................calcium
CAWC............California American Water Company
Cl....................chloride
CO_3.................carbonate
FO ....Fort Ord
HCO_3..............bicarbonate
K.....................potassium
MCWRA........Monterey County Water Resources Agency
Mg..................magnesium
mg/L...............milligrams per liter
MPWMD........Monterey Peninsula Water Management District
MSC...............Monterey Sand Company
MWCRA........Monterey County Water Resources Agency
Na...................sodium
PCA................Pacific Cement Aggregates
PVWMA........Pajaro Valley Water Management Agency
PWM..............Pure Water Monterey
SIAR ....Seawater Intrusion Analysis Report
SO_4.................sulfate
WY.................Water Year

EXECUTIVE SUMMARY

This report fulfills part of the annual reporting requirements contained in the Seaside Groundwater Basin Adjudication (California American Water v. City of Seaside, Monterey County Superior Court, Case Number M66343). The annual report addresses the potential for, and extent of, seawater intrusion in the Seaside Groundwater Basin (Basin).

Seawater intrusion may occur under basic hydrogeologic conditions as a wedge beneath fresh groundwater or in more complex hydrogeology with various intrusion interfaces among the different aquifers. Continued pumping in excess of recharge and freshwater inflows, coastal groundwater levels well below sea level, and ongoing seawater intrusion in the nearby Salinas Valley all suggest that seawater intrusion could occur in the Basin.

Seawater intrusion is typically identified through regular chemical analyses of groundwater which can identify geochemical changes in response to seawater intrusion. No single analysis definitively identifies seawater intrusion, however by examining various analyses it is possible to determine when fresh groundwater mixes with seawater. At low chloride concentrations, it is often difficult to identify incipient seawater intrusion. This is due to the natural variation in freshwater chemistry at chloride concentrations below 1,000 milligrams per liter (mg/L). Mixing trends between groundwater and seawater are more easily defined when chloride concentrations exceed 1,000 mg/L. Common geochemical indicators of seawater intrusion are cation and anion ratios, chloride trends, sodium/chloride ratios, and electric induction logging.

As noted in the previous 3 Seawater Intrusion Analysis Reports (SIARs) (M&A, 2019; M&A, 2020; M&A, 2021), monitoring well Fort Ord (FO)-10 Shallow, located outside and just north of the Basin, has experienced sustained chloride increases and currently has a sodium/chloride molar ratio below 0.86, which may suggest a seawater chloride source. This year, FO-10 Deep also experienced an increase in chloride from the previous year of 60 mg/L. Induction logging of the FO-10 nested well system took place in March 2021 and confirmed chloride concentrations in groundwater but was inconclusive as to whether this results from seawater intrusion (Feeney, 2021). Following this development, analysis of historical records conducted in February 2022 discovered that a 1,300 foot long 2-inch diameter steel tremie pipe had been stuck in the FO-10 borehole since its construction in 1997 (Feeney, 2022). The presence of this steel pipe, which conducts electricity through the borehole and may be allowing water to travel between upper and lower zones, explains the inconclusive results from the March 2021 induction logging. That this pipe may be acting as a conduit is further substantiated by the increasing chlorides in both FO-10 Deep and FO-10 Shallow, and the very uniform groundwater elevations seen in both wells over the past 2 years. It is suggested that FO-10 Shallow and FO-10 Deep be destroyed and replaced to maintain robust water quality monitoring in the area. Sentinel Well induction logs, now performed annually, remain stable over the historical record. No data collected in Water Year (WY) 2022 indicate that seawater intrusion is occurring within the Basin.

Based on the findings of this report, ongoing detrimental groundwater conditions that pose a direct threat of seawater intrusion are:

- Both the Paso Robles and Santa Margarita aquifers in the Seaside Groundwater Basin are susceptible to seawater intrusion. The Paso Robles aquifer is in direct hydrogeologic connection with Monterey Bay, and seawater will eventually flow into it if inland groundwater levels continue to be below sea level. The Santa Margarita aquifer may not be in direct connection with Monterey Bay. If that is the case, then seawater intrusion will take longer to appear because the pathway for seawater into that aquifer will be longer as seawater would need to move through the clay rich deposits overlying that aquifer before entering the aquifer itself and thereafter make its way into the Santa Margarita aquifer. It is not if, but when, seawater intrusion into these aquifers will occur if protective water elevations are not achieved.
- Santa Margarita aquifer groundwater levels in the Northern Coastal subarea continue to be below sea level. Water Year (WY) 2022 second quarter (winter/spring) coastal groundwater levels in that aquifer are more than 40 feet below sea level, and the fourth quarter (summer/fall) levels are more than 60 feet below sea level. Pumping depressions expanded both vertically and spatially from the previous year in both the Paso Robles and Santa Margarita aquifer systems.
- Groundwater levels remain below protective elevations in all Santa Margarita protective elevation monitoring wells (MSC Deep, PCA-W Deep, and sentinel well SBWM-3), and 2 of 3 Paso Robles protective elevation monitoring wells (MSC Shallow and PCA-W Shallow). Groundwater elevations of all 3 Santa Margarita monitoring wells are at the lowest in their historical records. Monitoring Elevations at PCA-W shallow were above protective elevations in early WY 2020 but have since dropped below. Besides CDM-MW4, all wells for which protective elevations have been established declined in elevation from the previous year.

Data that indicate that seawater intrusion is not occurring are described in the bulleted items below:

- Most groundwater samples for WY 2022 from depth-discreet monitoring wells generally plot in a single cluster on Piper diagrams, with no water chemistry changes toward seawater. Increased chloride in recent measurements at FO-10 Shallow and FO-10 Deep, north of the Basin, has shifted how these wells plot on Piper diagrams over the past 3 years. Currently, they appear to be shifting toward a chlorinated water type. As described above, induction logging of the FO-10 well nest was inconclusive as to whether seawater intrusion is causing this change in water quality due to the presence of an abandoned steel pipe in the borehole since the well's construction. This steel pipe may also be serving as a conduit to allow groundwater flow between aquifer zones. Groundwater quality in FO-10 Shallow and FO-10 Deep should continue to be monitored closely to identify if further increases occur, and it is suggested that both FO-10 Shallow and FO-10 Deep be destroyed and replaced to maintain a water quality record in the area.

- In some production wells, groundwater quality plots differently on Piper diagrams compared to monitoring wells. This may be a result of mixed water quality from both the Paso Robles and Santa Margarita aquifers in which these wells are perforated. None of the production wells' groundwater qualities are indicative of seawater intrusion.
- None of the Stiff diagrams for monitoring and production wells show the characteristic chloride spike that typically indicates seawater intrusion in Stiff diagrams. The Stiff diagram for monitoring well FO-10 Shallow shows a slightly different shape than other Paso Robles aquifer wells because of increased chloride.
- Chloride concentration trends are stable for most monitoring wells, with the notable exception of FO-10 Shallow and FO-10 Deep. FO-10 Shallow experienced a 48 mg/L increase in chloride concentrations in WY 2020 and has risen by another 8 mg/L since then. FO-10 Deep experienced a 60 mg/L increase in WY 2022. However, the sustained elevated concentrations in themselves do not indicate seawater intrusion. As noted above, recent induction logging was unable to conclusively determine whether seawater intrusion is the source of the elevated chloride level, and the well's integrity for water quality sampling may be compromised by a steel tremie pipe stuck in the borehole since 1997.
- Sodium/chloride molar ratios in most monitoring wells remained constant or increased over the past year. The sodium chloride ratio in 2 of the 3 samples taken at FO-10 Shallow in WY 2022 were lower than what has been seen historically at the location. The ratio from 5 of the 7 samples tested since September 2020 are below 0.86. A sodium/chloride ratio less than 0.86 signifies a potential seawater chloride source. It is likely the groundwater quality changes in FO-10 Shallow are permanent and the well should continue to be monitored consistently to track if chloride concentrations increase further. If the well is destroyed and replaced due to the stuck steel pipe mentioned above, water quality from the replacement well should similarly be closely monitored to evaluate changes in chloride over time.
- Maps of chloride concentrations for the Paso Robles aquifer do not show chlorides increasing toward the coast. Santa Margarita aquifer chloride concentration maps show that the highest chloride concentrations are limited to coastal monitoring wells PCA-West

Deep and MSC Deep, but these are not indicative of seawater intrusion since their concentrations are less than 155 mg/L and they do not have increasing trends. Two wells, Pasadera Golf- Paddock and Ord Terrace Shallow, sustained a >20 mg/L chloride increase from WY 2021, but as evidenced by their distance from the coast this is not a result of seawater intrusion.

- Induction logging data at the coastal Sentinel Wells do not show historical or recent changes over time that are indicative of seawater intrusion.

Other important findings from the analysis contained in this report are:

- Due to its distance from the coast, seawater intrusion is not an issue of concern in the Laguna Seca subarea. However, groundwater levels in the eastern Laguna Seca subarea have historically declined at rates of 0.6 feet per year in the Paso Robles aquifer, and up to 4 feet per year in the Santa Margarita aquifer. These declines have occurred since 2001, despite triennial reductions in allowable pumping. The cause of the declines is due in part to the Natural Safe Yield of the subarea being too high and in part due to the influence of wells east of the Seaside Basin. In WY 2022, groundwater elevations in the area appeared to experience some stabilization and recovery, potentially correlated with a cessation of pumping from California American Water Company (CAWC)'s Laguna Seca Subarea wells. This recovery has continued in WY 2022.
- Native groundwater production in the Seaside Groundwater Basin for WY 2022 was 2,870 acre-feet, which is 43 acre-feet more than WY 2021 but 129 acre-feet less than the Decision-ordered Operating Yield for WY 2022 of 3,000 acre-feet. Despite WY 2022 being a very dry year, recovery of 3,683 acre-feet of recycled water from Pure Water Monterey (PWM) helped offset pumping. Native groundwater production was below the Decision-estimated Natural Safe Yield of 3,000 acre-feet for the third year in the historical record, largely due to increased injection of highly treated recycled water.

The following recommendations should be implemented to monitor and track seawater intrusion.

- Following identification of a compromised well casing, monitoring well FO-9 Shallow was destroyed to prevent leakage of higher chloride water into the underlying aquifer. In accordance with current plans, a similarly constructed monitoring well will replace the destroyed well to ensure continuity of groundwater level measurements from this location. It is anticipated that a new well will be constructed in 2023.
- The discovery of a 1,300-foot steel tremie pipe in the FO-10 borehole complicates evaluation of water quality at the location and may act as a conduit allowing groundwater to flow between overlying sediments and the underlying aquifers. These wells are outside of the Basin, yet still provide critical information regarding the extent of seawater

intrusion north of the Basin in the Monterey Subbasin. Therefore, it is recommended that Monterey Peninsula Water Management District (MPWMD) develop plans to destroy both FO-10 Shallow and FO-10 Deep, and that MCWD install similarly constructed monitoring wells to maintain a continuous water quality record at the location. Because seawater intrusion cannot be excluded as the source of increasing chloride concentrations at FO-10 Shallow over the past several years, groundwater quality sampling at this well should continue at the increased quarterly frequency until the well is destroyed. When the well is replaced, the replacement well should likewise be sampled at a quarterly frequency. As detailed in the Monterey Subbasin GSP (MCWDGSA and SVBGSA, 2022) Section 9.4.7, additional monitoring wells may be installed in both the Lower 180-Foot and 400-Foot Aquifer and the Deep aquifers of the Monterey Subbasin. The proposed location for these wells is in an identified data gap area northeast of FO-10 Shallow (see Monterey Subbasin GSP Figures 7-7 and 7-8). When these wells are installed, they may provide additional insight into potential seawater intrusion in the area.

- Seawater intrusion is a threat to the Basin, and data must be collected and analyzed regularly to identify incipient intrusion. Maps, graphs, and analyses like those found in this report should continue to be developed every year.
- It is important to remain vigilant and to closely monitor groundwater quality even though seawater intrusion has not yet been observed in monitoring or production wells in the Basin. As outlined in the most recent Basin Management Action Plan (M&A, 2018a), it is important that the Watermaster continues to promote projects to obtain replenishment water for the Basin that is not extracted out as water supply.
- Based on the WY 2020's SIAR recommendation, groundwater elevation data from the Carmel River water Aquifer Storage and Recovery (ASR) project and PWM monitoring wells are now incorporated into the analysis of groundwater elevations. Although the Watermaster asked for this data to be provided, data from the PWM monitoring wells was not provided for this year's analysis. As these and any future projects are implemented, groundwater levels, groundwater flow directions, and potentially groundwater quality will change. It is important that data from monitoring wells associated with these projects be evaluated in future SIARs.

1 BACKGROUND AND INTRODUCTION

Historical and persistent low groundwater elevations caused by pumping in the Seaside Groundwater Basin have led to concerns that seawater intrusion may threaten the Basin's groundwater resources. This report addresses the potential for, and extent of, seawater intrusion in the Seaside Groundwater Basin. The report first reviews seawater intrusion mechanisms, analyzes historical water quality data for indications of seawater intrusion in the Seaside Groundwater Basin, and finally reaches conclusions on the extent of seawater intrusion and proposes recommendations for continued monitoring.

This report fulfills part of the annual reporting requirements contained in the Seaside Groundwater Basin Adjudication (California American Water v. City of Seaside, Monterey County Superior Court, Case Number M66343). The analyses in this report were developed by HydroMetrics Water Resources Inc. of Oakland, California, in cooperation with members of the Watermaster Technical Advisory Committee. Staff from the Monterey County Water Resources Agency (MWCRA) and Monterey Peninsula Water Management District (MPWMD) provided invaluable assistance, data, and review during the preparation of this report.

This report is the eleventh in a series of Seawater Intrusion Analysis Reports (SIAR) which are produced annually by the Watermaster. It builds on the work conducted in the preceding SIARs.

1.1 Overview of Seawater Intrusion

Seawater intrusion is a threat to many coastal groundwater basins along the California Coast. It has been observed and documented in a number of groundwater basins in both southern and central California.

In general, groundwater in coastal basins flows from recharge areas in local highlands toward discharge areas along the coast. In most undeveloped coastal groundwater basins, there is a net outflow of fresh water into the ocean. Seawater intrusion occurs when the outflow of freshwater ceases and seawater flows into the groundwater basin from the ocean.

In the simplest condition, seawater intrudes as a wedge beneath the fresh groundwater (Figure 1). This wedge shape is a result of seawater being denser than freshwater.

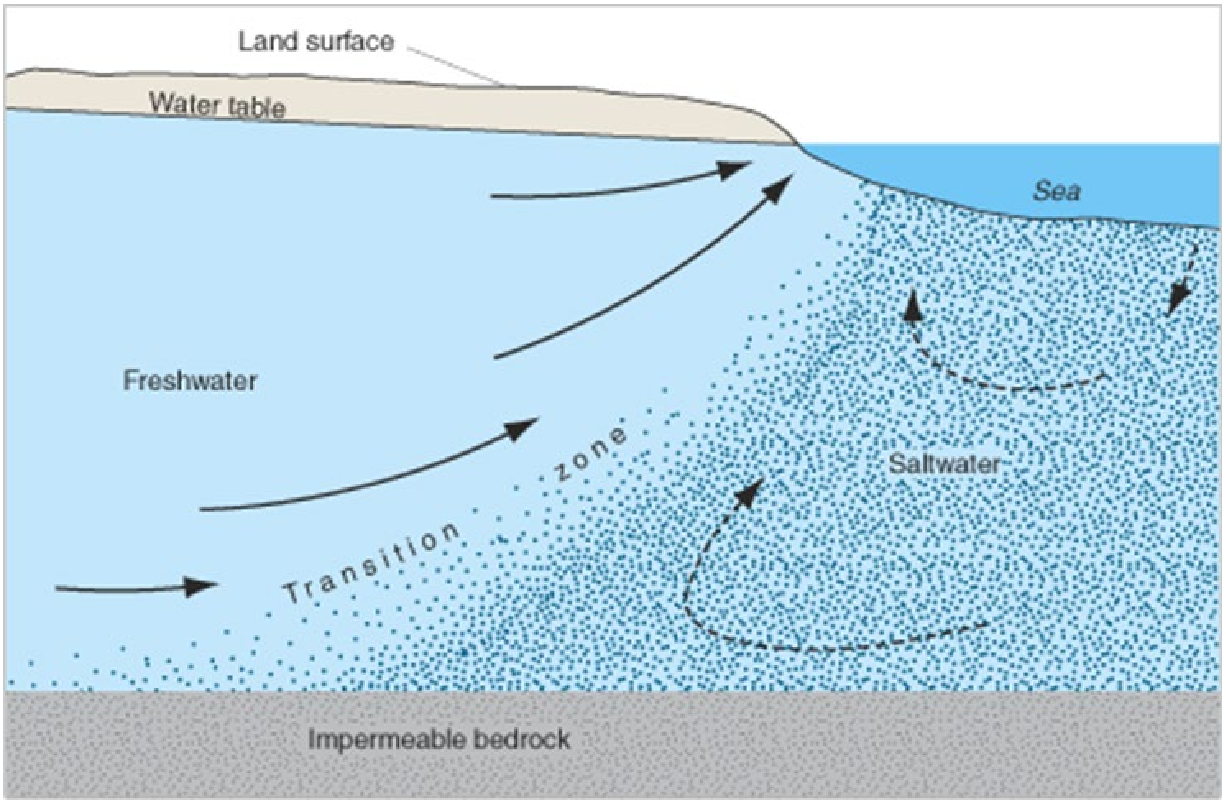

Figure 1. Seawater Wedge in a Simple Coastal Aquifer (from Barlow, 2003)

In more complex, layered groundwater systems, the location of the seawater/freshwater interface may vary among the different aquifers. Such a situation is illustrated on Figure 2, which shows a series of aquifers in blue that transmit water easily. The aquifers are separated by a series of tan aquitards, which transmit water relatively slowly. Each aquifer has a unique rate of outflow to the ocean, and therefore a unique location of the seawater interface. In these more complex situations, the locations of the seawater/freshwater interfaces are a complex function of the horizontal groundwater gradient in each aquifer, the aquifer hydraulic conductivities, and the vertical conductivity of the inter-layer aquitards.

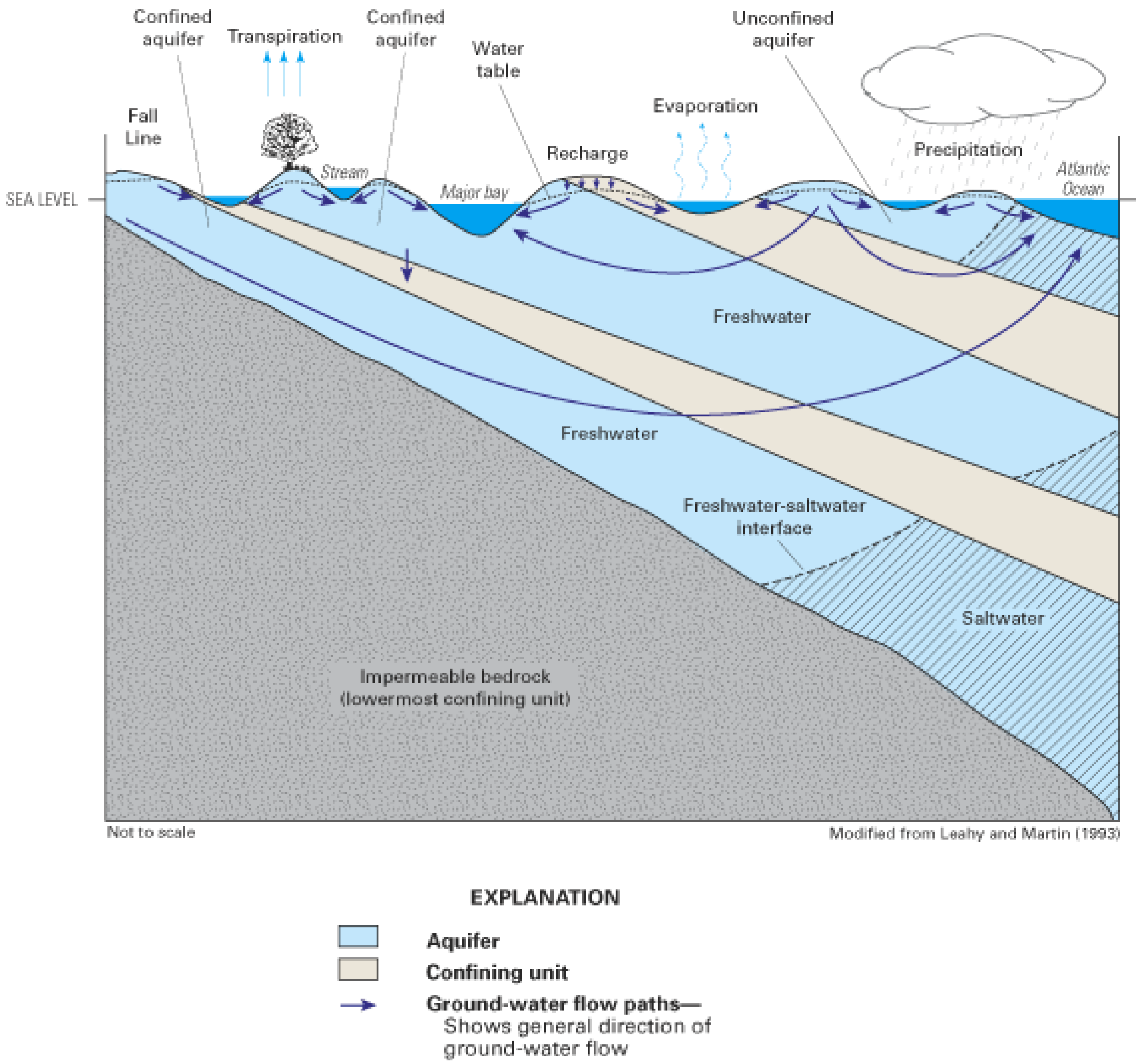

Figure 2. Seawater Wedge in a Layered Coastal Aquifer (from Barlow, 2003)

Figure 2 shows that under non-pumping conditions, the seawater interface in confined units can be located farther offshore than in surficial unconfined aquifers. The fresh water in an unconfined aquifer can flow readily into the ocean, allowing the seawater interface to exist near shore. Fresh water in the lower confined aquifers must seep out slowly through the overlying confining units. The slow seepage rates allow the fresh water to maintain pressure beneath the sea floor, pushing the seawater interface away from the coastline.

1.2 Groundwater Pumping and Seawater Intrusion

Pumping groundwater in a coastal aquifer reduces the amount of water discharging to the ocean. Sufficient pumping can eliminate ocean discharges, either locally or basin-wide, triggering seawater intrusion. The response of the seawater interface to groundwater pumping is manifested in 2 related ways: upconing and interface migration. Upconing refers to the ability of a pumping well to draw seawater up from below and only occurs if seawater exists directly below a pumping well. Because no seawater intrusion has been observed in the Seaside Groundwater Basin, upconing cannot occur and only seawater interface migration will be further addressed in this report.

As mentioned earlier, groundwater pumping reduces the amount of freshwater outflow to the ocean. This allows the interface to migrate shoreward. Substantial pumping can allow the interface to move onshore, potentially impacting municipal wells, private wells, or agricultural wells. Figure 3 shows a 2D cross section of how the freshwater/seawater interface may migrate in response to pumping.

As can be inferred from Figure 3, the degree of interface migration depends on the amount of water pumped from a particular aquifer, as well as the amount of leakage from overlying or underlying aquifers. Groundwater extracted from the lowest aquifer might be replaced by rainfall recharge, by seawater migrating shoreward, or by groundwater leaking from the overlying aquifer.

An additional issue that must be considered with seawater interface migration is the initial location of the seawater interface. An interface that starts far from the shore may take a considerable amount of time, often on the order of decades, to reach any production or monitoring well. Furthermore, the farther the interface is from the pumping well, the more area is available for fresh water to leak from overlying aquifers into the producing aquifer. This slows, or may completely stop, seawater intrusion in the pumped aquifer. Downward leakage, however, removes fresh water from overlying aquifers. This leakage may therefore exacerbate seawater intrusion in the overlying aquifer.

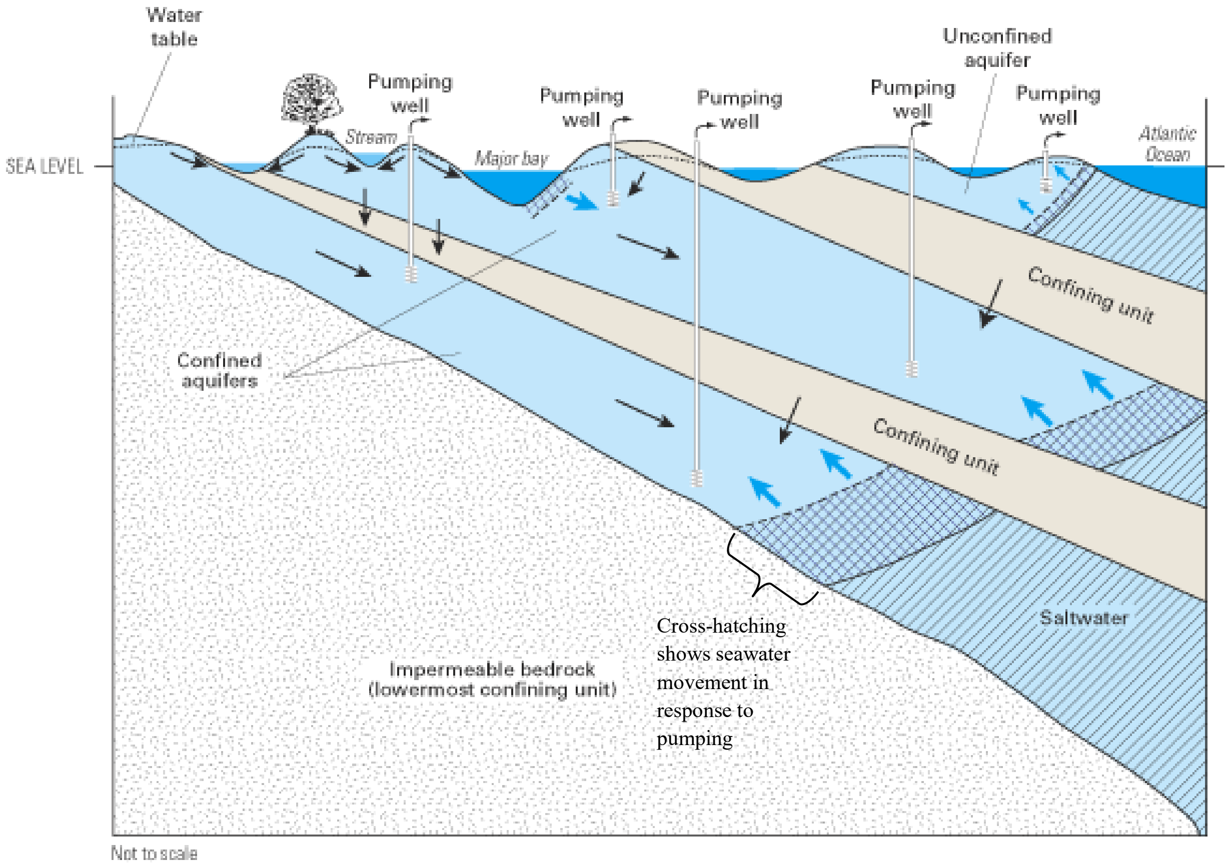

Figure 3. Interface Migration in Response to Groundwater Pumping (from Barlow, 2003)

1.3 Indicators of Seawater Intrusion

Seawater intrusion is generally identified through chemical analyses of groundwater. Groundwater levels below or near sea level indicate an opportunity for seawater intrusion, but the actual seawater intrusion is indicated by various geochemical changes in groundwater.

No single analysis definitively identifies seawater intrusion, however by looking at various analyses we can ascertain when fresh groundwater mixes with seawater. At low chloride concentrations, it is often difficult to identify incipient seawater intrusion. This is due to the natural variation in freshwater chemistry at chloride concentrations below 1,000 milligrams per liter (mg/L) (Richter and Kreitler, 1993). Mixing trends between groundwater and seawater are more easily defined when chloride concentrations exceed 1,000 mg/L

Common geochemical indicators of seawater intrusion are discussed and example analyses are presented in the following sections.

1.3.1 Cation/Anion Ratios

Molar ratios of cations and anions can prove distinctive for various groundwater systems. Seawater intrusion is often indicated by graphically analyzing shifts in these molar ratios. Two common graphical techniques for these analyses are Piper diagrams and Stiff diagrams.

1.3.1.1 Piper Diagrams

Example Piper diagrams are shown for data from the Pajaro Valley and Salinas Valley on Figure 4 and Figure 5, respectively. These figures are included to demonstrate the utility of Piper diagrams and show how they have been used in nearby basins. These figures are not provided for directly comparing data between basins; groundwater quality trends in basin will not necessarily correlate with trends in other basins.

On these Piper diagrams, the relative abundances of individual cations and anions are plotted in the left and right triangles, respectively, and their combined distribution is plotted in the central diamond. Waters from similar or related sources will generally plot together. The mixture of 2 waters will generally plot along a straight line between the 2 end-member types within the central diamond. The trend toward seawater intrusion, however, often plots along a curved path as shown on Figure 4. The red arrows track the evolution of water chemistry from freshwater to seawater. Often only the first, upward leg of this curve is observed, because wells become too saline to use before reaching the downward leg, and sampling is usually discontinued.

1.3.1.2 Stiff Diagrams

Example Stiff diagrams from the Salinas Valley are shown on Figure 6 and Figure 7. These figures are included to demonstrate the utility of Stiff diagrams and show how they have been used in nearby basins. On Stiff diagrams, the relative abundances of individual cations are plotted on the left side of the graph and the relative abundances of anions are plotted on the right side of the graph. Waters with similar chemistries will have similarly shaped Stiff diagrams.

Figure 6 shows Stiff diagrams characteristic of the unintruded portions of the Salinas Valley Pressure 400-Foot Aquifer. By contrast, Figure 7 shows Stiff diagrams from the intruded portion of the Salinas Valley Pressure 400-Foot Aquifer. The significantly higher chloride levels in the intruded aquifer result in the noticeable spike at the upper right side of the Stiff diagrams on Figure 7. This spike is indicative of incipient seawater intrusion.

The Stiff diagrams shown on Figure 7 are from wells that have acknowledged seawater intrusion based on multiple lines of evidence. The Stiff diagrams alone are often not sufficient to identify seawater intrusion because there is no standard for Stiff diagram shapes; the diagrams are most useful as a comparative tool, showing the evolution of water chemistry over time and space. The shape of these Stiff diagrams is considered indicative of seawater intrusion in Salinas Valley only because considerable data analyses have shown that locally, Stiff diagrams adopt this shape as seawater encroaches.

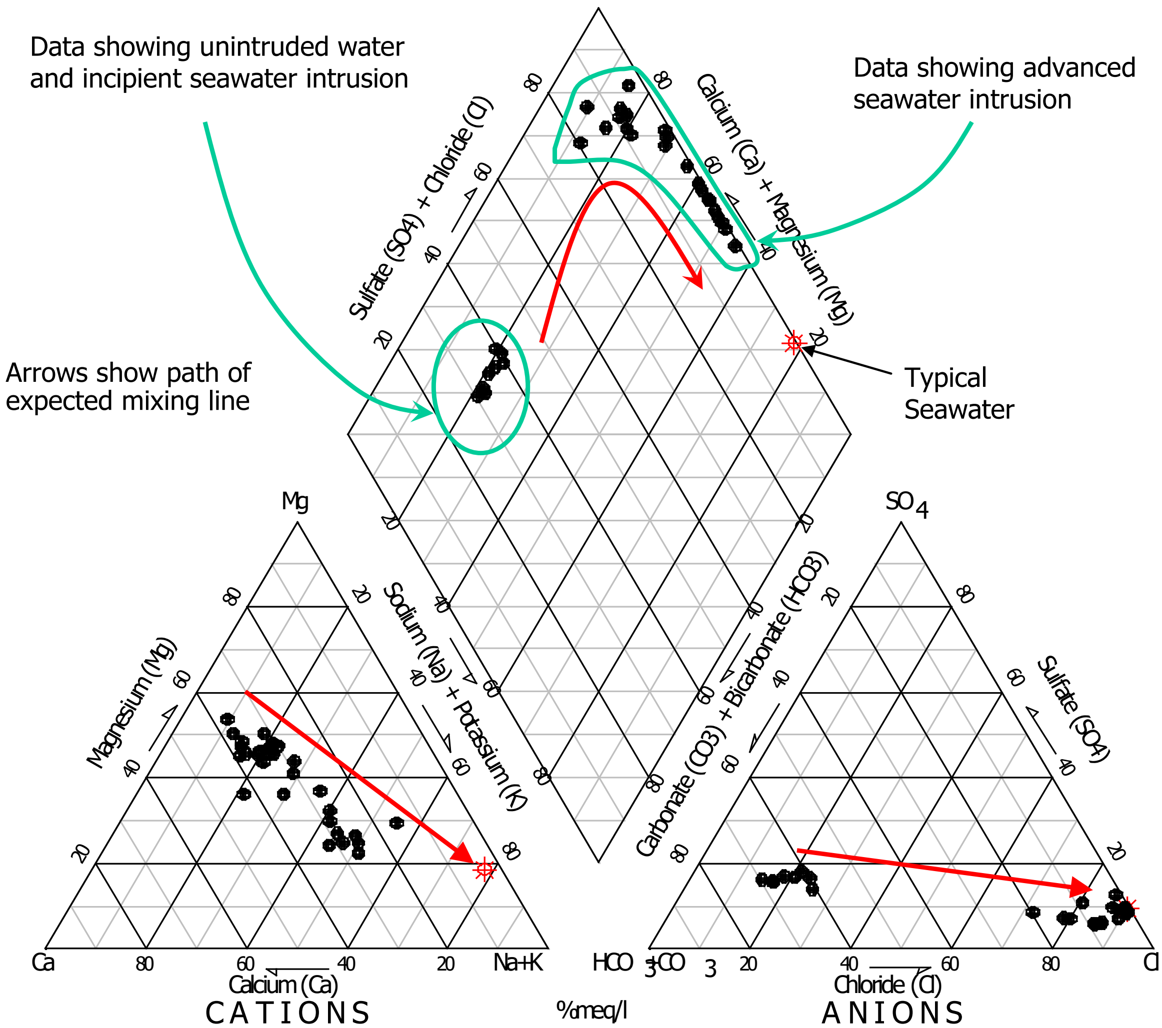

Figure 4. Piper Diagram for Groundwater in Pajaro Valley
(Data source: Pajaro Valley Water Management Agency [PVWMA])

The Stiff diagrams of seawater intruded wells on Figure 7 show calcium concentrations greater than sodium concentrations, although sodium is the dominant cation in seawater. Incipient seawater intrusion is often characterized by increasing calcium and decreasing sodium, due to cation exchange between sodium and calcium on the aquifer material. This concept is discussed further on page 15.

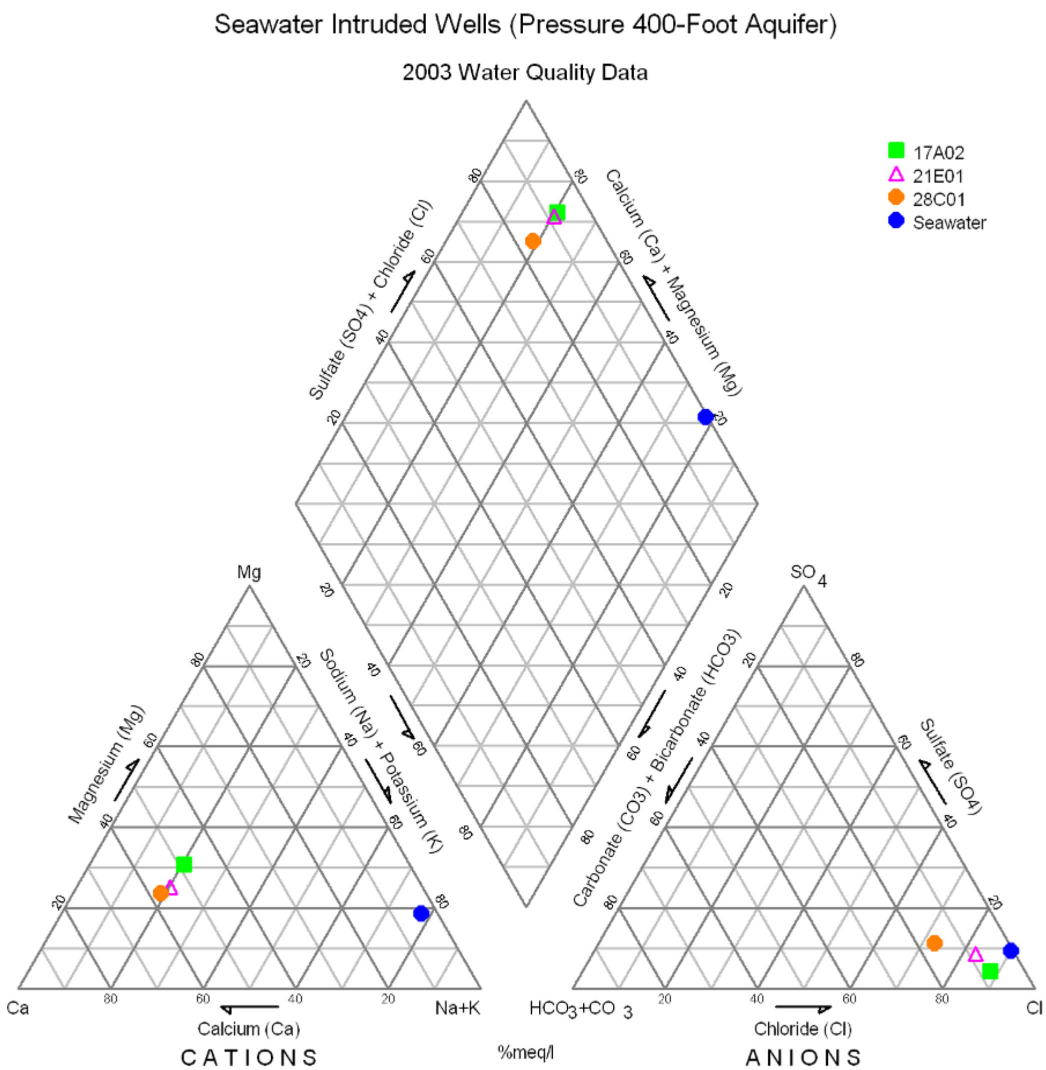

Figure 5. Piper Diagram for Groundwater in Salinas Valley
(Source: Monterey County Water Resources Agency [MCWRA])

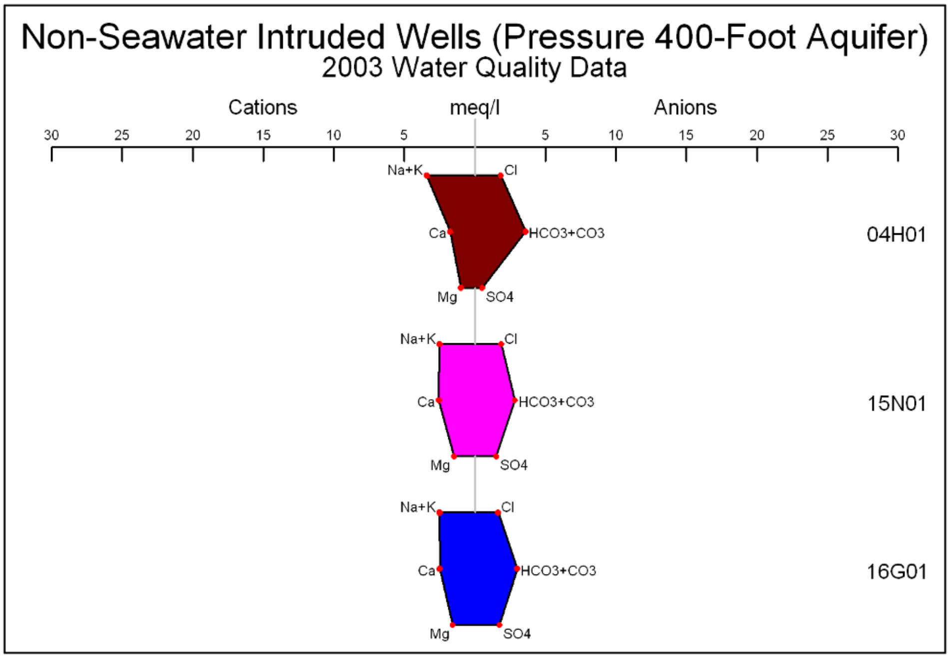

Figure 6. Stiff Diagrams from Salinas Valley Wells without Seawater Intrusion

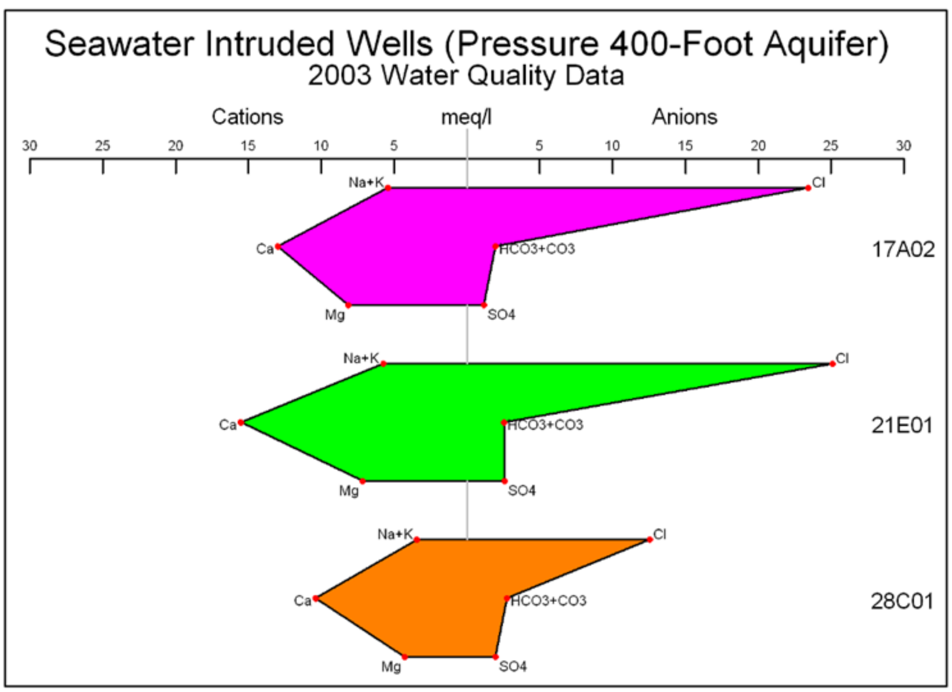

Figure 7. Stiff Diagrams from Salinas Valley Wells with Seawater Intrusion
(Source: MCWRA)

1.3.2 Increasing Chloride Concentrations

Seawater is chloride rich, whereas bicarbonate or sulfate are the dominant anions in many groundwater systems. Steadily increasing chloride concentrations over time is the one of the most commonly used indicators of seawater intrusion. At low chloride concentrations, trends are often as important as absolute concentrations because of natural variations in groundwater chemistry. As an example, in 2004 the coastal shallow Pacific Cement Aggregates (PCA) West well had a chloride concentration of 46 mg/L, whereas the much more inland well 2701882-016, located in the Laguna Seca subarea, had a chloride concentration of 225 mg/L. The higher chloride concentration in well 2701882-016 is fairly consistent, showing no increasing trend, and is clearly not an indicator of seawater intrusion.

Example graphs showing historical chloride concentration increases indicative of seawater intrusion are shown on Figure 8 and Figure 9. Figure 8 graphs steadily increasing chloride concentrations in a shallow well in the Salinas Valley. Figure 9 graphs increasing chloride concentrations in a well in the Pajaro Valley. Both of these graphs show that the rise in chlorides is a lengthy and persistent process; chloride concentrations began to increase in the representative Salinas Valley well in 1982, and took 6 years before exceeding the Safe Drinking Water Act secondary drinking water standard of 250 mg/L. This long-term and relatively slow increase in chlorides suggests that while chloride concentrations are strongly indicative of seawater intrusion, it often takes time for the increasing chloride trend to be recognizable.

1.3.3 Sodium/Chloride Molar Ratios

As mentioned earlier in this report, sodium often replaces calcium on the aquifer matrix through ion exchange in advance of the seawater front. This effectively removes sodium from the water and sodium/chloride ratios drop in advance of the seawater front. This can sometimes be used as an early indicator of seawater intrusion. Sodium/chloride ratios can also be used to differentiate between seawater intrusion and other sources of saltwater. Jones *et al*. (1999) suggest that sodium/chloride ratios in advance of a seawater intrusion front will be below 0.86 (molar ratio). This distinguishes seawater intrusion from domestic waste water, which typically has sodium/chloride ratios above 1.

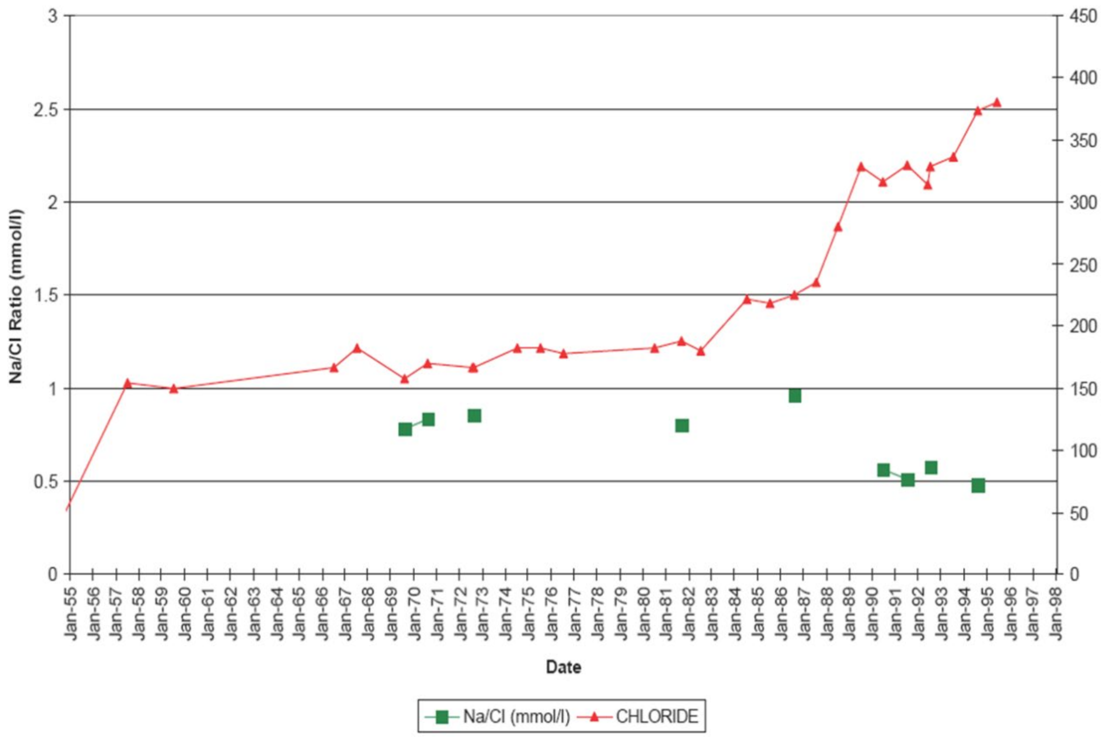

Figure 8. Historical Chloride Concentrations and Sodium/Chloride Ratios for a Well in Salinas Valley Showing Incipient Intrusion (Source: MCWRA)

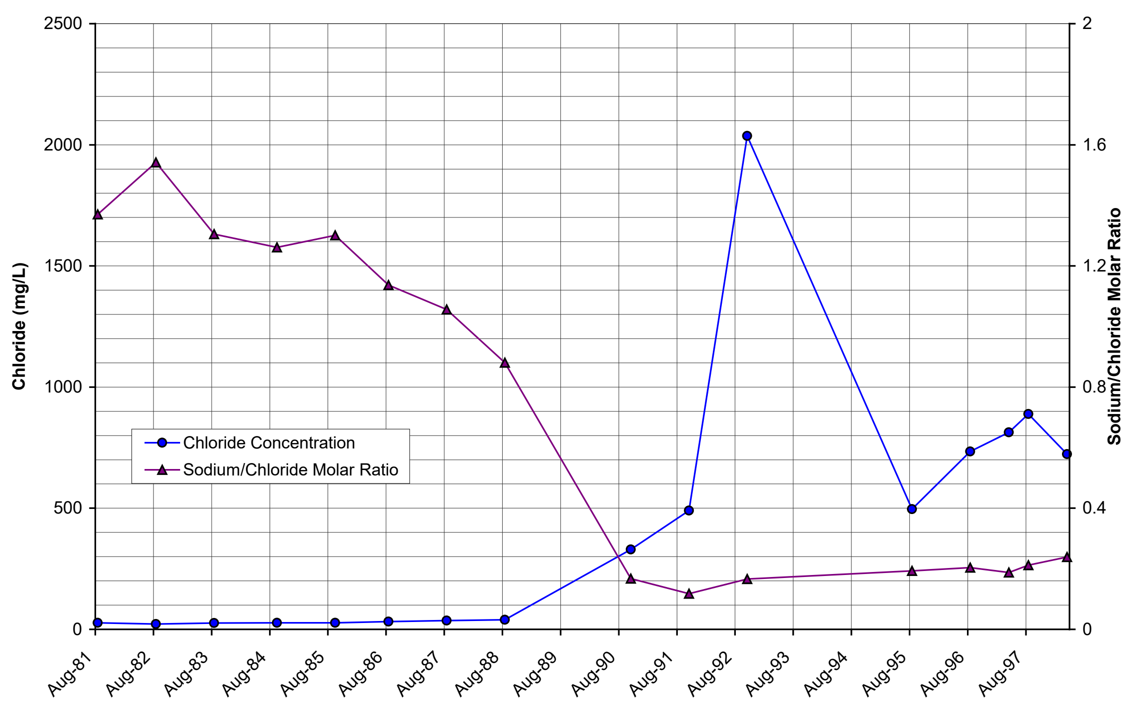

Figure 9. Historical Chloride Concentrations and Sodium/Chloride Ratios for a Well in Pajaro Valley Showing Incipient Intrusion (Data source: PVWMA)

In addition to plotting increasing chloride concentrations, decreasing sodium/chloride ratios are plotted on Figure 8 and Figure 9. The strong correlation between the 2 indicators of seawater intrusion can be observed on these 2 figures. The potential utility of sodium/chloride ratios as an early indicator of seawater intrusion is shown on Figure 9. This figure shows that by August 1988, chloride concentrations in the Pajaro Valley well had remained relatively constant yet sodium/chloride ratios were beginning to drop, suggesting incipient seawater intrusion. By September 1990, the rising chloride levels can be clearly correlated to dropping sodium/chloride ratios; definitively associating the high chlorides with seawater intrusion.

1.3.4 Chloride-Bicarbonate Ratios

The ratio of chloride to bicarbonate-plus-carbonate contrasts the relative abundance of the dominant seawater and freshwater anions. As a ratio of concentrations expressed in mg/L, the ratio for seawater exceeds 100 and values for groundwater unaffected by seawater are generally less than 0.3. For groundwater with relatively low total dissolved solids, this ratio provides little benefit over evaluating chloride concentrations alone and therefore is not used in the current analyses.

1.3.5 Electric Induction Logs

Changes in formation salinity can be measured from within a well using electric induction logging. Induction logging within the well measures the fluid conductivity within the adjacent formation up to a distance of 3 feet from the well casing. This technique can be used in wells that are completed with PVC casings and screens.

This method can be used as a cost-effective method of detecting seawater intrusion by measuring the electrical conductivity of the formation throughout the depth of the well. If over time, the conductivity increases relative to the baseline value, it could indicate seawater intrusion. One limitation of this method is that it does not provide concentrations of chloride or other ions that contribute to salinity. Therefore, the use of electric induction logs can only be used qualitatively.

Induction logging has been performed on the Watermaster's coastal Sentinel Wells since their completion in 2007.

1.3.6 Other Indicators

Hem (1989) suggested several other indicators for seawater intrusion, including the concentration ratio of calcium to magnesium (approximately 0.3 in seawater and greater in fresh water); the percentage of sulfate among all ions (approximately 8 percent in seawater and larger in fresh water); and the concentrations of minor constituents such as iodide, bromide, boron, and barium. These other indicators are not used in the current analyses for the following 2 reasons:

1. The analyses presented in the following sections overwhelmingly suggest that seawater intrusion has not advanced onshore in the Seaside Groundwater Basin.
2. No historical data exists for the minor constituents such as iodide and barium; and only limited historical data exist for bromide and boron. It should be noted that since 2012, the Watermaster has been analyzing samples from selected coastal monitoring and production wells for iodide, bromide, boron, and barium.

It is not necessary to use the above 2 indicators because as discussed in the preceding sections, there are other methods available for indicating seawater intrusion. Should the other methods start showing seawater intrusion, the minor constituents of iodide, bromide, boron, and/or barium will be included in future water quality analyses so that they can be used as supplemental indicators.

2 SEAWATER INTRUSION IN THE SEASIDE GROUNDWATER BASIN

The geochemical criteria discussed above, along with various maps showing spatial distributions of concentrations, can be used to estimate the presence or lack of seawater intrusion in the Seaside Groundwater Basin. While no single analysis is a definitive indicator of seawater intrusion, the combined weight of all analyses may be instrumental in detecting seawater intrusion.

2.1 Analysis Approach

As was used in previous Seawater Intrusion Analysis Reports (RBF, 2007; HydroMetrics LLC, 2008; HydroMetrics LLC, 2009a; HydroMetrics WRI, 2010; HydroMetrics WRI, 2011; HydroMetrics WRI, 2012a; HydroMetrics WRI, 2013a; HydroMetrics WRI, 2014; HydroMetrics WRI, 2015; HydroMetrics WRI, 2016b; HydroMetrics WRI, 2017b; Montgomery & Associates, 2018b; M&A, 2019; M&A, 2020; M&A, 2021), this SIAR includes multiple approaches to evaluate seawater intrusion. Results from all groundwater quality testing in Water Year (WY) 2022 are included in Appendix A.

Data for the second quarter of WY 2022 (sampled and measured January-March 2022) and fourth quarter of WY 2022 (sampled and measured July-September 2022) are analyzed and mapped to show the spatial distribution of groundwater quality and groundwater elevations. In addition to spatial mapping, historical data are graphed to assess geochemical trends. Data from the second quarter represent conditions during the wet time of the year; data from the fourth quarter represent conditions during the dry time of the year. In some cases when samples or measurements are not collected strictly within the second or fourth quarter, the quarter in which they were collected is provided with the data.

Where possible, analyses are separated by depth zone. Two depth zones have been chosen, following the system of Yates *et al*. (2005). Wells assigned to the shallow depth zone generally correlate to the Paso Robles Formation where it exists. This shallow zone is roughly at the same depth as the Salinas Valley Pressure 400-Foot Aquifer. Wells assigned to the deep zone correlate with the Santa Margarita Sandstone where it exists in the Seaside Groundwater Basin. The deep zone is roughly at the same depth as the Salinas Valley Pressure Deep Aquifers (900-foot and 1,500-foot Aquifers).

Analysis of current and historical precipitation is also included to help inform trends in groundwater elevations and production.

2.2 Cation/Anion Ratios

For the WY 2022 SIAR, 11 monitoring wells and 15 production wells were used for geochemical trend analyses. Locations of all monitoring and production wells used in the SIAR analysis are shown on Figure 10. Some of the production wells included in previous years' analysis are not included in this year's analysis because they were not pumped during the year and thus not sampled. Groundwater quality data are not collected in the Sentinel Wells for seawater intrusion analysis because in early 2017, it was concluded that groundwater samples collected using the low flow sampler were more representative of water within the well casing and not from the groundwater in the aquifer surrounding the well.

Eight monitoring wells used in this analysis represent 1 or both well pairs from the MPWMD monitoring well network and 1 is an observation well (Figure 10). A well pair comprises 2 wells drilled close to one another: 1 perforated in the Paso Robles aquifer (shallow zone) and the other perforated in the Santa Margarita aquifer (deep zone). Each well pair is represented with a unique color and symbol on Piper and Stiff diagrams.

Production wells included in the analysis are water purveyor wells that are sampled annually for general inorganic minerals per the Seaside Basin Monitoring and Management Program (Seaside Groundwater Basin Watermaster, 2006). The current schedule includes quarterly sampling at selected coastal monitoring wells. All other monitoring and production wells are sampled annually during the fourth quarter. Where samples are not available for analysis, the text and figures indicate as such.

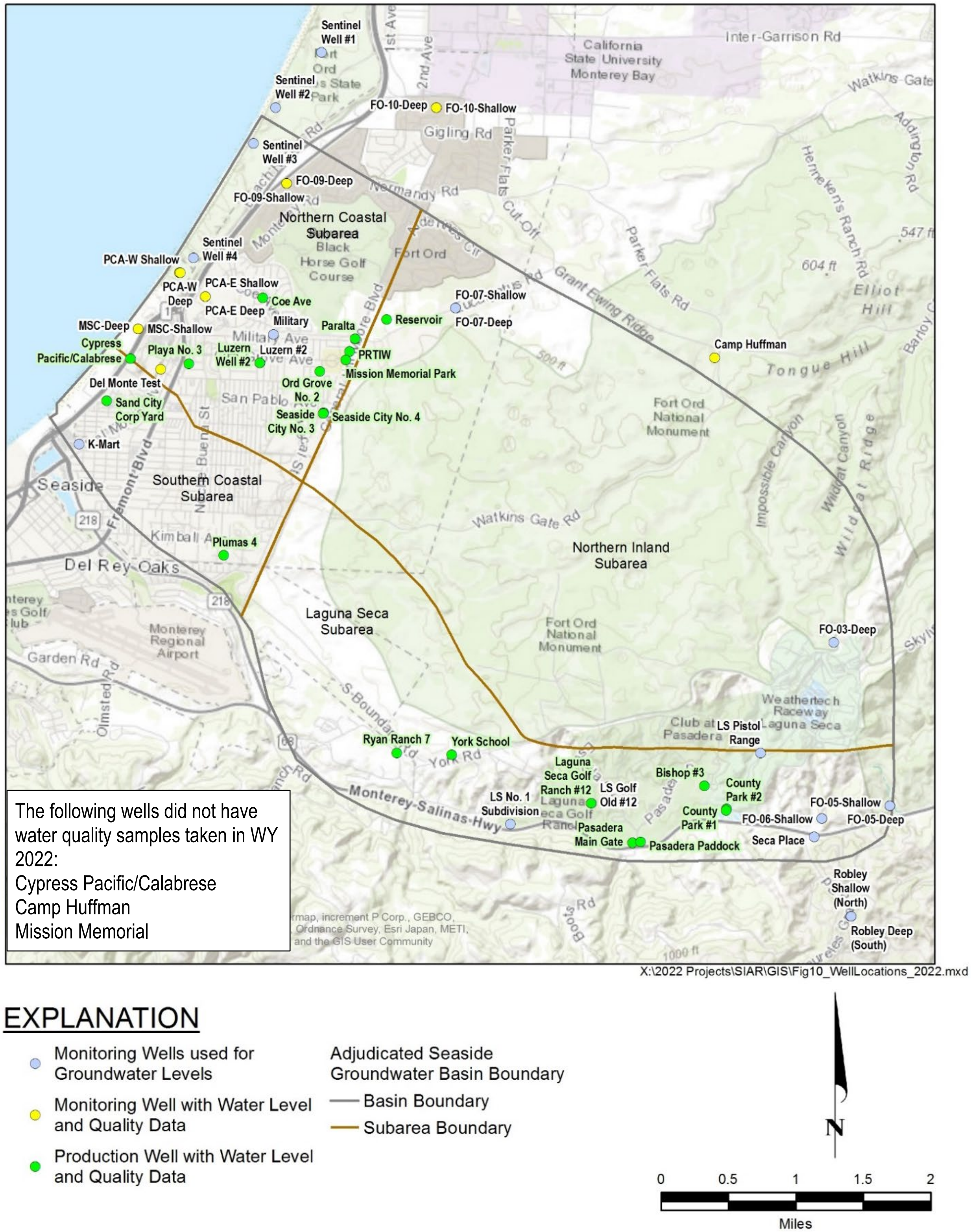

Figure 10. Wells Used for Seawater Intrusion Analyses Second Quarter Water Year 2022 (January-March 2022)

A Piper diagram displaying analyses from 6 monitoring wells in the Basin for the second quarter WY 2022 (January-March 2022) is shown on Figure 11. Analyses from only 6 wells are shown because the Sentinel Wells are only used for induction logging and are no longer sampled, and most of the monitoring well pairs are only sampled in the fourth quarter. Further, monitoring well FO-09 Shallow was destroyed last year due to a compromised casing. Appendix C includes individual Piper diagrams for each well to track their chemistry over time. Note that bicarbonate (HCO_3) presented on Piper and Stiff diagrams is derived from Total Alkalinity (as CaCO3).

The monitoring wells generally cluster in a single area on the Piper diagram that is consistent with previous data. The location on the Piper diagram indicates that groundwater from both the Santa Margarita (deep) and Paso Robles (shallow) well pairs straddle the sodium-chloride and sodium-bicarbonate type water[1].

As noted in the previous 2 SIARs (M&A, 2020; M&A, 2021) and shown on Figure 11, monitoring well FO-10 Shallow plots differently than the other wells on the Piper diagram and has exhibited a marked increase in chloride over the past 3 years, departing significantly from its historical trends (Appendix D: Figure D-9). This year FO-10 Deep also plots differently than other wells due to increased chloride (Appendix D: Figure D-10). Downhole logging at the FO-10 site and subsequent historical record search identified a 1,300 foot, 2-inch steel tremie pipe that has been stuck in the FO-10 borehole since the well's construction (Feeney, 2021; Feeney 2022). While comparison of WY 2021 resistivity at the well with a historical log does show increased conductivity in the well, which may be a sign of seawater intrusion, the presence of the steel pipe obfuscates water quality determinations by muting the induction log response. Further, this steel pipe may act as a conduit allowing flow between overlying intruded Dune Sands sediments and the underlying aquifer. In WY 2022, FO-10 Shallow and FO-10 Deep's anions and cations drifted further on the piper diagram, following the paths of intruded groundwater shown on Figure 4.

Stiff diagrams for the monitoring wells sampled during the second quarter of WY 2022 are shown in the left column on Figure 12 through Figure 14. None of the Stiff diagrams, including monitoring well FO-10 Shallow and FO-10 Deep, show the high chloride spike shown on Figure 7 that indicates seawater intrusion. FO-10 Shallow and FO-10 Deep do show a slightly different shape than other shallow wells because of their increased chloride. As described above, the exact mechanism behind the evolving shape of these wells on the stiff diagrams is not currently known, and it is recommended that the well nest is destroyed and replaced.

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[1] Where the data points fall in the Piper diagram triangle for anions and the triangle for cations determines the type of water. For example, if the points plot in the lower right corner of the anion triangle, the water is classed as chloride type water.

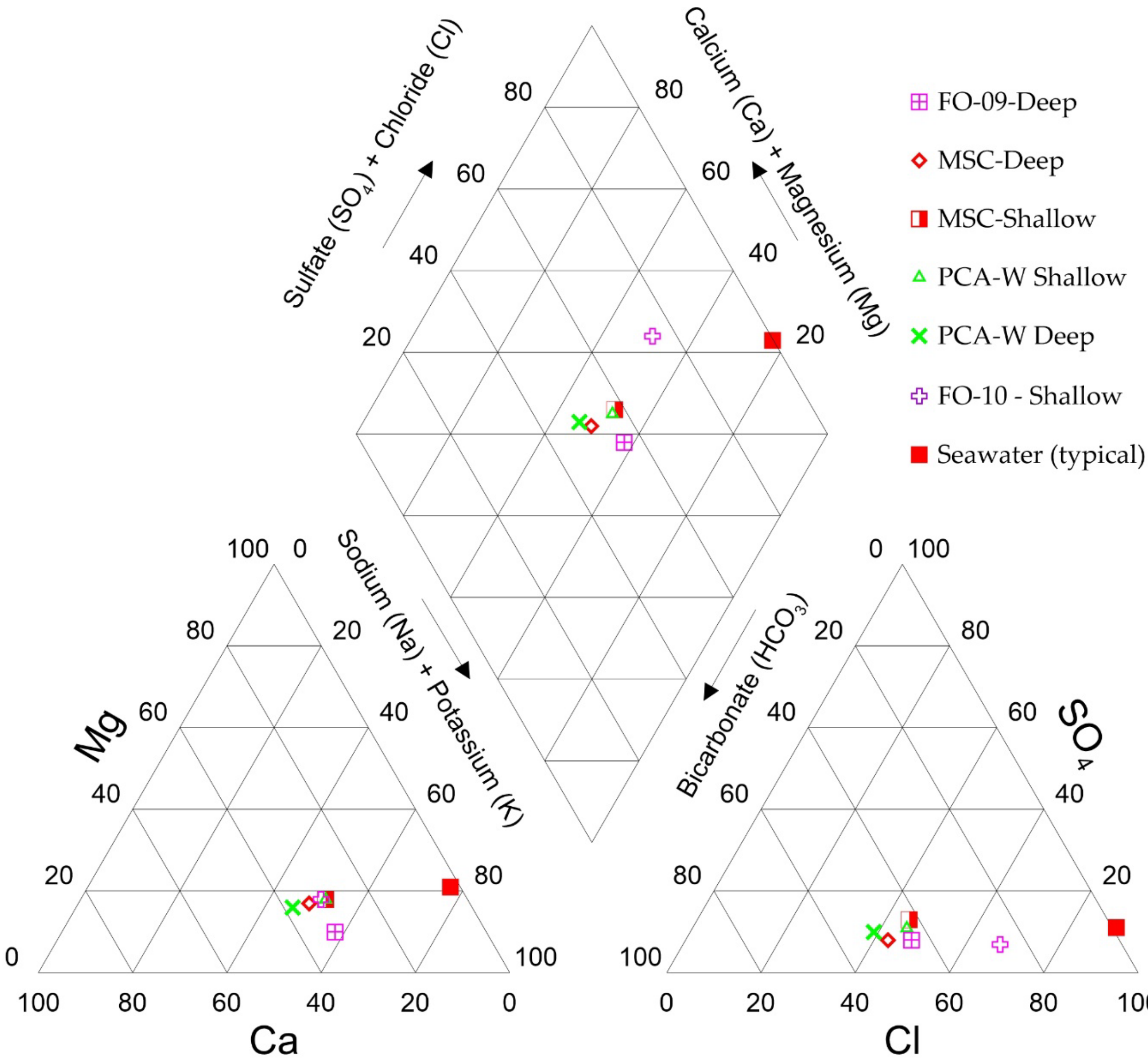


Figure 11. Piper Diagram for Seaside Groundwater Basin Monitoring Wells,
2nd Quarter Water Year 2022 (January-March 2022)
(Data source: Watermaster)

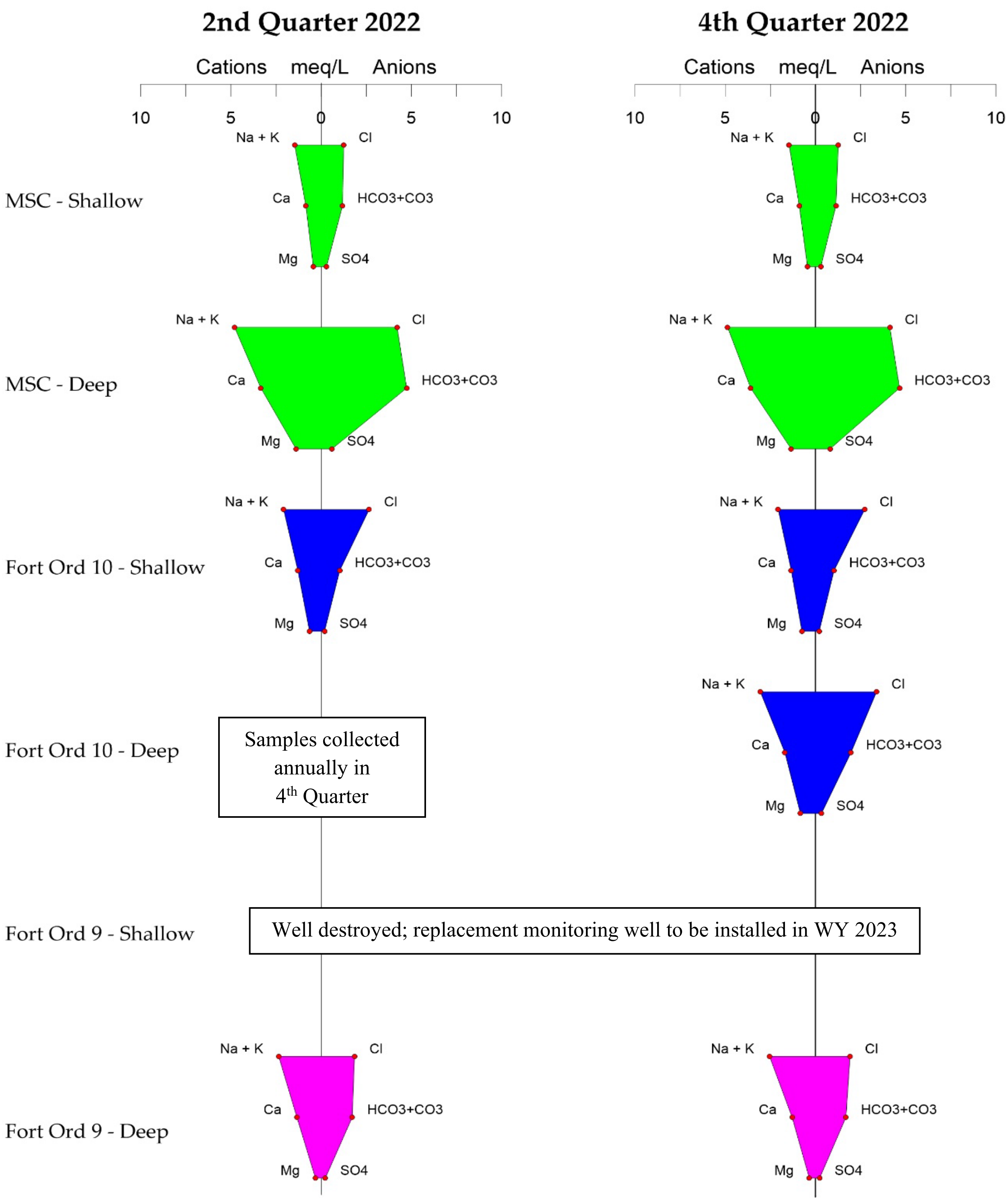


Figure 12. Stiff Diagrams for Monterey Sand Company (MSC), Fort Ord 9, and Fort Ord 10 Wells
(Data source: Watermaster)

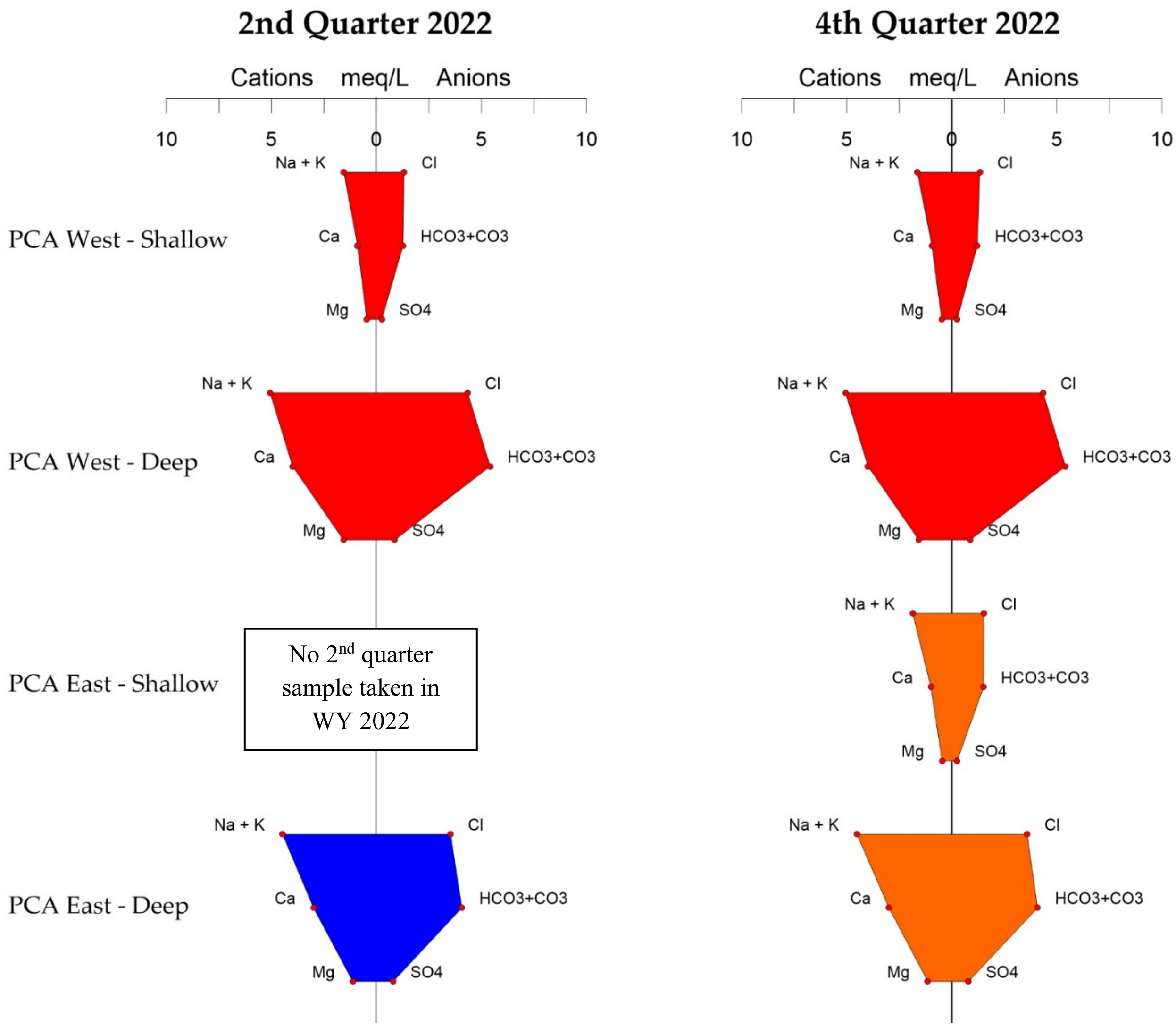


Figure 13. Stiff Diagrams for PCA West and PCA East Wells
(Data source: Watermaster)

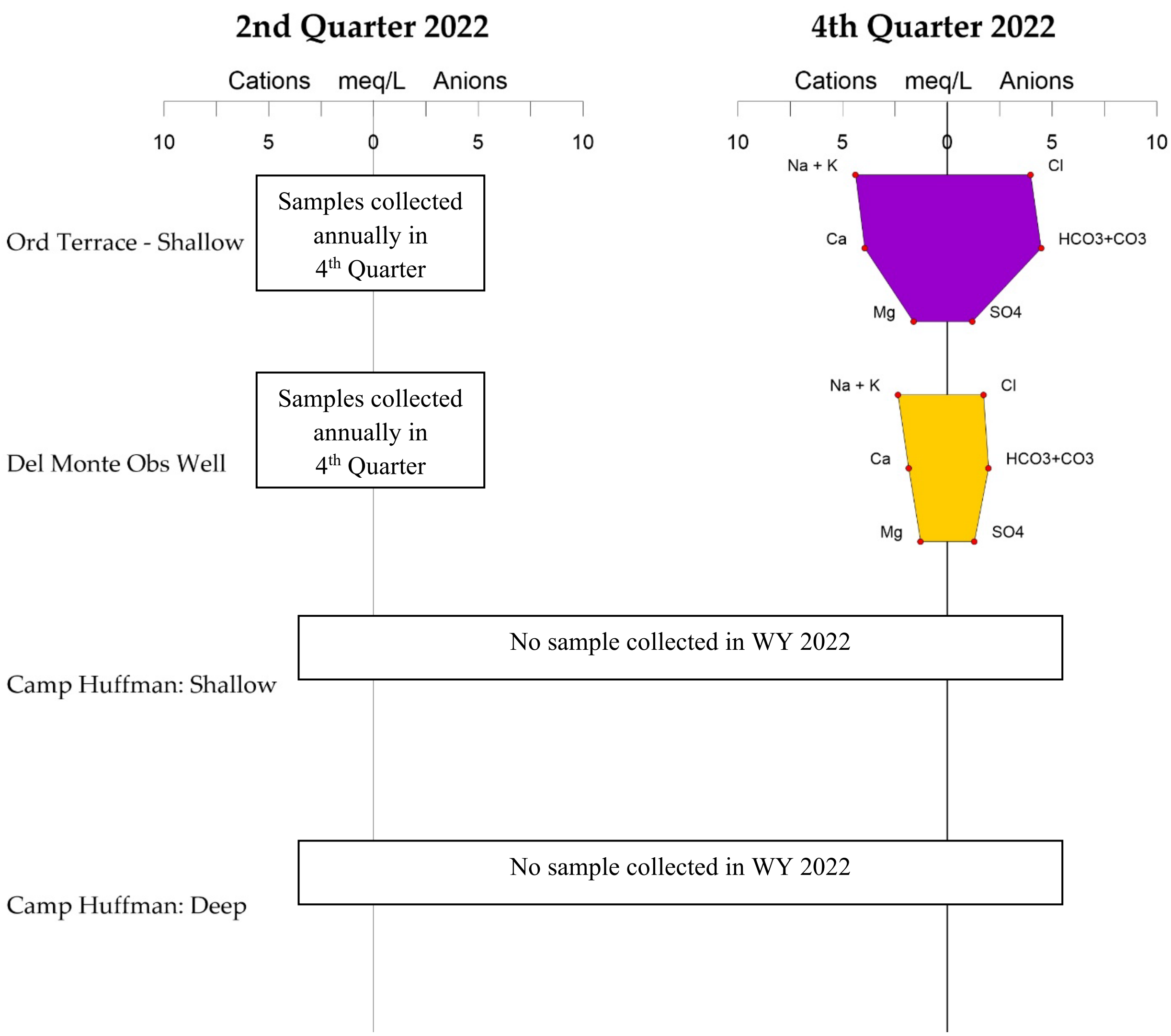


Figure 14. Stiff Diagrams for Watermaster Ord Terrace, Del Monte, and Camp Huffman Wells
(Data source: Watermaster and MPWMD)

2.2.1 Fourth Quarter Water Year 2022 (July-September 2022)

Piper diagrams displaying groundwater quality data from 11 monitoring wells and 14 production wells in the Seaside Groundwater Basin for the fourth quarter of WY 2022 (July-September 2021) are shown on Figure 15 and Figure 16, respectively. Appendix C includes individual Piper diagrams for each well to show trends over time.

The Piper diagram for monitoring wells (Figure 15) shows groundwater quality data clustering generally in a single area on the diagram. Groundwater is generally of a sodium-chloride/sodium-bicarbonate type and is not impacted by seawater. Monitoring well FO-10 Shallow and FO-10 Deep plot differently on both Piper (Figure 15) and Stiff (Figure 12) diagrams due to higher chloride than most other wells. As described above, current analysis is still inconclusive as to whether this is a result of seawater intrusion.

Figure 16 presents a Piper diagram for fourth quarter groundwater from production wells. The production wells plot in roughly the same location on the Piper diagram as most monitoring wells on Figure 15. The variation of the plot location on the Piper diagram for production wells is due to higher sulfate and chloride anions than in the monitoring wells. Groundwater from these wells is characterized as sodium-sulfate-chloride type waters. The York School well plots closest to typical seawater on this diagram, however its inland location precludes seawater intrusion as the cause for its observed water chemistry. Overall, the Piper diagram shows no indication of seawater intrusion at any of the production wells.

Stiff diagrams for 11 monitoring wells sampled during the fourth quarter of WY 2022 are shown in the right column on Figure 12 through Figure 14. The shapes of the Stiff diagrams for the paired monitoring wells are similar to the shapes of the Stiff diagrams for most prior years, with the exception of FO-10 Shallow and FO-10 Deep which have greater chloride equivalent concentration than HCO_3 compared to other shallow coastal wells.

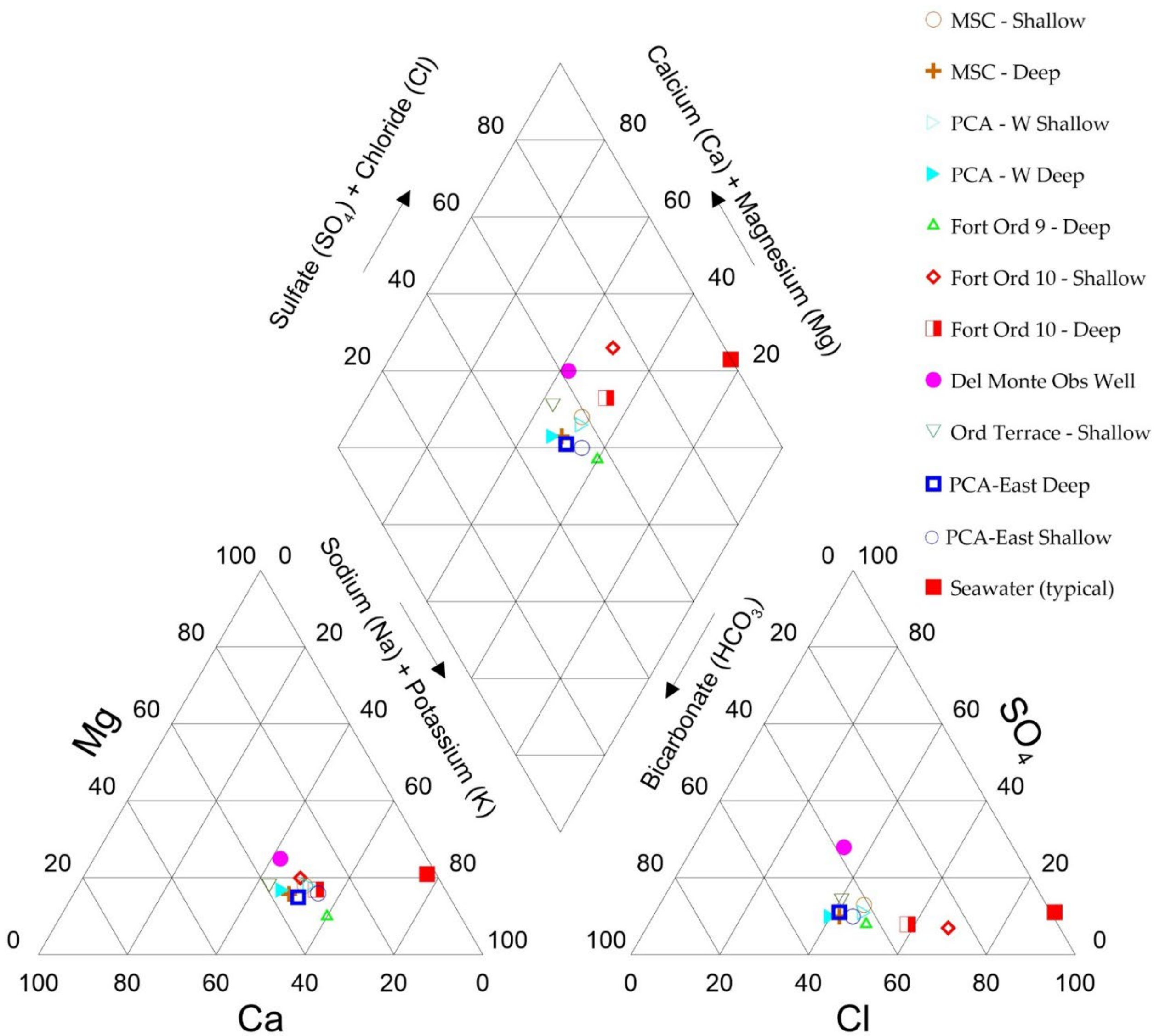


Figure 15. Piper Diagram for Seaside Groundwater Basin Monitoring Wells,
4th Quarter Water Year 2021 (July- September 2021)
(Data source: Watermaster)

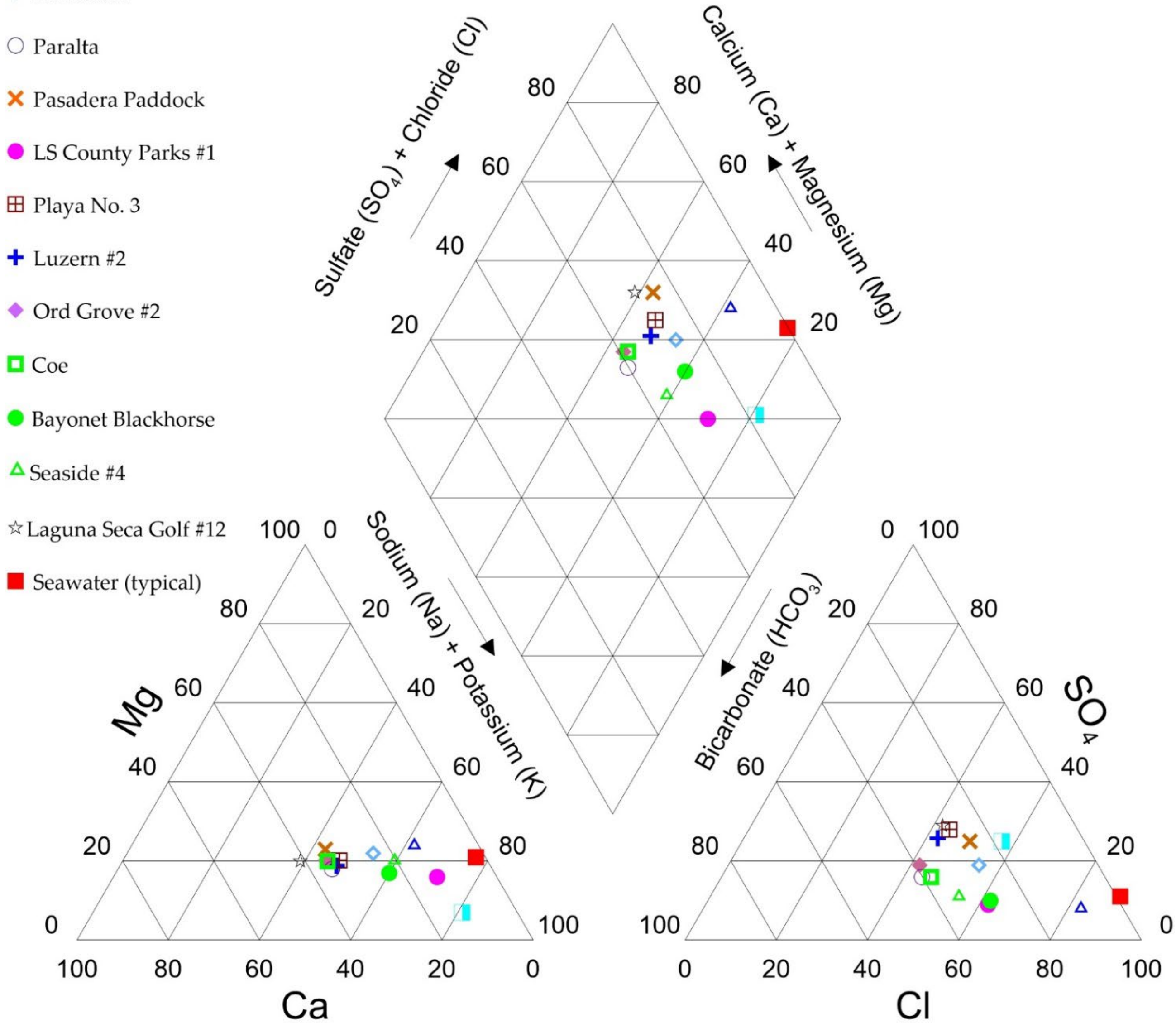


Figure 16. Piper Diagram for Seaside Groundwater Basin Production Wells, 4th Quarter Water Year 2021 (July-September 2021)
(Data source: Watermaster)

Stiff diagrams for 13 of the production wells sampled during the fourth quarter of WY 2022 are shown on Figure 17 through Figure 20. Production well Stiff diagrams show no significant changes from the shapes observed in previous years. Groundwater quality data for many of these wells was not available in WY 2022 at the time of this report. Ryan Ranch #7, #8, and #11 production wells were destroyed in 2021 and therefore groundwater quality data are no longer available for these wells. The Pasadera Paddock and LS Golf #12 production wells have a Stiff diagram shape that are slightly different from the other wells' chemistry. The cause of this could be localized mineralization. The Laguna Seca subarea is known to have higher salinity groundwater than the rest of the basin due to the underlying Monterey shale that was deposited in a marine environment. None of the Stiff diagrams for production wells near the coast show the high chloride spike shown on Figure 7 that indicates seawater intrusion.

The Sand City's Public Works Corp Yard production well in the Southern Coastal subarea and the York School production well in the Laguna Seca subarea typically have Stiff diagrams quite different from most other wells' groundwater quality. However, they do not have a large chloride spike associated with seawater intrusion as shown on Figure 7. None of the production wells sampled in WY 2022 and analyzed using Stiff and Piper diagrams show an indication of seawater intrusion.

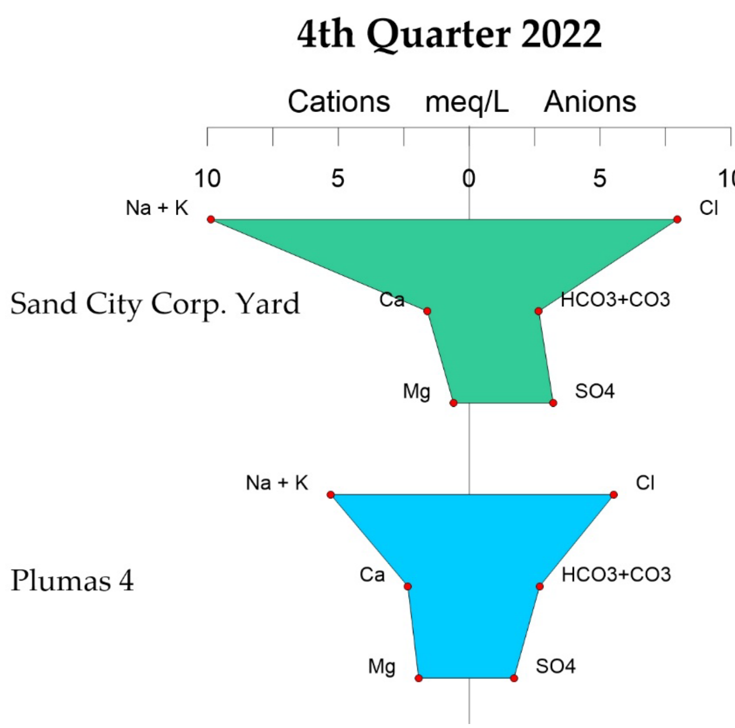


Figure 17. Stiff Diagrams for Southern Coastal Subarea Production Wells
(Data source: Watermaster)

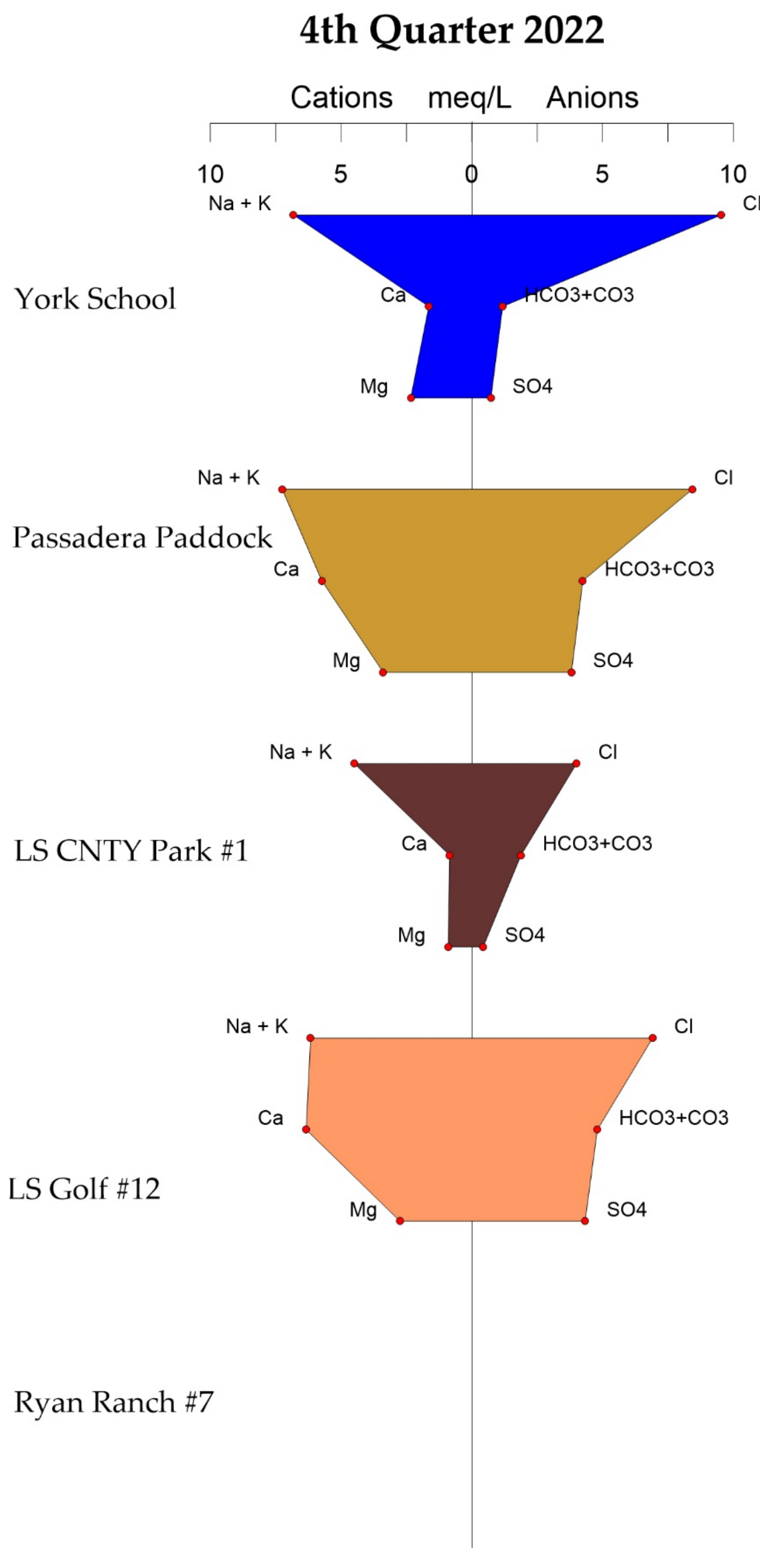


Figure 18. Stiff Diagrams for Laguna Seca Subarea Production Wells
(Data source: Watermaster)

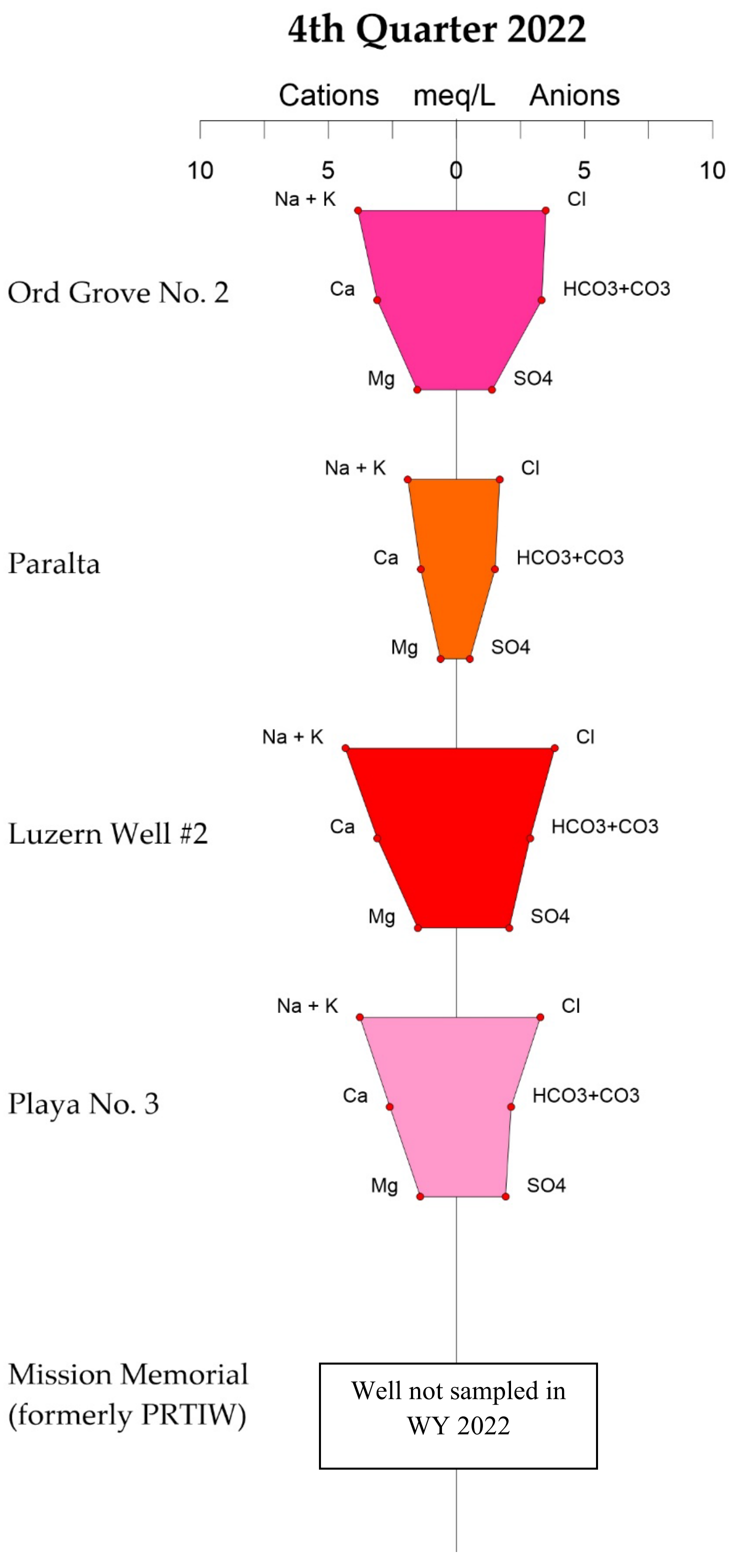


Figure 19. Stiff Diagrams for Northern Coastal Subarea CAWC and Mission Memorial Production Wells (Data source: Watermaster)

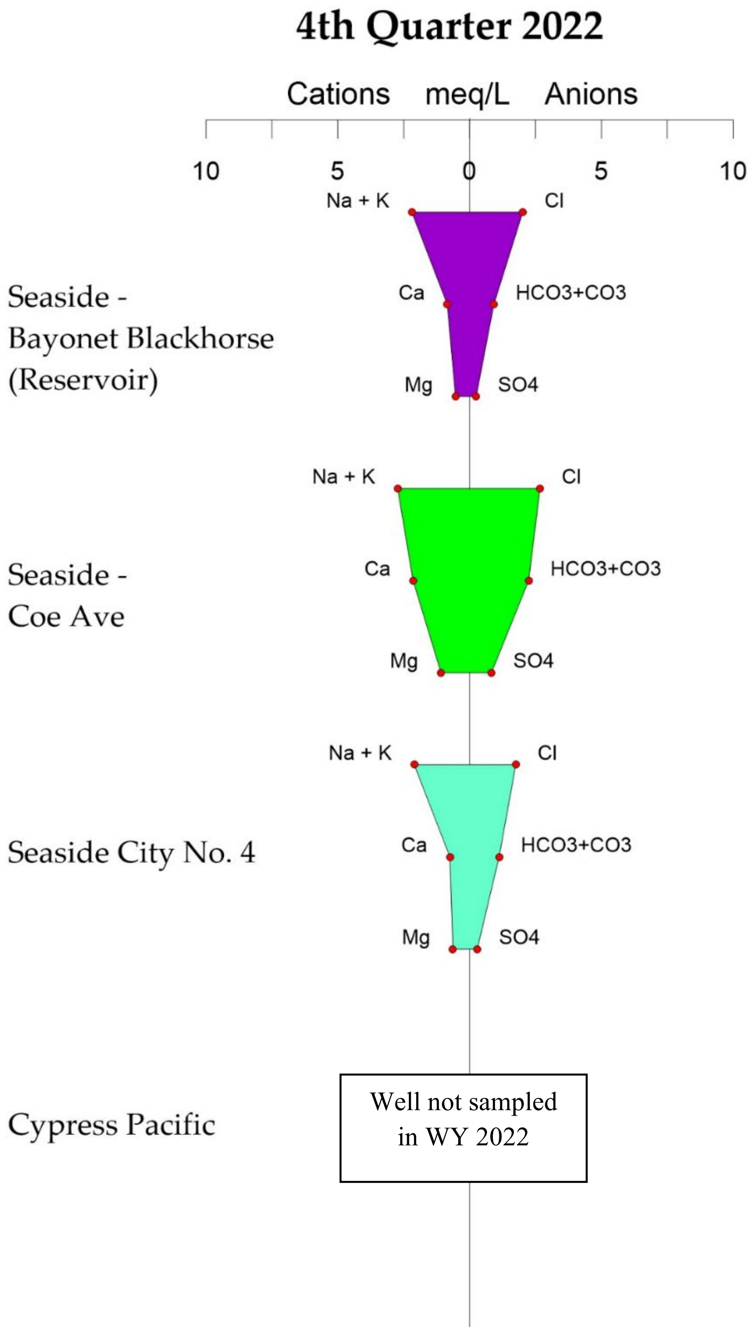


Figure 20. Stiff Diagrams for Northern Coastal Subarea City of Seaside and Cypress Pacific Wells
(Data source: Watermaster)

2.3 Chloride Concentrations

2.3.1 Trends

Chemographs showing chloride concentrations over time are plotted for each of the monitoring wells shown on the Piper and Stiff diagrams. An example plot displaying chloride concentrations for the shallow PCA-West Shallow monitoring well is shown on Figure 21. A complete set of chemographs is included in Appendix D. Chloride trends for most monitoring wells remain stable or fluctuate within a historical range.

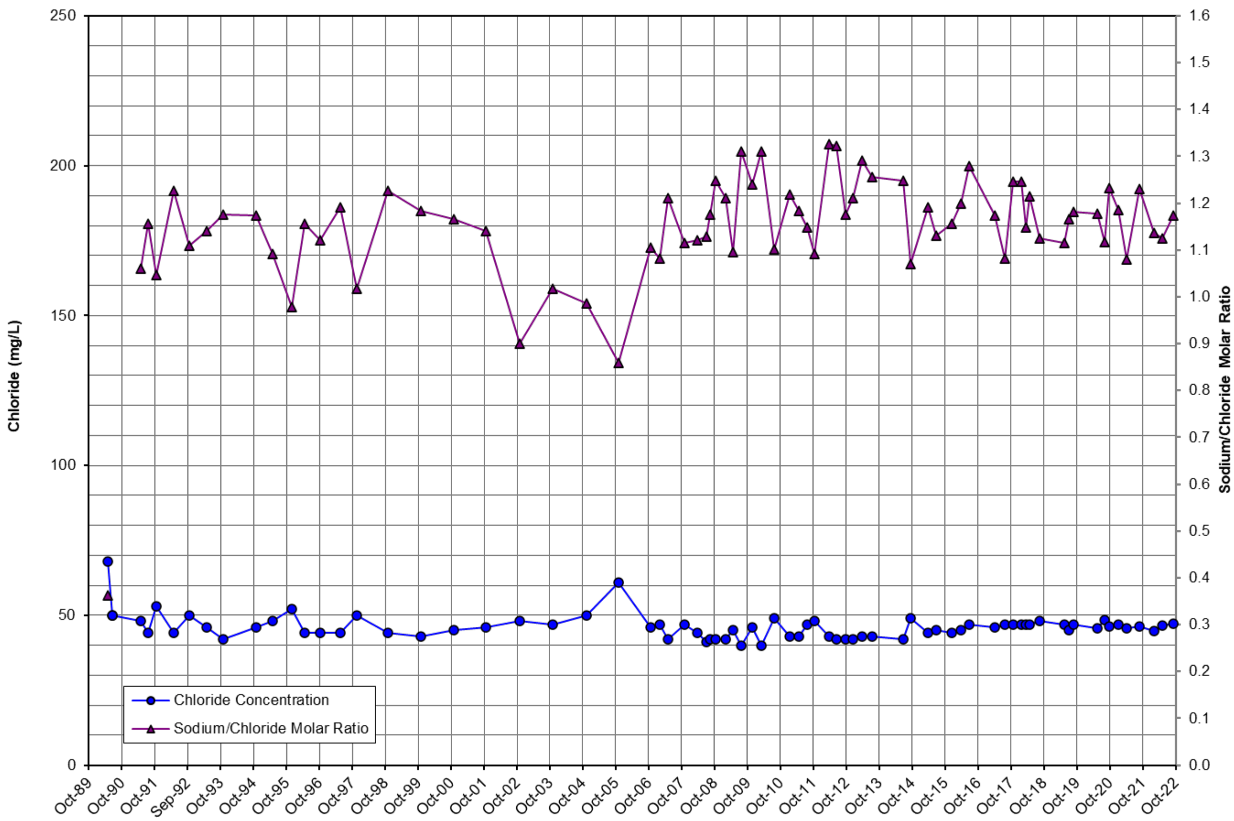


Figure 21. Historical Chloride and Sodium/Chloride Molar Ratios, PCA West Shallow

FO-10 Shallow has experienced increasing chloride concentrations since WY 2020 (Figure 22). Concentrations above 90 mg/L are more frequent than those less than 90 mg/L, with the most recent chloride concentration in September 2022 being 96.6 mg/L. Induction logging of FO-10 Shallow in 2021 were inconclusive regarding the presence of seawater intrusion in the well and were complicated by discovery of a 1,300-foot steel pipe that has been stuck in the borehole since the well's construction. As the presence of this steel pipe clouds interpretation of water quality results and may act as a conduit for groundwater in overlying sediments to enter underlying aquifers, it is recommended that both FO-10 Shallow and FO-10 Deep are destroyed and replaced to maintain a consistent water quality record in the area.

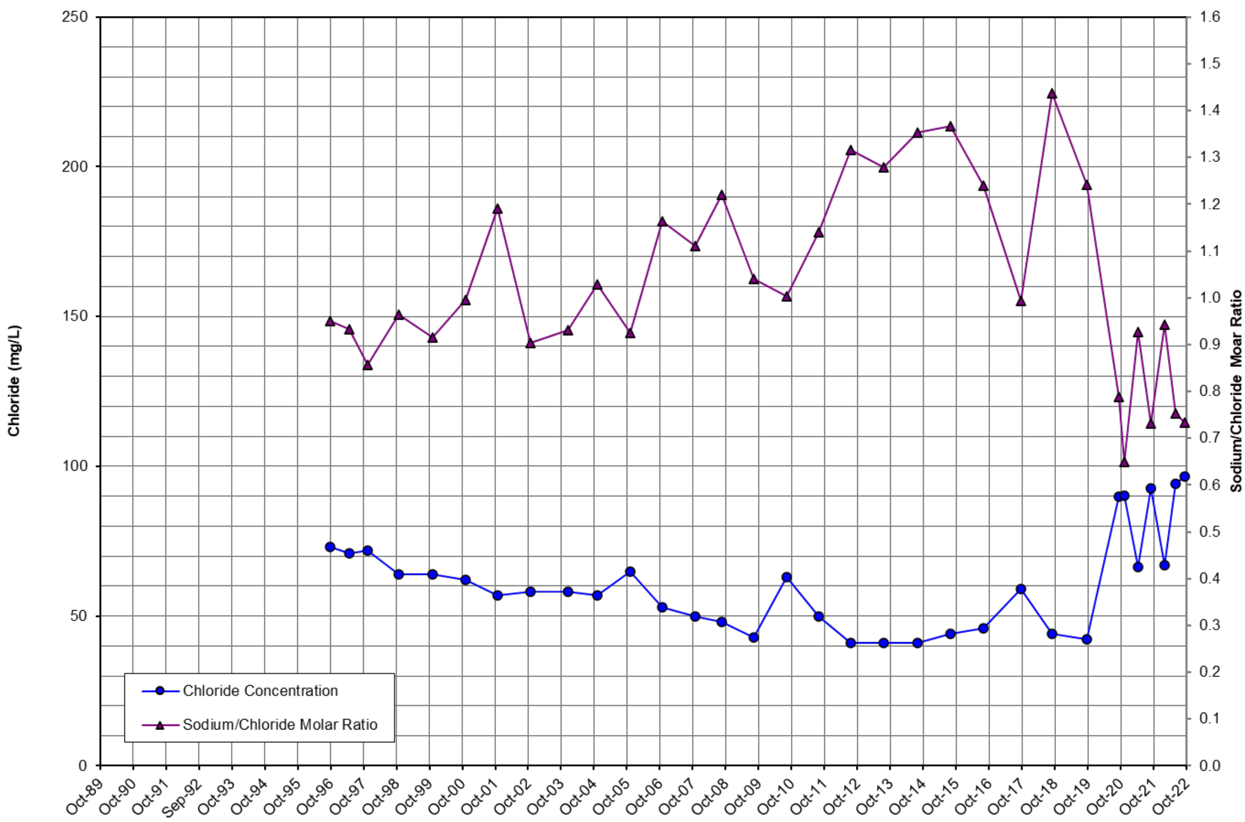


Figure 22. Historical Chloride and Sodium/Chloride Molar Ratios, FO-10 Shallow

In WY 2021, FO-09 Shallow was destroyed due to its damaged casing and is to be replaced in 2023. This monitoring wells had increasing chloride concentrations believed to have been caused by a cracked casing that introduced shallower high chloride water into the well.

2.3.2 Chloride Concentration Maps

2.3.2.1 Fourth Quarter Water Year 2022 (July-September 2022)

Fourth quarter WY 2022 chloride concentrations are mapped using data from August and September 2022. The maps for the Paso Robles (shallow) and Santa Margarita (deep) aquifer zones are included on Figure 23 and Figure 24 respectively.

The Santa Margarita aquifer fourth quarter WY 2022 chloride concentration map is shown on Figure 23. Chloride data from Santa Margarita aquifer wells are posted on this map but do not show a spatial distribution that can be readily contoured because of differences in concentrations in wells near each other. Except for FO-10 Shallow, Santa Margarita aquifer chloride concentrations have not varied much from previous water years. FO-10 Shallow is located 0.7 miles north of the Basin, just over 1 mile inland of the coast. Chloride concentrations in the well increased 29.6 mg/L from February to September 2022. September's concentration of 96.6 mg/l reflects a continuous and sustained increase from previous years. As shown on Figure 22, chloride concentrations at this well jumped about 48 mg/L between September 2019 (42.2) and September 2020 (89.9), and continued increasing through August 2021 (92.8) and September 2022 (96.6).

Chloride concentrations in the Santa Margarita aquifer of the coastal northern portion of the Northern Coastal subarea are roughly 70 mg/L. Just north of the Basin, because of FO-10 Shallow, chloride concentrations are around 90-97 mg/L. The more inland Northern Coastal subarea wells have slightly higher chloride concentrations that may be due to depositional mineralization differences in the Paso Robles Formation. Within the Monterey Subbasin, north of Seaside, chloride concentrations increase in a northward direction toward the currently understood extent of seawater intrusion (see Monterey Subbasin GSP Figure 5-29).

Sand City's Public Works Corp Yard well in the Southern Coastal subarea has historically had the highest chloride concentration of all shallow coastal wells (Appendix D, Figure D-13). The Piper and Stiff diagrams and sodium/chloride molar ratio for the well suggest the source of high chloride is not seawater.

The Santa Margarita aquifer fourth quarter WY 2022 chloride concentration map is shown on Figure 24. Chloride concentrations for the Sentinel Wells are not shown on this map because it was found that groundwater samples collected from them are not representative of the aquifer. Santa Margarita aquifer chloride concentrations near the coast range roughly between 65 mg/L and 160 mg/L and are similar to last year. In WY 2021, the Ord Grove #2 production well experienced a 14 mg/L increase in chloride from last year to 134 mg/L, but that decreased in WY 2022 back down to 124 mg/L. These concentrations are generally within the 120-130 mg/L range of historical fluctuations. Since the chloride data show no discernible spatial distribution, with high concentrations close to low concentrations, the data cannot be readily contoured.

Chloride concentrations at both the Pasadera Golf- Paddock and the Ord Terrace Shallow wells increased over 20 mg/L from the previous measured year (Figure 24). The WY 2022 concentrations are the highest measured at Pasadera Golf – Paddock, and the second highest at Ord-Terrace Shallow. Due to its inland location, the increase at the Pasadera Golf-Paddock well is not related to seawater intrusion. Likewise, the Ord Terrace Shallow concentration of

141 mg/L remains within its historical range between 100 and 155 mg/L and is not likely to reflect seawater intrusion. Chloride concentrations at FO-10 Deep increased 56 mg/L from the previous year. As described earlier, the mechanism for this increase is not currently known.

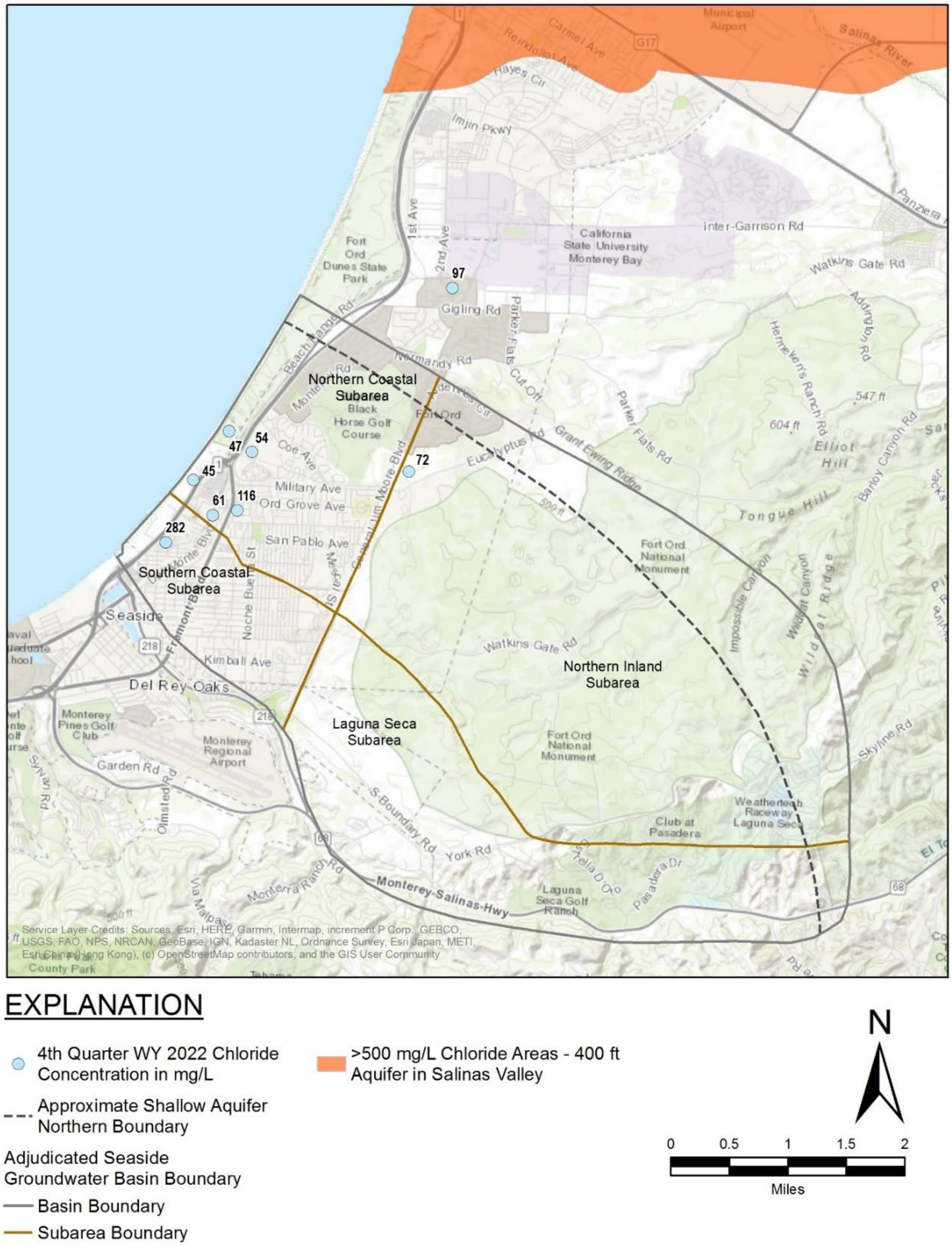


Figure 23. Paso Robles Aquifer (Shallow Zone) Chloride Concentration Map – 4th Quarter Water Year 2022

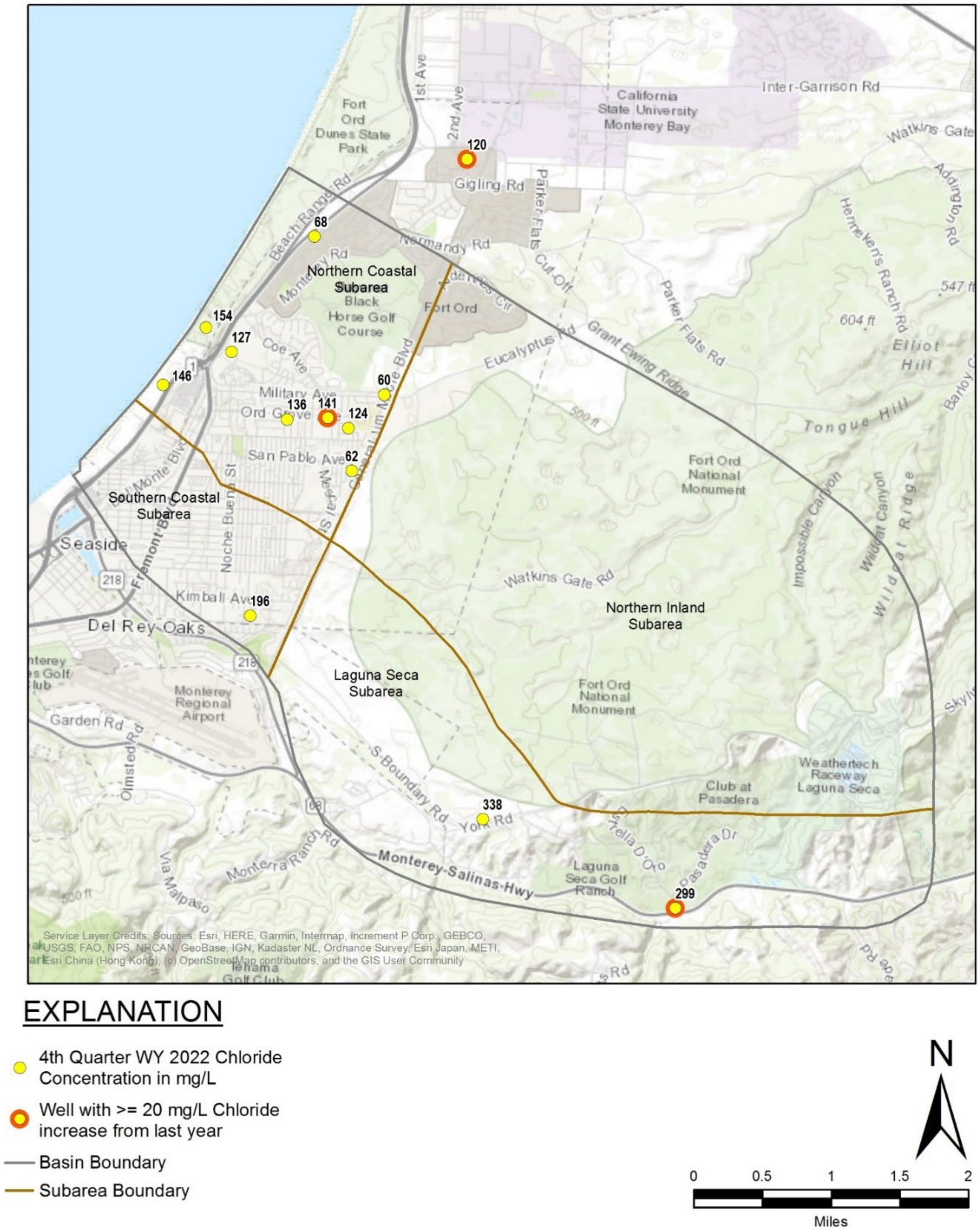


Figure 24. Santa Margarita Aquifer (Deep Zone) Chloride Concentration Map – 4th Quarter Water Year 2022

2.4 Sodium/Chloride Molar Ratios

Chemographs showing long-term sodium/chloride molar ratios over time are plotted for all 12 monitoring wells and 1 production well. Also included are historical chemographs for monitoring wells not sampled in WY 2022. An example plot displaying sodium/chloride molar ratios for the shallow PCA West well is shown on Figure 21. A complete set of chemographs is included in Appendix D.

Most of the sodium/chloride molar ratios in the monitoring wells remained constant or increased over the past year. Five of the last 7 samples from FO-10 Shallow have sodium/chloride molar ratios less than 0.86 (Appendix D: Figure D-9). Sodium/chloride ratios below 0.86 are significant because Jones *et al*. (1999) suggest that sodium/chloride ratios in advance of a seawater intrusion front will be below 0.86. The increasing chloride trend and decreasing sodium/chloride molar ratio indicate that FO-10 Shallow may be showing signs of incipient seawater intrusion. As described above, analysis of ongoing seawater intrusion at this well is complicated by the discovery of a steel pipe in the well's borehole. It is recommended that the FO-10 Deep and Shallow wells are destroyed and replaced to maintain a robust water quality record in the area.

2.5 Electric Induction Logs

Two induction logging events took place in the 4 Sentinel Wells for WY 2022. Due to inaccessibility, Sentinel Well 3 was not logged during the second event. Note that October 2022 logging technically occurred in WY 2023 but is used for this year's WY 2022 SIAR. Pacific Surveys conducted the logging as they have done since August 2014. The first logging event in WY 2022 took place in March 2022, and the second in October 2022.

Three different induction tools have been used during the project history, and while different tools show responses that are different in terms of absolute values, each tool has had internally consistent "same-tool" responses. The current induction tool (Tool 3 LIM) displays repeatable responses and is consistent with the other 2 induction tools used historically on site (Feeney (2020). Moving forward, all data presentations will be referenced to the current tool, as was done in 2014 when the tool change previously occurred.

Feeney (2007) described the original 2007 baseline induction logs for each of the wells as follows:

> *SBWM-1 — The upper 50 feet of this well shows very high conductivities. This signature is present in all of the wells and is the result of the 50-foot steel conductor casing. However, because the water table is below the conductor casing at all locations, the steel casing does not interfere with data collection within the saturated sediments below.*

Below the conductor casing in SBWM-1, the sediment materials are dry to a depth of approximately 115 feet. Below this depth, there is approximately 10 feet of sand containing fresh water. Below 125 feet and extending to approximately 350 – 400 feet is sand containing saline water with conductivities measuring as high as 10,000 mhos/cm. This saline water is contained within the Dune /Beach Sand Deposits and the Aromas Sand. Below this depth, conductivities are relatively low with the exception of the thick marine clay between approximately 600 -700 feet. The other conductive zones also correlate with clay zones.

SBWM-2 — As in SBWM-1 there is a thin layer of fresh water overlying a zone of saline water to approximately 130 feet within the Beach/Dune Sands and Aromas Sand. Below this depth, the materials become increasingly clayey, complicating the interpretation. Below this depth, there are no obvious zones of anomalous conductivity; that is, the zones that are more conductive correlate with clay zones.

SBWM-3 — In SBWM-3 saline water extends to a depth of approximately 100 feet within the Dune/Beach Sand and Aromas Deposits. Below 100 feet, the materials become clay and conductivities rapidly decline. Again, below the shallow saline water in the sand deposits, all zones of increased conductivity correlate with clay zones.

SBWM-4 — As with the other wells, the induction log reveals a thin layer of fresh water overlying saline water with the Dune Sands/Beach Deposits to a depth of approximately 100 feet. Below this depth the materials become clay and there are no additional zones of increased conductivity uncorrelated with clay zones.

Salinity changes shown on Figure 25 through Figure 28 for Sentinel Wells 1 – 4, respectively, are only relative, and do not allow direct measurement of TDS or chloride concentrations in the aquifer. They do, however, provide a means to determine changes in salinity over time. Induction logging in previous years indicated salinity in the Dune Sands and Aromas Formation overlaying the main production aquifers fluctuates from season to season; becoming more saline in the fall months when stresses on the aquifer are greatest. The logging events that took place in WY 2022 plot similarly on the figures below, suggesting very little net change in salinity over the course of the year. As has been the case historically, none of the wells show detectable changes in conductivity to the deeper aquifers where the majority of production wells extract groundwater.

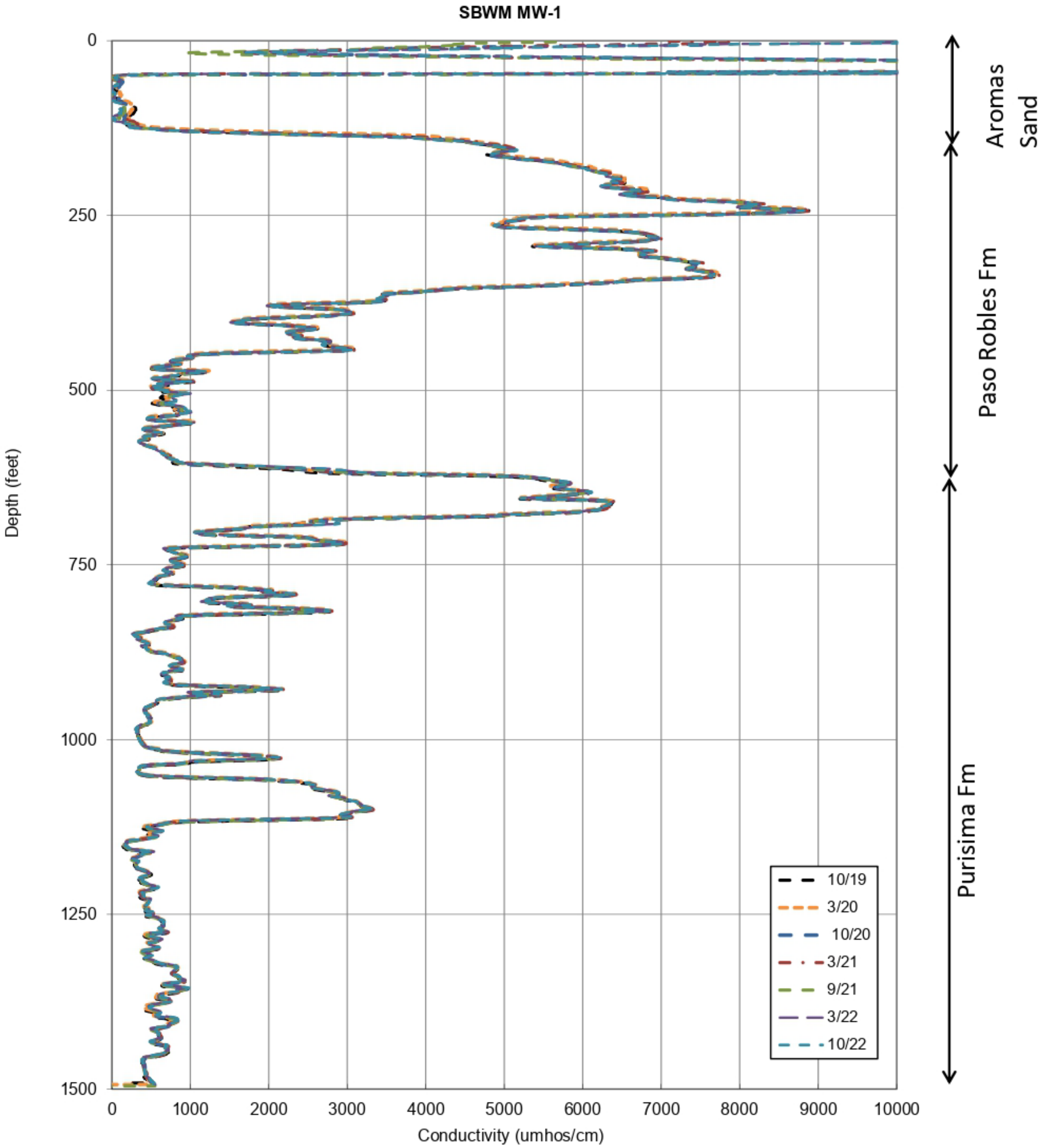


Figure 25. Sentinel Well SBWM MW-1 Induction Log

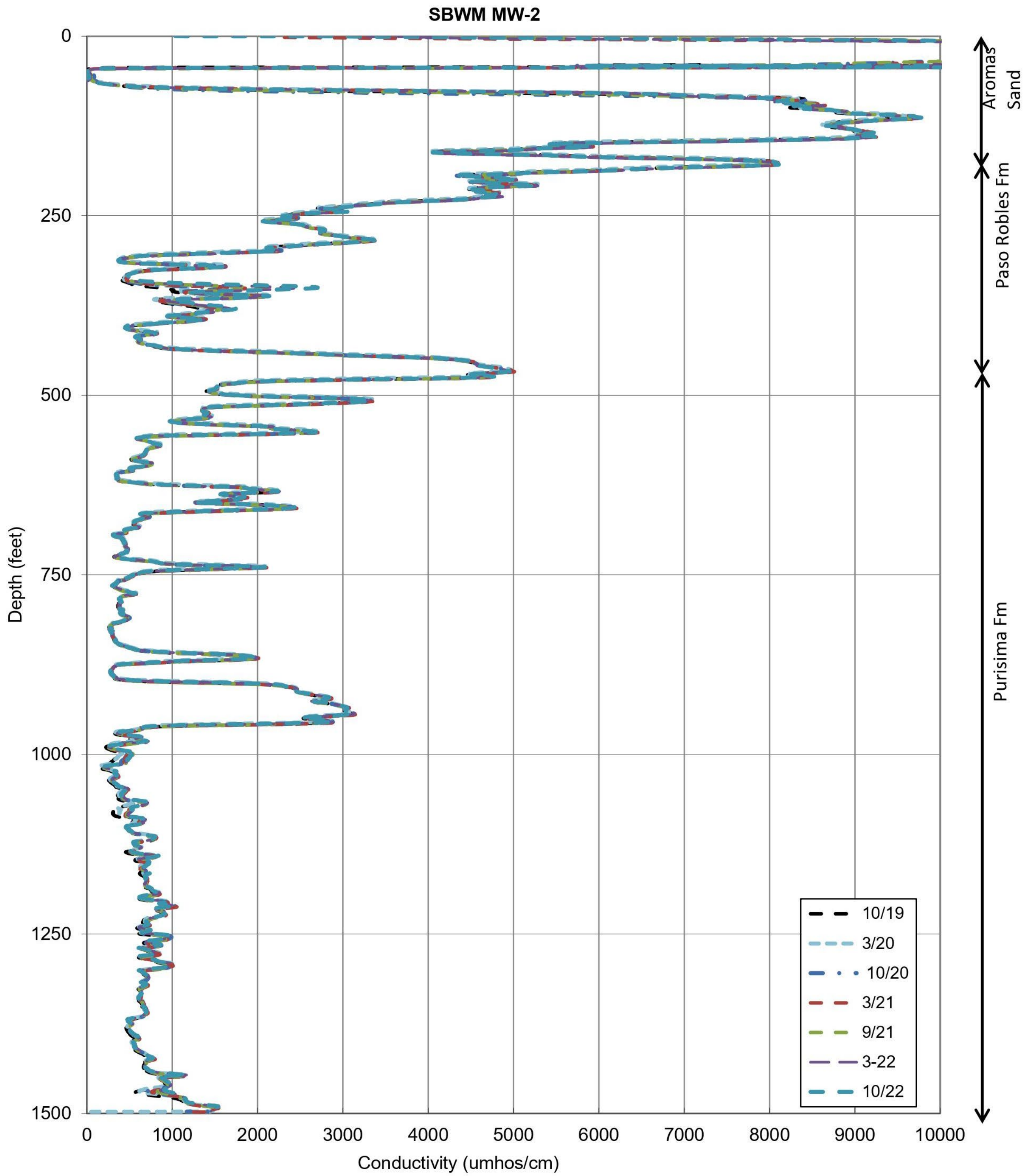


Figure 26. Sentinel Well SBWM MW-2 Induction Log

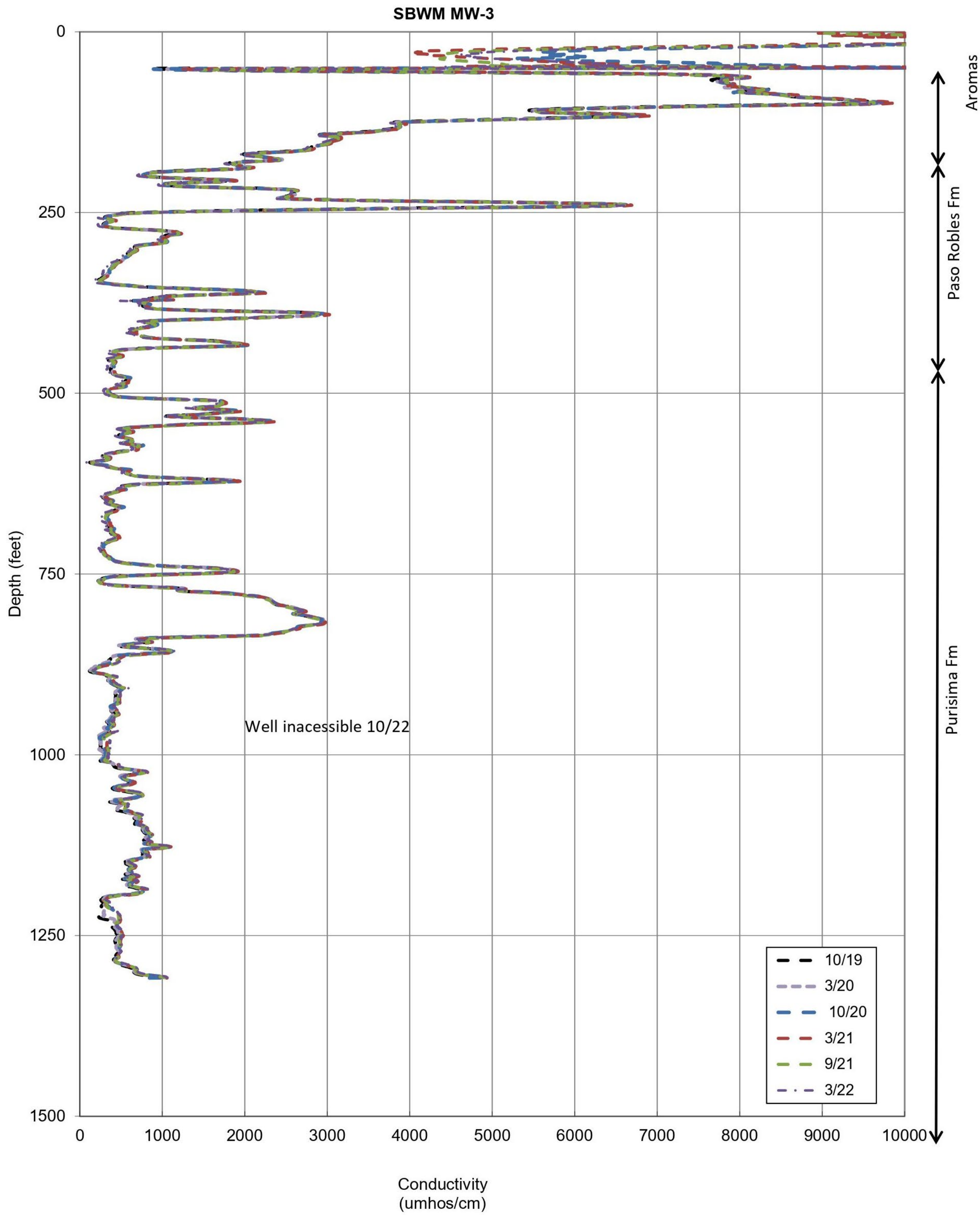


Figure 27. Sentinel Well SBWM MW-3 Induction Log

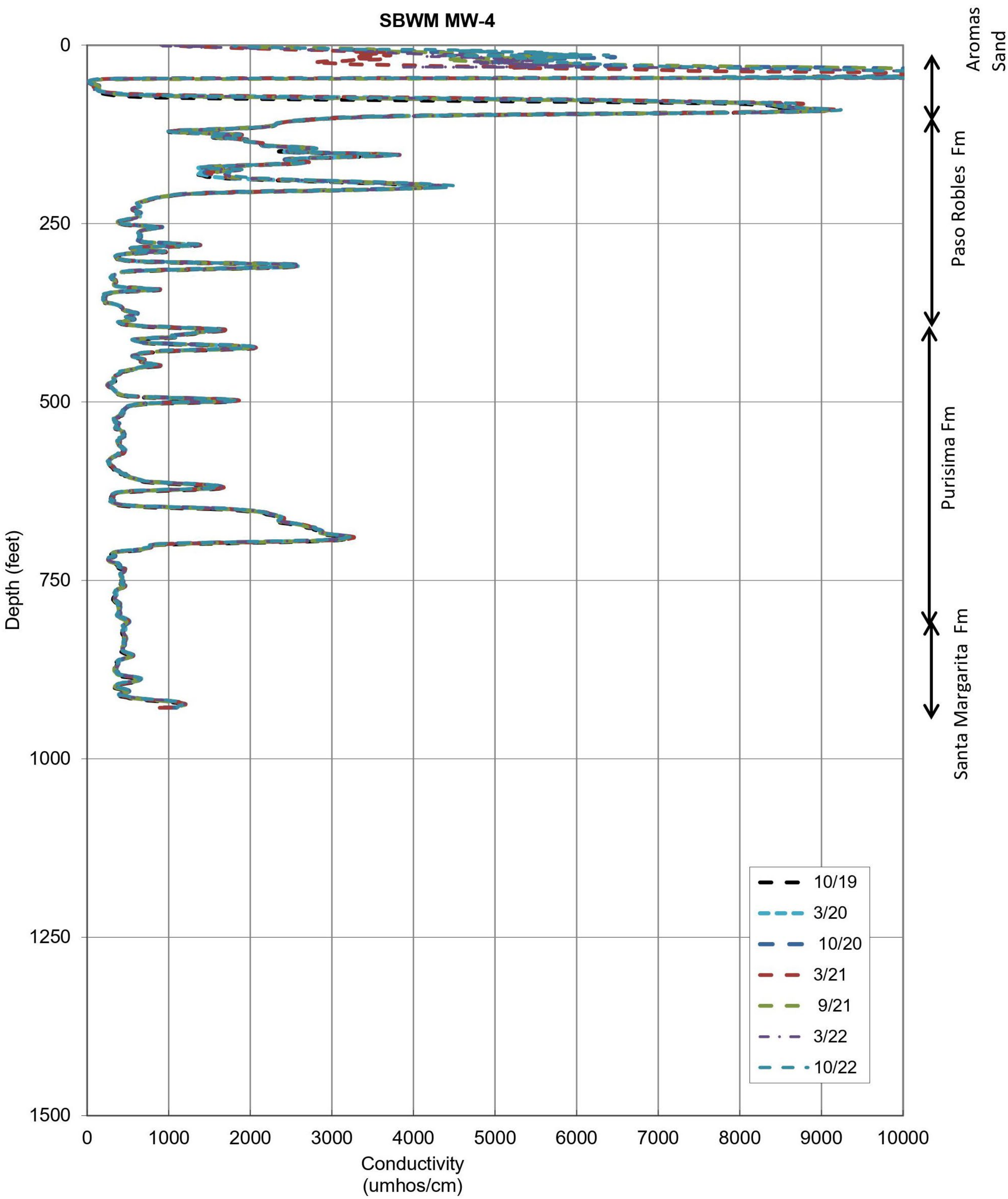


Figure 28. Sentinel Well SBWM MW-4 Induction Log

2.6 Groundwater Levels

Groundwater levels are not direct indicators of seawater intrusion, but indirectly suggest opportunities for seawater intrusion. Coastal groundwater levels at or near sea level are insufficient to repel seawater intrusion and will likely allow some amount of seawater intrusion unless groundwater levels increase. All groundwater level data collected in WY 2022 are included in Appendix B.

2.6.1 Precipitation

Precipitation is described here because of its relationship to groundwater recharge, which is one of the factors influencing groundwater levels. Figure 29 displays annual precipitation averaged for 2 National Oceanic and Atmospheric Administration climate stations in the Seaside area: the Monterey airport station (USC00045795) and the Salinas Airport station (USW00023233). Taking the average precipitation from these 2 stations results in a value representative of the spatial variation across the Basin. In WY 2022, precipitation from the 2 stations averaged 10.6 inches. This is higher than the past 2 water years, but still well below the historical average of 15.6 inches and amongst historic lows seen over the period of record shown on Figure 29. The solid line on Figure 29 tracks the cumulative departure of annual precipitation from the historical average. While there was high precipitation in WY 2019, the past 3 years have been well below average. This low rainfall has resulted in less groundwater recharge to the Basin. The effects of recharge are first seen in the shallow aquifer, which is unconfined by clay layers and most directly impacted. The deep aquifer exhibits more delayed recharge impacts because of its depth and confined nature.

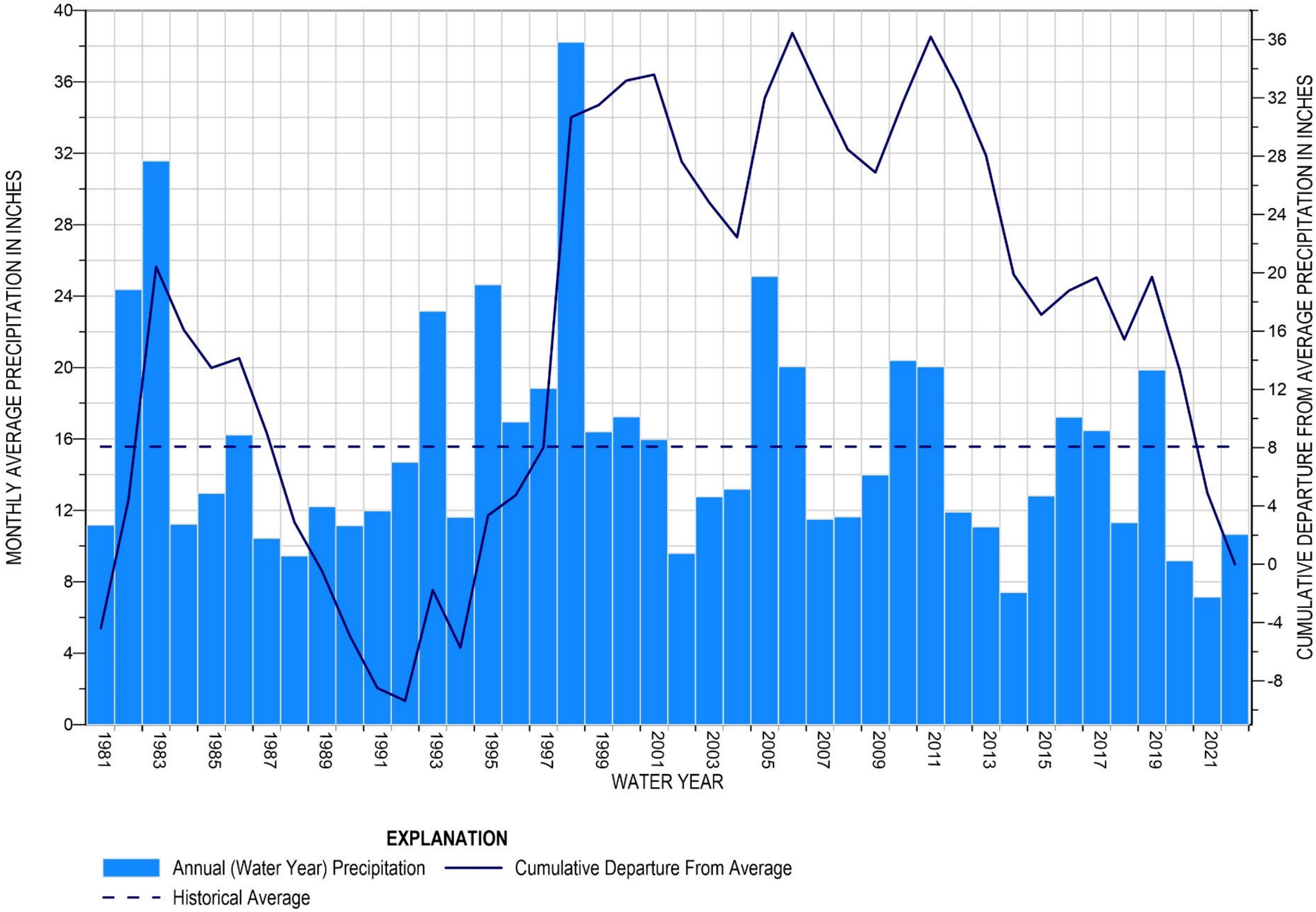


Figure 29. Annual Precipitation in Seaside Basin (Average of Monterey Airport and Salinas Airport Stations)

2.6.2 Groundwater Level Trends

2.6.2.1 Northern Coastal Subarea

Groundwater levels measured at the PCA-East well are generally representative of groundwater levels in the Northern Coastal subarea, west of nearby production wells. The hydrograph shows peaks and lows that are strongly influenced by pumping by the nearby CAWC production wells on groundwater levels in the deep zone and injection of Carmel River water and Pure Water Monterey (PWM) highly treated recycled water at the eastern boundary of the subarea (Figure 30). Other influences such as tides which can cause up to a 1-foot fluctuation in the deep completion of PCA-East are also recognized. Because of all the possible influences on groundwater levels, it is difficult to compare the present year to the previous year directly. What is more important is to look at long-term trends.

The Santa Margarita aquifer (deep zone) has limited connection to the ocean and is highly confined by the layers above it. This means that the amount of recharge entering the Santa Margarita Sandstone is limited and is therefore always susceptible to depletion if more water is pumped than is being recharged.

PCA-East deep (blue line on Figure 30) shows an overall decline in groundwater levels until WY 2009, levels increase and then more or less stabilize over the next 2 years, then from WY 2011 to WY 2016 experienced a continued decline. Groundwater levels recovered slightly in WY 2017 due to above average rainfall, and remained at similar levels since through WY 2020, with no clear increasing or decreasing trend (Figure 30). The start of the overall decline in groundwater levels in the deep completion of PCA-East corresponds with the shift in CAWC's production from their shallow Paso Robles wells to deeper Santa Margarita wells.

Seasonal fluctuations are noticeable in the winter season when deep groundwater elevations are at their highest for the year. For example, the 2017 winter high in PCA-East deep increased to a level last seen in 1995, because 2,345 acre-feet of excess Carmel River water was injected as it was a very wet year. As described in Section 2.6.1, WY 2022 was a very dry year, resulting in a limited excess Carmel River Water for ASR injection. Dry conditions and limited ASR injection resulted in some of the lowest on record seasonal high elevations shown on Figure 30. The well has since then experienced decline over the past 2 years; in WY 2022 both seasonal high and seasonal lower groundwater elevations were amongst the lowest on record. Despite dry conditions, the groundwater level decline is likely ameliorated by PWM injection of 3,647 acre-feet.

To complement Figure 30, Figure 31 displays groundwater elevations in a wider set of Santa Margarita Northern Coastal Subarea wells, including PCA-East. Elevations in all these wells have been below sea level since the late 1990s. The discrepancy between wells near the center of the inland pumping depression (Ord Grove Test) and more coastal and inland wells helps illustrate the gradient of the deep aquifer's pumping depression over time, shown for WY 2022 on Figure 38 and Figure 40. This discrepancy is illustrative of conditions near the very center of the pumping depression as compared to those further from its center. Because the Ord Grove Test is highly influenced by pumping at the Ord Grove #2 well, it is better to compare seasonal highs between this well and others in the Northern Coastal Subarea. The discrepancy between this well and others in the Northern Coastal Subarea tends to widen during dry periods in response to lessened recharge and increased groundwater demand (See October 2012 through October 2016 on Figure 31). Over the past 4 years this discrepancy has shrunk for 2 reasons. First, elevations in the deeper portion of the pumping depression have risen somewhat over the past 4 years, likely a result of ASR injection in WY 2019 and WY 2020, and PWM injection in WY 2021 and WY 2022 (See October-2018 through October 2022 on Figure 31). Secondly, elevations in some of the wells further from the center of the pumping depression have fallen over the past 4 years (FO-07 Deep, FO-09 Deep, PCA-W Deep, MSC-Deep). As discussed above, elevations at PCA-East Deep have likewise fallen over the past 2 years. From this we can conclude that although the depth of the pumping depression's center has decreased in the past few years, its lateral extent continues to grow. How the shape and gradient of this deep pumping depression evolves over time should be examined to inform projects and sustainability in the Northern Coastal Subarea.

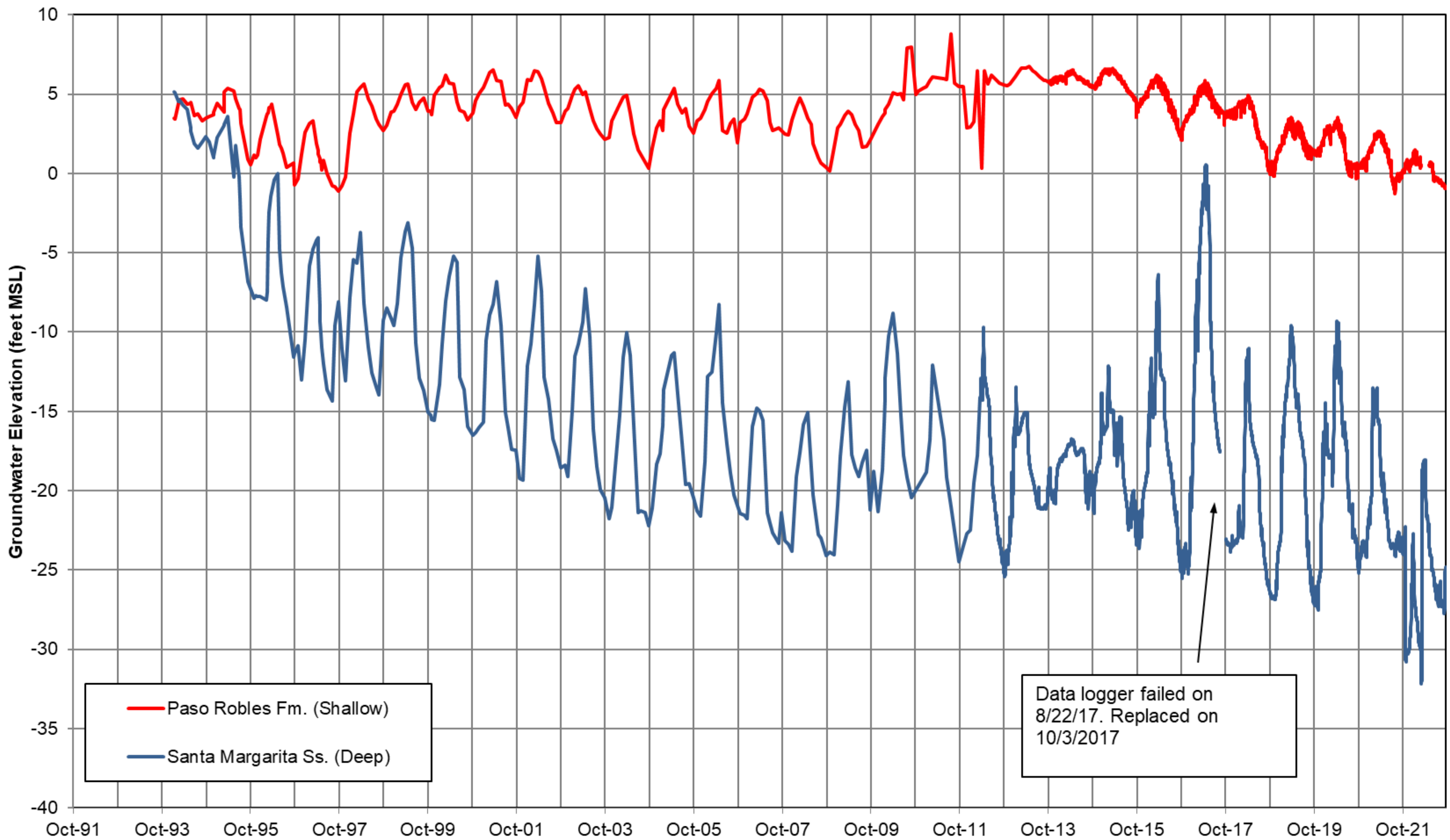


Figure 30. PCA-East Deep and Shallow Monitoring Well Hydrograph (Source: Watermaster)

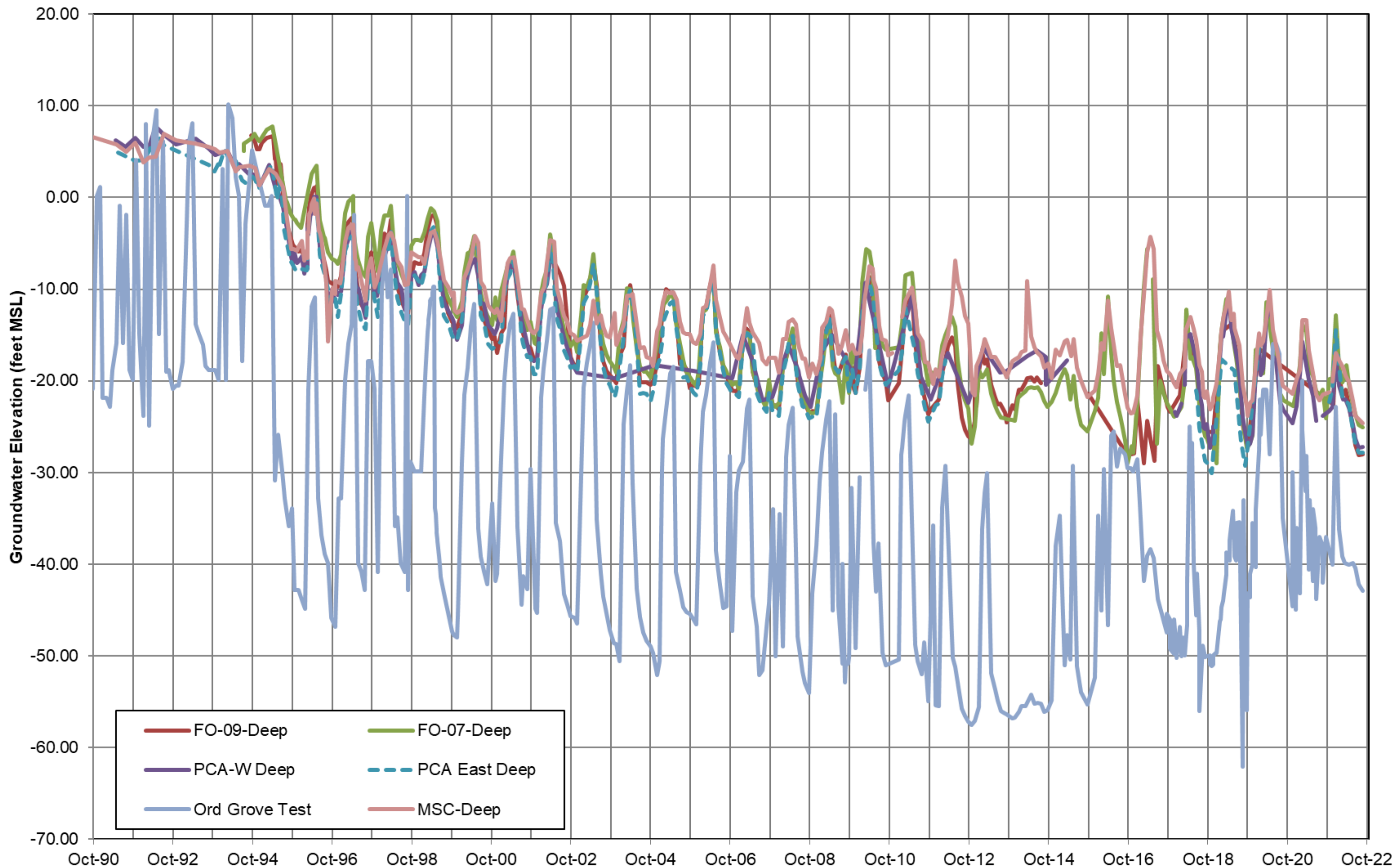


Figure 31. Santa Margarita Aquifer Northern Coastal Subarea Wells

Figure 32 includes hydrographs of groundwater elevations for the 4 deep coastal Sentinel Wells. Groundwater elevations on this chart are collected from dataloggers in each well that record levels every 30 minutes. The hydrographs plot daily average elevations, thereby smoothing out the more detailed data which are affected by tidal variations. Hydrographs for the Sentinel Wells are similar to the PCA-East Deep hydrograph and show that groundwater elevations over winter and spring were the highest in WY 2017 because of increased ASR injection. Comparison between WY 2021 and WY 2022 is complicated by a lack of WY 2021 data at SBWM-1 and WY 2022 data at SBWM- 2. Data at SBWM-1 were not available during WY 2021 due to an unresponsive datalogger, but the logger was reinstated in WY 2022. Data at SBWM-2 were not available during WY 2022 due to a lost field sheet. Seasonal low groundwater levels in WY 2022 at SBWM-1 are the lowest over its period of record (Figure 32).

Seasonal high groundwater elevations in WY 2022 are very similar to the previous year. However, seasonal low elevations are roughly 4 feet lower than the previous year, likely a result of continued dry conditions and a lack of available surface water to support ASR injection (Section 2.6.1; Section 2.7).

The hydrograph of Paso Robles aquifer groundwater levels in PCA-East shows a steadily declining trend since WY 2014, where levels have dropped about 7 feet over the past 8 years (Figure 30). The decline in Paso Robles aquifer groundwater levels and greater seasonal fluctuations corresponds with the recommencement of pumping at the Coe Ave and Black Horse Bayonet golf course irrigation wells after being supplied water by Marina Coast Water District from WY 2009 through 2014/2015. Since WY 2018, groundwater levels are below protective elevations at this coastal monitoring well as described further in Section 2.6.4. Seasonal level increases in the Paso Robles aquifer are usually related to reduced wintertime production and increased pumping during summer. Although the Paso Robles aquifer seasonal fluctuations correspond with Santa Margarita aquifer fluctuations, it is because seasonal pumping occurs in both aquifers, and not because the aquifers are closely connected.

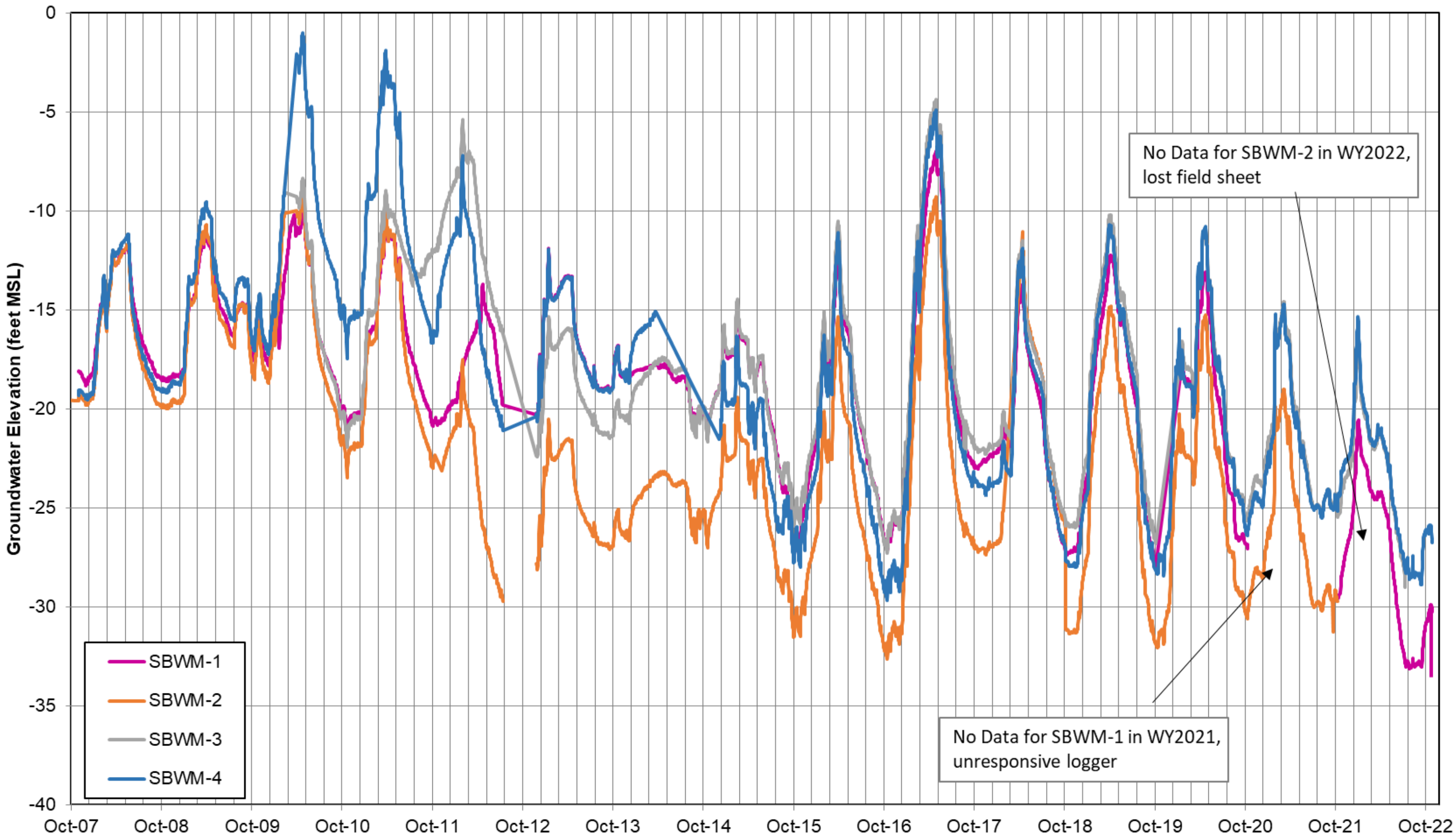


Figure 32. Sentinel Well Hydrographs (Source: Watermaster)

2.6.2.2 Southern Coastal Subarea

In the Southern Coastal subarea, the K-Mart and CDM MW4 monitoring wells are representative of groundwater levels near the coast. Figure 33 shows that groundwater elevations have remained above sea level and continue to be fairly stable. A data gap exists at the K-Mart monitoring well from November 2019 to July 2022 due to COVID safety concerns from a nearby homeless encampment. While access to the well has been restored in late WY 2022, the nearby CDM MW4 monitoring well is added to the hydrograph on Figure 33 to show groundwater elevation trends in the subarea during the data gap period.

2.6.2.3 Laguna Seca Subarea

Although the Laguna Seca subarea is far enough from the coast not to have seawater intrusion, there is concern that since 2001 this area has experienced ongoing groundwater level declines that have not been controlled or improved by triennial pumping reductions. It is believed this is occurring due in part to the Natural Safe Yield of the subarea being too high and in part due to influences of groundwater pumping east of the Seaside Basin boundary (HydroMetrics WRI, 2016a). Figure 10 shows the location of wells with hydrographs on Figure 34 while Figure 36 shows the location of all wells, including production wells in the eastern Laguna Seca subarea.

In the eastern portion of the subarea between 1999 and 2014, Paso Robles groundwater levels declined at a rate of approximately 0.6 feet per year and Santa Margarita groundwater levels declined up to 4 feet per year, as shown on Figure 34. Although there was some stabilization between WY 2014 and WY 2016, groundwater levels continue to decline at a general rate of roughly 0.5 feet per year in both the Paso Robles and Santa Margarita aquifer systems, including in WY 2022. Similar trends are present in the central portion of the subarea, as shown on Figure 35, though Bishop #3 has experienced some recovery due to cessation of pumping in CAWC’s Bishop unit.

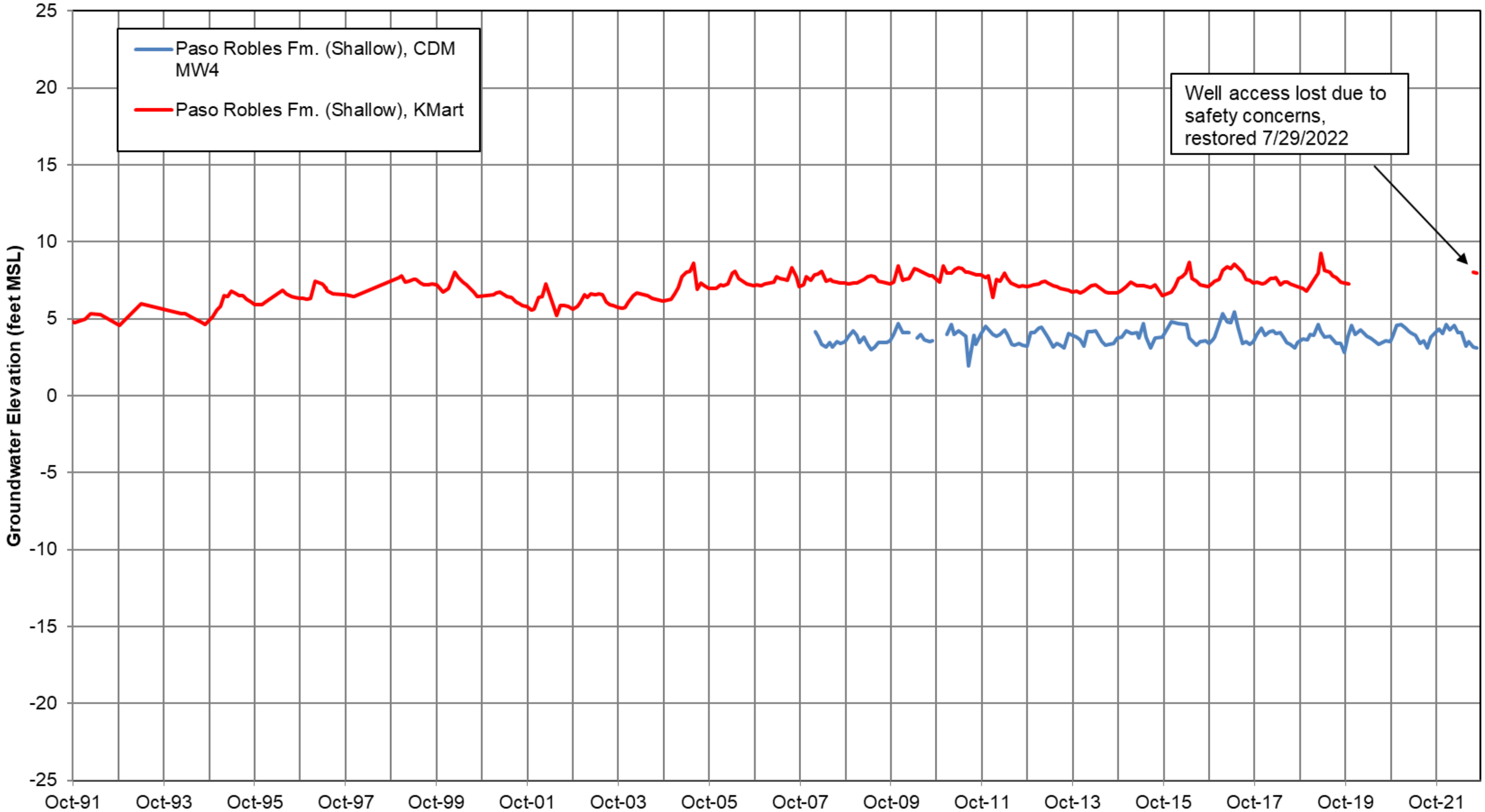


Figure 33. K-Mart and CDM MW4 Hydrographs, Southern Coastal Subarea (Source: Watermaster)

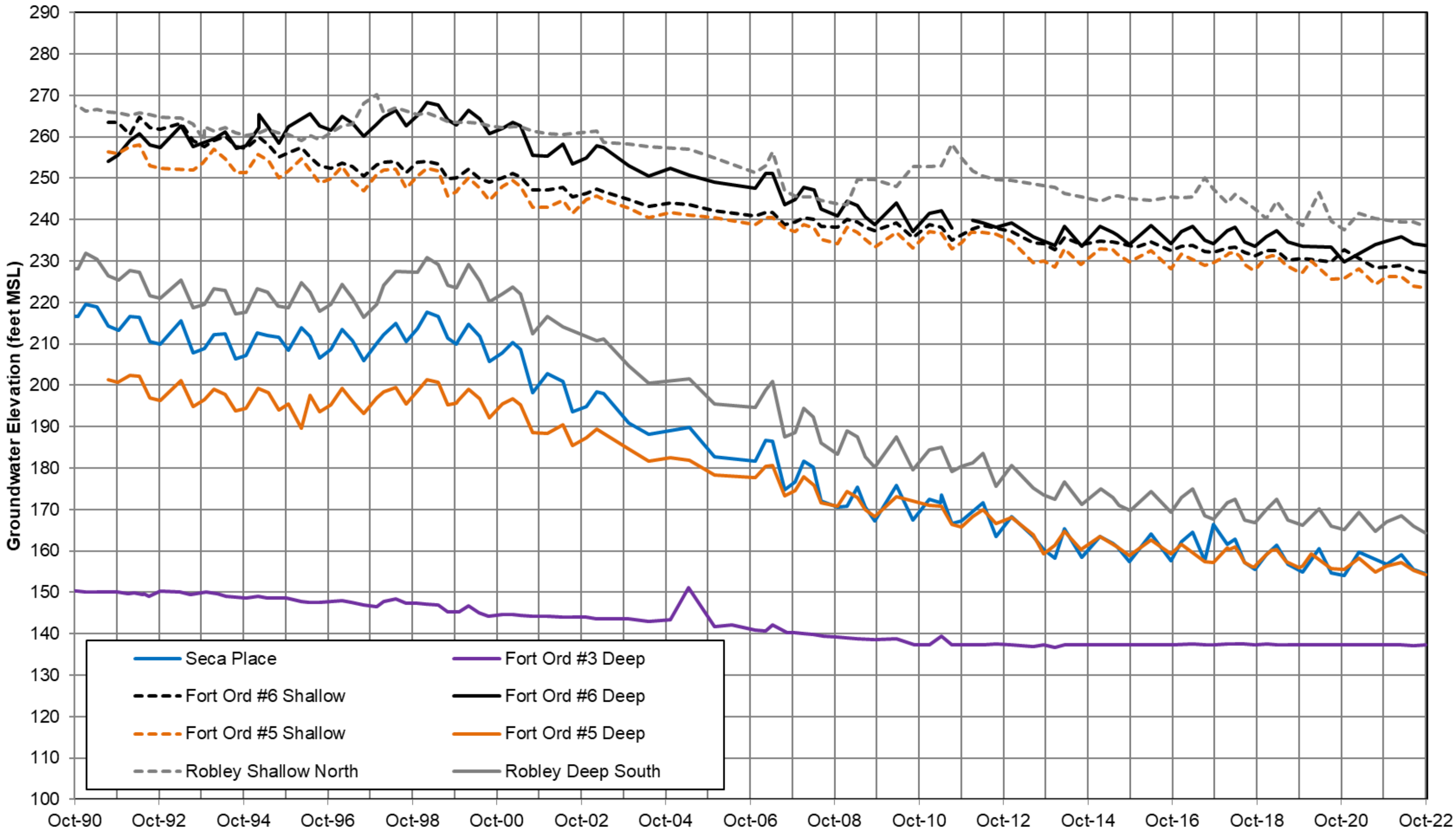


Figure 34. Eastern Laguna Seca Subarea Hydrographs

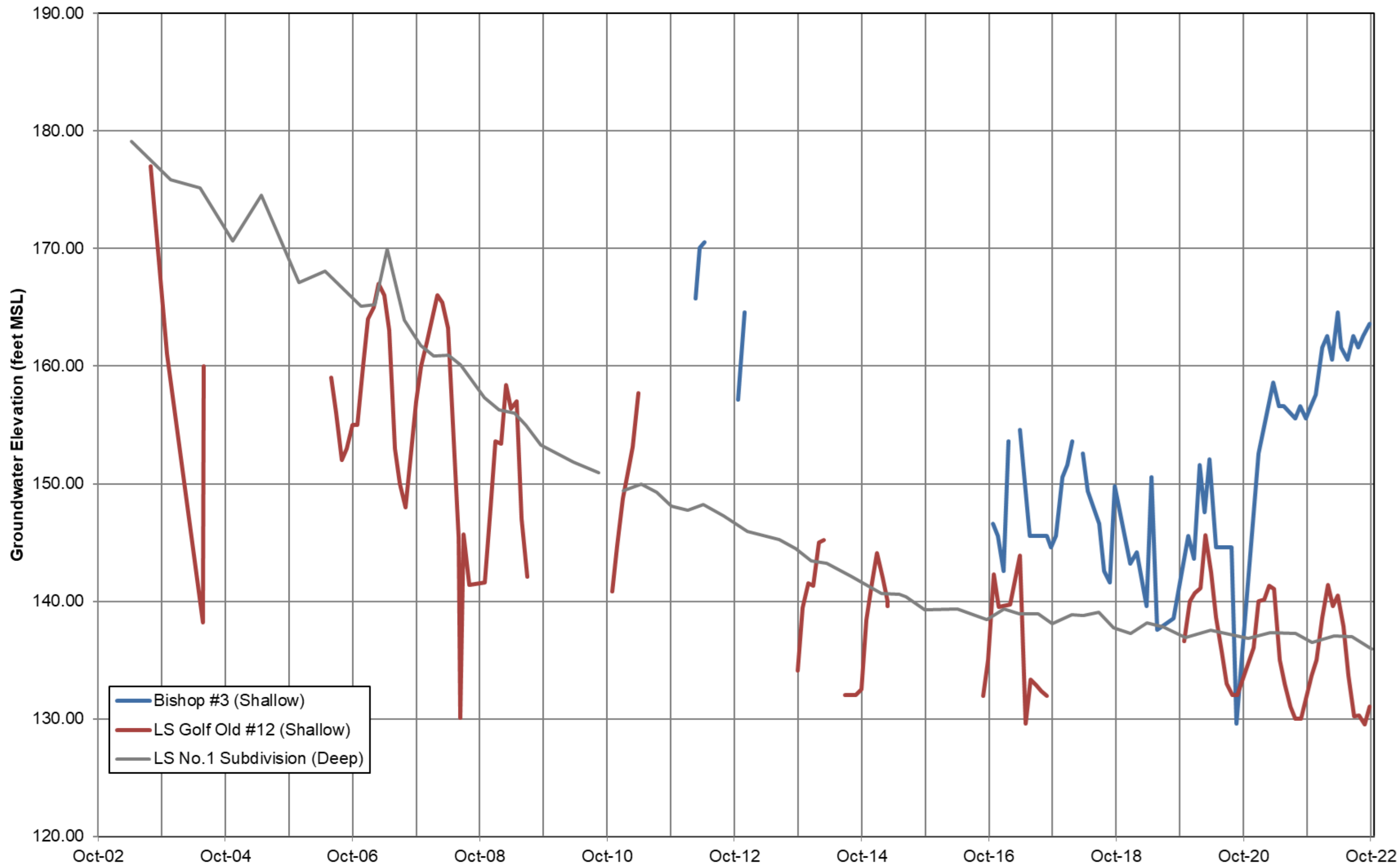
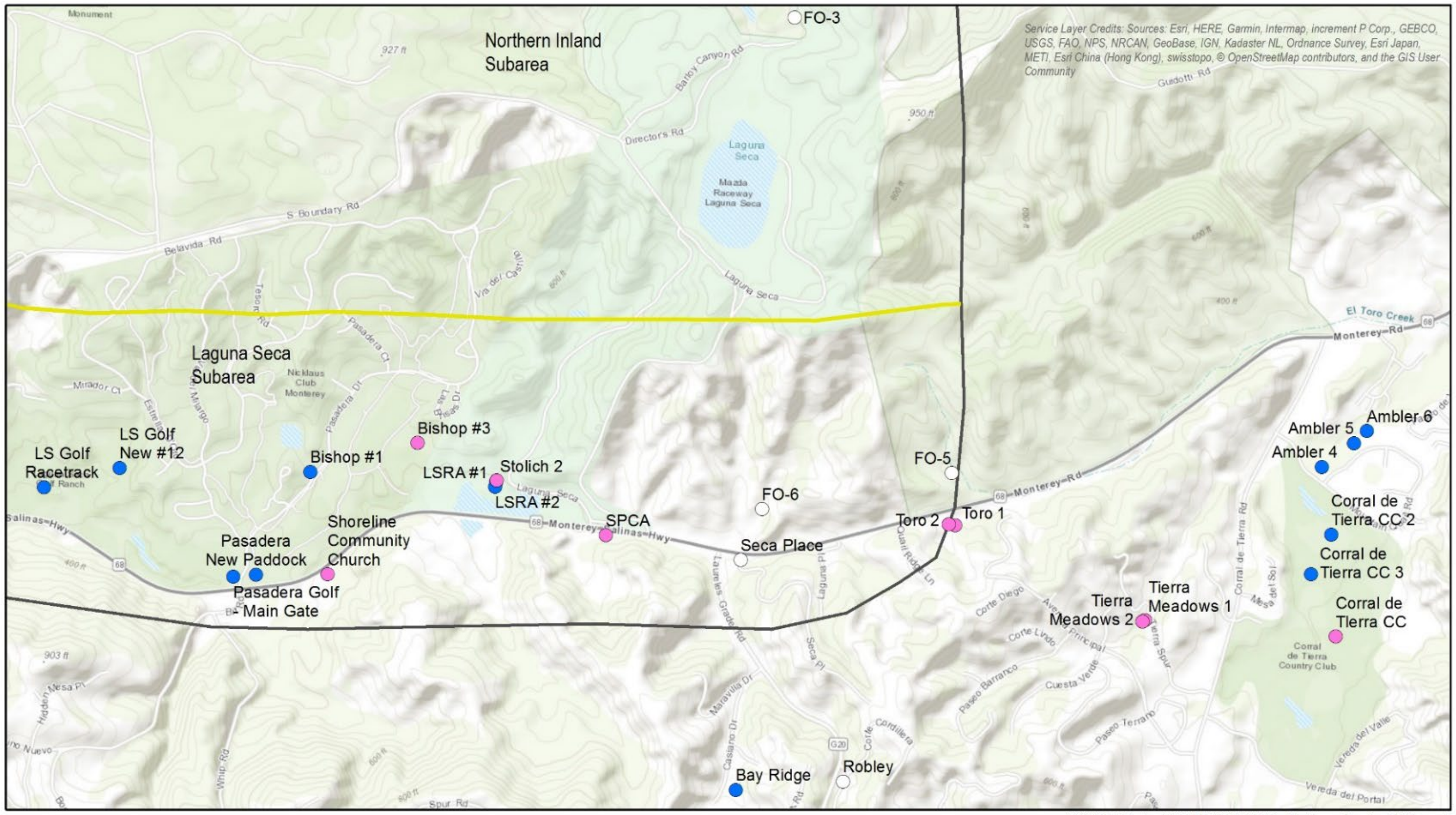


Figure 35. Central Laguna Seca Subarea Hydrographs



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EXPLANATION

Adjudicated Seaside Groundwater Basin

- Basin Boundary
- Subarea Boundary
- Select Monitoring Wells

Production Wells

- Well Screened Interval Entirely Within Paso Robles Aquifer (Shallow)
- Well Screened Interval Includes Santa Margarita Aquifer (Deep)

N

0 1,000 2,000 3,000 4,000
Feet

Figure 36. Eastern Laguna Seca Subarea Wells

2.6.3 Groundwater Elevation Maps

2.6.3.1 Second Quarter Water Year 2022 (January-March 2022)

Groundwater level maps for the Paso Robles aquifer (shallow) and Santa Margarita (deep) aquifers for the second quarter of WY 2022 are shown on Figure 37 and Figure 38, respectively. The groundwater elevation contour maps now include groundwater elevations from the ASR and PWM monitoring wells, though PWM monitoring well data was not received in WY 2022. The area of influence from injection is identified by an opaque shaded area, which approximates the influence of injection on each aquifer. Under current injection operations, the influence of PWM injection is significantly larger in the Santa Margarita aquifer than the Paso Robles aquifer.

Other than in areas of active groundwater pumping, the Santa Margarita aquifer does not show seasonal fluctuations to the same extent as the Paso Robles aquifer. The following are observations on the second quarter groundwater elevation contours for the Paso Robles aquifer (Figure 37):

- In the Northern Coastal subarea and just north of the subarea (outside of the basin), second quarter (spring) Paso Robles groundwater elevations generally declined around 1 to 12 feet from second quarter WY 2021 levels.
- The Paso Robles aquifer second quarter pumping depression in the Northern Coastal subarea remained of similar size in WY 2022 compared to last year, though its eastern extent is slightly larger than the previous year. The eastern extent of the pumping depression is controlled in part by PWM injection and ASR operations. Because PWM monitoring well data was not received in WY 2022, quantifying the magnitude injection influence is more difficult. However, WY 2022 total injection was 43 acre-feet more than the previous year, likely leading to similar radius of injection influence.
- The Southern Coastal subarea continues to have stable groundwater levels.
- The pumping depression caused by the Laguna Seca Golf Ranch wells in the central Laguna Seca subarea remains of similar size to recent years, though the extent of the depression is difficult to quantify given the limited wells in the area with spring 2022 groundwater elevation data. Spring 2022 groundwater elevations at the Bishop #3 well rose roughly 6 feet from the previous year.
- Spring levels in the eastern Laguna Seca subarea are similar to last year.
- In the eastern portion of the Northern Inland subarea, an area of the Paso Robles aquifer is indicated to be potentially dry due to geologic structural control.

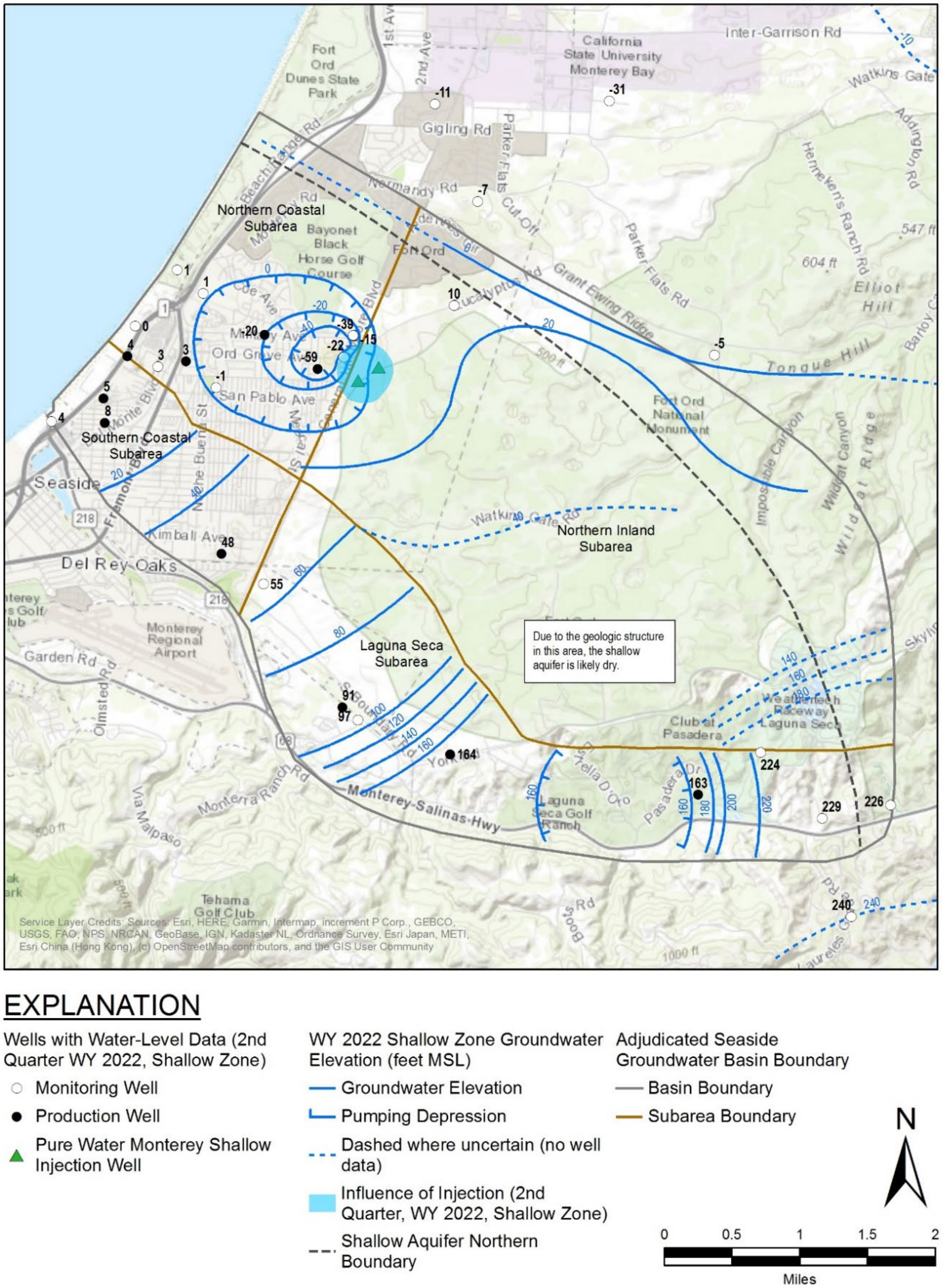


Figure 37. Paso Robles Aquifer (Shallow Zone) Water Elevation Map – 2nd Quarter Water Year 2022 (January-March 2022)

In the Santa Margarita aquifer, second quarter (spring) groundwater levels particularly along the coast are usually higher than fourth quarter (fall) groundwater levels by up to 7 feet due to seasonal groundwater demand. The following are observations on the second quarter groundwater elevation contours for the Santa Margarita aquifer (Figure 38):

- In the Northern Coastal subarea, along the coast, and just north of the subarea, Santa Margarita groundwater levels along the coast declined roughly 1 to 7 feet from last spring.
- The Santa Margarita pumping depression in the Northern Coastal subarea expanded since WY 2021, with the -20 feet msl contour line now reaching FO-07 Deep monitoring well to the east.
- Groundwater levels in the area of injection remain below sea level.
- The pumping depression associated with pumping at the Laguna Seca golf courses is similar to spring levels last year.
- The eastern portion of the Laguna Seca subarea has groundwater levels similar to last year. Groundwater elevations at the Ryan Ranch #8 well rose 7 feet from last year, as there was not pumping in the Ryan Ranch unit during WY 2022.

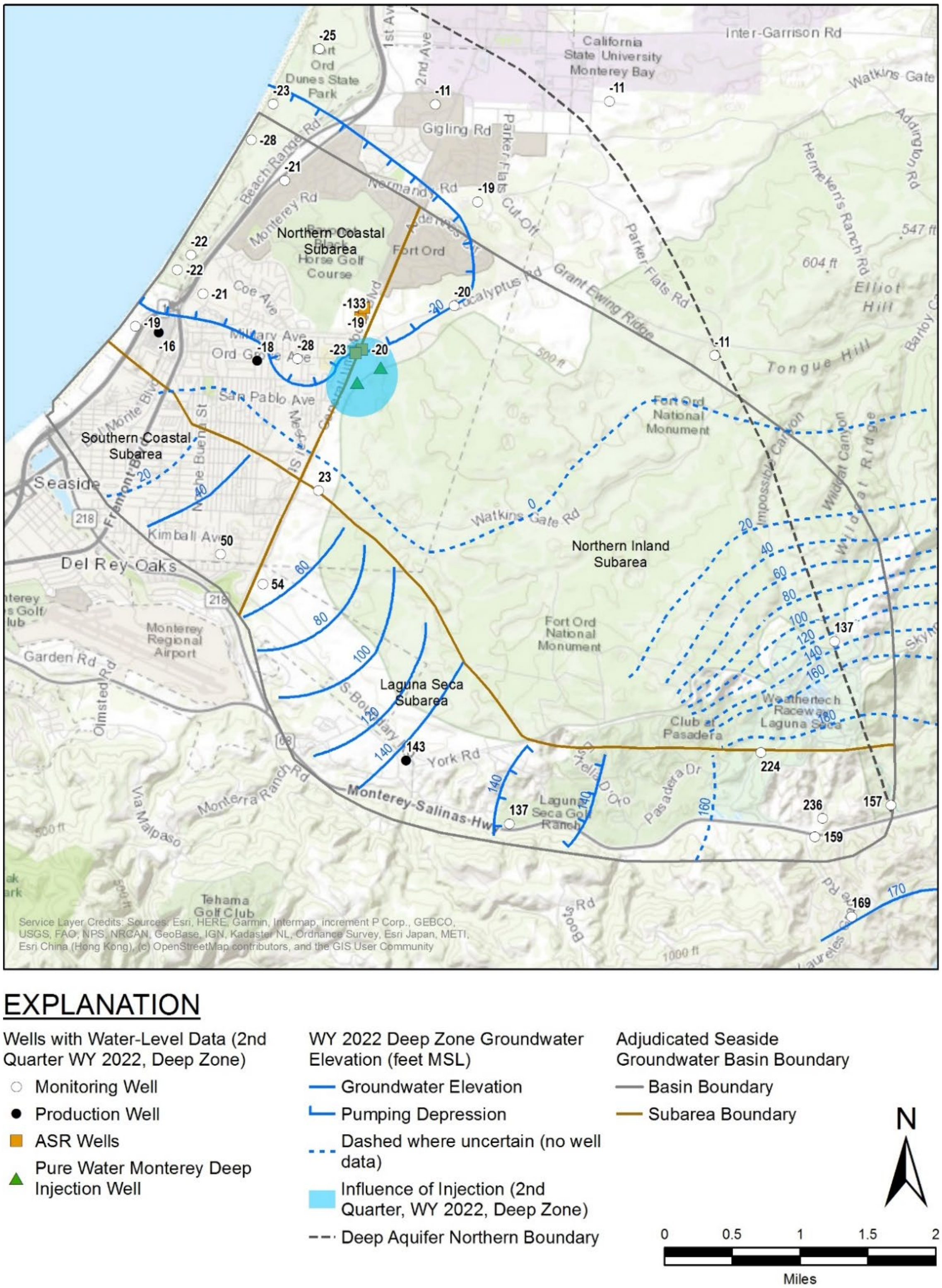


Figure 38. Santa Margarita Aquifer (Deep Zone) Water Elevation Map – 2nd Quarter Water Year 2022 (January-March 2022)

2.6.3.2 Fourth Quarter Water Year 2022 (July-September 2022)

Groundwater elevation maps for the Paso Robles (shallow) and Santa Margarita (deep) aquifers for the fourth quarter of WY 2022 are shown on Figure 39 and Figure 40, respectively.

The following are observations on the fourth quarter groundwater elevation contours for the Paso Robles aquifer (Figure 39):

- Northern Coastal subarea groundwater elevations, including just outside of the northern Basin boundary), decreased up to 5 feet from the fourth quarter of WY 2021. Groundwater elevations at the coastal Sentinel wells were 1 foot below sea level during fourth quarter of WY 2022, identical to the previous year.
- The Northern Coastal subarea pumping depression in the shallow aquifer is larger in WY 2022, related to it being a consecutive dry year and pumping at the Ord Grove #2 well.
- Southern Coastal subarea groundwater levels are generally stable, and elevations at the Design Center well rose 4 feet from the previous year.
- The local 120-foot elevation pumping depression around York School remains the same as last year.
- Elevations in the eastern portion of the Laguna Seca subarea remain similar to last year, with declines of less than 1 foot. With the cessation of pumping at CAWC's Bishop unit, the Bishop #3 in the central Laguna Seca area has experienced recovery of over 10 feet starting in late WY 2021 through WY 2022.

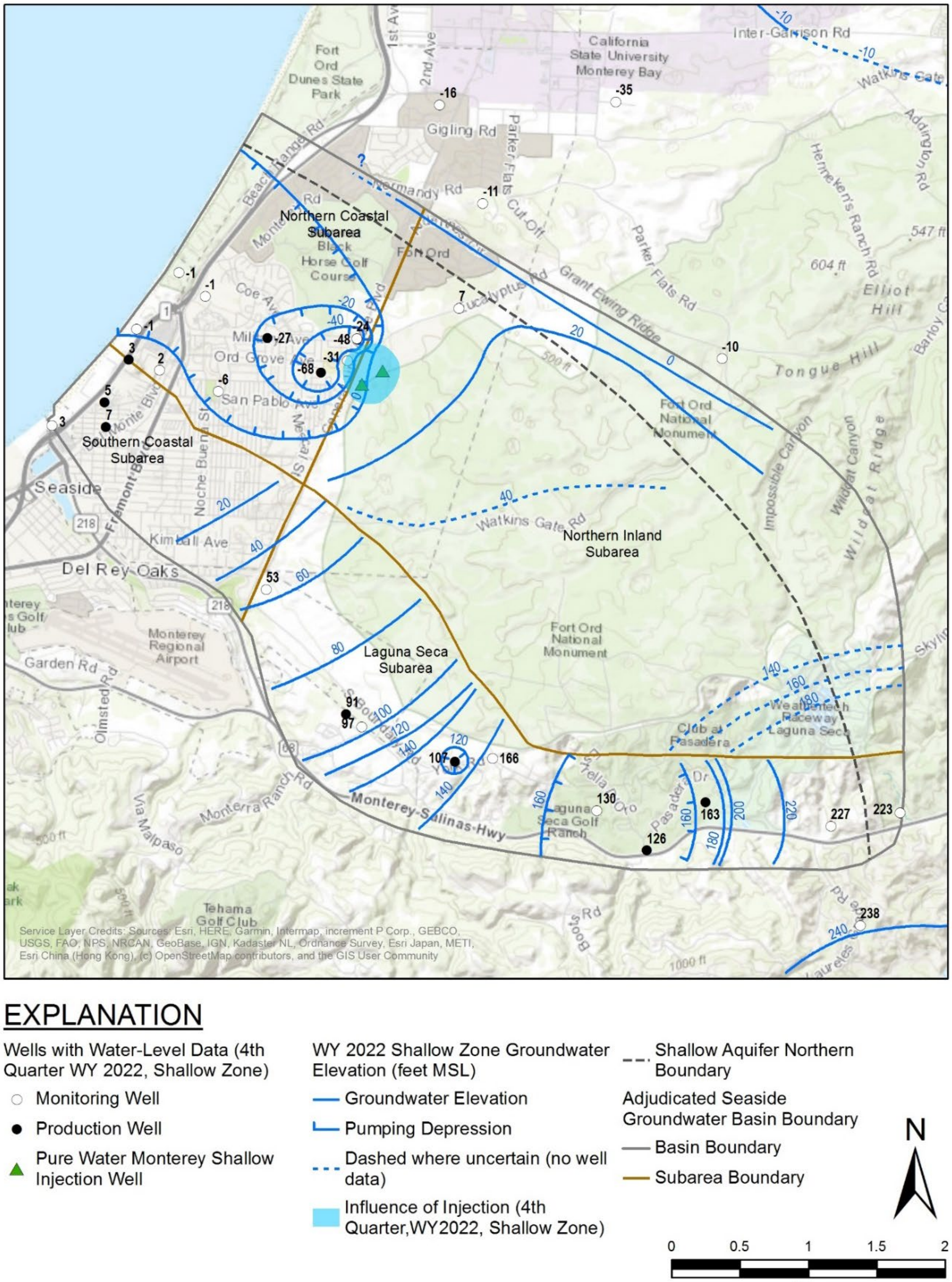


Figure 39. Paso Robles Aquifer (Shallow Zone) Water Elevation Map – 4th Quarter Water Year 2022 (August/September 2022)

The following are observations on the fourth quarter groundwater elevation contours for the Santa Margarita aquifer (Figure 40):

- North of the Northern Coastal subarea, Santa Margarita aquifer groundwater elevations declined up to 5 feet from last year. The northern -20-foot contour has pushed slightly northeast, due to a 2- and 5-foot drop in groundwater elevations at FO-07 Deep and FO-08 Deep monitoring wells, respectively.
- At the coast, Santa Margarita aquifer groundwater levels in the Northern Coastal subarea declined 1 to 5 feet from the previous year.
- The Northern Coastal subarea deep aquifer's pumping depression is larger in extent than last year. The southeastern extent of the depression appears to be significantly controlled by the large volume of PWM injection in WY 2022.
- The pumping depression associated with pumping at the Laguna Seca golf courses is similar to fall levels last year.
- The eastern portion of the Laguna Seca Subarea has groundwater levels similar to last year. Groundwater elevations at Ryan Ranch #8 area increased roughly 2 feet compared to last fall.

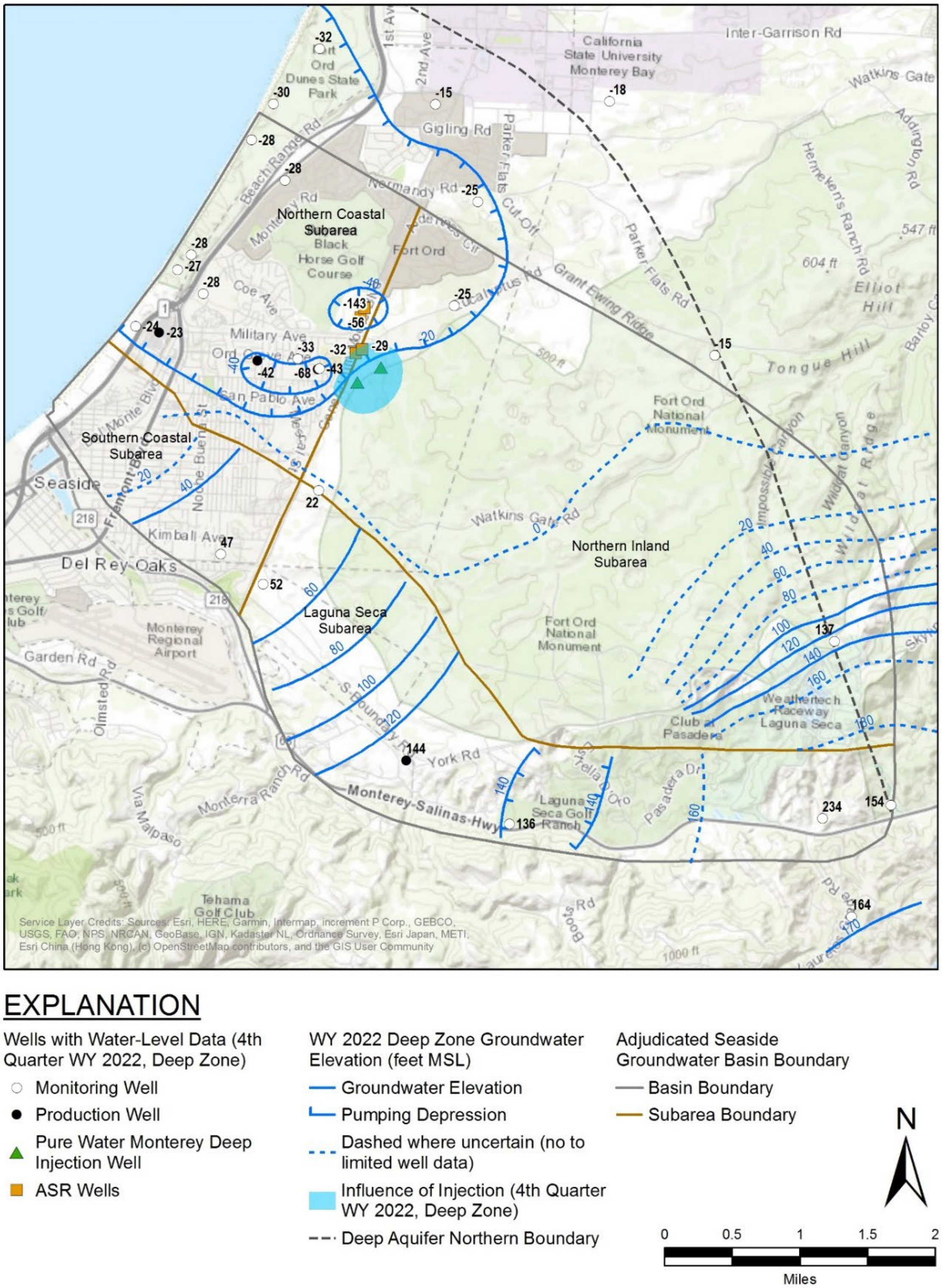


Figure 40. Santa Margarita Aquifer (Deep Zone) Water Elevation Map – 4th Quarter Water Year 2022 (July/September 2022)

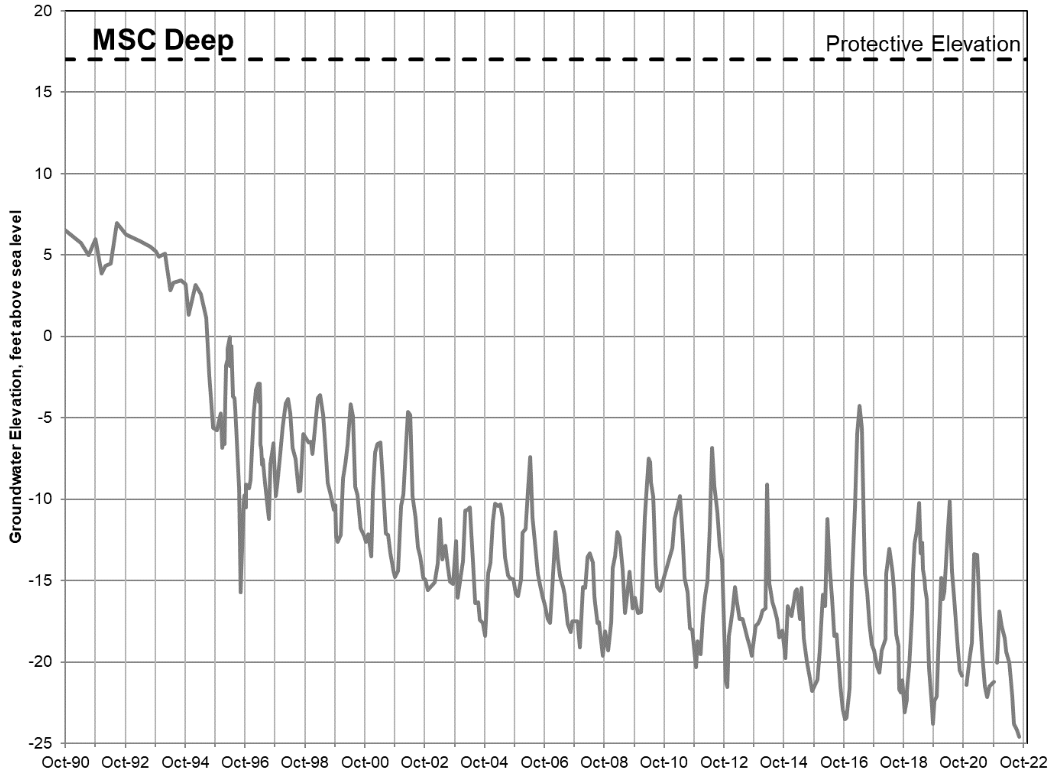
2.6.4 Protective Groundwater Elevations

Protective groundwater elevations were determined in 2009 using the Seaside Groundwater Basin groundwater flow model and cross-sectional modeling (HydroMetrics LLC, 2009b). A subsequent study in 2013 to revisit and update the protective groundwater elevations concluded that the calibrated parameters in the basin wide model do not indicate that protective elevations should be lowered (HydroMetrics WRI, 2013b). Protective elevations for both the Santa Margarita (deep) and Paso Robles (shallow) aquifers were established for monitoring well pairs with both a shallow and deep completion. Protective elevations for the 6 wells with protective elevations are shown in Table 1. Groundwater levels below protective elevations have a greater potential to cause seawater intrusion that will impact production wells.

Table 1. Summary of Protective Elevations at Coastal Monitoring Wells

Subarea	Well	Completion	Protective Elevation, Feet above sea level	Currently Above or Below Protective Elevations
Northern Coastal	MSC	Santa Margarita (Deep)	17	below
		Paso Robles (Shallow)	11	below
	PCA-W	Santa Margarita (Deep)	17	below
		Paso Robles (Shallow)	2	below
	Sentinel Well 3	Santa Margarita (Deep)	4	below
Southern Coastal	CDM-MW4	Paso Robles (Shallow)	2	above

Figure 41 through Figure 44 show the historical groundwater elevations at each of the target protective elevation monitoring wells. Groundwater levels continue to be below protective elevations in all Santa Margarita target monitoring wells (MSC deep, PCA-West deep, and Sentinel Well 3). All 3 Santa Margarita monitoring wells' groundwater levels are now at the lowest in their historical records. Monitoring well CDM-MW4 is the only 1 Paso Robles well (1 of 3 Paso Robles wells total) with its groundwater level above its protective elevation. Groundwater levels in the PCA West Shallow well fell below protective elevations in WY 2020 and remain below through WY 2022. Groundwater levels in the MSC Shallow well continue to be below its protective elevation. Other than CDM-MW4, all of these wells exhibit declining trends in elevation.



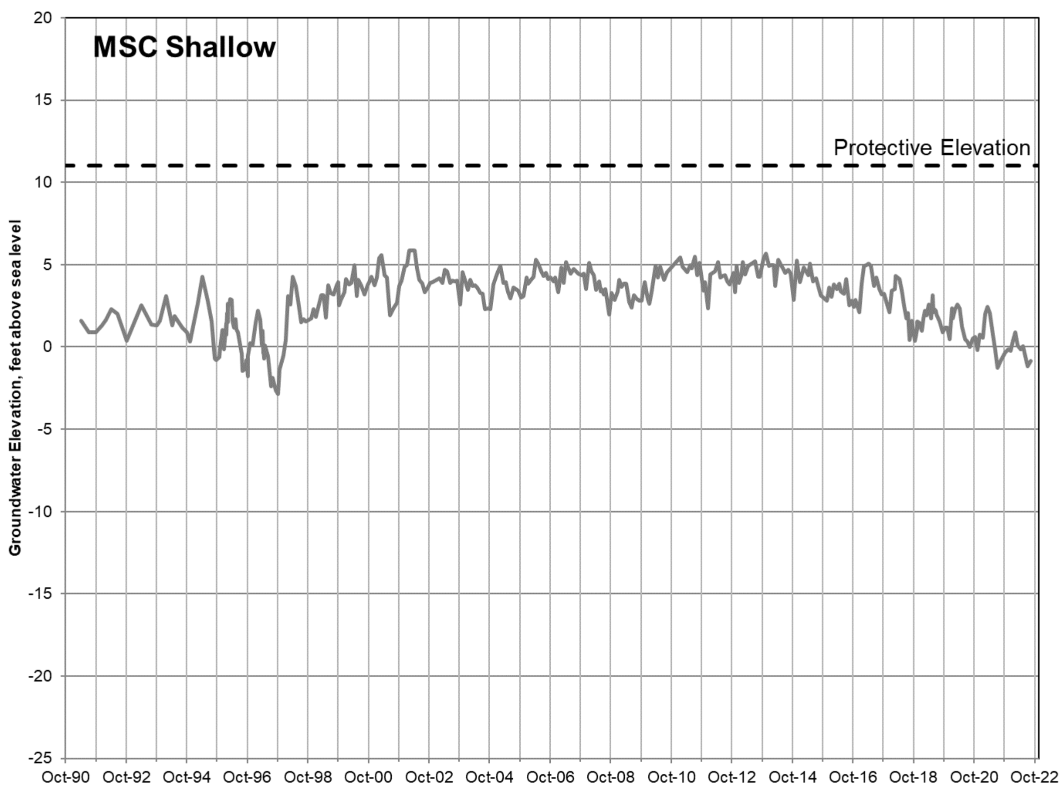


Figure 41. MSC Deep and Shallow Groundwater and Protective Elevations

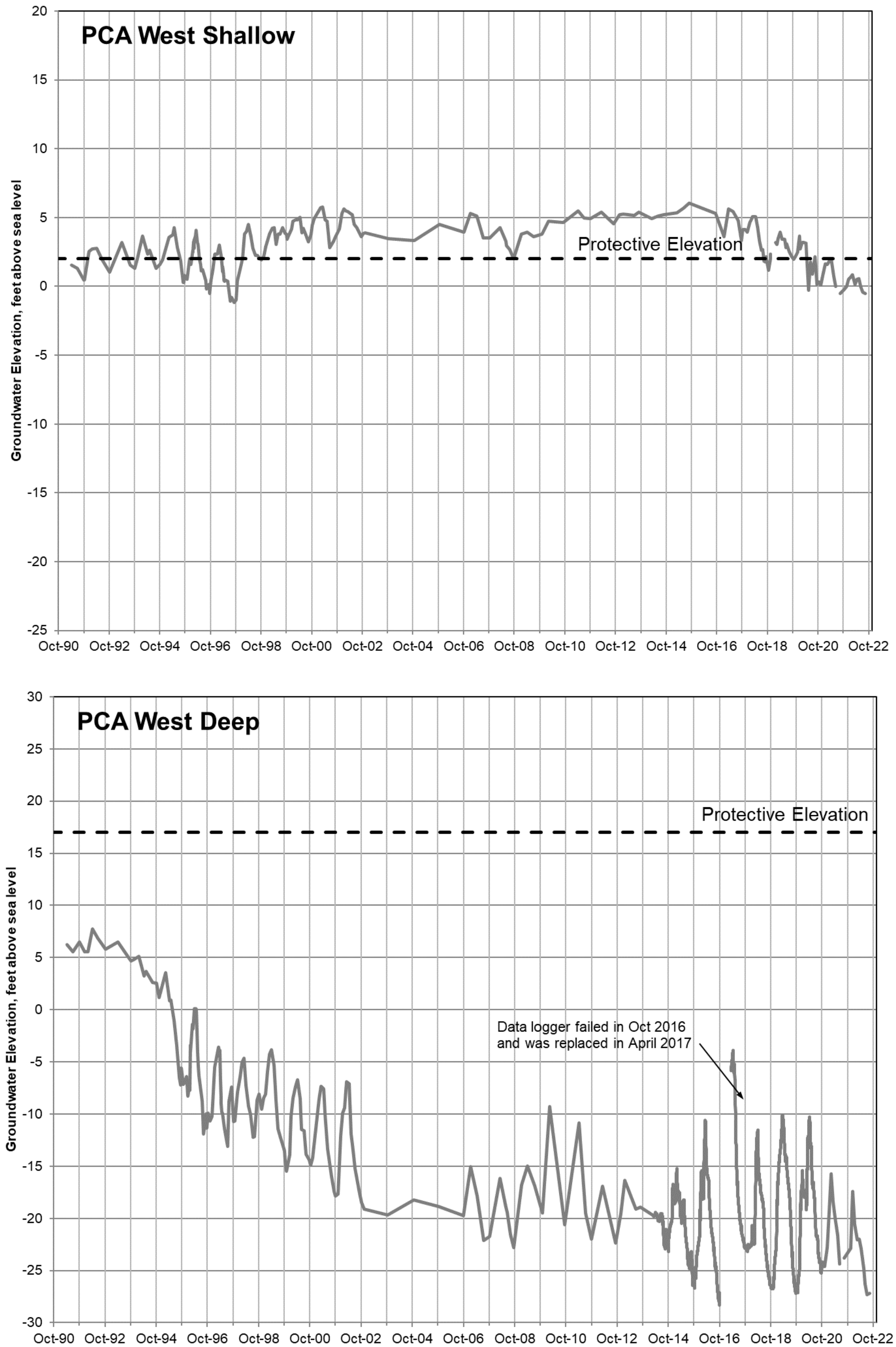


Figure 42. PCA West Deep and Shallow Groundwater and Protective Elevations

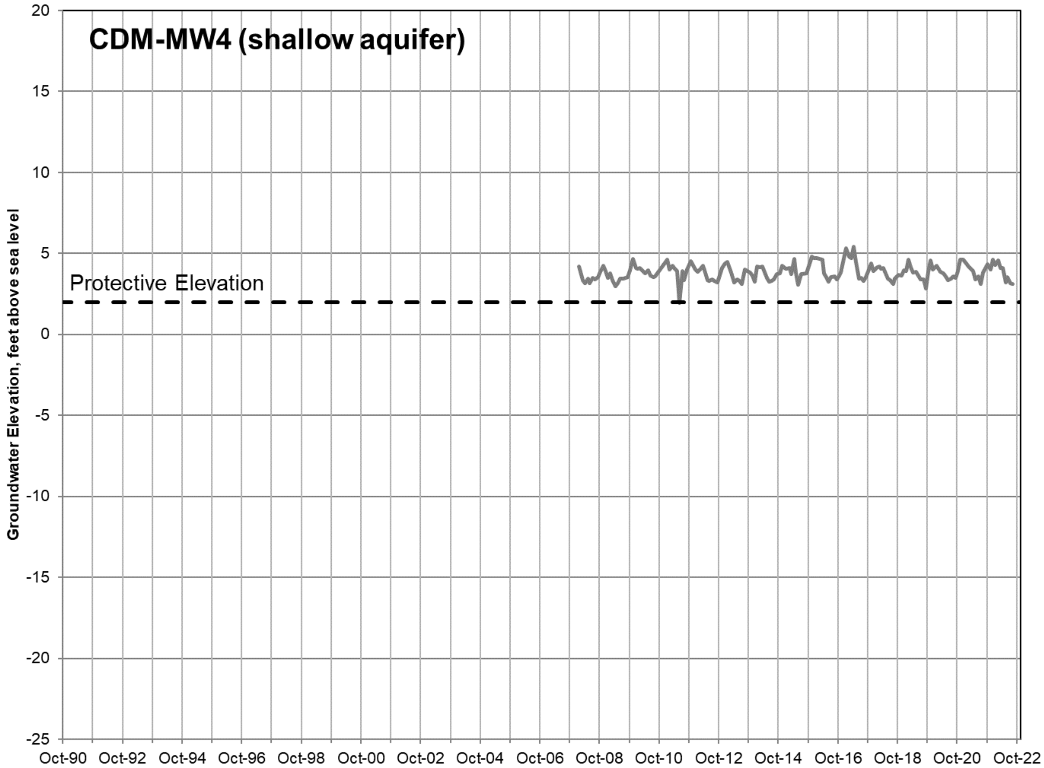


Figure 43. CDM-MW4 Groundwater and Protective Elevations

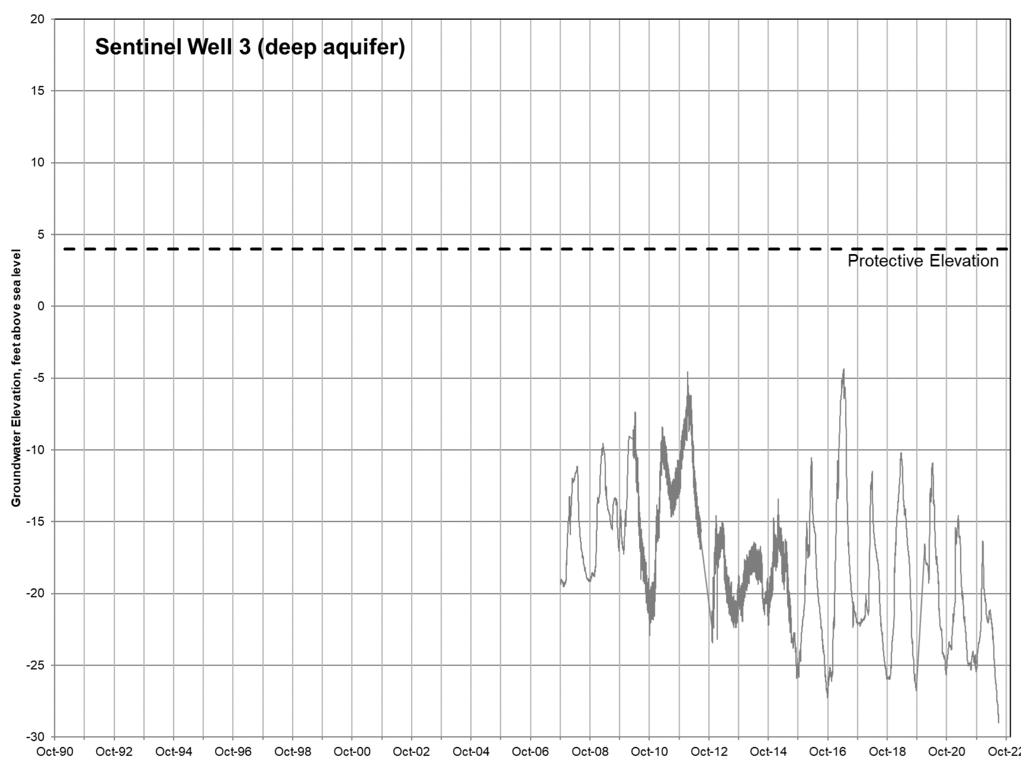


Figure 44. Sentinel Well 3 Groundwater and Protective Elevations

2.7 Groundwater Production

Groundwater pumping in excess of freshwater recharge and subsurface inflow from adjacent areas is the primary cause of seawater intrusion. Mapping pumping volumes gives an indirect indication of the threat of seawater intrusion. Ideally, to avoid seawater intrusion, pumping should be equally distributed throughout a basin and occur inland of the coast.

Gross pumping by Watermaster producers in WY 2022 was 6,554 acre-feet, which includes 3,683 acre-feet of recovery from the PWM project. Net or native groundwater pumping is the amount of groundwater pumped after both ASR and PWM recovery are considered. It is possible that in years where there is water injected and recovered, more water may be pumped from CAWC's wells to recover water injected the previous operational year.

In WY 2022, ASR and PWM wells injected 71 and 3,647 acre-feet, respectively, for a total of 3,718 acre-feet of injection. Of this injected water, 3,683 acre-feet were recovered by PWM. As reported by the Watermaster, net or native groundwater production is 2,871 acre-feet (gross pumping less recovery), which is 129 acre-feet below the Decision-ordered Operating Yield for WY 2022 of 3,000 acre-feet (Figure 45). The net or native groundwater produced from the basin in WY 2022 was roughly 43 acre-feet more than in WY 2020. The Decision-ordered Operating Yield will continue to be 3,000 acre-feet until a revised Sustainable Yield is developed.

Figure 46 shows the distribution of pumping through the basin and the volumes pumped at each production well for the past 2 years. The blue bar charts on Figure 46 reflect the actual or gross amounts pumped from each well and the green bar charts reflects the volume of ASR or PWM injection. In WY 2022, the majority of pumping in the basin occurred at CAWC's Ord Grove No. 2, Santa Margarita #1, Santa Margarita #3, and Paralta production wells.

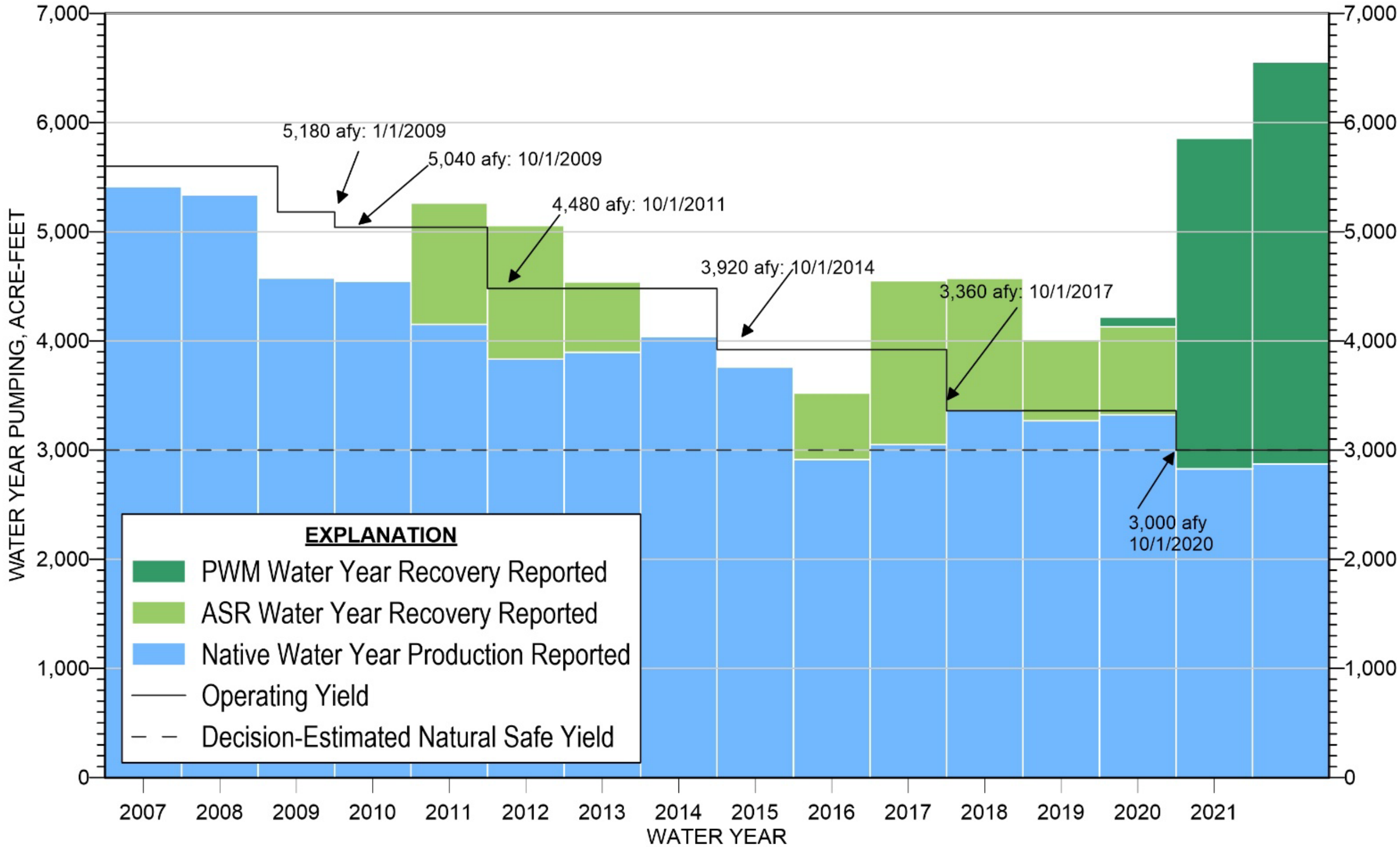


Figure 45. Annual Reported Groundwater Production and Operating Yield for Watermaster Producers

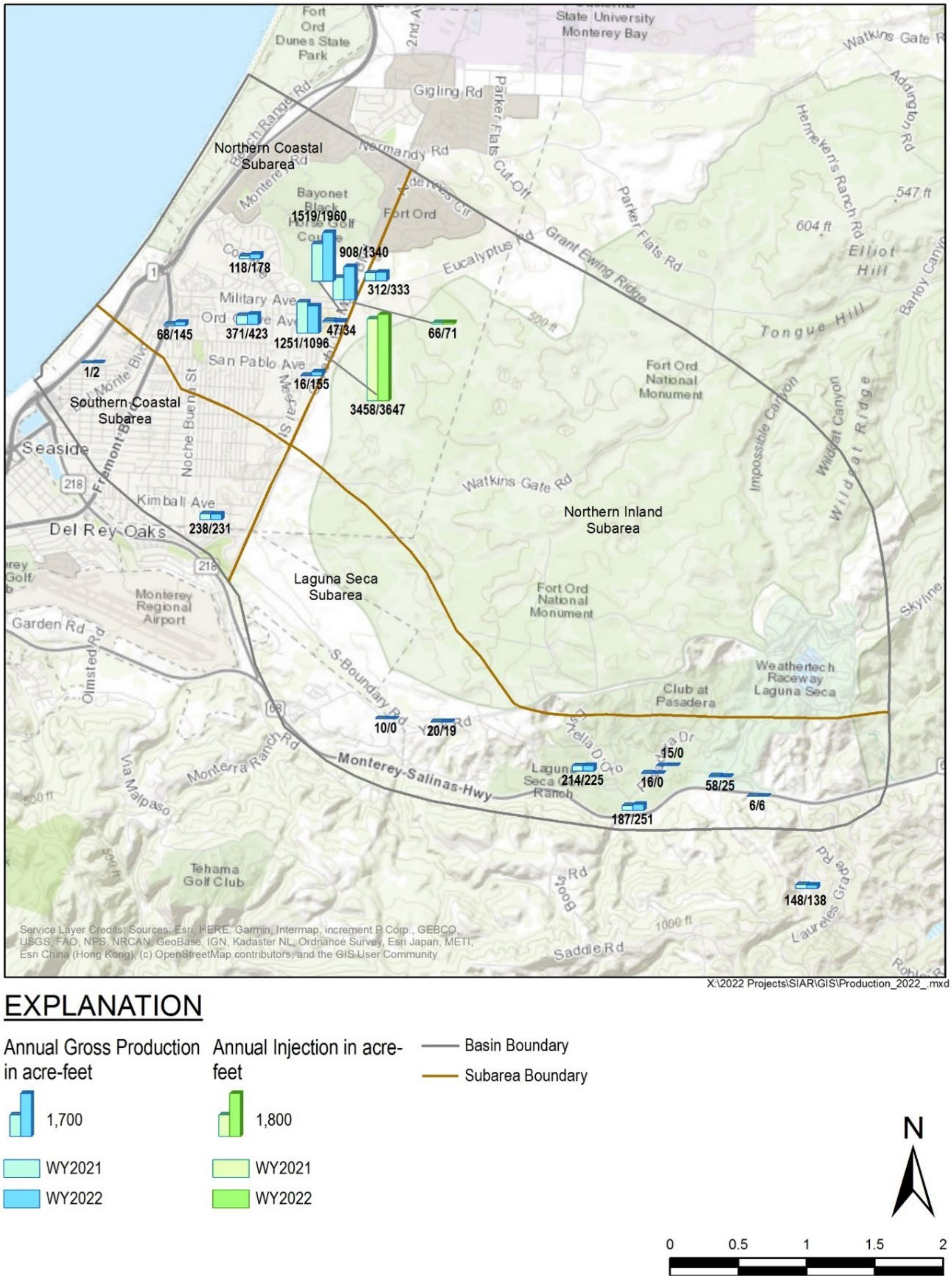


Figure 46. Watermaster Producers' Pumping Distribution for Water Years 2021 and 2022

3 CONCLUSIONS

No data collected in WY 2022 indicate that seawater intrusion is occurring within the Seaside Groundwater Basin. As noted in the previous 3 SIARs (M&A, 2019; M&A, 2020; M&A, 2021), monitoring well FO-10 shallow, located outside and just north of the Basin, has experienced sustained increased chloride concentrations and currently has a sodium/chloride molar ratio below 0.86, which may suggest a seawater chloride source. This well is located north of the Seaside Basin (Figure 10). Induction logging of this well took place in March 2021 and confirmed chloride concentrations in groundwater but was inconclusive as to whether this results from seawater intrusion (Feeney, 2021). Following this development, analysis of historical records conducted in February 2022 revealed that a 1,300-foot-long, 2-inch diameter steel tremie pipe has been stuck in the FO-10 borehole since its construction in 1997 (Feeney, 2022). The presence of this steel pipe, which conducts electricity through the borehole and may be allowing water to travel between upper and lower zones, explains the inconclusive results from the March 2021 induction logging. FO-10 Deep also a 60 mg/L chloride increase during WY 2022 and has shown extremely similar groundwater elevations to FO-10 Shallow over the past 3 years. These results could further indicate that the steel pipe is acting as a conduit. It is suggested that FO-10 Shallow and FO-10 Deep are destroyed and replaced to maintain robust water quality monitoring in the area and to prevent cross contamination between the Paso Robles and Santa Margarita aquifers, and the overlying Dune Sands. Sentinel Well induction logs, now performed annually, remain stable over the historical record. No data collected in WY 2022 indicate that seawater intrusion is occurring within the Basin.

Ongoing detrimental groundwater conditions continue to occur within the Basin that pose a potential threat of seawater intrusion. Groundwater levels below sea level, the cumulative effect of pumping in excess of recharge and freshwater inflows, and ongoing seawater intrusion in the nearby Salinas Valley all suggest that seawater intrusion has the potential to occur in the Seaside Groundwater Basin. Based on the findings of this report, the following ongoing detrimental groundwater conditions pose a direct threat of seawater intrusion:

- Both the Paso Robles and Santa Margarita aquifers in the Seaside Groundwater Basin are susceptible to seawater intrusion. The Paso Robles aquifer is in direct hydrogeologic connection with Monterey Bay, and seawater will eventually flow into it if inland groundwater levels continue to be below sea level. The Santa Margarita aquifer may not be in direct connection with Monterey Bay. If that is the case, then seawater intrusion will take longer to appear because the pathway for seawater into that aquifer will be longer as seawater would need to move through the clay rich deposits adjacent to that aquifer before entering the aquifer itself and thereafter make its way into Santa Margarita production wells. It is not if, but when, seawater intrusion into these aquifers will occur if protective water elevations are not achieved.

- Santa Margarita aquifer groundwater levels in the Northern Coastal subarea continue to be below sea level year round. WY 2022 second quarter (winter/spring) deep aquifer coastal groundwater levels are more than 40 feet below sea level and the fourth quarter (summer/fall) levels are more than 60 feet below sea level. Pumping depressions expanded both vertically and spatially from the previous year in both the shallow and deep aquifer system.
- Groundwater levels remain below protective elevations in all Santa Margarita aquifer protective elevation monitoring wells (MSC deep, PCA-W Deep, and sentinel well SBWM-3), and 2 of 3 Paso Robles protective elevation monitoring wells (MSC Shallow and PCA-W Shallow). All 3 Santa Margarita monitoring well groundwater elevations are now the lowest in their historical record. Beside PCA-W Shallow, these wells have all been uniformly below protective elevations over the period of record shown on Figure 41 through Figure 44. Elevations at PCA-W shallow were above protective elevations in early WY 2020 but have since dropped below. All wells with set protective elevations besides CDM-MW4 declined in elevation from the previous year.

It is important to remain vigilant and to closely monitor groundwater quality even though seawater intrusion has not yet been observed in monitoring or production wells in the Seaside Groundwater Basin. As outlined in the most recent Basin Management Action Plan (Montgomery & Associates, 2018a), it is important that the Watermaster continues to identify ways to reduce pumping native groundwater and/or to recover groundwater elevations with water that is left in the basin and is not extracted out as water supply.

The following evidence from this report demonstrates that seawater intrusion is not occurring:

- Most groundwater samples for WY 2022 from depth-discreet monitoring wells generally plot in a single cluster on Piper diagrams, with no water chemistry changes toward seawater. Increased chloride in recent measurements at FO-10 Shallow and FO-10 Deep, north of the Basin, has shifted how these wells plots on Piper diagrams. Currently, they appear to be shifting toward a chlorinated water type. As described above, induction logging of the FO-10 nest was inconclusive as to whether seawater intrusion is causing this change in water quality due to the presence of an abandoned steel pipe in the borehole since the well’s construction. This steel pipe may also be serving as a conduit to allow groundwater flow between aquifer zones. Groundwater quality in FO-10 Shallow and FO-10 Deep should continue to be monitored closely to identify if further increases occur, and it is suggested that both FO-10 Shallow and FO-10 Deep are destroyed and replaced to maintain a water quality record in the area.

- In some production wells, groundwater quality plot on Piper diagrams is different than the groundwater quality in the monitoring wells. This may be a result of mixed water quality from both the Paso Robles and Santa Margarita aquifers in which these wells are perforated. None of the production wells' groundwater qualities are indicative of seawater intrusion.
- None of the Stiff diagrams for monitoring and production wells show the characteristic chloride spike that typically indicates seawater intrusion in Stiff diagrams. The Stiff diagrams for monitoring wells FO-10 Shallow and FO-10 Deep show a slightly different shape than other shallow wells because of increased chloride.
- Chloride concentration trends are stable for most monitoring wells, except FO-10 Shallow and FO-10 Deep. FO-10 Shallow experienced a 48 mg/L increase in chloride concentrations in WY 2020 and has risen by another 8 mg/L since then. FO-10 Deep experienced a 60 mg/L chloride increase in WY 2022. However, the sustained elevated concentrations in themselves do not indicate seawater intrusion. As noted above, recent induction logging of the well was unable to provide data with regard to whether seawater intrusion is the source of the elevated chloride level, and the well's integrity for water quality sampling may be compromised by a steel tremie pipe stuck in the borehole since 1997.
- Sodium/chloride molar ratios in most monitoring wells remained constant or increased over the past year. The sodium chloride ratio in 2 of the 3 samples taken at FO-10 Shallow in WY 2022 were lower than what has been seen historically at the location. The ratio from 5 of the 7 samples tested since September 2020 are below 0.86. A sodium/chloride ratio less than 0.86 signifies a potential seawater chloride source. It is likely the groundwater quality changes in FO-10 Shallow are permanent and the well should continue to be monitored consistently to track if chloride concentrations increase further. If the well is destroyed and replaced due to the stuck steel pipe mentioned above, water quality from the replacement well should similarly be closely monitored to evaluate changes in chloride over time.
- Maps of chloride concentrations for the shallow aquifer do not show chlorides increasing toward the coast. Santa Margarita aquifer chloride concentration maps show that the highest chloride concentrations are limited to coastal monitoring wells PCA-West Deep and MSC Deep, but these are not indicative of seawater intrusion since their concentrations are less than 155 mg/L and they do not have increasing trends. Two wells, Pasadera Golf- Paddock and Ord Terrace Shallow, sustained a >20 mg/L chloride increase from WY 2021, but as evidenced by their distance from the coast this is not a result of seawater intrusion.

- Induction logging data at the coastal Sentinel Wells do not show historical or recent changes over time that are indicative of seawater intrusion.

Other important findings from the analysis contained in this report are:

- Due to its distance from the coast, seawater intrusion is not an issue of concern in the Laguna Seca subarea. However, groundwater levels in the eastern Laguna Seca subarea have historically declined at rates of 0.6 feet per year in the shallow aquifers, and up to 4 feet per year in the deep aquifers. These declines have occurred since 2001 despite triennial reductions in allowable pumping. The cause of the declines is due in part to the Natural Safe Yield of the subarea being too high and in part due to the influence of wells east of the Seaside Basin. Since WY 2021, groundwater elevations in the area have appeared to experience some stabilization and recovery, potentially correlated with a cessation of pumping at the Ryan Ranch wells.
- Native groundwater production in the Seaside Groundwater Basin for WY 2022 was 2,870 acre-feet, which is 43 acre-feet more than WY 2021 and 129 acre-feet less than the Decision-ordered Operating Yield for WY 2022 of 3,000 acre-feet. Despite WY 2022 being a very dry year, recovery of 3,683 acre-feet of recycled water from PWM helped offset pumping. Native groundwater production was below the Decision-estimated Natural Safe Yield of 3,000 acre-feet for the third year in the historical record, largely due to this increased injection of highly treated recycled water.

4 RECOMMENDATIONS

The analyses presented previously in this report are based on existing data. While informative, the data are spatially incomplete and temporally sporadic. The following recommendations should be implemented to monitor and track seawater intrusion.

Execute Plans to Replace FO-9 Shallow with New Monitoring Well

Following identification of a compromised well casing, monitoring well FO-9 Shallow was destroyed to prevent leakage of higher chloride water underlying aquifers. In accordance with current plans, a similarly constructed monitoring well will replace the destroyed well to ensure continuity of groundwater level measurements from this location. It is anticipated that a new well will be constructed in 2023.

Destroy and Replace FO-10 Shallow and FO-10 Deep

The discovery of a 1,300-foot steel tremie pipe in the FO-10 borehole complicates evaluation of water quality at the location and may act as a conduit allowing groundwater to flow between overlying sediments and the underlying aquifers. This is further supported by similar trends in groundwater elevation and chemistry over the past 3 years. These wells are outside of the Basin, yet still provide critical information regarding the extent of seawater intrusion north of the Basin in the Monterey Subbasin. Therefore, it is recommended that MPWMD develop plans to destroy the well and that MCWD install a similarly constructed monitoring to maintain a continuous water quality record at the location. Because seawater intrusion cannot be excluded as the source of increasing chloride concentrations at FO-10 Shallow over the past several years, groundwater quality sampling at this well should continue at the increased quarterly frequency until the well is destroyed. When the well is replaced, the replacement well should likewise be sampled at a quarterly frequency.

As detailed in the Monterey Subbasin GSP (MCWDGSA and SVBGSA, 2022) Section 9.4.7, additional monitoring wells may be installed in both the Lower 180-Foot and 400-Foot Aquifer and the Deep aquifers of the Monterey Subbasin. The proposed location for these wells is in an identified data gap area northeast of FO-10 Shallow (see Monterey Subbasin GSP Figures 7-7 and 7-8). When these wells are installed, they may provide additional insight into potential seawater intrusion in the area.

Continue to Analyze and Report on Water Quality Annually

Seawater intrusion is a threat to the basin, and data must be collected and analyzed regularly to identify incipient intrusion. Maps, graphs, and analyses similar to what are found in this report should continue to be developed every year.

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