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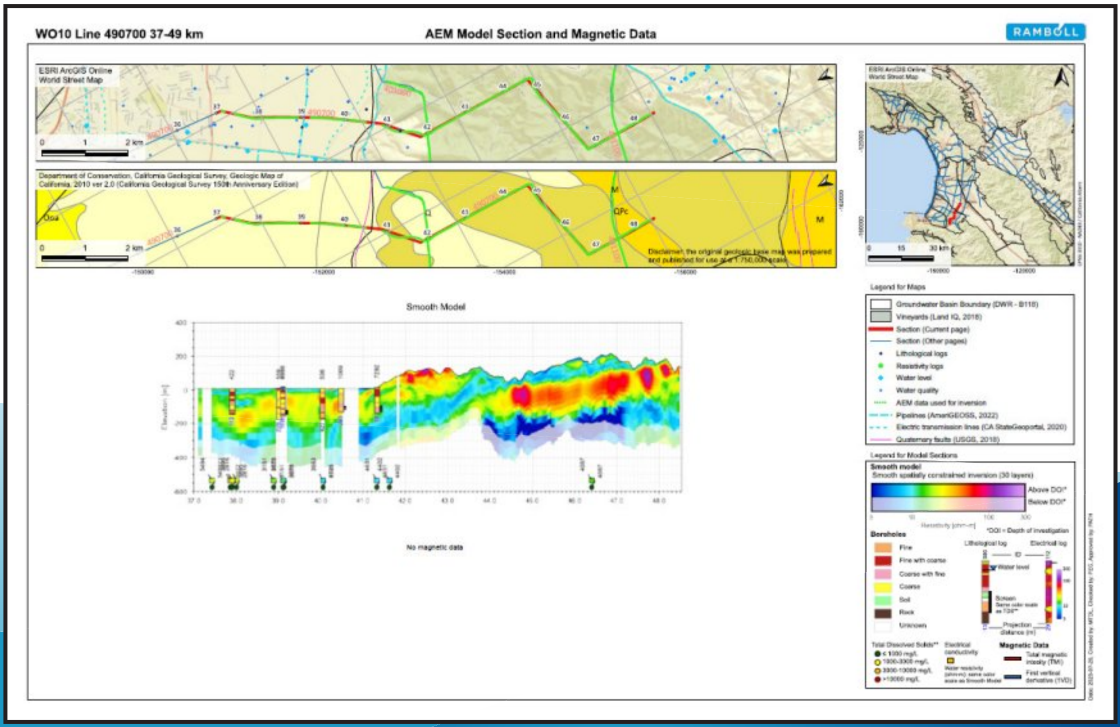
FINAL REPORT

April 2024

Deep Aquifers Study

Prepared for:

SVBGSA and Collaborative Funding Partners



201 Hoffman Ave, Suite 9, Monterey, CA
elmontgomery.com

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Deep Aquifers Study

Prepared for:

Salinas Valley Basin Groundwater Sustainability Agency and Collaborative Funding Partners

Prepared by:

Montgomery & Associates

201 Hoffman Ave, Suite 9, Monterey, CA 93940

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ACRONYMS & ABBREVIATIONS

AEM..............Airborne Electromagnetic
AF/yr.............acre-feet per year
ASR...............aquifer storage and recovery
BOS...............Board of Supervisors
CSIP..............Castroville Seawater Intrusion Project
DDW.............Division of Drinking Water
DWR.............California Department of Water Resources
ft/day.............feet per day
ft^2/d................square feet per day
GEMS...........Groundwater Extraction Management System
GMWL..........Global Mean Water Line
GSA...............Groundwater Sustainability Agency
GSP...............Groundwater Sustainability Plan
GTAC............Groundwater Technical Advisory Committee
ILRP..............Irrigated Lands Regulatory Program
InSAR...........Interferometric Synthetic-Aperture Radar
M&A.............Montgomery & Associates
MBGWFM.....Monterey Basin Groundwater Flow Model
MCWD..........Marina Coast Water District
MCWRA........Monterey County Water Resources Agency
mg/L..............milligrams per liter
MMP.............Monitoring and Management Plan
PWM.............Pure Water Monterey
RMS..............Representative Monitoring Site
SGMA...........Sustainable Groundwater Management Act
SVBGSA........Salinas Valley Basin Groundwater Sustainability Agency
SVIHM..........Salinas Valley Integrated Hydrologic Model
SWI Model.....Seawater Intrusion Model
SWIG............Seawater Intrusion Working Group
SWIG TAC....SWIG Technical Advisory Committee
SWRCB..........State Water Resources Control Board
TDS...............total dissolved solids
USGS............United States Geological Survey
VSMOW........Vienna Standard Mean Ocean Water
WCR.............well completion report
‰...................per mil unit

EXECUTIVE SUMMARY

The Deep Aquifers increasingly provide vital groundwater resources for drinking water, irrigation, and industrial uses in the Salinas Valley. The Salinas Valley Basin Groundwater Sustainability Agency (SVBGSA) and collaborative funding partners jointly financed this Study of the Deep Aquifers to address critical questions regarding the geology and hydrogeology of the Salinas Valley's Deep Aquifers and provide a scientific basis for sustainable management.

Introduction

Declining groundwater elevations in the Deep Aquifers over the past few decades prompted the need for this Study. Despite chronic groundwater elevation declines in most Deep Aquifers wells, well installations continued. Extractions from the Deep Aquifers in the Seaside, Monterey, and coastal 180/400-Foot Aquifer Subbasins have been occurring since the 1980s, increasing at a steeper rate over the past decade in the coastal 180/400-Foot Aquifer and Monterey Subbasins. Since 2014, many new agricultural Deep Aquifers wells have been installed in the areas that are seawater-intruded in the 180- and 400-Foot aquifers, and where the Castroville Seawater Intrusion Project (CSIP) does not deliver an alternative water supply. Data indicate that recent surface water has not infiltrated into the Deep Aquifers under current climate conditions, and groundwater elevation declines highlight the risk of seawater intrusion and subsidence.

This Study compiles all available data into a scientifically robust report characterizing the geology and hydrogeology of the Deep Aquifers in the Salinas Valley. Collection and integration of different types of data fills key data gaps and provides science-based guidance for management.

Definition of the Deep Aquifers

This Study builds on the various definitions used in prior studies and analyses by defining the Deep Aquifers as the aquifer system present below the 400-Foot Aquifer or its stratigraphic equivalent. More specifically, it defines the Deep Aquifers as the water-bearing sediments that are below a relatively continuous aquitard or area of higher clay content encountered between approximately 500 feet and 900 feet below land surface within the Salinas Valley Basin. The relatively continuous high-clay aquitard, or 400/Deep Aquitard, must be below the identified 400-Foot Aquifer or its stratigraphic equivalent, and the sediments must be within the Paso Robles Formation, Purisima Formation, and/or Santa Margarita Sandstone.

Hydrogeologic Conceptual Model

Previous studies, existing data, and Study-generated data are integrated to develop a hydrogeologic conceptual model that summarizes the physical framework in which groundwater occurs and moves. Based on the definition of the Deep Aquifers, Figure ES-1 shows the extent of the Deep Aquifers as well as areas labeled as uncertain, which are areas with uncertain presence or continuity of the 400/Deep Aquitard. The scant aquifer test data for the Deep Aquifers indicate the aquifer properties are typical of deep confined aquifers with specific storage ranging from $1x10^{-5}$ to $1x10^{-6}$ 1/foot (Hanson, *et al*., 2002), which is typical for other deep aquifers in coastal areas and generally smaller than storage values in overlying aquifers that are less confined and less consolidated. Measured hydraulic conductivity values range from 2 to about 36 feet per day (ft/day), with a geometric mean of about 10 ft/day. These Deep Aquifers values are generally lower than those of the overlying aquifers, indicating groundwater moves more slowly in the Deep Aquifers; however, available data are limited to the coastal areas.

Water chemistry shows the Deep Aquifers' water type is distinct from the overlying aquifer. Within the Deep Aquifers, the chemistry differs between the south coastal and north coastal areas, transitioning in the middle of the Monterey Subbasin. There are no samples from the inland part of the Deep Aquifers southeast of the City of Salinas. Isotopic analysis indicates the areas sampled have received no recharge of surficial water since at least 1953.

This Study identifies areas of hydraulic connectivity that could be potential pathways for subsurface inflows and outflows. Because the Deep Aquifers are defined as being below an aquitard, there are no surficial outcrops of the Deep Aquifers and no natural, direct surficial recharge. The geologic formations that constitute the Deep Aquifers extend beyond the 400/Deep Aquitard, and the Deep Aquifers are likely in hydraulic communication with these adjacent areas through subsurface inflow and outflow. Therefore, groundwater inflow to and outflow from the Deep Aquifers can come from adjacent aquifers and/or the slow leakage of water between the Deep Aquifers and overlying 400-Foot or equivalent aquifer.

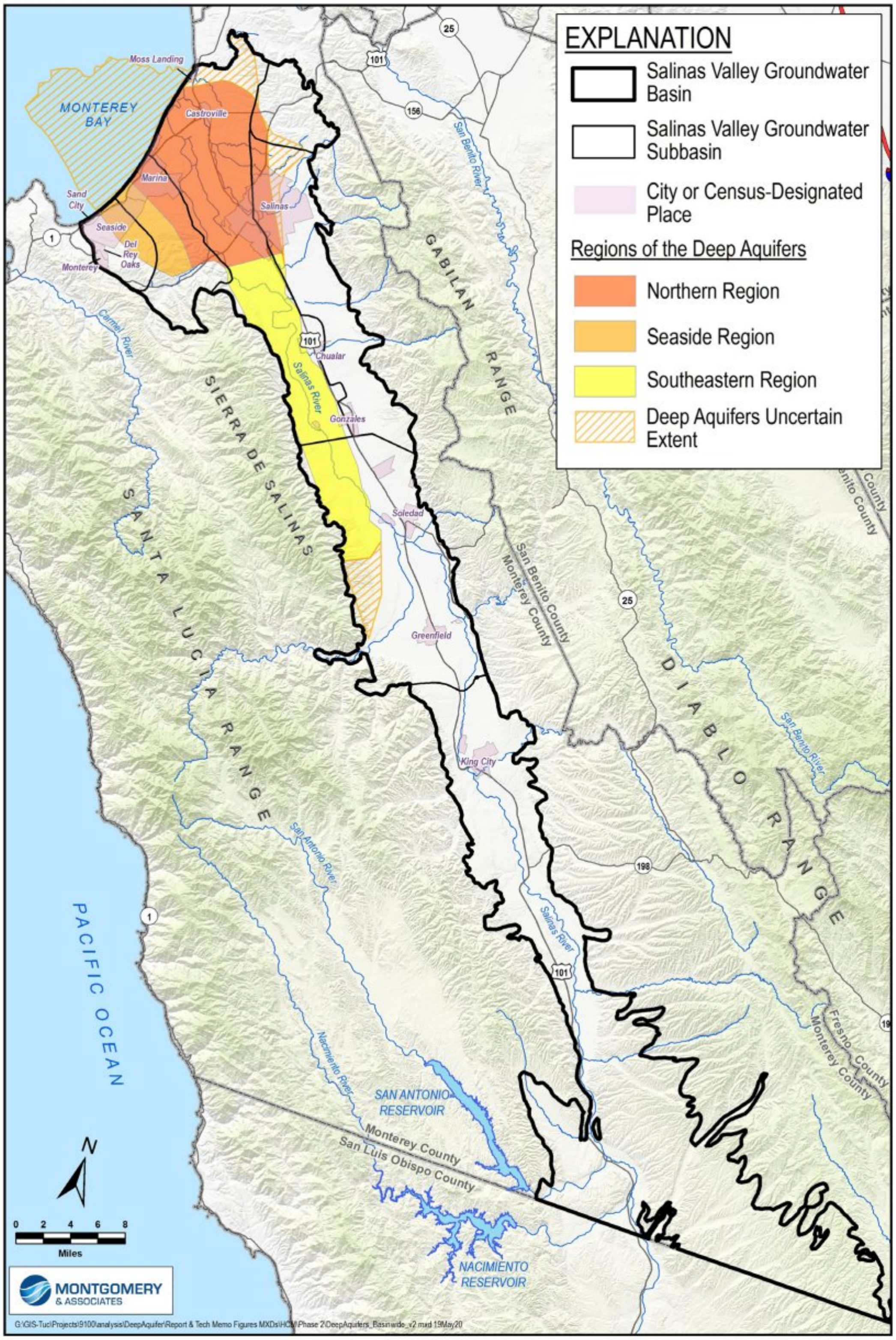


Figure ES-1. Extent of the Deep Aquifers in the Salinas Valley

Regions of the Deep Aquifers

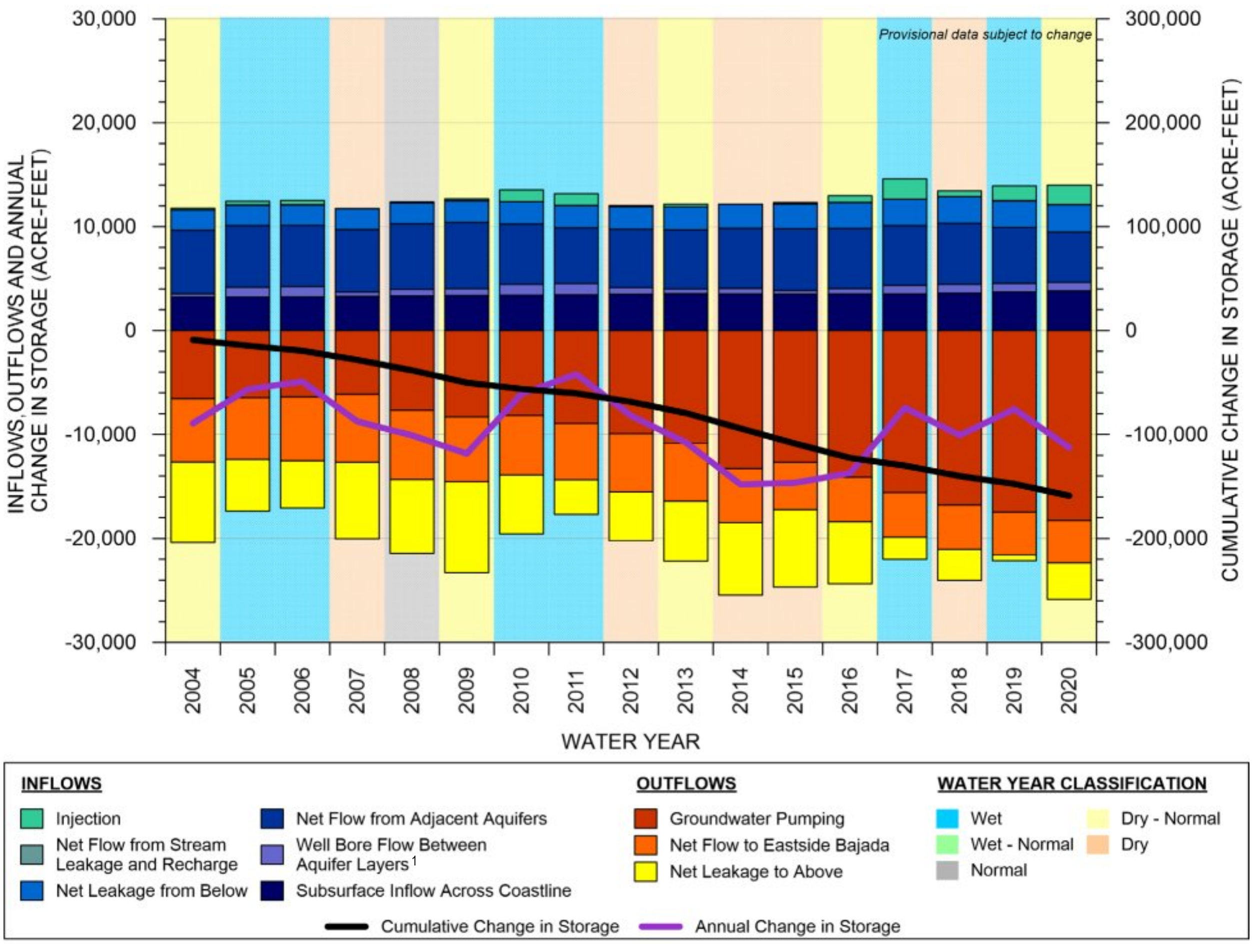
The Deep Aquifers area is divided into the 3 regions shown on Figure ES-1 based on differing geology, water chemistry, groundwater elevation trends, and aquifer use. The Seaside Region includes the portion of the Deep Aquifers within the Seaside Subbasin, as well as the adjacent southern portion of the Monterey Subbasin. The water chemistry in the Seaside Region differs from the adjoining Northern Region, and the Santa Margarita Sandstone is encountered in wells in the Seaside Region but not the Northern Region. The boundary is delineated by an approximate groundwater divide location, separating groundwater flowing toward the Seaside Subbasin from groundwater flowing toward the north. However, the divide can migrate based on changes in pumping. While the boundary does not coincide with subbasin boundaries, all extraction and injection in the Seaside Region occurs within the Seaside Subbasin.

The Northern Region is the north coastal area that includes the northern part of the Monterey Subbasin and 180/400-Foot Aquifer Subbasin down to the south side of Salinas. It includes the area covered by CSIP; cities of Marina, Salinas, and Castroville; and the agricultural area west of Salinas.

The Southeastern Region is the inland or up valley portion of the Deep Aquifers, delineated just south of the City of Salinas. This Region is separated due to lack of true Deep Aquifers groundwater elevation and chemistry data. There is also limited pumping within the Southeastern Area, and most pumping is from wells screened across both the 400-Foot and Deep Aquifers.

Water Budgets

The Deep Aquifers water budget developed for this Study provides reasonable estimates of groundwater entering and leaving the Deep Aquifers, and annual changes in groundwater storage using currently available tools. Based on an evaluation of available groundwater models, this Study uses the Salinas Valley Integrated Hydrologic Model (SVIHM) and Salinas Valley Seawater Intrusion Model (SWI Model) to develop a historical (2004-2017) and recent (2018-2020) water budget for the Deep Aquifers. The water budget for the entire extent on Figure ES-2 shows groundwater storage has declined on average 9,000 AF/yr in the historical water budget and 9,600 AF/yr in the recent water budget. Pumping and injection have increased, while flow upward to the 400-Foot Aquifer has decreased. The recent water budget shows subsurface inflow from adjacent aquifers around the extent except for outflow to the Gabilan Bajada along the eastern edge of the Deep Aquifers.



1 "Well Bore Flow Between Aquifer Layers" is described in Appendix F.

Figure ES-2. Inflows, Outflows, and Change in Storage for the Full Deep Aquifers

The water budget is disaggregated into the 3 regions. The largest groundwater storage decline is in the Northern Region, increasing in the recent period in response to an increase in pumping. The Seaside Region storage decline fell to zero in the recent period, largely thanks to the added injection. Limited Deep Aquifers data exist in the Southeastern Area for model calibration, so there is greater uncertainty than in the Northern and Seaside Regions. These estimates will be revised as additional data are acquired and groundwater models are refined.

Historical and Current Conditions

Currently, 43 pumping wells are screened solely in the Deep Aquifers and 9 wells are completed with screens across both the 400-Foot and Deep Aquifers. In this Study, the wells screened solely in the Deep Aquifers are referred to as true Deep Aquifers wells. Water Year 2022 groundwater extraction from the Deep Aquifers ranged from 13,800 AF from the true Deep Aquifers wells to 17,700 AF, with the difference being extraction from wells that are screened in the Deep Aquifers and overlying 400-Foot Aquifer. Figure ES-3 shows the spatial distribution of extraction. The circle symbol size correlates with the relative amount of 2022 Deep Aquifers extraction, and wells completed in both the 400-Foot and Deep Aquifers are designated with a star, indicating that the pumping draws from both aquifers.

Groundwater elevations in the Deep Aquifers fluctuated historically but have been on a general downward trend over the last 2 decades. Cumulative groundwater elevation change is shown on Figure ES-4. While pumping has been relatively stable in the Seaside Region since 1995, groundwater elevations have still declined due to the concentration of pumping in 1 main area. Pumping has increased dramatically since 2014 in the Northern Region, and Deep Aquifers groundwater elevations have declined in response. The cumulative groundwater elevation change is based on wells with long historical records, and as such, the last few years do not capture the declines in the area where new agricultural wells have been installed due to lack of historical data. In some recent years, fall groundwater elevation measurements have increased in some wells, likely due to lower pumping in the months immediately preceding the groundwater elevation measurements; however, groundwater elevations continued to decline throughout much of the Northern Region. In the Southeastern Region, true Deep Aquifers groundwater elevations are not available.

Spatially, there are 3 pumping depressions: near Castroville, west of the City of Salinas where the recent agricultural wells have been installed, and in Seaside.

Pumping increases in the Deep Aquifers have caused groundwater elevations in the Deep Aquifers to fall below groundwater elevations in the overlying 400-Foot or equivalent aquifer, reversing the vertical gradient from upward to downward across most of the Northern and Seaside Regions of the Deep Aquifers. The current downward gradient puts the Deep Aquifers at risk of seawater intrusion from the overlying aquifer through poorly constructed wells or vertical leakage through the 400/Deep Aquitard, which is known to contain intermittent pockets of sands and have a variable thickness across the extent of the Deep Aquifers. Low groundwater elevations also create an inland hydraulic gradient that increases the risk of seawater intruding laterally from the ocean.

If seawater does not fill in the pore spaces, the low groundwater elevations leave the Deep Aquifers at risk of subsidence. In confined aquifer systems like the Deep Aquifers, groundwater withdrawals result in imbalanced pressure between the aquifers and aquitards that can cause water to slowly seep out of the clays and collapse. This depressurizing, or dewatering, can result in land subsidence. Although subsidence has not been seen to date, because of its associated time delays subsidence still may be triggered by current groundwater elevations.

Arsenic is the only groundwater quality constituent found to be above the Maximum Contaminant Limit (MCL) in the most recent sampling. Historically, arsenic has only been found above the MCL in 1 Castroville well. While not found within the most recent sampling, iron and manganese have been found above the MCL within the past 5 years in Deep Aquifers wells.

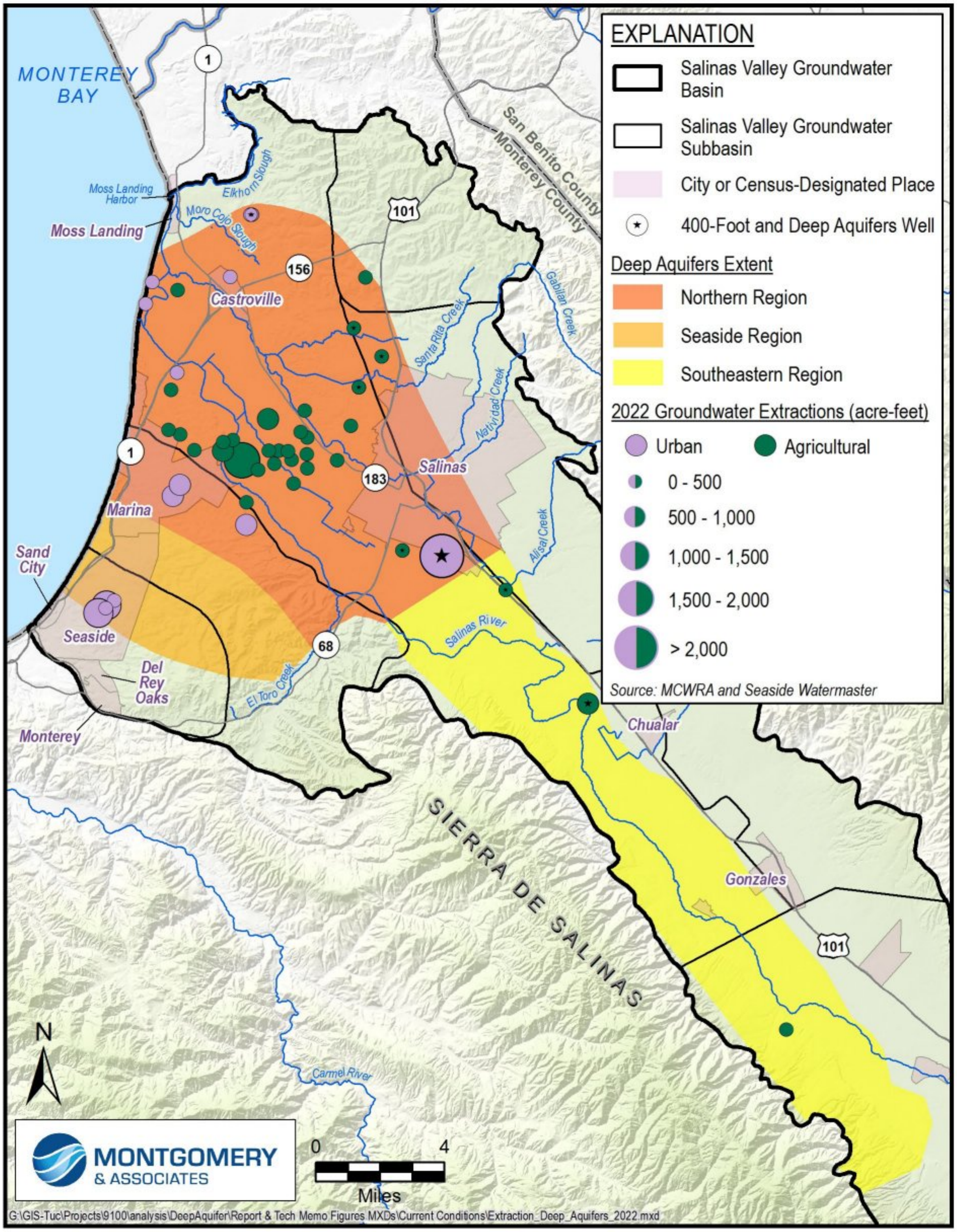


Figure ES-3. 2022 Extraction in the Deep Aquifers

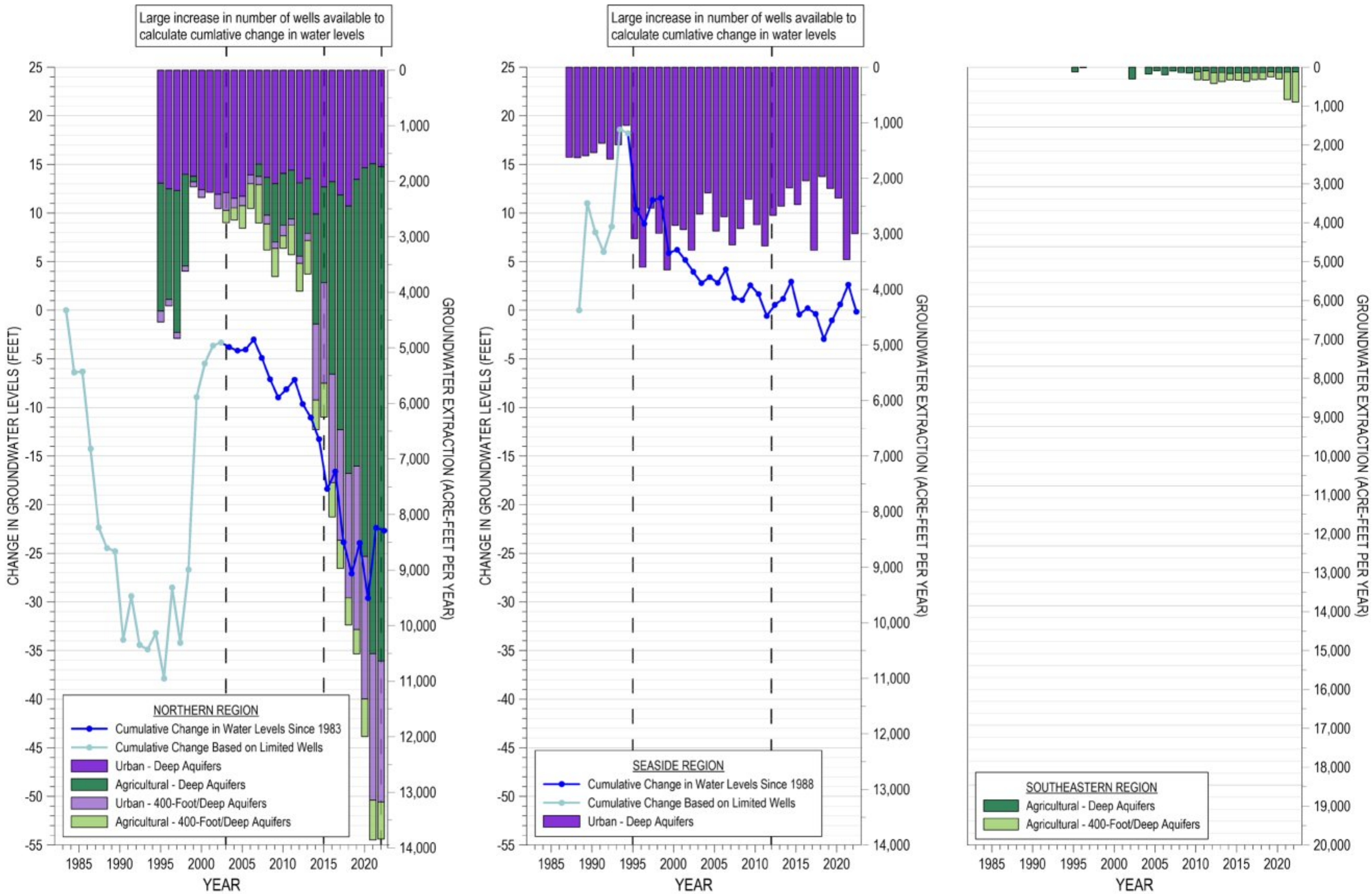


Figure ES-4. Cumulative Change in Groundwater Elevations in the Deep Aquifers by Region

Guidance for Management

Guidance for managing the Deep Aquifers is based on the findings of the Study. Management must fit within the existing regulatory context, including the adjudication of the Seaside Subbasin, Sustainable Groundwater Management Act (SGMA), and well permitting process. Lack of proper management could result in seawater intrusion and subsidence, both of which can result in a severe economic impact.

The Study provides 12 pieces of guidance aimed at halting further degradation and improving groundwater elevations to prevent seawater intrusion and subsidence. These focus on providing science-based guidance where there is sufficient data for managing the Deep Aquifers. It does not extend to policy decisions, as those are beyond the current Study scope and should be done together with local groundwater management agencies and key stakeholders.

Type of Management

1. Manage the Deep Aquifers through a combination of 3 general types of management actions and projects: demand management, provision of alternative water supply, and injection.

Location of Management

2. Differentiate groundwater management by the 3 Regions within the extent of the Deep Aquifers: Northern Region, Seaside Region, and Southeastern Region.

Recommended Principles of Management

3. To prevent seawater intrusion from downward migration through the 400/Deep Aquitard or wells, maintain protective groundwater elevations higher than the overlying 400-Foot or equivalent aquifer groundwater elevations where intrusion is present.
4. Assess the preferred option for controlling lateral seawater intrusion.
5. To prevent subsidence, keep Deep Aquifers groundwater elevations above historical lows at a minimum.
6. In the Northern and Seaside Regions, use sustainable/safe yield by Region based on the best available tools to guide initial groundwater management, and adjust management over time according to changes in observed groundwater elevations.
7. In the Southeastern Region, manage groundwater if declining groundwater elevations in true Deep Aquifers wells indicate a state of chronic overdraft.
8. Manage the Deep Aquifers together with overlying and adjacent aquifers.

Regulation of Wells

9. Ensure any new wells installed in the Deep Aquifers within the Northern and Seaside Regions do not increase net extraction since existing extraction, or existing extraction and

injection in the case of Seaside, is still resulting in groundwater elevation declines. New wells in the Southeastern Region should not cause increased net extraction if Deep Aquifers groundwater elevations are found to be declining.

10. In the Areas of Uncertainty outside the delineated extent, take a precautionary approach to new wells by preventing increases in net extraction unless it is determined the Deep Aquifers do not extend into them.
11. Destroy wells that may facilitate seawater intrusion leakage into the Deep Aquifers if evidence of leakage is detected and the leakage was caused by the well.

Process to Manage

12. Adaptively manage Deep Aquifers such that quantity of extraction and injection is reviewed and revised periodically based on groundwater elevations.

Monitoring Recommendations

This Study makes recommendations for refining existing monitoring networks to track trends, identify changes, and enhance the understanding of groundwater conditions in the Deep Aquifers. Based on the definition, extent, and data analysis in this Study, wells to keep or add to the monitoring networks are recommended. All groundwater extraction of wells installed into the Deep Aquifers should be reported. The Study recommends 82 wells for the groundwater elevation monitoring network that are to be monitored at least quarterly, including 7 new wells that are recommended to fill data gaps. Groundwater quality monitoring, including general mineral chemistry, is currently conducted through the existing MCWRA, SWRCB, Seaside Watermaster, and ILRP programs. The Study recommends this monitoring be continued under the specifications of each respective program, with the monitoring frequency potentially increased based on risk of seawater intrusion and constituents of concern found. The recommended water quality monitoring network consists of 66 wells, including 7 wells needed to fill data gaps. Finally, periodic assessment of the relationship between extraction, groundwater elevations, and quality and stable isotope sampling is recommended every 3 to 5 years to better understand the impact of extraction and injection and provide insight on the relationship between the Deep Aquifers and adjacent and overlying aquifers.

1 INTRODUCTION

The Deep Aquifers increasingly provide vital groundwater resources for drinking water, irrigation, and industrial use in the Salinas Valley. The Salinas Valley Basin Groundwater Sustainability Agency (SVBGSA) and collaborative funding partners jointly financed this Study of the Deep Aquifers to address critical questions regarding the geology and hydrogeology of the Salinas Valley's Deep Aquifers and provide a scientific basis for sustainable management. SVBGSA selected Montgomery & Associates (M&A) to collect additional data to fill key knowledge gaps and conduct the Study.

1.1 Background

Previous studies have pointed to the need to monitor and manage the Deep Aquifers due to declining groundwater elevations and resulting risk of seawater intrusion (Feeney and Rosenburg 2003, MCWRA 2017, MCWRA 2020). In addition, the 2014 Sustainable Groundwater Management Act (SGMA) requires that aquifers be managed sustainably by 2040 for the 180/400-Foot Aquifer Subbasin and 2042 for the remaining subbasins in the Salinas Valley that fall partially or entirely under the jurisdiction of SVBGSA.

This Study builds on several local efforts that identified the following deteriorating groundwater conditions of the Deep Aquifers:

- **2017 *Recommendations to Address the Expansion of Seawater Intrusion in the Salinas Valley Groundwater Basin* report and its *2020 Update*:** Monterey County Water Resources Agency (MCWRA) prepared reports that identified the risk of seawater intrusion to the Deep Aquifers and included recommendations for prevention, further investigation of the hydraulic properties, and long-term viability of the Deep Aquifers.
- **90-Day Working Group and Monterey County Ordinances No. 5302 and 5303**: MCWRA staff convened a Working Group to develop an interim urgency ordinance to address the issues presented in the 2017 *Recommendations* Report. The Monterey County Board of Supervisors (BOS) approved the resulting Ordinance No. 5302 in May 22, 2018, which was extended by Ordinance No. 5303 on June 26, 2018. The Ordinances prohibited construction of new wells in the Deep Aquifers unless exempted by ordinance, and required certain data be collected from wells drilled into the Deep Aquifers. The Ordinances expired on May 21, 2020.
- **Groundwater Sustainability Plans (GSPs):** The 180/400-Foot Aquifer Subbasin GSP, Monterey Subbasin GSP, and Eastside Subbasin GSP highlight the need to address the declining groundwater levels in the Deep Aquifers and include management actions to do so. Annual reports since GSP development have shown that Deep Aquifers groundwater levels continue to decline.

- **Seawater Intrusion Working Group (SWIG) and SWIG Technical Advisory Committee (SWIG TAC)**: SVBGSA convened the SWIG and SWIG TAC to address seawater intrusion, including the threat of seawater intrusion to the Deep Aquifers. The SWIG and SWIG TAC recommended topics that should be addressed in this Study.

These local efforts highlighted the need for additional studies about the Deep Aquifers to investigate the potential for seawater intrusion and provide a scientific basis for managing groundwater sustainability. Building on studies done by MCWRA, the SVBGSA assumed the role of organizing collaborative funding partners for the Deep Aquifers Investigation, issuing the Request for Qualifications, and overseeing the completion of the Deep Aquifers Study. The collaborative funding partners include the following:

- Agriculture
- Alco Water
- California Water Service
- Castroville Community Services District
- City of Salinas
- Marina Coast Water District GSA
- County of Monterey
- MCWRA
- SVBGSA

1.2 Study Motivators

The following Deep Aquifers conditions and concerns prompted the need for this Study:

- **Declining groundwater elevations:** Chronic groundwater elevation declines have occurred in most Deep Aquifers wells. Declines began in the coastal areas in the 1990s and have accelerated as more wells have been installed (Feeney and Rosenberg, 2003). In the coastal Deep Aquifers of the 180/400-Foot Aquifer Subbasin, groundwater levels rebounded after the Castroville Seawater Intrusion Project (CSIP) came online in 1998, and then have mostly been declining again since 2000. No groundwater levels from wells solely screened in the Deep Aquifers are available south of the City of Salinas. Figure 1-1 shows a cumulative groundwater elevation change since 2004 for coastal regions of the Deep Aquifers as defined in this Study, based on wells screened solely in the Deep Aquifers. The slight rise in recent years is due to a reduction in pumping in certain wells in the months preceding the fall measurements. The early reduction in pumping allows groundwater elevations in the coastal area to rebound prior to the fall measurements. However, groundwater elevations continue to decline across most of the Deep Aquifers.

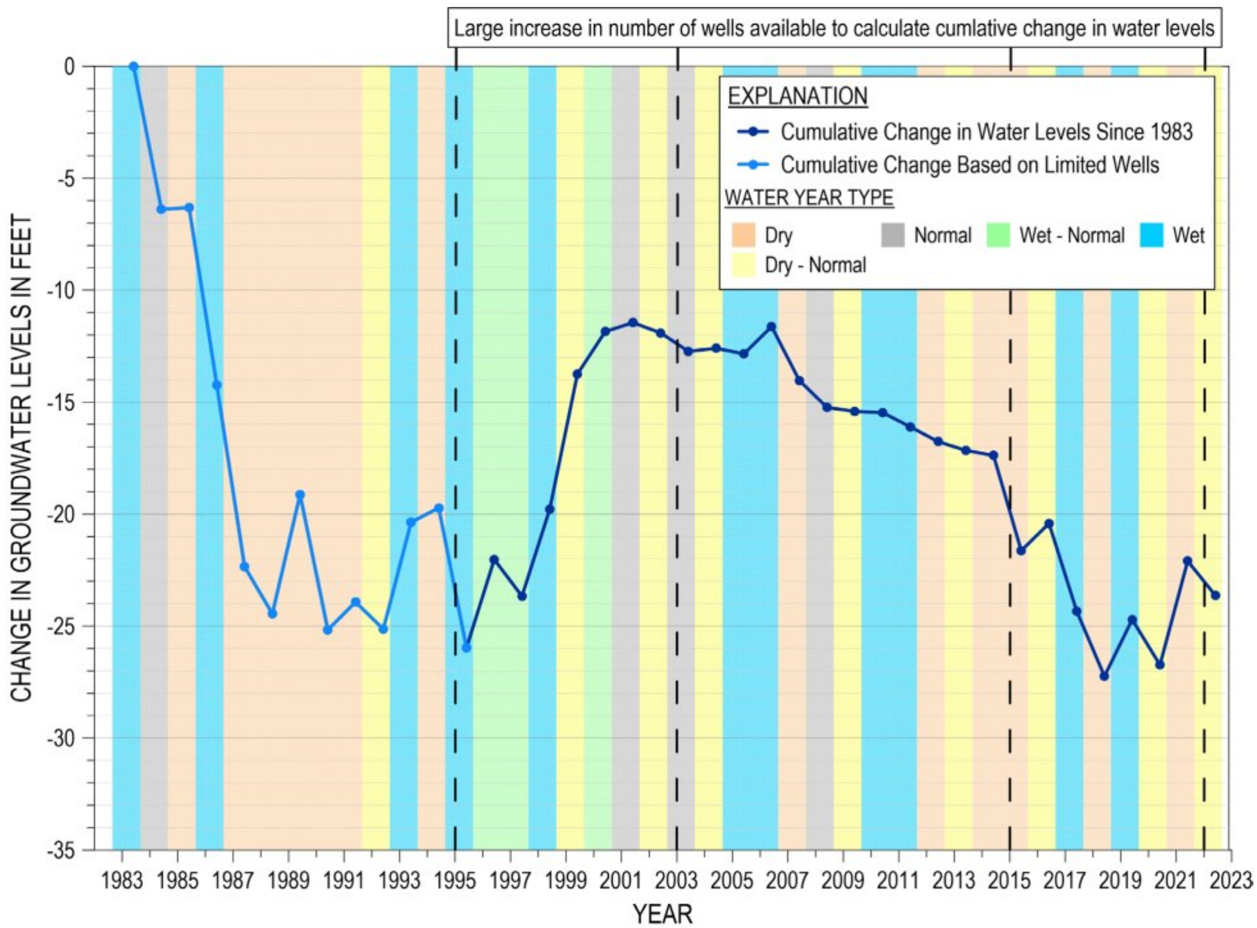


Figure 1-1. Cumulative Change in Groundwater Elevations in the Deep Aquifers

- **New well installations and increasing extraction**: As shown on Figure 1-2, installation of wells partially or entirely completed in the Deep Aquifers increased over time. This includes some wells that are also screened across the overlying 400-Foot Aquifer. The figure shows how the extraction corresponding to those wells was fairly steady through 2013, increased dramatically, and is continuing to increase.

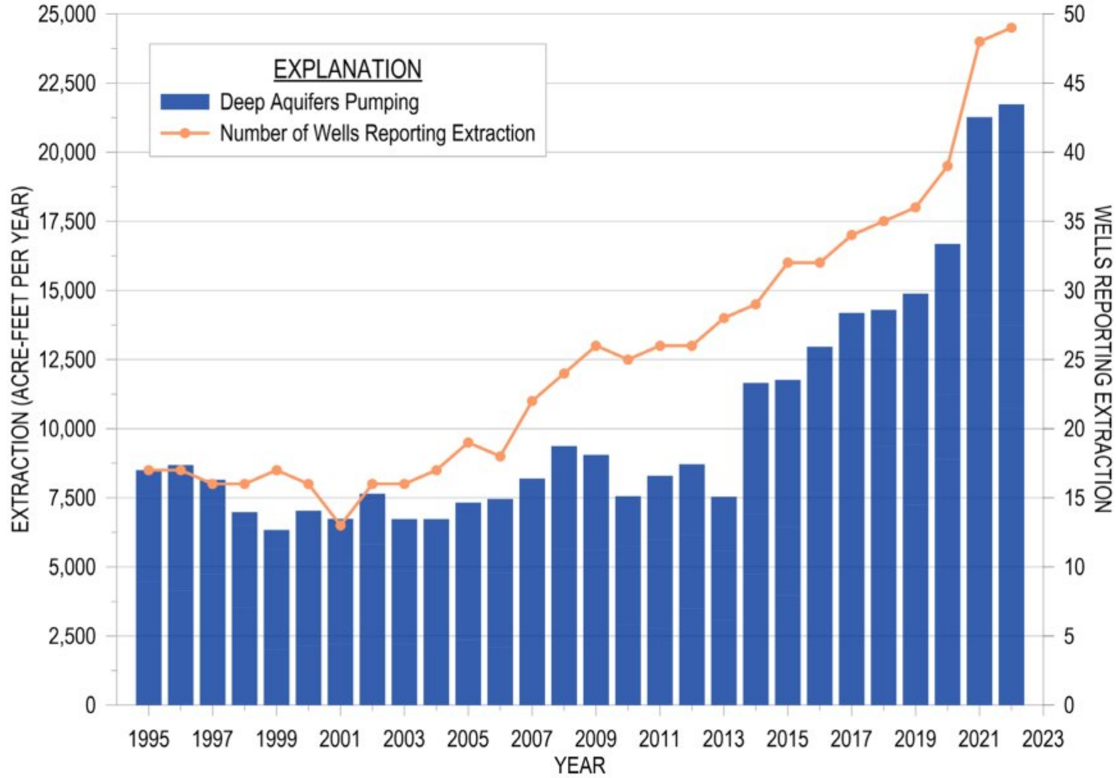


Figure 1-2. Total Deep Aquifers Extraction with Count of Wells Reporting Extraction

- **Limited or uncertain inflows:** Groundwater from the Deep Aquifers has been age dated to approximately 25,000 years old from a well installed at the coast near the City of Marina (Hanson et al., 2002). While that information indicates limited or no recent surficial water has flowed into the Deep Aquifers under current climate conditions, little data exist in other locations of the Deep Aquifers. Whether the Deep Aquifers receives inflow from adjacent aquifers or leakage from the overlying aquifer has been uncertain.

- **Threat of seawater intrusion and subsidence:** Decline in the groundwater elevations in the Deep Aquifers increases the risk of both seawater intrusion and subsidence. Downward migration of highly saline water could occur through leaky wells or through gaps in the 400/Deep Aquitard from the overlying 400-Foot or equivalent aquifer to the Deep Aquifers, like what has occurred from the 180-Foot Aquifer to the 400-Foot Aquifer. Further, low groundwater levels above and below the 400/Deep Aquitard clays increases the risk of dewatering the clays and subsequently inducing land subsidence from the collapse of the subsurface sediments.

- **Limited data:** While the Deep Aquifers are being relied upon for water supplies, limited data has inhibited a refined understanding of the Deep Aquifers. As a result, the extent of the Deep Aquifers had not previously been delineated, and subsequent studies focused solely on the coastal areas. Furthermore, wells with long screen intervals screened across multiple geologic formations or across the 400-Foot and Deep Aquifers complicate the understanding of their conditions. Although Deep Aquifers have at times been denoted as separate aquifers, available data are insufficient to demonstrate they are distinct aquifers rather than water-bearing zones within 1 aquifer system. Additional data have been required to determine not only where the Deep Aquifers occur, but also hydraulic connectivity to overlying and adjacent aquifers and connectivity within the Deep Aquifers.

1.3 Study Purpose

The purpose of this Study is to compile all available data into a scientifically accurate report characterizing the geology and hydrogeology of the Deep Aquifers in the Salinas Valley. This includes filling key data gaps and integrating different types of data. The Study provides a basis for management based on currently available data. Management guidance focuses on the SGMA 50-year planning horizon and understanding aspects of the Deep Aquifers needed to manage sustainably within that horizon. The Study does not address water rights, approaches for managing, or who should undertake management efforts, as those are policy questions for the various water agencies. Rather, the management section extends the scientific analyses in the Study to provide more direct guidance for management.

This Study focuses on the following key questions:

- **What constitutes the Deep Aquifers?** Previous studies and management efforts have inconsistent definitions of what constitutes the Deep Aquifers, resulting in different interpretations of the depth and extent of the Deep Aquifers. A consistent conceptual definition of what constitutes the Deep Aquifers was necessary to delineate the Deep Aquifers from other water-bearing units, guide the Study, and objectively review data in a systematic manner.
- **What is the geology, hydrogeology, and extent of the Deep Aquifers?** While Thorup (1976) established the Deep Aquifers as far south as San Ardo based on the presence of the Paso Robles Formation, most reports focused on the seawater intruded area of impact because that was the primary location of Deep Aquifers well installations, and subsequent risk area. Understanding the geology and hydrogeology of the Deep Aquifers enables questions surrounding aquifer properties, water chemistry, seawater intrusion risk, water budget, groundwater inflows, and sustainable management to be addressed.
- **What is the water budget for the Deep Aquifers? In particular, where and how much groundwater inflow do the Deep Aquifers receive?** No water budget specific to the Deep Aquifers had been developed prior to this Study. Water budgets help understand groundwater inflows and outflows that are not directly measurable, and the impact of pumping on groundwater storage changes.

- **What are the Deep Aquifers current conditions?** While numerous studies have highlighted declining groundwater conditions in the Deep Aquifers, it is important to analyze these conditions within a defined extent.
- **What management guidance can be inferred from scientific analyses?** Managing groundwater extraction must balance existing regulations and agreements, and consequences of lack of management. Within this context, the Study provides scientific guidance for management based on the findings of this Study. In particular, what geographic area should be managed? How should management address the risk of seawater intrusion and land subsidence? What parameters should guide management?
- **How should the Deep Aquifers be monitored?** Ongoing monitoring of groundwater conditions will be important for tracking trends, identifying changing conditions, and strengthening the understanding of the Deep Aquifers. Regular monitoring and periodic assessments provide data to adapt management over time.

1.4 Technical Approach and Methods

The Deep Aquifers Study was conducted in a manner to provide interim analyses, collect additional data to fill key data gaps, and synthesize data to provide useful information for sustainable management. The technical approach comprised 7 main steps, including the following:

1. **Developing a conceptual definition of what constitutes the Deep Aquifers**: Previous definitions of the Deep Aquifers were reviewed and options for a definition were presented to the Groundwater Technical Advisory Committee (GTAC). Feedback from GTAC resulted in development of a definition and flow chart for integrating multiple types of data to guide continued data analysis, data collection, and synthesis.
2. **Conducting a Preliminary Investigation based on existing data:** Existing data were analyzed using the new conceptual definition to identify a preliminary extent of the Deep Aquifers and provide interim recommendations for monitoring and management. The additional data to be collected as part of the Study was refined based on the preliminary investigation.
3. **Collecting data**: The following 3 types of data were collected during the Study:
    a. *Geophysics*: M&A partnered with Ramboll to collect 300.3 kilometers of Airborne Electromagnetic (AEM) surveys with equipment that yielded a deeper depth of investigation than prior surveys to generate a clearer understanding of the extent of the Deep Aquifers. This was paired with analysis of previously flown AEM surveys and e-logs and integrated into the Hydrogeologic Conceptual Model analysis. *See Appendix B.*

b. *Aquifer tests*: To complement collected data on aquifer properties within the coastal parts of the Deep Aquifers, M&A completed 2 aquifer tests in wells within the southern portion of the preliminary lateral extent of the Deep Aquifers. Analysis of AEM data showed both wells were outside of the final Deep Aquifers extent; however, the tests provide valuable data on transmissivity and hydraulic conductivity at similar depths. *See Appendix C.*

c. *Groundwater chemistry and isotope analysis*: Water chemistry data were complemented by isotope analysis. M&A analyzed 76 samples taken by MCWRA during summer of 2022 for stable isotopes. 8 wells were later sampled for stable isotopes and tritium to look for evidence of inflow of recent water and potential connectivity. *See Appendix E.*

4. **Developing the Hydrogeologic Conceptual Model:** Existing data, Study-generated data, and previously published reports were synthesized to develop the conceptual model of the Deep Aquifers. This resulted in a refined Deep Aquifers extent, and included a more complete assessment of the composition, structure, and chemistry of the Deep Aquifers.
5. **Developing the Water Budget:** Based on comparison of groundwater models, the water budget of the Deep Aquifers was developed using a combination of groundwater models.
6. **Providing Guidance for Management and Monitoring Recommendations:** The Study includes recent groundwater conditions for the Deep Aquifers based on the extent and analyses conducted. Based on current conditions and risk of seawater intrusion and land subsidence, this Study provides guidance for management, as well as recommended improvements to the monitoring networks.

1.5 Process and Peer Review

To build in peer review throughout the process of developing the Study, results were brought to the GTAC at key points. The GTAC is comprised of 18 technical experts with extensive experience working with local hydrogeology. Their expertise and perspectives were invaluable in providing robust guidance on refining the Deep Aquifers definition. GTAC members asked critical questions to ensure data analysis and interpretation was thorough and balanced. The GTAC was consulted on the following topics:

- Conceptual definition of the Deep Aquifers
- Results from the Preliminary Investigation
- Newly collected data
- HCM of the Deep Aquifers
- Deep Aquifers water budget
- Current conditions
- Monitoring and management guidance

2 DEFINITION OF THE DEEP AQUIFERS

Previous studies and management efforts have inconsistent definitions of what constitutes the Deep Aquifers and where it is delineated, if at all, with extents ranging from a coastal focus to extending up-valley to San Ardo (Thorup, 1976). The conceptual definition of the Deep Aquifers developed as part of this Study provides the framework for delineating the extent of the Deep Aquifers. As described in more detail in Appendix A, this definition builds on previous definitions and was developed with input from local hydrogeological experts. It incorporates historical data and understandings, maintains flexibility to incorporate future data, and guides the analyses in the Study.

The Deep Aquifers are generally defined as the water-bearing sediments below the 400-Foot Aquifer or its stratigraphic equivalent. More specifically, the guiding definition of the Deep Aquifers is the water-bearing sediments that*:*

1. *Are below a relatively continuous aquitard or area of higher clay content that is often encountered between approximately 500 feet and 900 feet below land surface within the Salinas Valley Basin and potentially shallower where uplifted. The relatively continuous high-clay aquitard, or 400/Deep Aquitard, must be below the identified 400-Foot Aquifer, or its stratigraphic equivalent.*
2. *Are within the Paso Robles Formation, Purisima Formation, and/or Santa Margarita Sandstone.*

Given the limited data available for the Deep Aquifers, the definition of the Deep Aquifers also includes a set of optional secondary characteristics to account for uncertainty and subsurface complexity when evaluating whether a well is in the Deep Aquifers. The secondary characteristics include electrical resistivity, screen interval depth and extent, similar lithology and/or borehole geophysics to established nearby Deep Aquifers wells, differences in water quality from overlying and adjacent aquifers, and differences in groundwater levels from the overlying 400-Foot or equivalent aquifer.

The definition focuses primarily on the presence of a single 400/Deep Aquitard, or zone with higher incidence of clay, to separate the 400-Foot Aquifer from the Deep Aquifers, and requires the Deep Aquifers be in specific geologic formations. Other distinct clay bodies may occur in the subsurface at similar depths as the 400/Deep Aquitard but from distinct depositional environments, and therefore are not considered the 400/Deep Aquitard; rather they are considered discontinuous and overlying or adjacent to Deequifers materials, but they are not the Deep Aquifers. The continuous 4/Deep Aquitard is encountered within the Paso Robles Formation and may occur at shallower depths where uplifted.

Figure 2-1 shows a flowchart developed for this guiding definition and was used throughout this investigation to analyze existing and Study-generated data. Additional explanation is included in Appendix A.

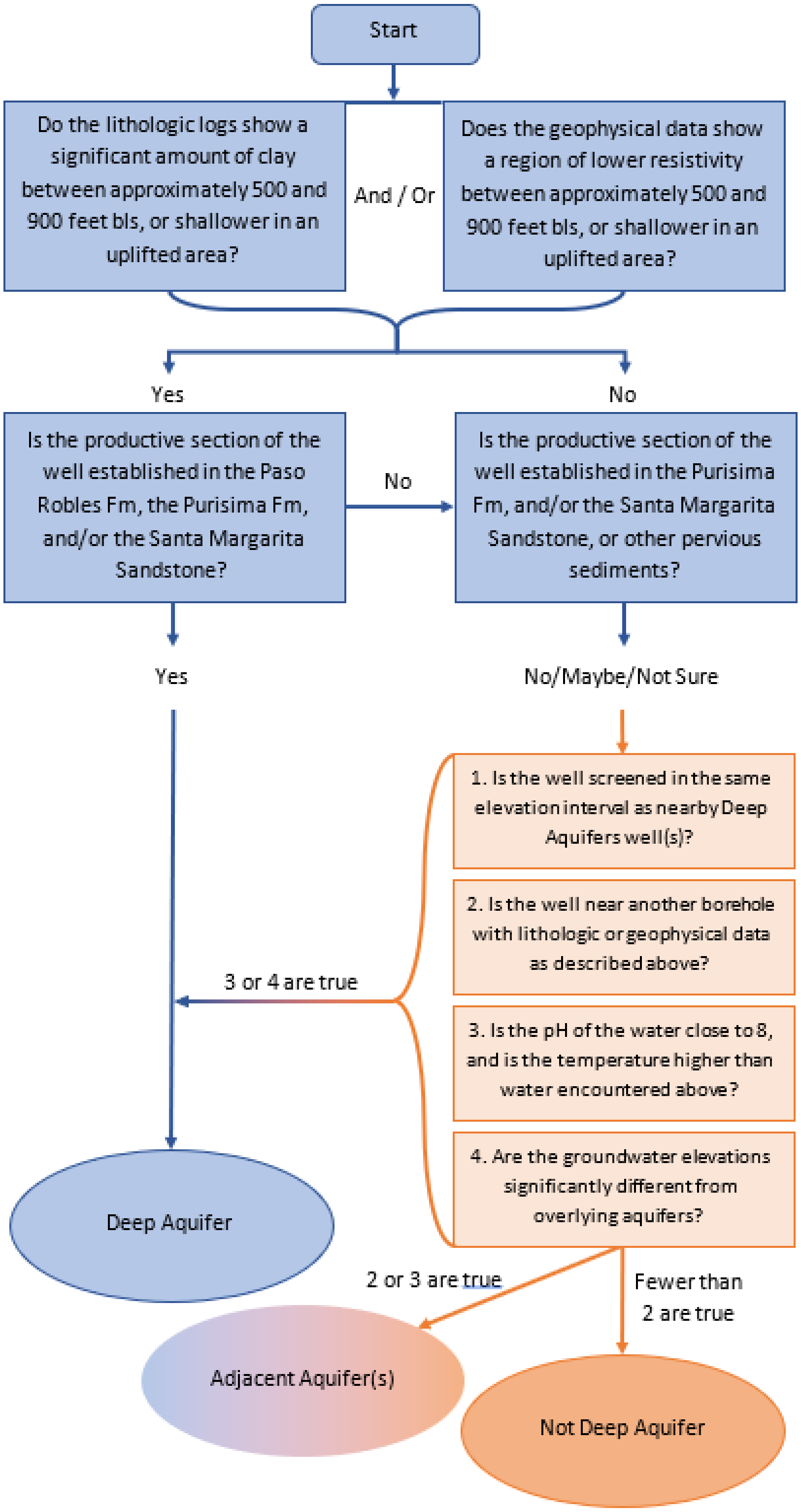


Figure 2-1. Definition Flow Chart Used for Analysis of Well Completion Reports and Other Data

3 HYDROGEOLOGIC CONCEPTUAL MODEL

The geology and hydrogeology of the Basin controls the locations and depths of aquifers and aquitards and provides the physical framework in which groundwater occurs and moves. The Study delineates the extent of the Deep Aquifers based on the definition of the Deep Aquifers and analysis of existing and Study-generated data. Aquifer properties characterize how groundwater is stored and moves in the subsurface, and groundwater chemistry and isotopes add insight on the relationship with overlying and adjacent aquifers, as well as differences across the extent.

3.1 Geology and Hydrogeology

The geologic descriptions are derived primarily from previously published scientific reports and investigations conducted by the United States Geological Survey (USGS), State of California, and academic institutions. Wells installed in the Basin confirm the findings of these previous publications and enhance the overall understanding of the Basin over time. These data sources continue to be the best available data.

3.1.1 Geology

The Basin was formed in a tectonically active area on the eastern edge of the Pacific Plate and went through periods of structural changes of faulting, fracturing, and folding, as well as periods of marine and terrestrial sedimentation (Brown & Caldwell, 2015). Table 3-1 presents the Basin's geologic sequence and conceptual hydrostratigraphy, which is a result of basin fill sedimentation from both Salinas River fluvial and Pacific Ocean marine deposition. Most of the Basin sediments are a mix of sands, gravels, and clays. The geologic formations that form the Deep Aquifers rarely outcrop on the land surface within the Salinas Valley Basin, with small outcrops in the Toro Park region, and more extensive outcrops closer to the Monterey-San Luis Obispo County line. From youngest to oldest, these include the Paso Robles Formation (QTc), the Santa Margarita Sandstone (Tsm), and the Purisima Formation (Tp).

> **Paso Robles Formation –** This Pliocene to lower Pleistocene unit is composed of lenticular beds of sand, gravel, silt, and clay from terrestrial deposition (Thorup, 1976; Durbin *et al.*, 1978). The depositional environment is largely fluvial but also includes alluvial fan, lake, and floodplain deposition (Durbin *et al*., 1978; Harding ESE, 2001; Thorup, 1976; Greene, 1970). Individual beds of fine and coarse materials typically have thicknesses of 20 to 60 feet (Durbin *et al*., 1978). The Formation is approximately 1,500 feet thick near Spreckels and 1,000 feet thick near Salinas, with variable thicknesses due to erosion of the upper part of the unit (Durham, 1974). The Paso Robles Formation underlies most of the Basin but is rarely exposed at the surface. There are 3 primary members of the Formation, with the middle member being clay-dominant (Thorup, 1976; Harding

ESE, 2001). This is where the continuous 400/Deep Aquitard delineating the Deep Aquifers is encountered.

Purisima Formation –This Pliocene unit consists of interbedded siltstone, sandstone, conglomerate, clay, and shale deposited in a shallow marine environment (Greene, 1977; Harding ESE, 2001). The Purisima Formation ranges from 500 to 1,000 feet in thickness, underlying the coastal portions of the Basin (Feeney & Rosenberg, 2003).

Santa Margarita Sandstone – This Miocene unit is a friable arkosic sandstone that generally underlies the Paso Robles Formation near the southern coastal regions of the Basin and sometimes where the Purisima Formation is absent (Greene, 1977).

Monterey Formation – The Miocene unit is a relatively impervious shale or mudstone deposited in a shallow marine environment (Harding ESE, 2001; Greene, 1977). The top of the Monterey Formation is defined as the bottom of the Deep Aquifers where the water-bearing formations are in contact with it.

The location of a cross section used to exemplify the Deep Aquifers is shown on the map on Figure 3-1, and the cross section is on Figure 3-2. The cross section shows how the formations that constitute the Deep Aquifers rise as they reach the Seaside Subbasin, and how the Santa Margarita Sandstone is present in the wells close to and within the Seaside Subbasin. These are discussed further in Appendix A.

Table 3-1. Generalized Geologic-Hydrogeologic Relationships

Period/Epoch	Geological Unit	Principal Aquifers and Aquitards
Holocene	Recent Dune Sand (Qd) Older Dune Sand (Qod)	**Dune Sand Aquifer**
Pleistocene	Old Alluvium / Valley Fill Deposits (Qo/Qvf)	Fort Ord-Salinas Valley Aquitard
		180-Foot Aquifer
	Aromas Sand (Qar)	180/400-Foot Aquitard
		400-Foot Aquifer
	Paso Robles Formation (QTp)	40/Deep Aquitard
Pliocene	Purisima Formation (Tp)	**Deep Aquifers**
	Santa Margarita Sandstone (Tsm)	
Miocene	Monterey Formation (Tm)	N/A (Minimally Water-Bearing)

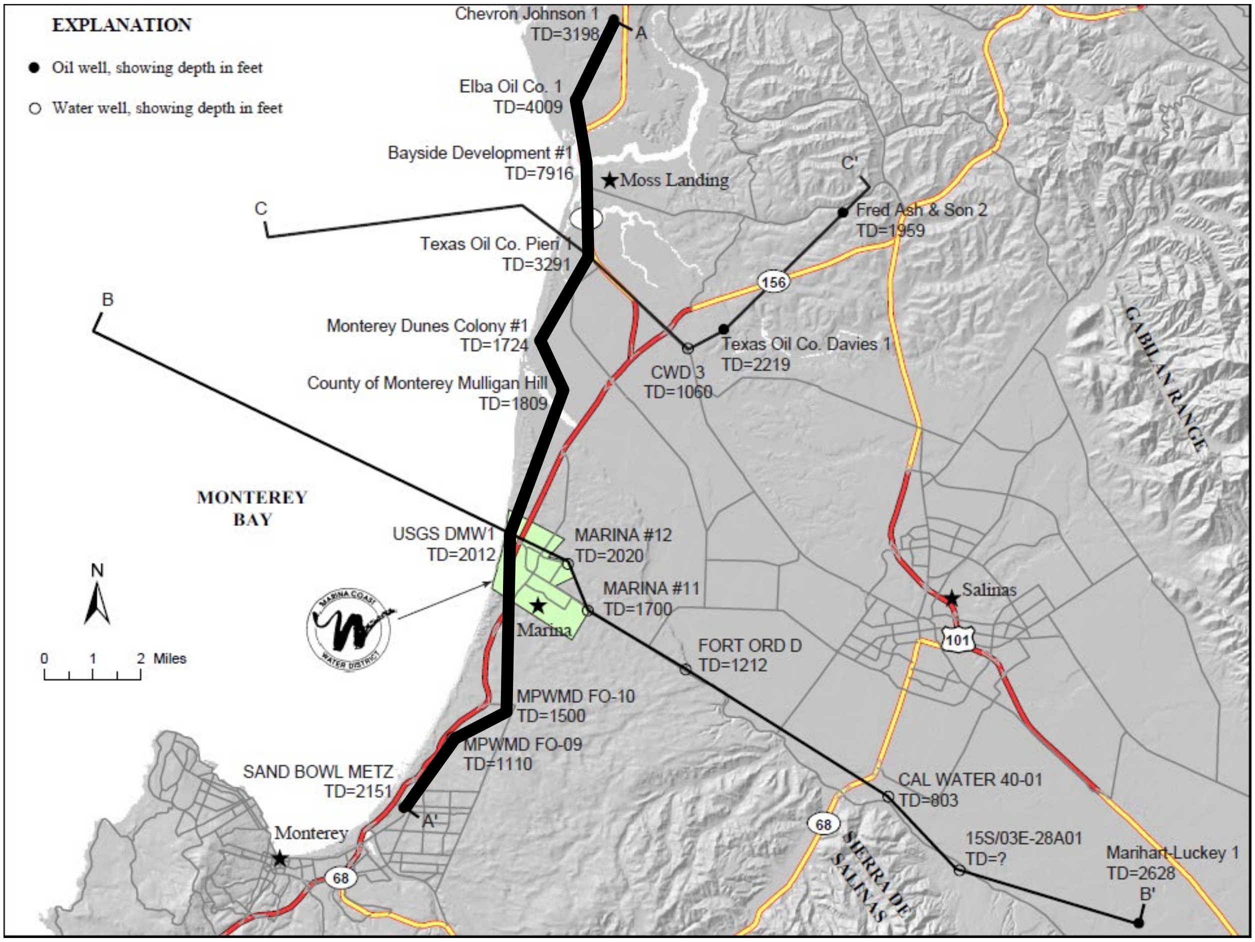


Figure 3-1. Map of Key Cross Sections to Exemplify the Deep Aquifers (Feeney and Rosenberg, 2003)

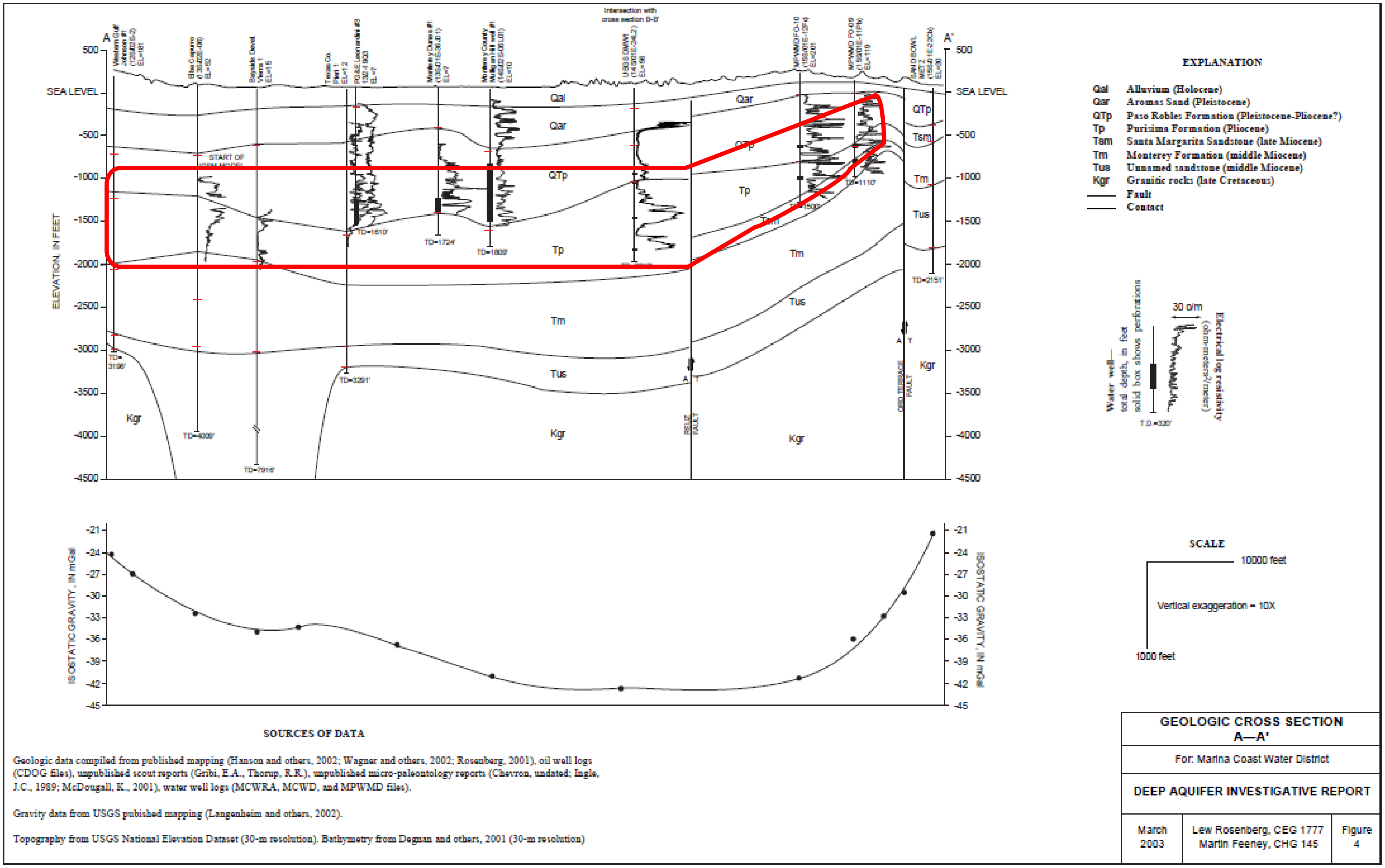


Figure 3-2. Cross Section A-A' from Feeney and Rosenberg, 2003, Adapted to Exemplify the Deep Aquifers' Geology and Generalized Zone where the Deep Aquifers are Encountered (as shown with red outline)

3.1.2 Structure

The Salinas Valley Basin is an elongated trough dipping from south to north toward Monterey Bay. This is demonstrated in the basin bottom elevation map for the Salinas Valley shown on Figure 3-3. The contours on Figure 3-3 represent the depth of the usable portions of the groundwater basin as determined by Durbin *et al.* (1978). While this does not necessarily coincide with the contact between basin fill sediments and either the relatively impervious Monterey Formation or crystalline rocks, it does demonstrate the recognized Basin structural form. Some studies have shown different depths to the Basin bottom in specific areas; however, this is still the most comprehensive understanding of the bottom of the Basin. Included in this figure are contours through the southern coastal region representing the top of the Monterey Formation due to its impermeability.

The deepest portions of the Basin are along the west side of the Basin where the Reliz/Rinconada Fault system displaces the basin bottom by a few thousand feet, shown on Figure 3-3 (Durbin *et al*., 1978; Garrison *et al*., 1990). The Reliz/Rinconada Fault has not been previously shown to impact groundwater flow across displacement within the same formations, such as the Paso Robles Formation (Feeney and Rosenberg, 2003), or across sediments with similar composition and hydraulic properties (MCWD GSA and SVBGSA, 2022). However, evaluation of groundwater elevation contours for this Study suggests that the fault zone could be acting as a barrier to flow in the City of Marina area, as described in Section 5.2.2.

Other key structural features include the Laguna Seca Anticline and minor faults in the Corral de Tierra and Seaside areas, which have exposed the Monterey Formation and granitic rocks at the surface (Figure 3-3 and Figure 3-4). This group of structural features does impact groundwater flow patterns, as illustrated in the curved groundwater elevation contours and diverging flow components in the vicinity of the structures on figures in the Monterey Subbasin GSP (MCWD GSA and SVBGSA, 2022).

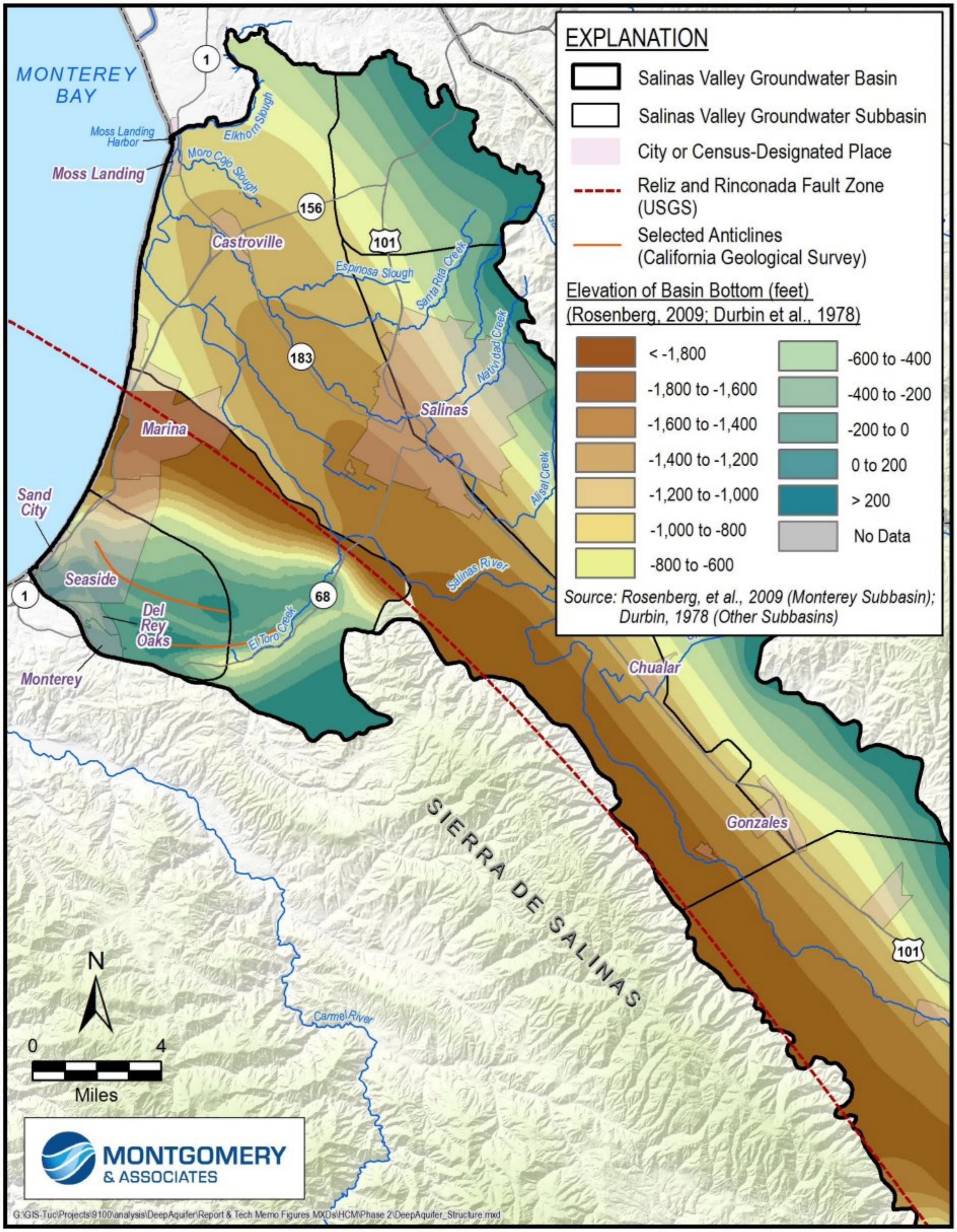


Figure 3-3. Elevation of Basin Bottom

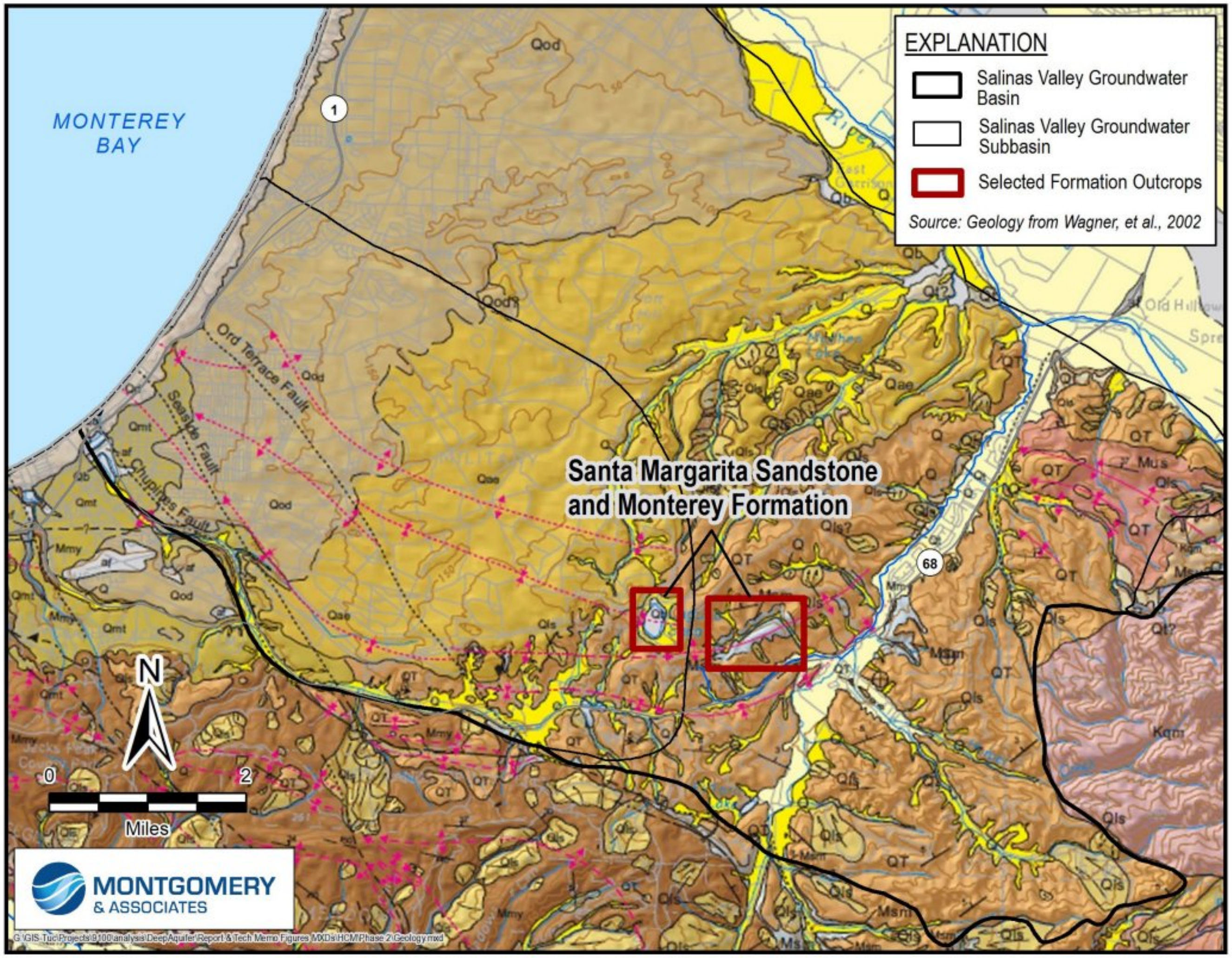


Figure 3-4. Portion of Surface Geology Map Focusing on Seaside and Monterey Subbasins and Demonstrating Formation (from Wagner, *et al.*, 2002)

3.1.3 Hydrogeology

The geology of the region impacts groundwater flows. Deposits with greater sand and gravel content facilitate groundwater flow more than places with more clay content. Within the geologic formations previously described, several sediment types have been deposited over time. This depositional environment results in lithologic complexity that controls hydraulic processes and connectivity both within and adjacent to the formations. In this way, the hydrostratigraphy of the basin fill sediments, and more specifically, the Deep Aquifers, is both related to and distinct from the geologic formations in the Basin.

The sediments of the Deep Aquifers are a series of sands, gravels, and clays. MCWRA has historically looked for a significant sequence of clays separating the Deep Aquifers from overlying water-bearing sediments (MCWRA staff, personal communication, 2022). Other consultants in the area have confirmed the presence of significant amounts of clay between the 400-Foot Aquifer and the Deep Aquifers, which are referenced here as the 400/Deep Aquitard. This interval is effectively a portion of the subsurface where there is a higher incidence of clay, or a series of clay lenses, which acts as an aquitard. These clays occur in the middle member of the Paso Robles Formation, which is why portions of both the 400-Foot Aquifer and Deep Aquifers are found in the Paso Robles Formation (Hanson *et al.*, 2002; Brown and Caldwell, 2015). The Paso Robles Formation includes 3 distinct hydrogeologic units: the 400-Foot Aquifer, the 400/Deep Aquitard, and the Deep Aquifers, shown in Table 3-1.

Within the Deep Aquifers, several clay layers separate different depths of water-bearing strata, historically denoted as the 800-Foot, 900-Foot, 1,100-Foot, and 1,500-Foot Aquifers. The earliest Deep Aquifers wells were installed to specifically capture individual water-bearing zones with narrower screened intervals. Over time, Deep Aquifers wells have been installed with longer screened intervals to capture all of the water-bearing zones in order to maximize production. Having many wells screened across multiple formations limits the ability to discern the differences between groundwater conditions specific to the geologic formations that constitute the Deep Aquifers.

The hydrostratigraphy of the Deep Aquifers comprises the water-bearing sediments of the Paso Robles Formation below the 400/Deep Aquitard, the Purisima Formation, and the Santa Margarita Sandstone. Wells completed in the Purisima Formation or Santa Margarita Sandstone are generally considered to be drawing exclusively from the Deep Aquifers, where they occur below the continuous 400/Deep Aquitard (Figure 3-1 and Figure 3-2).

The Monterey Formation is not considered a significant or important water-bearing formation, and thus is defined as the base of the Deep Aquifers in this Study. The Monterey Formation is relatively impervious and only produces very minor amounts of groundwater primarily from fractures (J. Oliver, personal communication, 2023). In places where the Monterey Formation is not present in the subsurface, granitic rocks and to a lesser extent, metamorphic rocks, constitute the Basin bottom (M. Feeney, personal communication, 2023).

3.2 Extents

Previous studies have defined various lateral extents of the Deep Aquifers ranging from only the near coastal area, where most of the extraction occurs, to most of the Salinas Valley south to San Ardo. This Study establishes the current best approximation of the Deep Aquifers' extent based on the definition of the Deep Aquifers presented above. As discussed in Section 3.6, delineation of this extent does not negate that there are overlying and adjacent aquifers that may be hydraulically connected to the Deep Aquifers.

While the geologic formations that constitute the Deep Aquifers may extend beyond the delineated extent, this Study focuses on the manageable area for agencies within Monterey County. Management guidance and implementation are only within the context of managers and their domains. Therefore, for the purposes of this Study the Deep Aquifers are defined as being solely within the Salinas Valley Groundwater Basin.

To delineate the extent, this Study integrates all known available data, including well completion reports (WCRs) of 133 deep wells, basin structure from previous geologic reports, 2 previous AEM surveys, and 91 borehole e-logs. In addition, the Study collected an additional 300.3 line-km (186.6 line-miles) of AEM surveys. A detailed lithologic analysis of well completion reports and prior studies were used to define an initial preliminary lateral extent and define locations for additional data collection. Then, AEM surveys and all available data were integrated to produce the refined final Deep Aquifers extent presented here. The data and methods are described in greater detail in Appendix A. The Deep Aquifers lateral extent is shown on Figure 3-5. This figure includes areas labeled as uncertain, which indicate areas with uncertain presence or continuity of the 400/Deep Aquitard. Future investigations may clarify whether these uncertain areas are part of the Deep Aquifers or are adjacent to, and in hydraulic connection with, the Deep Aquifers.

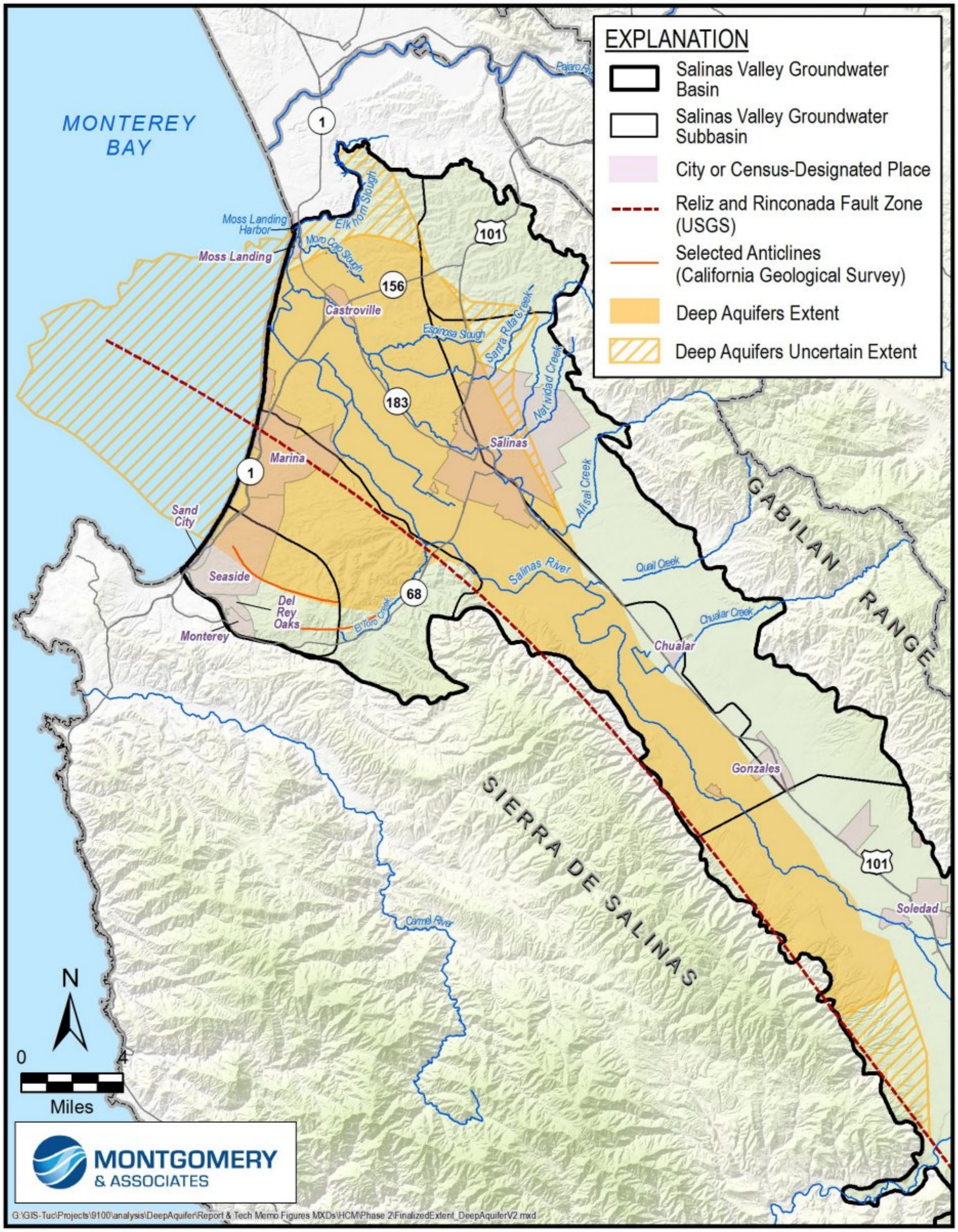


Figure 3-5. Finalized Extent of the Deep Aquifers in the Salinas Valley

3.2.1 Deep Aquifers Physical Lateral Boundaries

The Deep Aquifers within the Salinas Valley are bounded by the following physical features:

- **The Monterey Bay shoreline**. The western boundary is defined by the Monterey Bay shoreline. The geologic formations that constitute the Deep Aquifers extend to and across this boundary into the subsurface underlying Monterey Bay and there are no hydrogeologic barriers limiting groundwater flow across this coastal boundary. The practical western extent of the Deep Aquifers is controlled by the California Department of Water Resources (DWR) Bulletin 118 subbasin boundaries. Although the Deep Aquifers undoubtably extend offshore beneath Monterey Bay, the offshore portion of the Deep Aquifers are not part of any groundwater basin, have no wells that provide data, and cannot be legally managed by any entity. Therefore, the portion of the Deep Aquifers' geologic formations that exist under the Monterey Bay and crop out in Monterey Canyon are considered an uncertain lateral extent.

Figure 3-6 shows a geologic map of the Monterey Bay region, including the mapped geology in the Bay. The coastline is highlighted in black, and the exposed Purisima Formation is circled in red.

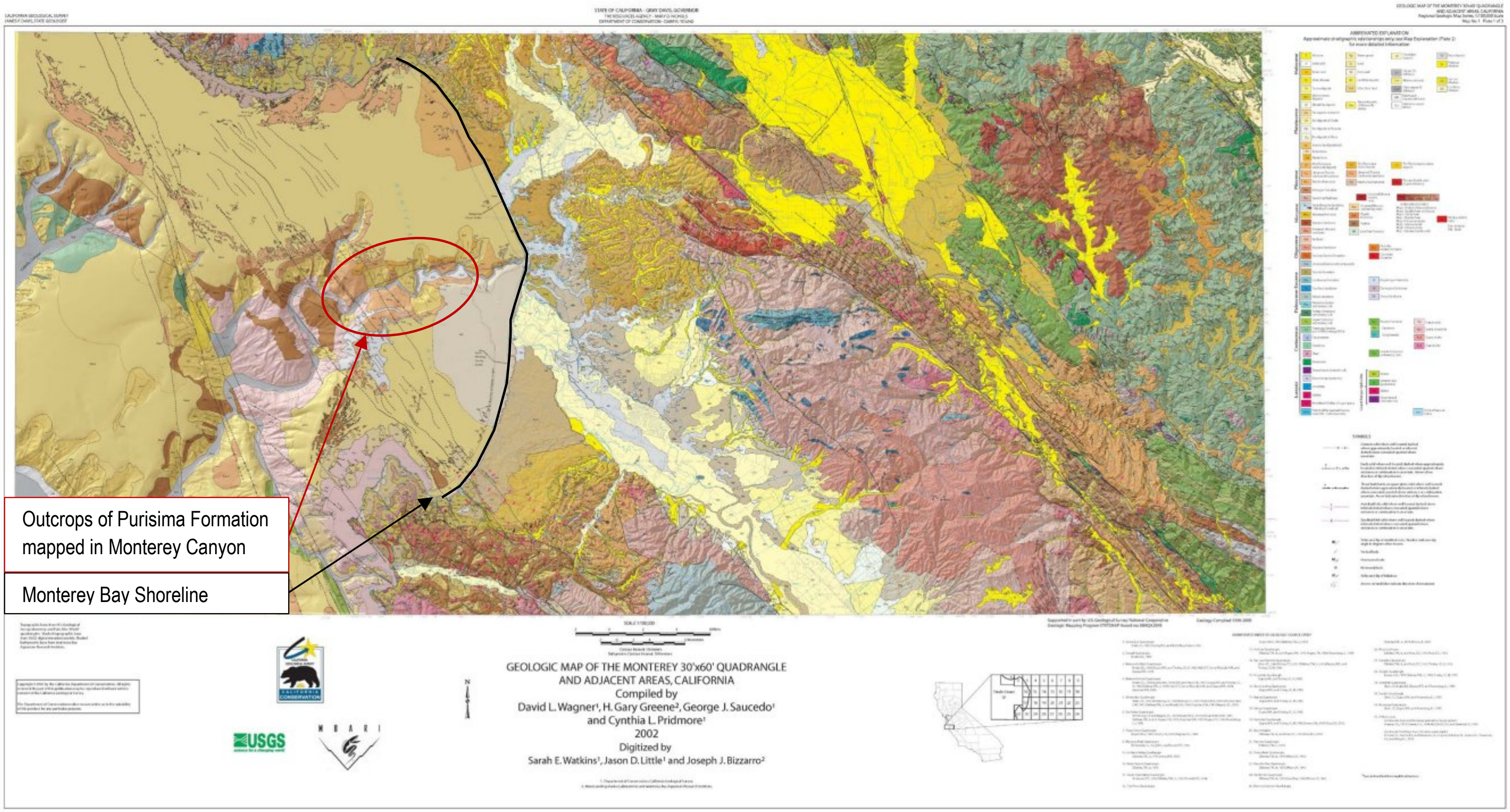


Figure 3-6. Example of Key Supporting Data - Map of Monterey Bay Region Geology (adapted from Wagner, et. al, 2022)

- **Elkhorn Slough and North Salinas**. The northern boundary of the Deep Aquifers generally parallels, and is south of, the current course of Elkhorn Slough. Elkhorn Slough is a buried and clay-filled paleo-drainage that is at least 400 feet deep, and represents a potential discontinuity in the 400/Deep Aquitard that defines the presence of the Deep Aquifers (Durbin, *et al.*, 1978; Fugro West, 1995). The Purisima Formation continues north of Elkhorn Slough, ultimately cropping out near Santa Cruz (Feeney and Rosenberg, 2003; Fugro West, 1995). However, the clays commonly found in the Paso Robles Formation that are a part of the continuous aquitard do not. The area between known 400/Deep Aquitard presence in well logs in the northern part of the Basin, and the lack of Paso Robles Formation to the north, represents an area of uncertainty. The area north of the City of Salinas has sparse data available, both as wells and as AEM flightlines. Identifying and locating the continuous 400/Deep Aquitard is difficult, and complicated by potentially buried structural features as well as the shallowing of the Gabilan Range granitic rocks in the subsurface (Fugro West, 1995). Only 1 well near Prunedale shows a definitive thickness of clay in the WCR, and anchors the extent. Thus, this Study delineates the northern boundary where deep wells confirm the presence of the 400/Deep Aquitard and Deep Aquifers, although the Deep Aquifers may extend farther north where there is uncertainty regarding the presence of the Paso Robles Formation, a general abundance of clays in the subsurface, and no deep wells to confirm the 400/Deep Aquitard occurrence. Figure 3-7 demonstrates a definable clay interval below the 400-Foot Aquifer in a well and the clay-filled Slough. Everything between these points is currently uncertain.

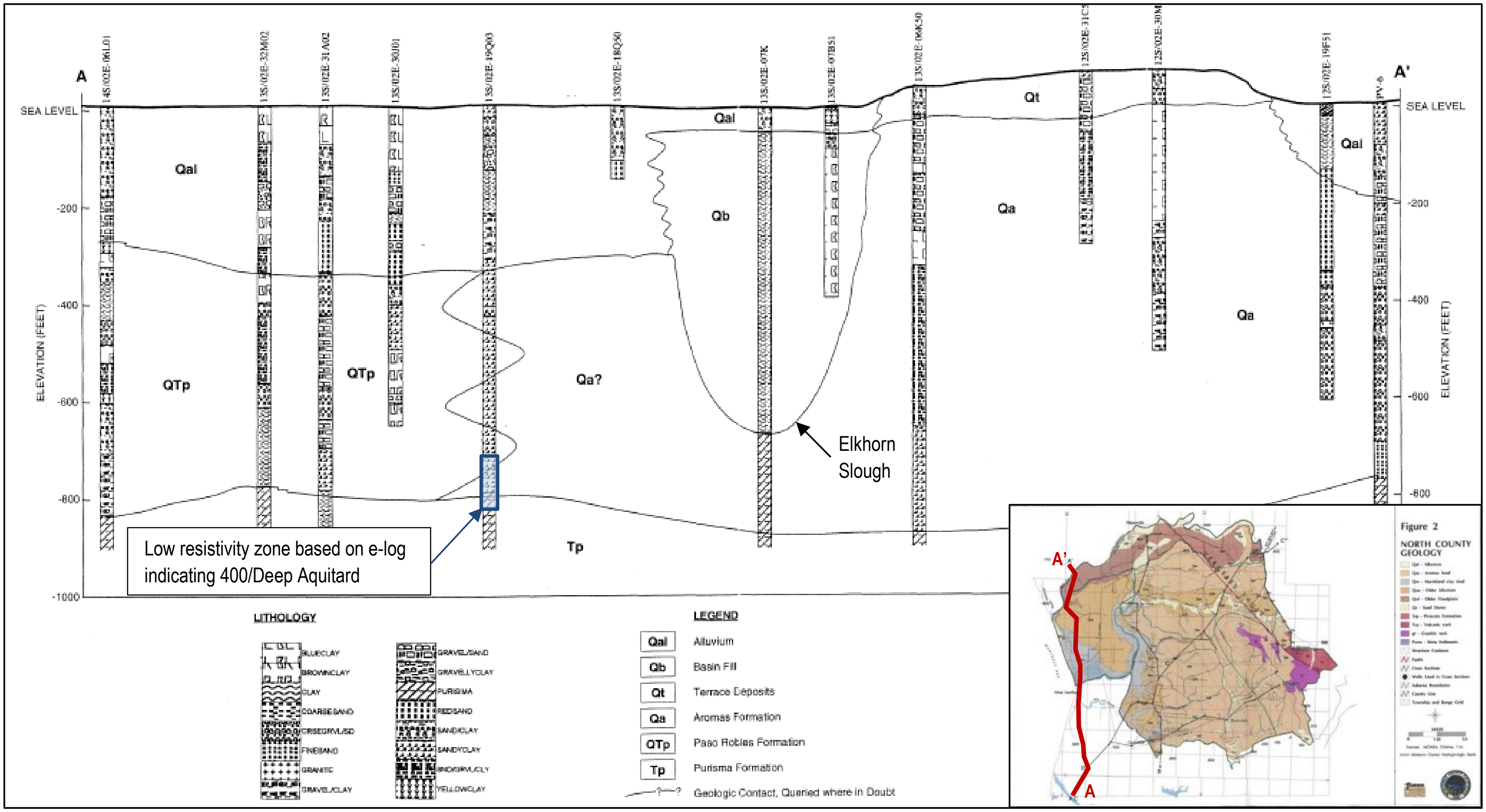


Figure 3-7. Example of Key Supporting Data - Coastal Cross-section A-A' (Adapted from Fugro West, 1995)

- **Gabilan Range Bajada**. The eastern boundary is defined by the extent of the Eastside alluvial fan complex, or bajada, along the Gabilan Range where streams have deposited sediments in overlapping fan shapes over time. This Gabilan Range Bajada consists of multiple alluvial fans that have developed along this mountain front. These fans represent a discontinuity in the 400/Deep Aquitard. Although these fans have resulted in an abundance of clay in the subsurface, the clays are not of the same source as the 400/Deep Aquitard, and they overlie different sediments than those of the Deep Aquifers. This bajada represents an adjacent aquifer system, called the deep zone of the Basin Fill Aquifer or Eastside Deep Zone. Figure 3-8 shows a series of AEM flightline cross-sections that highlight the dipping alluvial fan clays in relation to the 400/Deep Aquitard. These resistivity data were interpreted together with lithologic logs, e-logs, and previously published cross sections.

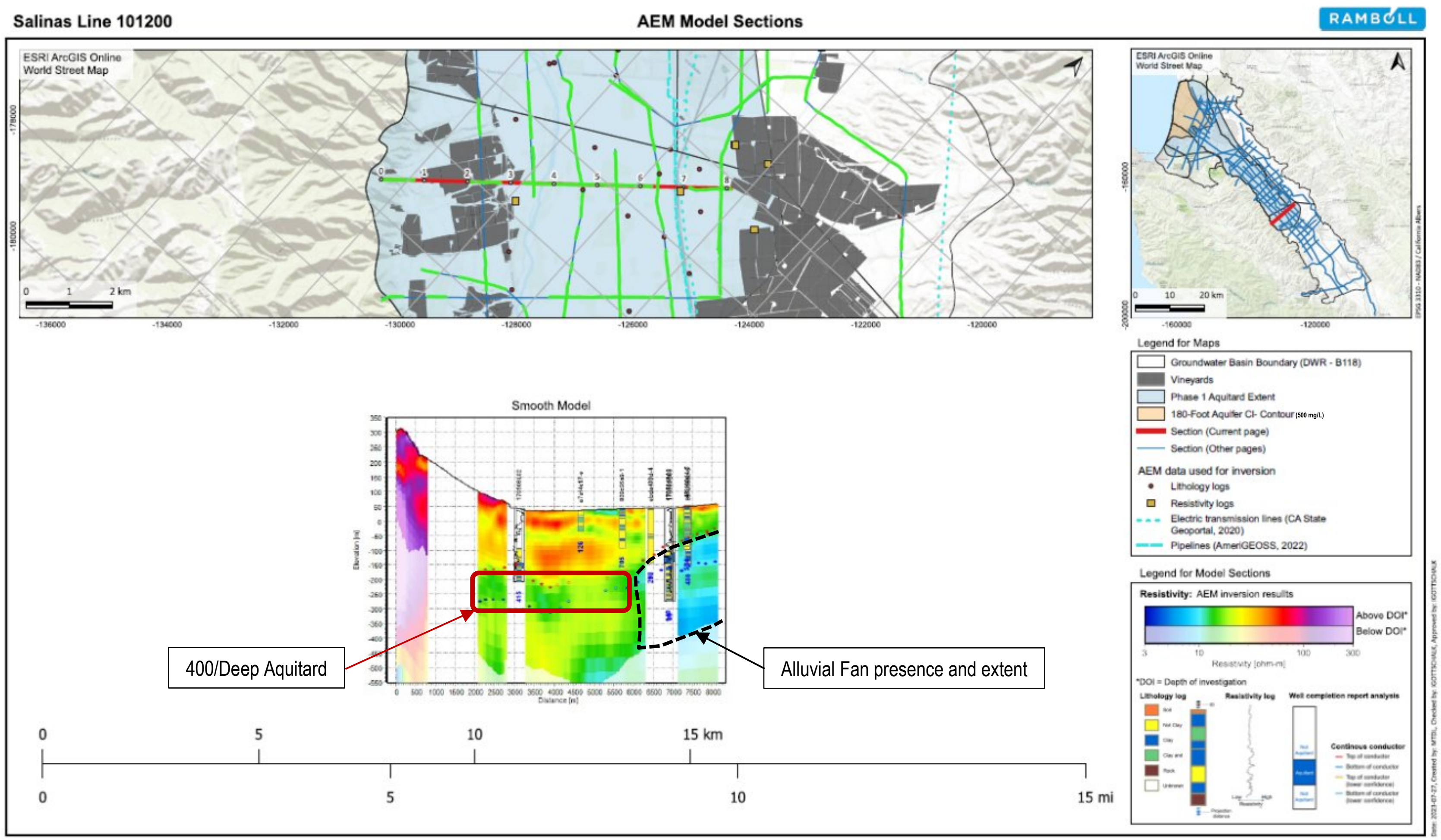


Figure 3-8. Gabilan Range Bajada Data Example of Key Supporting Data - Cross-Basin AEM Profile (see detail in Appendix B)

- **Arroyo Seco Cone**. The southern boundary of the Deep Aquifers is generally defined by the Arroyo Seco Cone. This is an area where the continuity of 400/Deep Aquitard is interrupted by the alluvial fans from the Arroyo Seco River and Reliz Creek, as well as the up-valley continuation of alluvial fans from the Gabilan Range. This boundary was delineated primarily based on the AEM surveys (DWR, 2020; Study-generated data reported in Appendix B) and previously published reports and cross-sections (Feeney, 1994; Durham 1974; Brown and Caldwell, 2015). The AEM surveys revealed a unique relationship between the Salinas Valley sediments, which include the Paso Robles Formation, and the Arroyo Seco Cone. AEM data confirm the presence of the 400/Deep Aquitard, overlain by different sediments indicative of the Arroyo Seco Cone shown on Figure 3-9. There appears to be a 400/Deep Aquitard in discontinuous AEM sections well under the northern part of the Cone sediments. However, this occurrence becomes more muddled as the AEM data becomes more discontinuous, and as the Arroyo Seco Cone interacts with the structural changes southward towards King City. Previously published reports discuss a structural shallowing on the south end of the Cone, as well as minor outcrops of Paso Robles Formation in the foothills of the Sierra de Salinas, broken up by the presence of the Reliz Fault Zone. Combining the published reports and cross-sections with the AEM data, the southernmost extent of the Deep Aquifers is delineated at the AEM cross-sections with the clearest view and indication of continuous aquitard in the subsurface related to the northward cross-sections. There are additional indications that the continuous aquitard extends farther south, however these data are sparse and intermittent, and therefore classified into an uncertain region of the extent. The Deep Aquifers do not appear to extend past the structural rise at this boundary, even with the zone of uncertainty delineated by the hashed areas on the map on Figure 3-12.

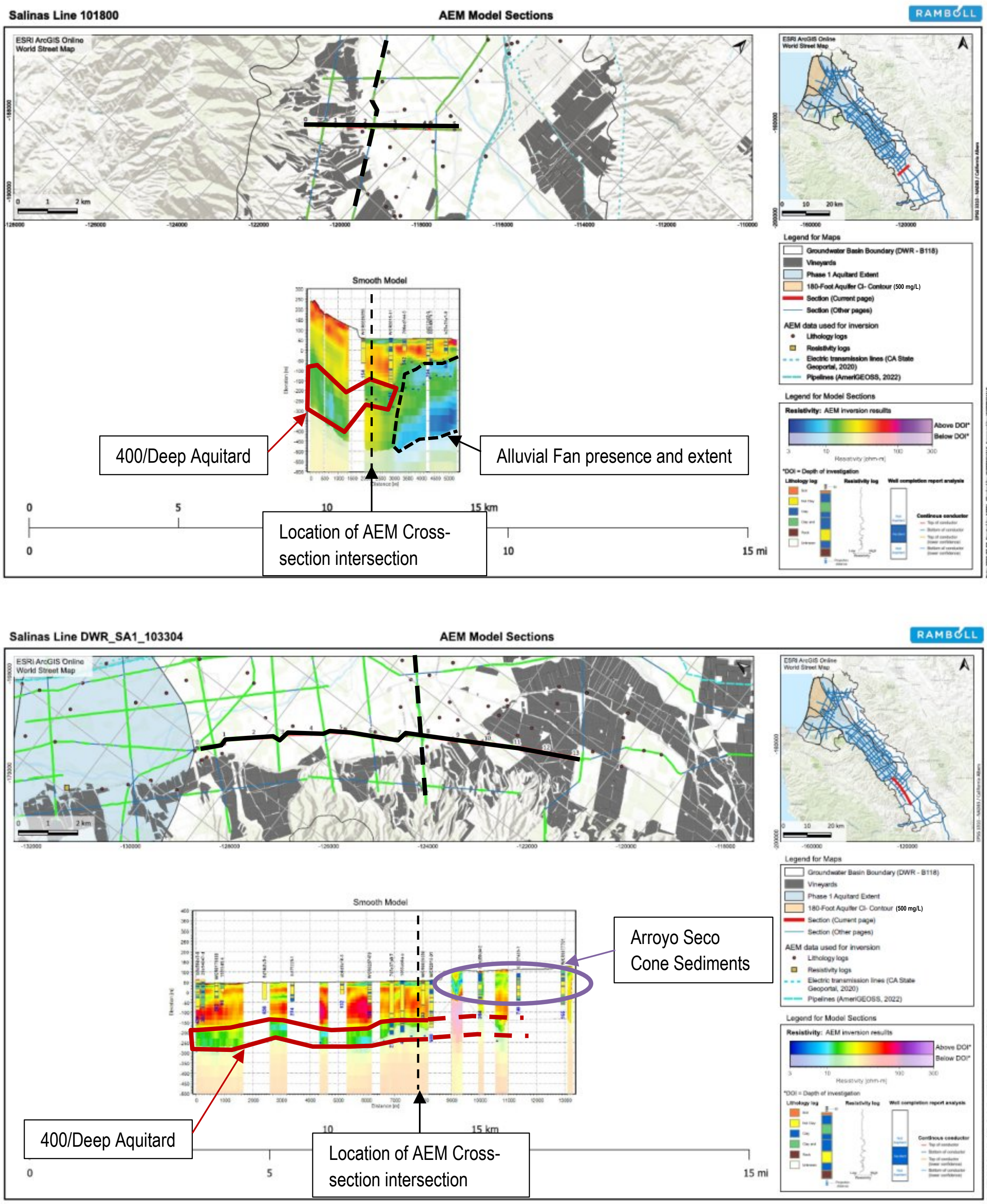


Figure 3-9. Arroyo Seco Cone Boundary Example of Key Supporting Data - AEM Profiles (see detail in Appendix B)

- **Sierra de Salinas/Reliz Fault**. The inland western boundary is defined by the presence of the Reliz Fault that corresponds to the contact between the Quaternary deposits and the low-permeability crystalline basement rocks of the Sierra de Salinas. This geologic contact creates a groundwater flow barrier and the western hydrogeologic boundary of the Basin, and the Deep Aquifers. The 400/Deep Aquitard is easily seen juxtaposed against the crystalline rocks in the AEM data. This boundary was primarily delineated based on the AEM surveys (DWR, 2020; Deep Aquifer Study, 2023). The cross-basin flightlines showed displacement between higher and lower resistivities of the sediments across the same elevations. The Salinas Valley Sediments, including the Paso Robles Formation, do not extend laterally across this displacement, and as such the displacement from the fault represents a discontinuity, shown on Figure 3-10.

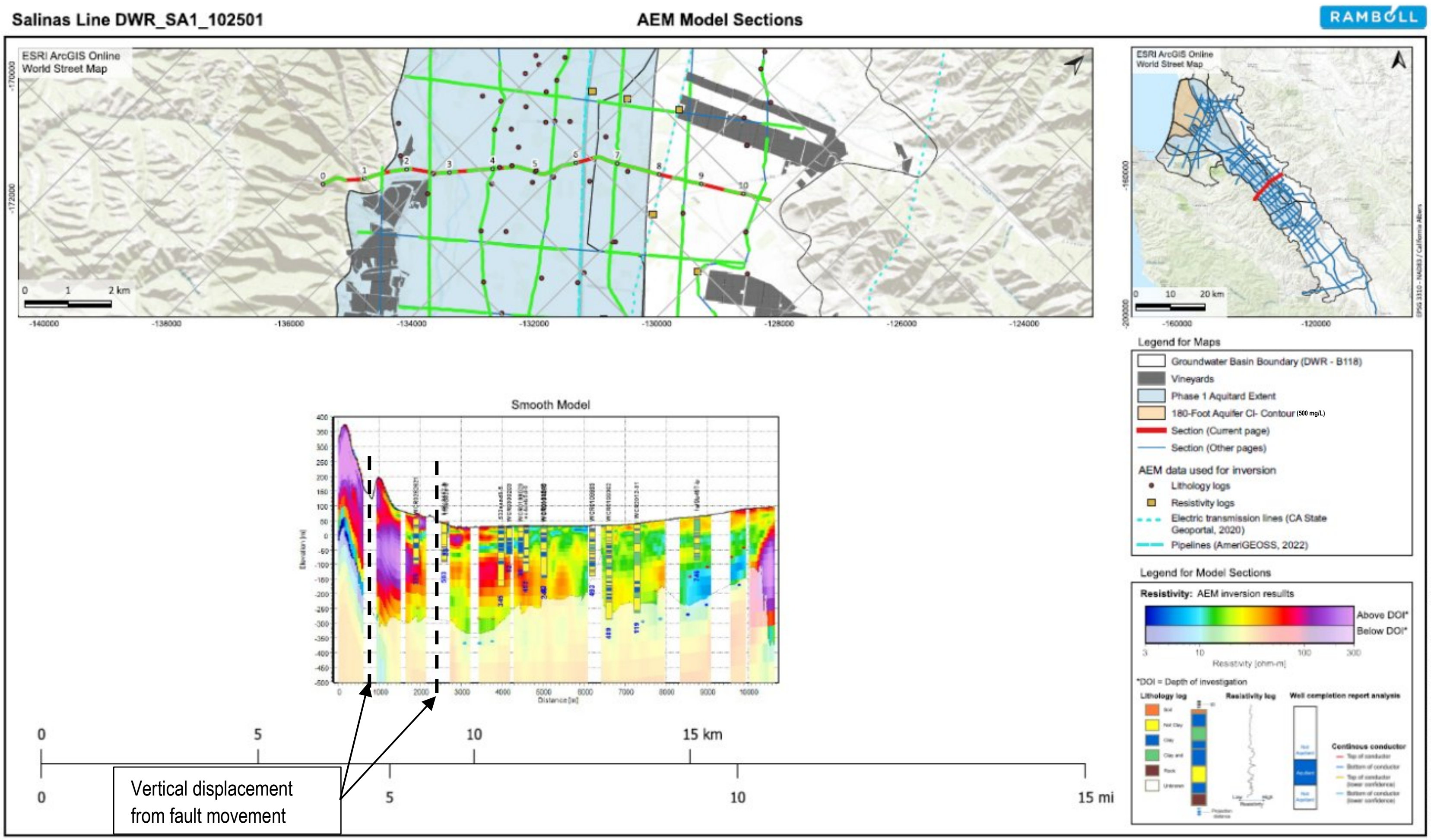


Figure 3-10. Sierra de Salinas/Reliz Fault Boundary Example of Key Supporting Data - AEM profile (see detail in Appendix B)

- **South Coastal/Laguna Seca Anticline Axis**. The coastal southwest boundary is defined by the Laguna Seca Anticline axis, which was formed during a period of structural uplift and deformation. The Anticline axis generally follows a semi-parallel orientation as Highway 68, traversing through the Seaside Subbasin and angling northward near the Toro Park region, with Toro Creek and the El Toro Primary Aquifer System on the outer side of the Anticline. The north-dipping arm is clearly visible in AEM data, and the 400/Deep Aquitard is readily discernable from the Anticline axis into the main Salinas Basin where aquitard designations based on WCRs align with the AEM lower resistivity values. Figure 3-11 shows these hydrostratigraphic relationships between the AEM resistivity data, well data, and jurisdictional boundaries for orientation. The south-dipping arm is clearly visible and terminates at the Ord-Terrace Fault, depicted in the A-A' cross section (Figure 3-2) from Feeney and Rosenberg (2003). The Reliz Fault bisects the north-dipping arm but does not act as a barrier to flow, as established by equipotential lines for the principal aquifers described in both GSPs for the Monterey and 180/400-Foot Aquifer Subbasins. The AEM surveys confirm and refine the anticline mapped in previously published reports and cross sections (MCWD, 2019; DWR, 2020; DWR, 2022; Deep Aquifer Study, 2023; Feeney and Rosenberg, 2003; Hanson *et al*, 2002; Yates, Feeney, and Rosenberg, 2005; HydroMetrics, 2009; Feeney, 2007; Feeney, 2010; MacTec, 2005; Harding ESE, 2001). In addition, installed wells with known screen intervals in the Paso Robles Formation and the Santa Margarita Sandstone added site-specific lithologic data to support the AEM data. The Santa Margarita Sandstone is encountered within this region as evidenced by the distinct screen intervals as well as higher resistivity data. The Santa Margarita Sandstone does not appear in wells on the northern side of the Monterey Subbasin. Where the Santa Margarita Sandstone underlies the 400/Deep Aquitard, it is included in the Deep Aquifers because it is part of the known and defined stratigraphic sequence for this Basin. The boundary parallel to the Toro Creek area reflects the continued structural deformation northward and traces the contact with the crystalline rocks along Toro Park. Figure 3-11 shows the Laguna Seca Anticline on the right side of the DWR 2022 AEM profile and highlights the continuous aquitard presence underlain by the Santa Margarita Sandstone in the Seaside Subbasin and adjacent Monterey Subbasin.

Figure 3-12 summarizes the lateral extent and key data used for its delineation.

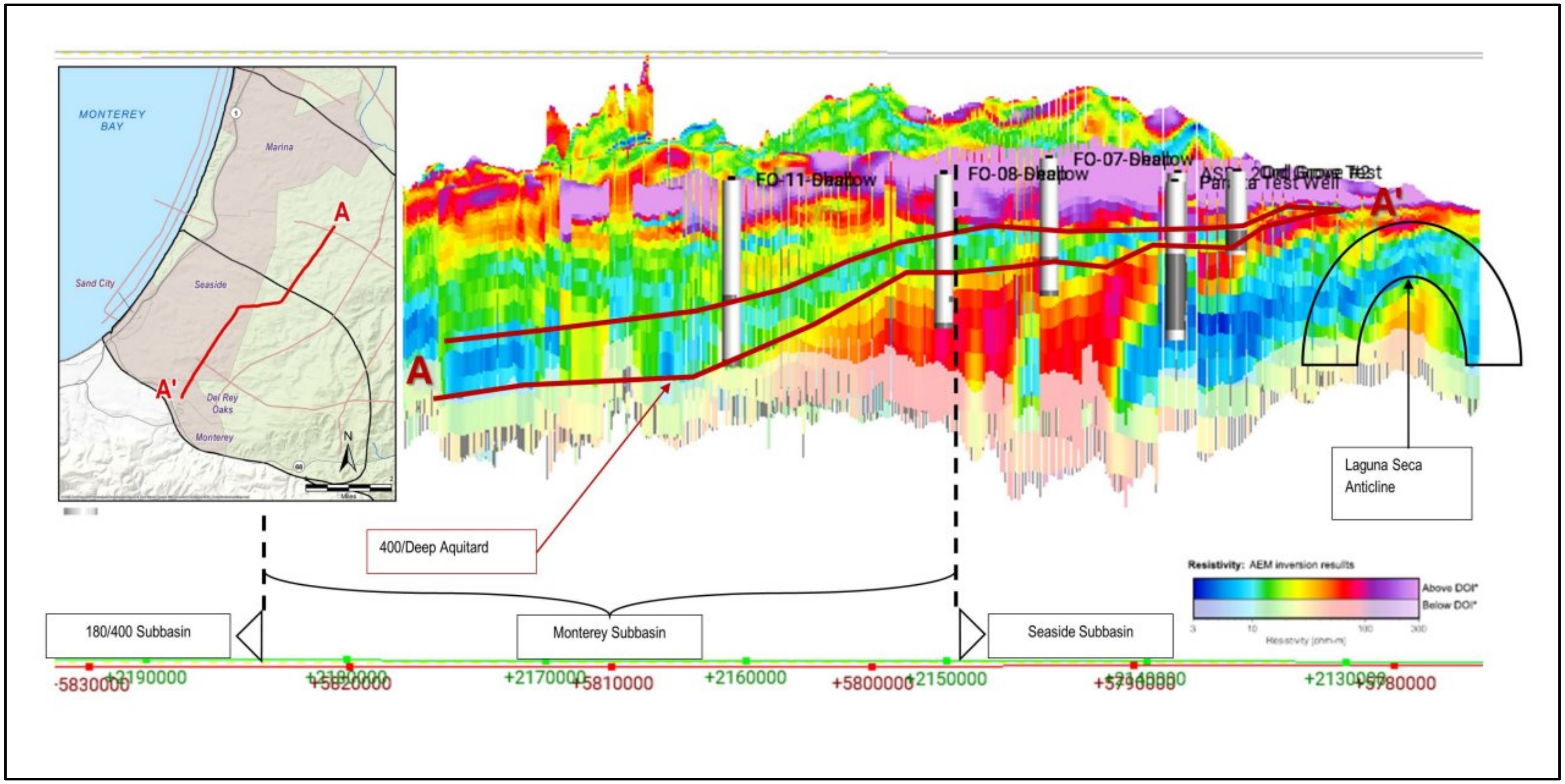


Figure 3-11. South Coastal/Laguna Seca Anticline Axis Boundary Example of Key Supporting Data – Visualization of AEM Cross Sections and Well Log Analysis in Leapfrog Software (see Appendix A for more detail)

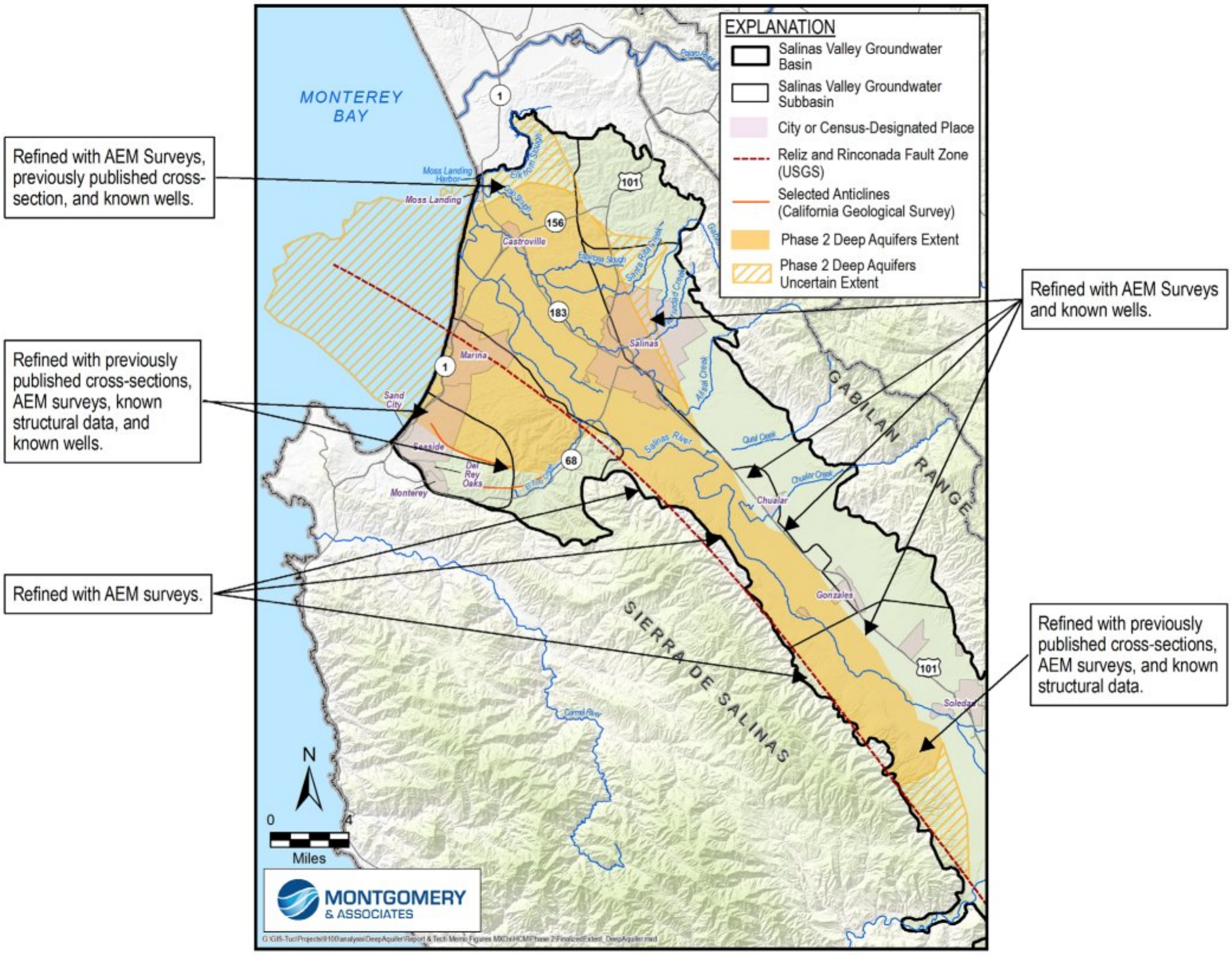


Figure 3-12. Final Deep Aquifers Extent and Final Refinements with Data Commentary

3.2.2 Vertical Extent

The Deep Aquifers extend vertically from the bottom of the aquitard below the 400-Foot Aquifer or its stratigraphic equivalent to the contact with either the Monterey Formation or crystalline basement rocks; effectively, anything below the bottom of the 40/Deep Aquitard is considered the Deep Aquifers. This means the thickness of the Deep Aquifers is variable as well, depending on the basement contact, and the impacts of structural deformation and erosional forces over time. As a result of complex depositional environments, the aquitard is a series of clay layers that together act as an effective aquitard above the water-bearing strata of the Deep Aquifers. However, there may be gaps in the 400/Deep Aquitard that allow for more direct hydraulic connection with the 400-Foot Aquifer. The top of the Monterey Formation is mapped on Figure 3-3.

3.3 Aquifer Hydraulic Properties

The movement and storage of groundwater through an aquifer is dependent on hydraulic properties that reflect structural and geological characteristics. Information on aquifer hydraulic properties is needed to understand current groundwater conditions, predict future groundwater conditions, and assess strategies for sustainable management.

The following are 2 general types of aquifer properties relevant to groundwater management:

- **Aquifer storage properties**, which control how much water is released from storage in the aquifer from a change in groundwater elevation in the aquifer
- **Groundwater flow properties**, which control how groundwater moves through the aquifer

In previous studies, the values and distribution of aquifer properties in the Deep Aquifers have not been well characterized and documented. To address this data gap, this Study aggregated all available existing aquifer property data, extracted aquifer property estimates from regional numerical groundwater flow models for the Salinas Valley, and analyzed results of 2 additional aquifer tests of deep wells. The deep wells that were tested for this Study were identified based on the preliminary extent. Refinement of the aquifer extent resulted in these wells being located just outside the final Deep Aquifers extent; however, the test results still provide information of aquifer properties at similar depths and adjacent to the Deep Aquifers.

3.3.1 Aquifer Storage Properties

Specific storage and storativity are important aquifer storage properties for confined aquifers like the Deep Aquifers. Specific storage is the volume of water released from or taken into storage in the aquifer per unit change in groundwater elevation, and values are in units of 1/Length, such as 1/foot. Specific storage reflects storage from both compression of the sediments and the expansion of water. As water is released from a confined aquifer, pressurized water expands slightly and the sediments collapse slightly, which compensates for the volume of released water (Schwartz and Zhang, 2003). Storativity, or storage coefficient, is equal to specific storage multiplied by the aquifer saturated thickness. Limited data exist for storage properties of the Deep Aquifers. Slug test analyses conducted by the USGS and MCWRA for DMW-1 assumed a range for specific storage from $1x10^{-5}$ to $1x10^{-6}$ 1/foot for estimating aquifer transmissivity (Hanson, *et al,* 2002). These specific storage values are typical for other deep aquifers in coastal areas (Hanson and Nishikawa, 1996), and are generally smaller than storage values in the overlying aquifer that is less confined and less consolidated. All available data are for wells in the coastal Deep Aquifers area. Individual test values are summarized in a table in Appendix D.

3.3.2 Aquifer Flow Properties

Hydraulic conductivity describes the rate of groundwater movement through the aquifer. Hydraulic conductivity is expressed in units of length per unit time, such as feet per day. Groundwater flows easier through aquifer material with higher hydraulic conductivities like sands and gravels than through aquifer material with lower hydraulic conductivities like silt and clay. Transmissivity is equal to the hydraulic conductivity multiplied by the aquifer saturated thickness. Few estimates of either hydraulic conductivity or transmissivity exist for the Deep Aquifers. Data compiled for this Study include estimated properties from Feeney and Rosenberg (2003), Hanson *et al.* (2002), and other studies, as summarized in Appendix D. Transmissivity values estimated for Deep Aquifers wells range from about 50 to 6,000 feet squared per day (ft^2/day), with geometric mean of about 1,500 ft^2/day. Estimated hydraulic conductivity values range from 2 to 36 feet per day (ft/day), with geometric mean of about 10 ft/day. All available estimates are from wells located in the coastal areas, and they represent a variety of depth intervals with screen lengths ranging from 20 to more than 800 feet. These data indicate that hydraulic conductivities in the Deep Aquifers are generally lower than those in the overlying 400-Foot and 180-Foot Aquifers and are within the range common for fine to coarse sand and silt aquifer material (Sterrett, 2009).

3.4 Groundwater Chemistry

The general chemical characteristics of groundwater are determined by the source water and sediments with which the groundwater is in contact. Analyzing the concentrations of dissolved minerals, particularly the major cations and anions, contributes to the overall understanding of how the Deep Aquifers developed hydrogeologically, connectivity across the Deep Aquifers, and potential groundwater inflow dynamics. Previous analyses of water chemistry by MCWRA described Deep Aquifers groundwater as having "a distinct character, with higher pH than groundwater in the overlying aquifers, relatively low calcium and high sodium concentrations, and an elevated temperature” (MCWRA, 2017). This Study builds on that previous characterization by analyzing the water chemistry samples from 127 wells, which includes 62 wells screened solely in the Deep Aquifers and 65 wells in adjacent or overlying aquifers.

In addition, analyzing isotopic signatures of Deep Aquifer groundwater helps characterize water sources and potential relationships between the surface or overlying aquifers. This Study analyzed the stable isotopes of oxygen and hydrogen since different water sources often have unique isotopic signatures. Tritium and carbon-14 are isotopes that contribute to understanding residence times of groundwater. Adding to prior Deep Aquifers isotope data that included 2 carbon-14 samples, this Study adds 9 samples analyzed for tritium and stable oxygen and hydrogen isotopes, some of which are outside of the Deep Aquifers extent to add data on connectivity and groundwater inflow.

3.4.1 General Groundwater Chemistry

The groundwater chemistry of the Deep Aquifers reveals both some unique characteristics and also a transition or journey that results from groundwater flowing through different sediments over time. Analysis of water chemistry type according to the major cations and anions shows that Deep Aquifers groundwater is generally distinct from overlying and adjacent aquifers, but also changes chemical composition with geography. Analysis of all samples together indicate that Deep Aquifers groundwater does not fit discretely within a single water type classification. Deep Aquifers groundwater is a mixed water type between sodium bicarbonate and sodium chloride water types. The water type changes with geography, as described in the following sections. The general mineral chemical composition of the Deep Aquifers water type is followed by a refined evaluation describing differences in compositions within the aquifer extent.

All water quality samples of wells solely screened in the Deep Aquifers confirm MCWRA’s description of the groundwater being relatively low in calcium and high in sodium, particularly compared to the overlying 400-Foot or equivalent aquifer. Figure 3-13 shows the major cations and anions plotted for both aquifers, broken down into the 2 areas described in the subsequent Section 3.4.2. Data represent the most recent sample from each well. Although there is overlap in the water quality data for the 400-Foot Aquifer and the Deep Aquifers, Figure 3-13 shows that calcium is relatively higher in many 400-Foot Aquifer wells and comparatively lower in some Deep Aquifers wells. The plot also shows that many 400-Foot Aquifer wells have relatively lower sodium when compared to the Deep Aquifers wells that have relatively higher sodium. An oval is drawn around the clusters of data points in 2 areas of interest: Northern Region and Seaside Region, based on differences in water type, as described in Section 3.4.2. The ovals are also shown on subsequent trilinear plots to aid with visual comparison of chemical compositions.

Where present, groundwater chemistry data for wells screened at similar depths to the Deep Aquifers, but located immediately outside the aquifer extent, provide comparison to adjacent aquifers. No deep wells exist to the north and northeast of the Deep Aquifers extent. Data for the deep wells immediately outside of the Deep Aquifers extent in the Gabilan Range alluvial fans southeast of the City of Salinas indicate that these wells are of calcium bicarbonate water type, as illustrated on Figure 3-14, and generally more similar to the water of the 400-Foot Aquifer. No water chemistry data are available for deep wells within the Deep Aquifers extent south of Salinas or outside of the extent up-valley. In the south coastal area, samples from 1 well in the Seaside Subbasin indicate that the chemical composition of groundwater at the well is a mixed water type, as shown on Figure 3-15.

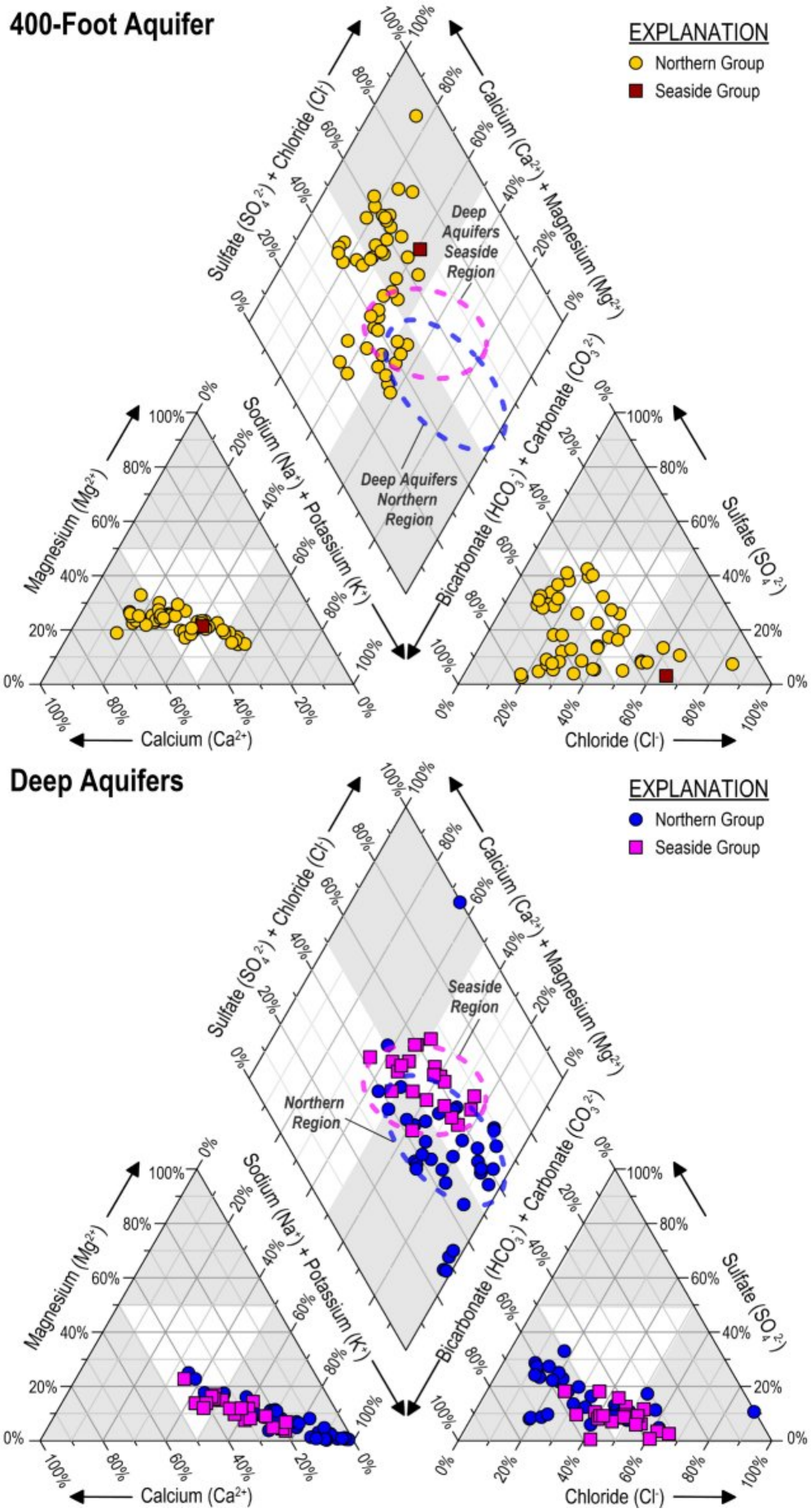


Figure 3-13. Comparison of Chemical Composition of Most Recent Groundwater Samples from Wells Screened in the Deep Aquifers (bottom) and the Overlying 400-Foot or Equivalent Aquifer (top)

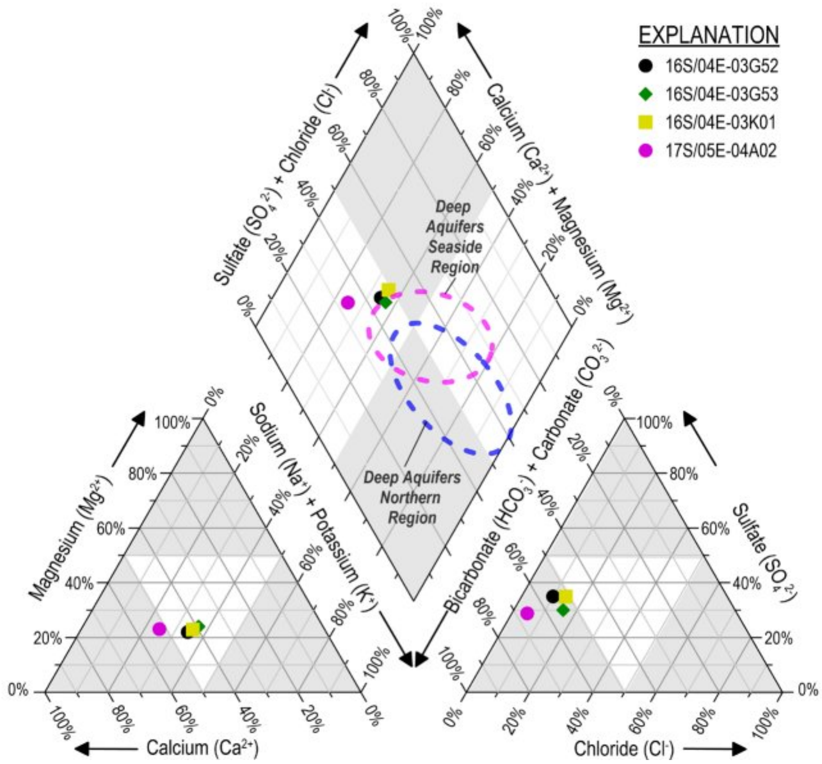


Figure 3-14. Trilinear Diagram for Most Recent Groundwater Samples from Wells Screened in Gabilan Range Alluvial Fans

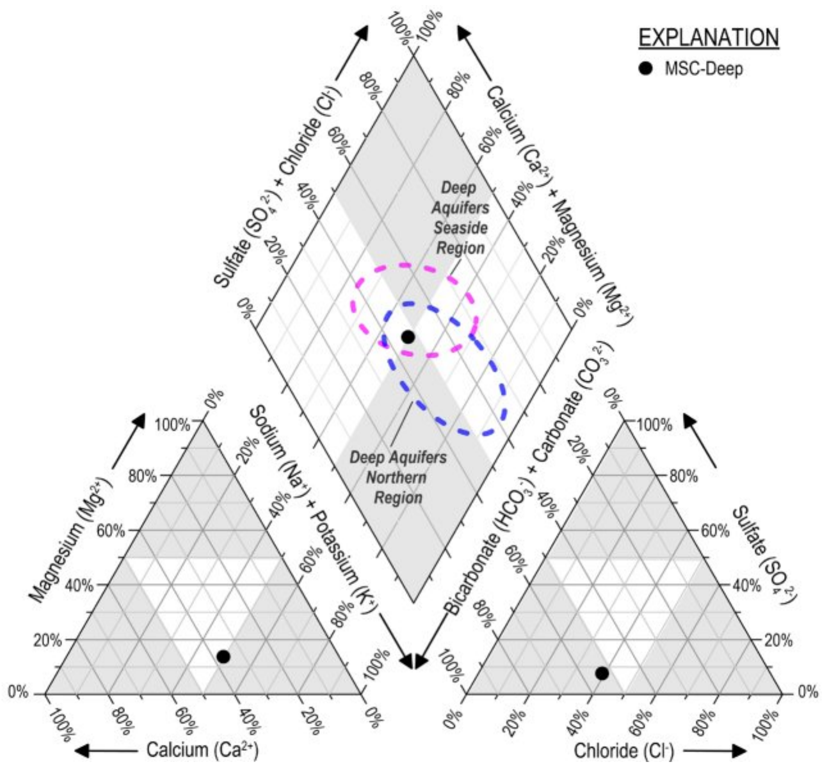


Figure 3-15. Trilinear Diagram for Most Recent Groundwater Sample from a Seaside Subbasin Well Outside the Deep Aquifers Extent

Groundwater pH measurements at wells installed solely in the Deep Aquifers or the 400/Deep Aquitard are shown on Figure 3-16. The measurements indicate that groundwater in the Deep Aquifers generally has a pH greater than 7.6. However, data for a few wells in or close to the Seaside Subbasin indicate pH less than 7.6. A spatial trend is not apparent, except that pH could be lower in the Seaside area than in the northern Salinas Valley portion of the Deep Aquifers. Additional samples are needed to verify this possible trend. No pH data are available for Deep Aquifers south and east of Salinas.

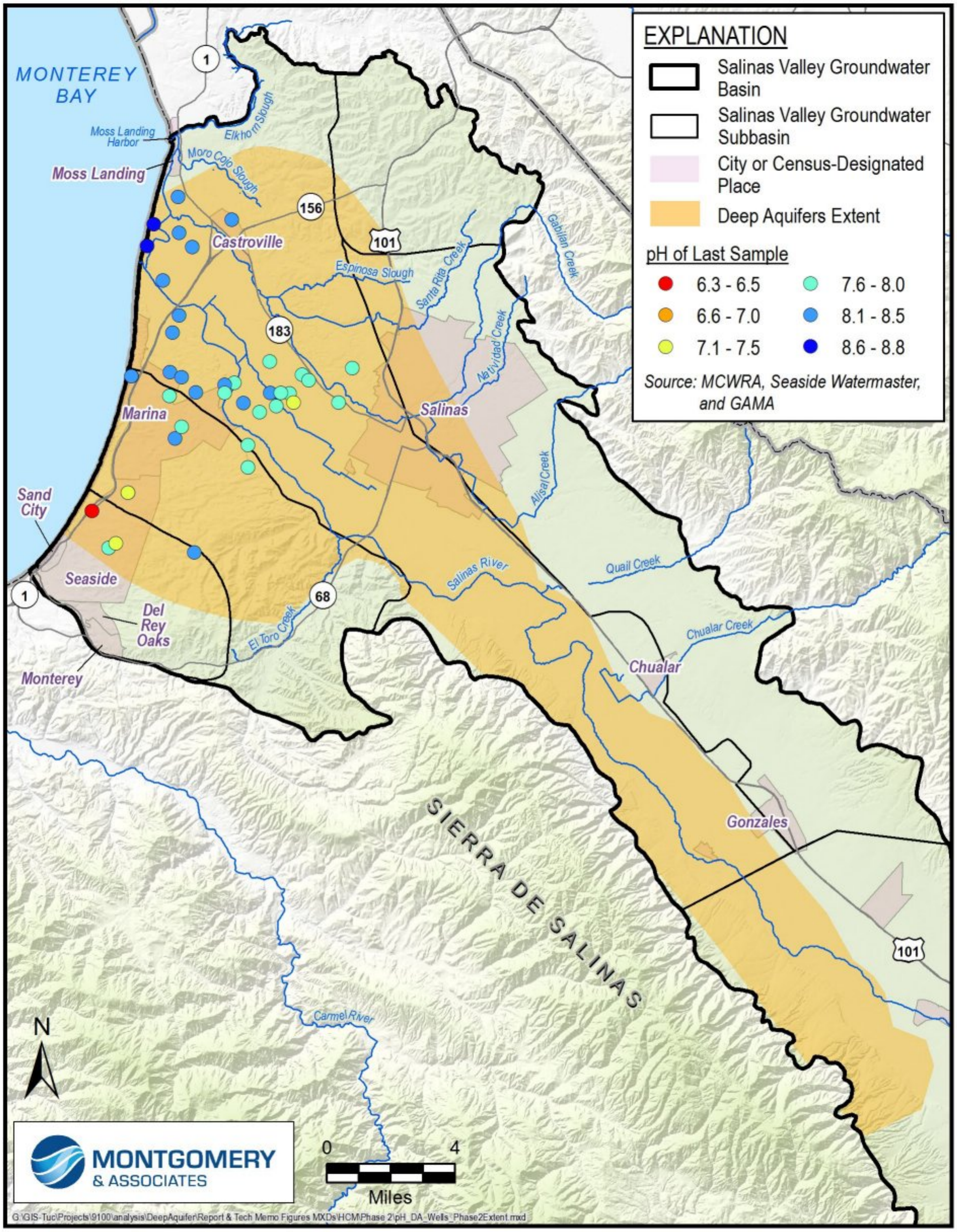


Figure 3-16. Measurements of pH in Deep Aquifers

3.4.2 Spatial Water Chemistry Differences Across the Deep Aquifers

More detailed analysis of water chemistry within the extent of the Deep Aquifers shows how its groundwater differs spatially. Analysis of water samples shows that the general water type breaks down into more distinct types that occur in 2 regions. Figure 3-17 shows the groups of wells within each of the following 2 regions:

- Seaside Region – Deep Aquifers wells within the Seaside Subbasin and southwestern adjacent part of the Monterey Subbasin
- Northern Region – Deep Aquifers wells in the northern part of the Deep Aquifers, including northern part of the Monterey Subbasin

Lack of water quality samples south of the City of Salinas limit analysis of the Deep Aquifers water type in the southern Salinas Valley extent of the Deep Aquifers. One well (14S-02E-25A03) in the Northern Group is anomalous and exhibits water chemistry more similar to the 400-Foot Aquifer and Gabilan alluvial fans. While the well is clearly screened in the Deep Aquifers below a thick body of clay, there are no other samples from Deep Aquifers wells to the south or east with which to compare. It is marked as anomalous on the plots in this Study. Figure 3-17 maps the 2 regions and shows representative stiff diagrams of wells in each group, including the anomalous well. Additional stiff diagrams are located in Appendix E.

The shapes of the stiff diagrams are different for each well group, indicating that areas of the Deep Aquifers have slightly different water chemistry compositions. The water chemistry at wells in the Northern Region show the higher sodium and lower sulfate and magnesium concentrations, resulting in a top left-leaning shape of the stiff diagram. The stiff diagrams for wells in the Seaside Region are a V-shaped pattern. The different shapes of the diagrams indicate that the chemical composition of Deep Aquifers groundwater differs between the Seaside Region and the Northern Region of the Salinas Valley.

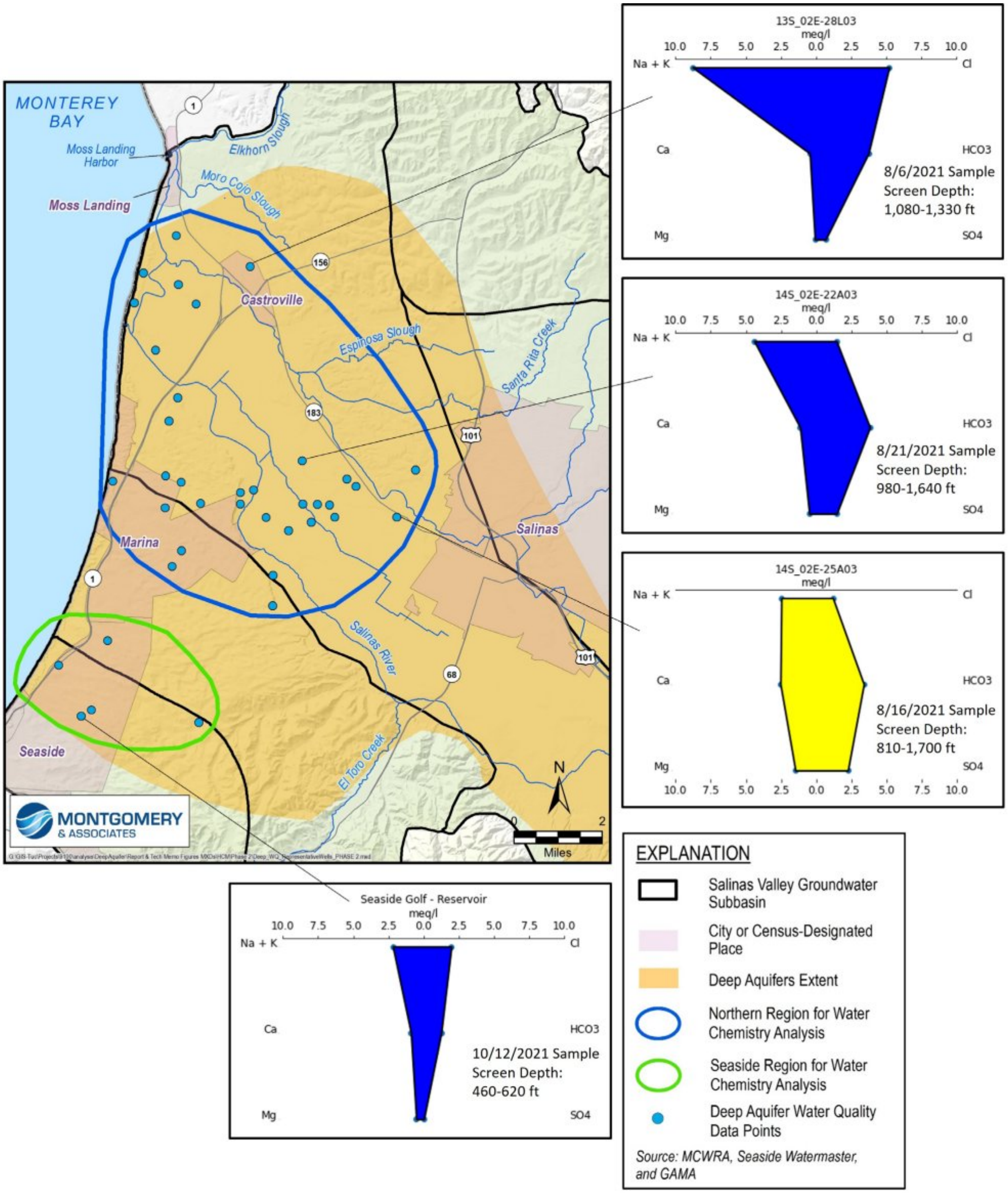


Figure 3-17. Stiff Diagrams for Selected Deep Aquifers Wells Showing Differences in Hydrochemical Composition

Figure 3-18 and Figure 3-19 show trilinear diagrams for the most recent sample collected from wells in each region. Trilinear plots showing historical data for the selected wells with long periods of historical data are included in Appendix E.

In the Northern Region, the water type is primarily sodium bicarbonate and sodium chloride as shown on Figure 3-20. The large range in composition in the Northern Region could reflect a mixing of water from the Paso Robles Formation at the calcium end (continental deposition) and the Purisima Formation at the sodium end (marine deposition). As groundwater flows from the inland areas to the coast, the changing composition from a slightly calcium bicarbonate water type to sodium bicarbonate or sodium chloride water type indicates a general decrease in calcium and increase in sodium at these wells. Although there is insufficient data to draw conclusions, the reasons for the gradation could be different geologic formations present in those regions, movement of groundwater, or interaction with the 400-Foot Aquifer. One well, 14S/01E-24L04, completed in the Upper Purisima Formation, has much higher chloride than the other wells in the Northern Region. The high salinity is not caused by seawater intrusion, but rather the dissolution of salts from saline marine clays that occur within the depositional setting in this portion of the aquifers (Hanson *et al.*, 2002).

In the Seaside Region, the chemical composition of the Deep Aquifers samples are generally in the sodium chloride category with some sodium bicarbonate, based on the most recent sample shown on Figure 3-15 and the historical analysis of samples in Appendix E. Although this composition is generally more similar to the Northern Region than overlying and adjacent aquifers, the Seaside Group wells have slightly higher chloride concentrations than the Northern Region wells. This could be because the Santa Margarita Sandstone that is encountered only in the Seaside Group tends to have native groundwater with higher chloride levels than other formations.

Figure 3-21 shows the wells screened in the Santa Margarita Sandstone versus the Paso Robles and Purisima Formations; however, given that the portion of the Paso Robles below the aquitard is sandy and directly above the Santa Margarita, they may be hydraulically connected. Alternatively, injected groundwater could be influencing the water chemistry in this region, even though the Paralta well, which has been clearly identified as being influenced, was removed from these plots.

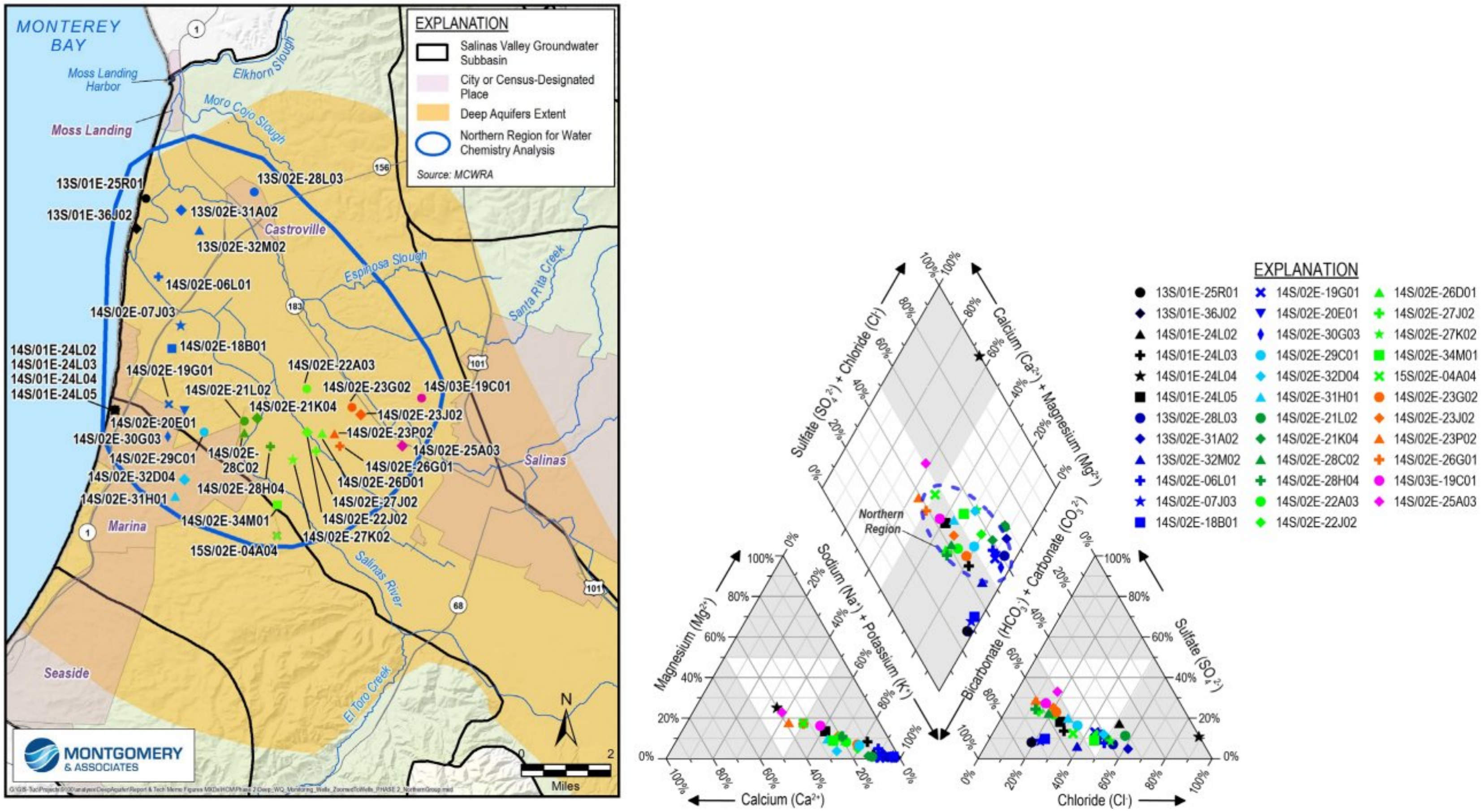


Figure 3-18. Locations and Trilinear Diagram of Wells with Most Recent Hydrochemical Data in the Northern Region of Deep Aquifer Extent

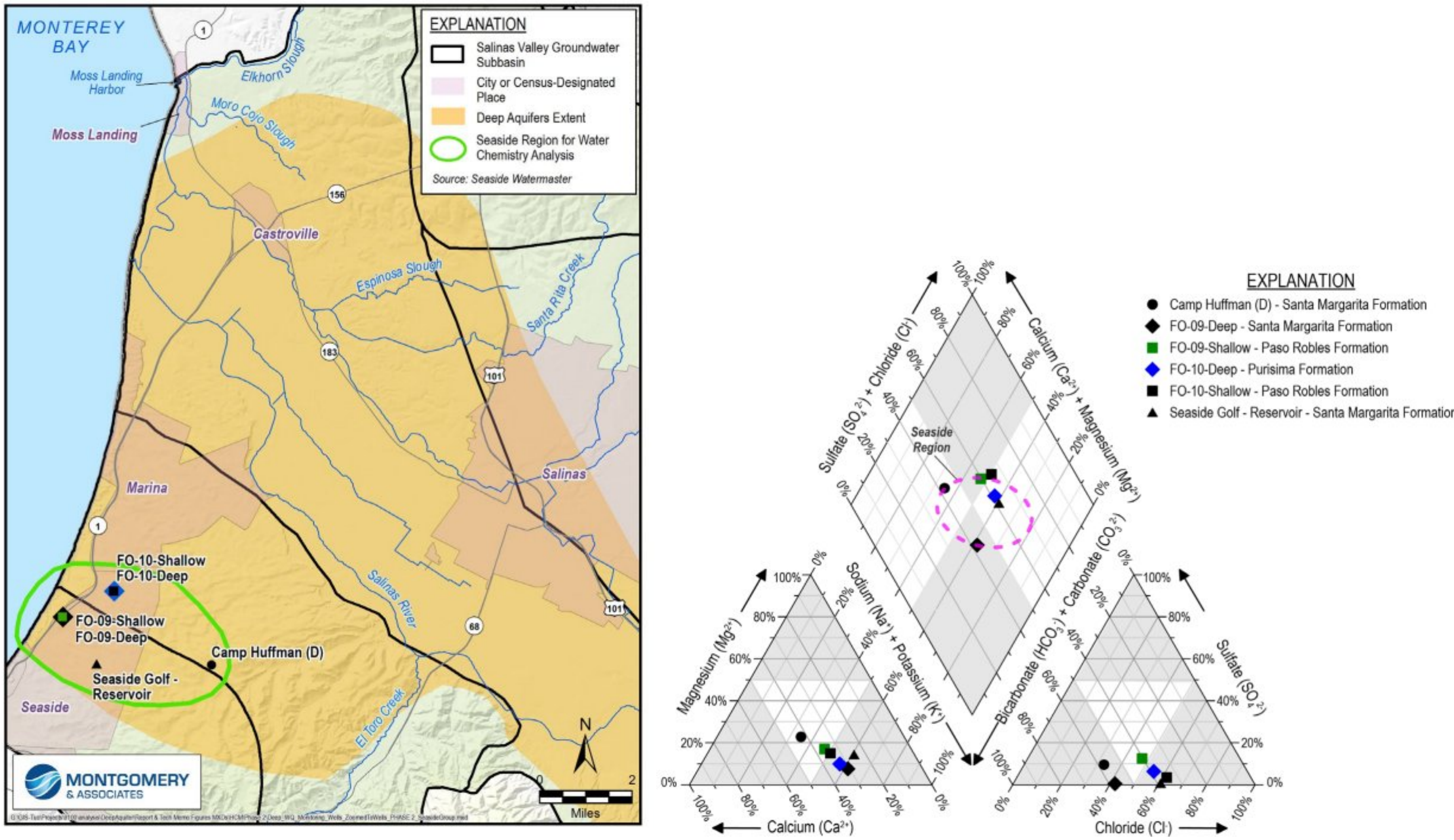


Figure 3-19. Locations and Trilinear Diagram for Most Recent Samples from Deep Aquifer Wells: Seaside Region

3.4.2.1 Connection to Overlying 400-Foot Aquifer or Equivalent Aquifer

In addition to evaluating the overall difference in chemical composition between the Deep Aquifers and the 400-Foot Aquifer, this Study examined the differences at local scale to attempt to identify any areas of potential hydraulic connection between the Deep Aquifers and the 400-Foot Aquifer. Historical water chemistry data for nearby wells installed in the Deep Aquifers and in the 400-Foot Aquifer are shown on Figure 3-19 and Figure 3-20 for the coastal and inland portions of the Northern Region, respectively. Although the data representing with 400-Foot Aquifer overlaps with Deep Aquifers compositions, the data show differences in water chemistry for each aquifer, which could indicate a lack of hydraulic connection or a slow connection between the aquifers. Available data are too limited to provide a more complete understanding of possible connectivity. Figure 3-21 shows that the water chemistry of the Deep Aquifers and the sediments above the 400/Deep Aquitard in the Seaside Region is more similar than that in the Northern Region. This could suggest more connection between the aquifers in the Seaside Region than the Northern Region. However, available data are limited for making strong conclusions about connectivity. One notable observation is that the change in chemical composition in the Deep Aquifers from inland areas to the coast in the Northern Region, as previously described, does not occur to the same degree in the 400-Foot Aquifer as shown on Figure 3-19 and Figure 3-20. While water in the 400-Foot Aquifer does show a shift from calcium bicarbonate towards sodium bicarbonate water type, the change is not as pronounced as in the Deep Aquifers, which moves from a mixed type to either sodium bicarbonate or sodium chloride.

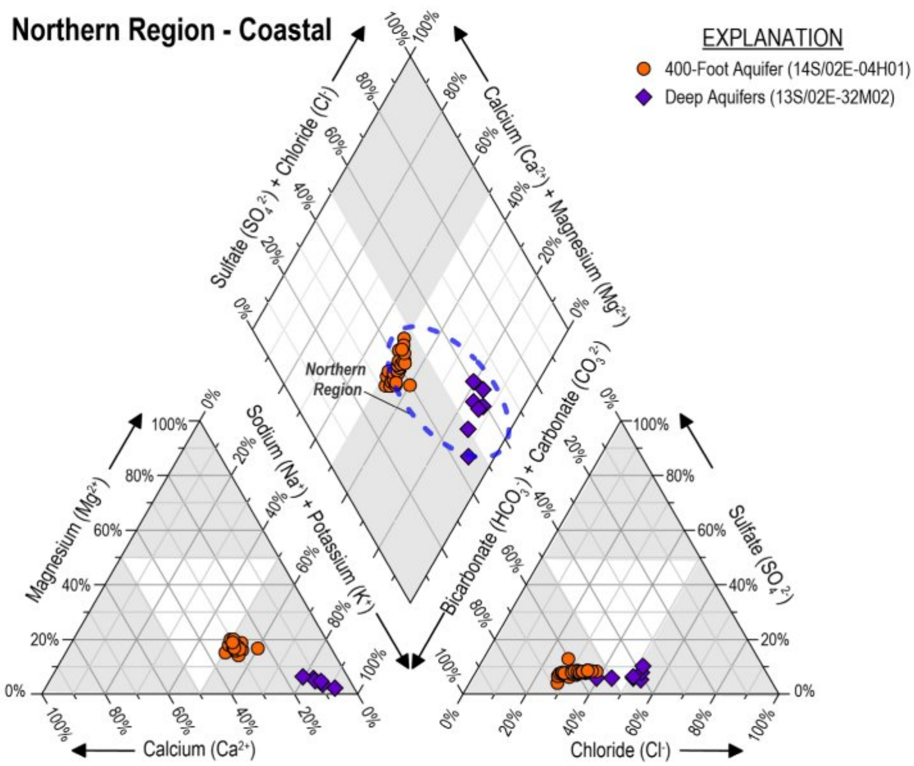


Figure 3-19. Trilinear Diagram Showing Historical Measurements for Individual Representative Wells in the Deep Aquifers and 400-Foot Aquifer in Coastal Part of the Northern Region

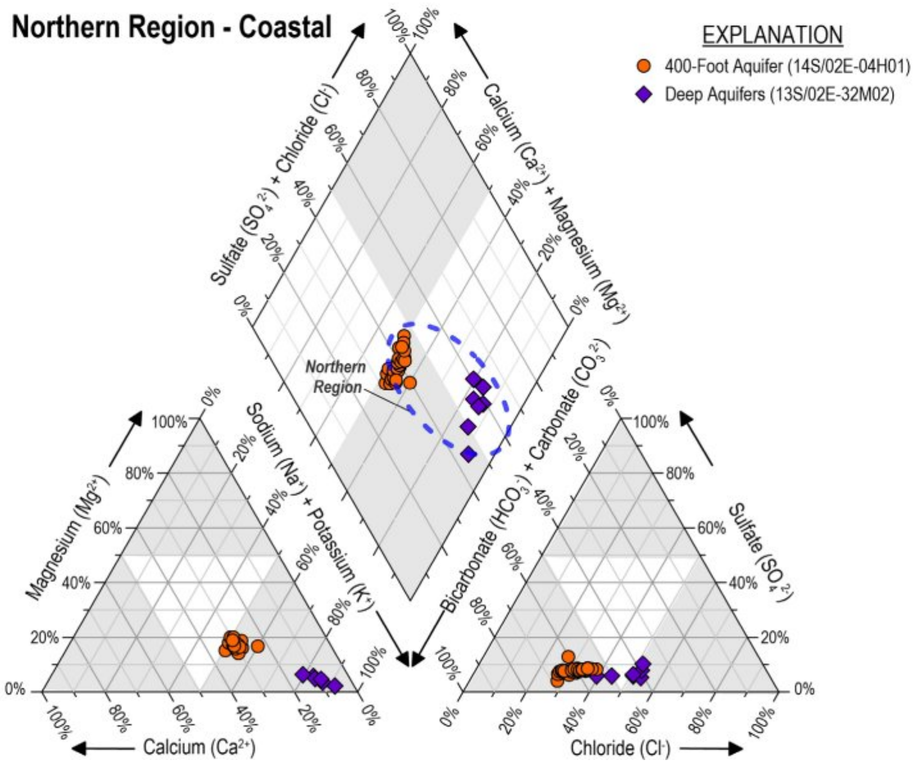


Figure 3-20. Trilinear Diagram Showing Historical Measurements for Individual Representative Wells in the Deep Aquifers and 400-Foot Aquifer in Inland Part of Northern Region

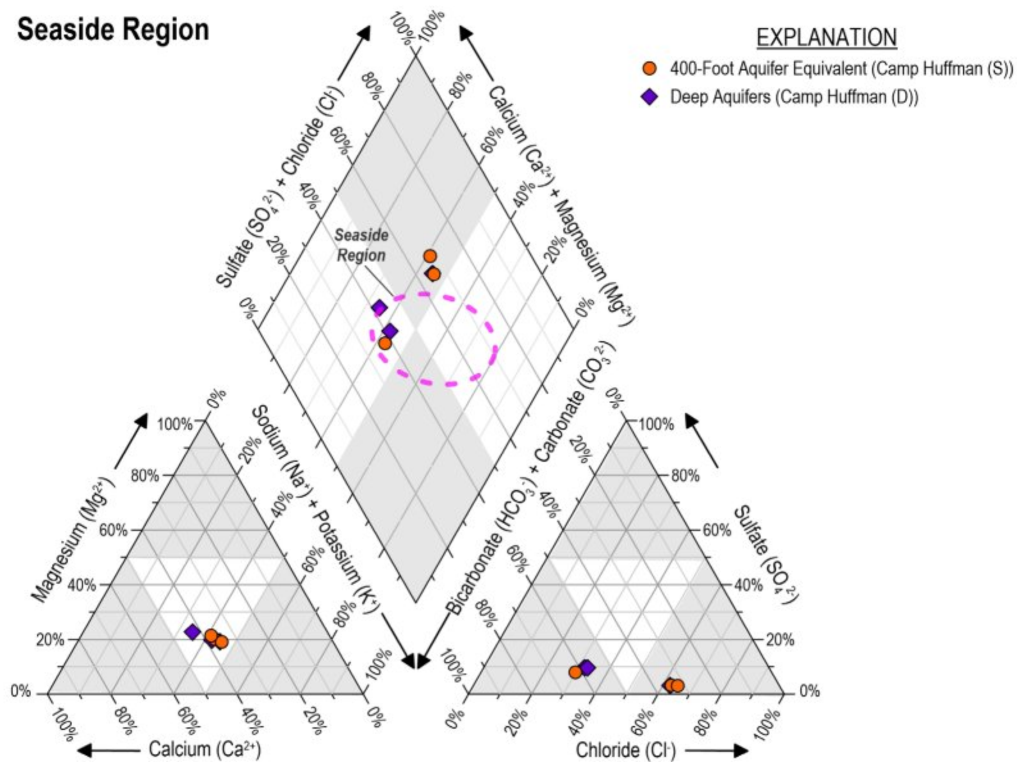


Figure 3-21. Trilinear Diagram Showing Historical Measurements for Individual Representative Wells in the Deep Aquifers and 400-Foot Aquifer Equivalent in Seaside Region

3.4.2.2 Historical Trends in Groundwater Chemistry

This Study plotted historical water chemistry for wells with longer historical records. The water chemistry of most wells remained relatively stable over time throughout the aquifer extent. While a few wells showed transitions over time in water type, no trend was detected across wells nor was there a conclusive reason identified for the transitions. Appendix E shows the historical trilinear plots for selected wells.

3.4.3 Isotopic Data/Age of Deep Aquifers Groundwater

Stable isotopes of oxygen-18 and hydrogen-2 in water ($\partial^{18}O$ and $\partial^{2}H$) can be used in hydrologic studies to identify potential water sources. Different water sources often have unique isotopic signatures due to fractionation of these isotopes during processes such as evaporation and precipitation (Clark and Fritz, 2000). In general, lighter (more negative) stable isotope values are associated with cooler, wetter climate conditions such as winter precipitation, high elevation precipitation, or even an entirely different climate regime such as the late Pleistocene when conditions were generally colder and wetter. Heavier (less negative) stable isotope compositions are typical of warmer conditions such as summer precipitation or precipitation at lower elevations. The global meteoric water line, based on the stable isotope composition global precipitation, is commonly plotted on stable isotope figures as a reference line (Craig, 1961).

Samples that trend to the right of the reference line can be interpreted as having an evaporative signature, which can occur in the atmosphere and terrestrially (Clark and Fritz, 2000).

This Study analyzed 108 samples for stable isotope analysis. Most of the samples were collected by MWCRA in 2022, while 9 wells were sampled in 2023 for this Deep Aquifers Study. The results were assigned to the Deep Aquifers, the 400-Foot Aquifer, an adjacent aquifer, or both the 400 and Deep Aquifers based on reported well construction information and borehole lithology analyses for this Study. Sample locations shown on Figure 3-22 and Figure 3-23 show a plot of stable oxygen and hydrogen isotope data. For comparison, isotopic results from recent surface water samples collected from reservoirs, the river, and tributaries in Salinas Valley by Vengosh *et al.* (2002) and Moran *et al.* (2012) were also included in this assessment. The data indicate that groundwater in the Deep Aquifers is generally isotopically lighter (more negative values) than surface waters and groundwater in the 400-Foot Aquifer and adjacent aquifers. Although there is overlap in stable isotopic composition between samples from the 2 aquifers and surface waters, $\partial^{18}O$ and $\partial^{2}H$ values in 400-Foot Aquifer and surface waters water tend to be greater (heavier) than about -7 ‰ and -46 ‰, respectively, using the Vienna Standard Mean Ocean Water (VSMOW) as a reference, and Deep Aquifers water tends to be less (lighter) than those values Figure 3-23). Mean values for stable isotopes for different sample groups are summarized in Table 3-2 for comparison.

Table 3-2. Mean Stable Isotope Values for Selected Sample Groups

Sample Group	Sample Count	$\partial^{18}O$ (‰ VSMOW)	$\partial^{2}H$ (‰ VSMOW)
Deep Aquifers – North Area	53	-7.61	-50.66
400-Foot Aquifer	36	-6.45	-41.09
Eastside Deep (adjacent)	5	-6.85	-44.08
El Toro (adjacent)	1	-6.45	-44.1
Seaside (adjacent)	1	-6.5	-42.6
Screened in Both 400-Ft and Deep Aquifers	12	-6.69	-43.06

Data points for the Deep Aquifers generally plot close to the Global Mean Water Line (GMWL), shown as a solid line on Figure 3-23, indicating that the Deep Aquifers groundwater has not been subject to strong evapotranspiration processes. This suggests the Deep Aquifers either do not receive inflow or that any inflow received is from aquifers located at depths such that they are not experiencing surficial recharge. The apparent difference in stable isotopic signatures of these aquifers and surface waters is likely due to different climate conditions when the waters were initially recharged.

A few Deep Aquifers groundwater samples have similar stable isotopic signatures as 400-Foot Aquifer samples (Figure 3-23). Some Deep Aquifers samples with similar isotopic signatures as the 400-Foot Aquifer were collected from wells located near the central portions of the aquifer extent south of the CSIP distribution area. The reason for isotopically heavier water to occur within the Deep Aquifers extent is unclear. The similar isotopic compositions could indicate a hydraulic connection between the aquifers, possibly through the perforated intervals of wells intercepting both aquifers; however, the data are not conclusive evidence of connection. Additional sampling from these wells could help clarify this understanding.

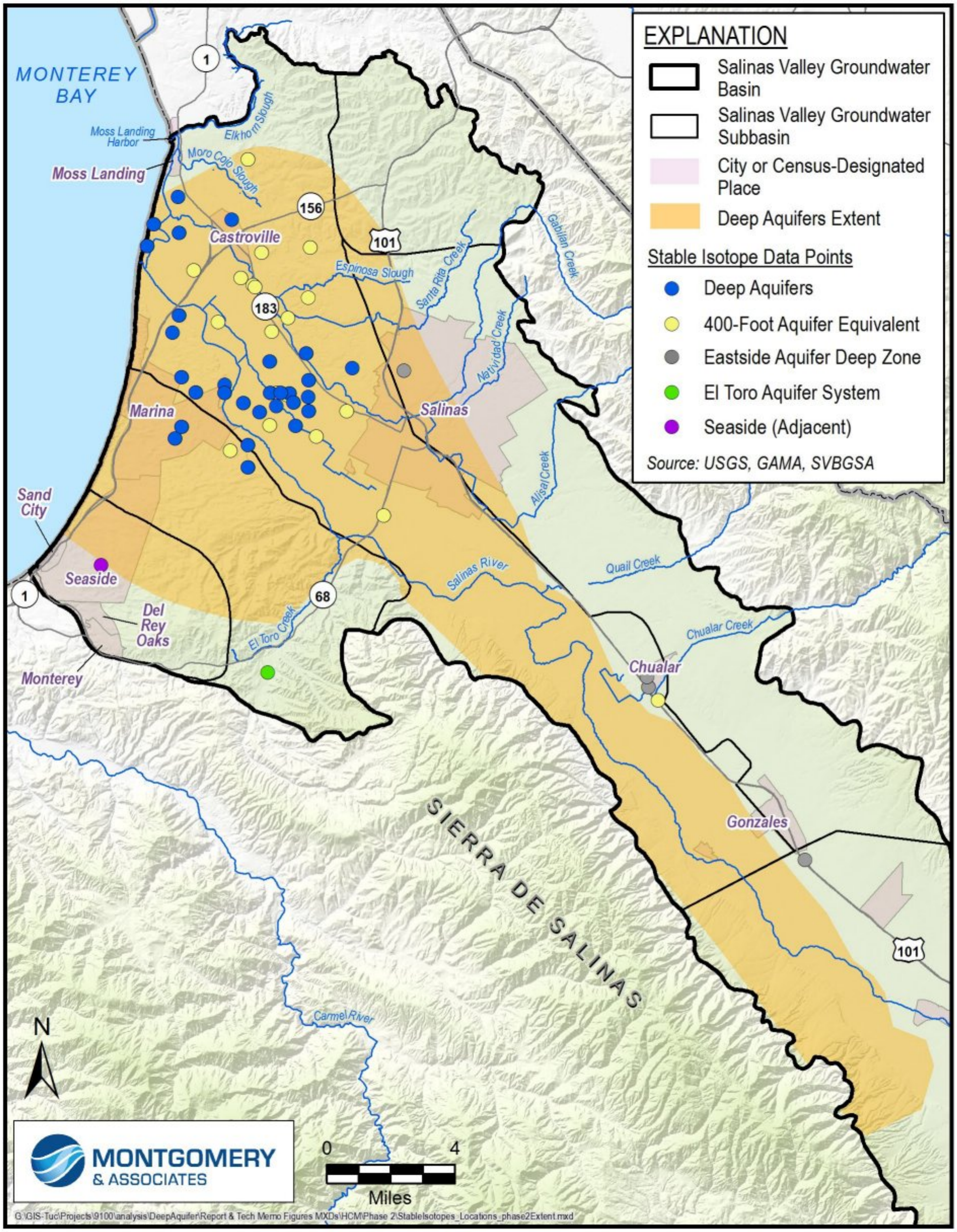


Figure 3-22. Locations of Stable Isotope Data Points for Deep Aquifers and 400-Foot Aquifer

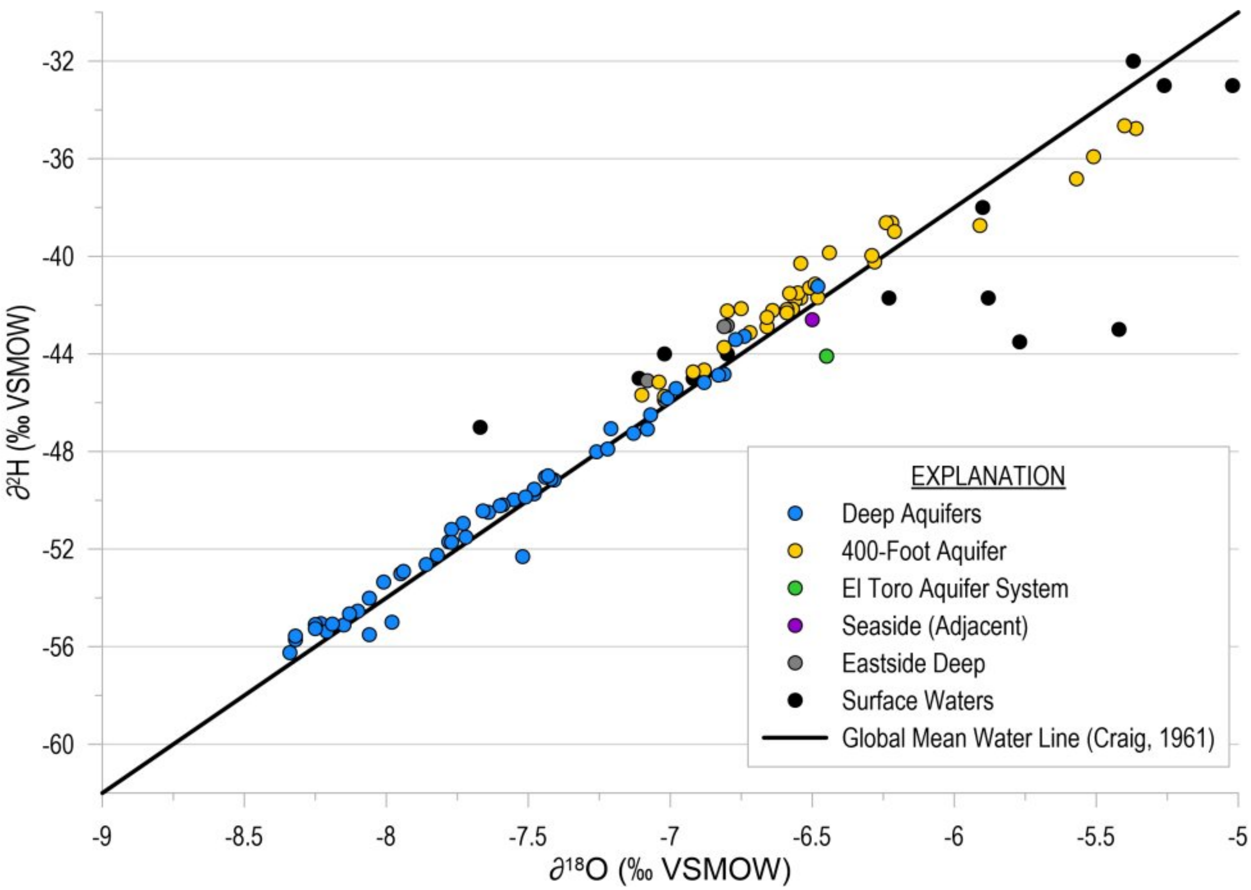


Figure 3-23. Stable Isotope Ratios in Deep Aquifers, 400-Foot Aquifers, and Equivalent Adjacent Aquifers

Tritium (^3H) and carbon-14 (^{14}C) are isotopes used to estimate recharge rates and residence times of groundwater. Tritium data provide information regarding the presence or absence of modern-day recharge (Clark and Fritz, 2000). Tritium values are indicative of the following different water ages:

- Less than 1 tritium unit (TU) is generally considered to be pre-modern water. These values are considered lack of tritium in a water sample, which indicates that the water is older than about 70 years (1950s post-WWII bomb pulse).
- 1 TU or above suggests older water mixed with modern water (Clark and Fritz, 2000).
- Tritium values greater than about 10 TU indicate modern (post-1952) age of water (Drever, 1997).

Similarly, lower carbon-14 activities (i.e., smaller percent modern carbon) indicate groundwaters with longer residence times (i.e., older water). Previous tritium and carbon-14 analyses of Deep Aquifers groundwater indicated that the water is old and recharged thousands of years before the present time (Hanson *et al.*, 2002; MCWRA, 2017). Data analyzed for this study also indicate that groundwater in the Deep Aquifers has long mean residence times (i.e., relatively old water).

Tritium results for wells screened in the Deep Aquifers and the 400-Foot Aquifer are shown on Figure 3-24. The majority of tritium data were from the USGS GAMA program; additional tritium samples were analyzed by M&A in summer 2023 as part of this Study. Some wells have multiple data samples shown on Figure 3-24. Tritium data are available for only 4 Deep Aquifers wells, and all 4 have tritium concentrations of <1 TU, indicating pre-modern water. Samples for most 400-Foot Aquifer wells indicate the presence of pre-modern water, while samples for 2 wells suggest a mixture of pre-modern and recent waters. Data for wells in the El Toro Primary Aquifer System and the Gabilan Bajada (Eastside Deep) areas, which are adjacent to the Deep Aquifers extent, indicate that groundwater in these areas is largely pre-modern in age. However, the data also suggest that recent water could be infiltrating to these adjacent aquifers in some local areas in the adjacent aquifers, as shown by points with >1 TU on Figure 3-24 near Quail Creek and Gonzales. The data for the Eastside Deep portion of the Gabilan Bajada are from intervals equivalent to the 400-Foot Aquifer; however, a hydraulic connection between the Eastside aquifer system and the Deep Aquifers could exist. Although the El Toro Primary Aquifer System shares the same geologic units as the Deep Aquifers, limited evidence exists to conclude that they are hydraulicly connected. No tritium data exist for upgradient adjacent aquifer in the Forebay Aquifer Subbasin, where deep groundwater may be moving into the Deep Aquifer zone. Additional isotope analyses should be conducted to assess surficial recharge and any potential hydraulic connections between the Deep Aquifers and adjacent aquifer systems.

Carbon-14 data for the Deep Aquifers are very limited and located along the coast, which makes it difficult to draw conclusions that apply to inland portions of the Deep Aquifers. Carbon-14 data for GAMA wells MSMB-03 and MSMB-12 show small percent modern carbon indicating that Deep Aquifers water has long residence times and is thousands of years old. Carbon-14 data for Deep Aquifers are currently not available for south (or inland) portions of the aquifers.

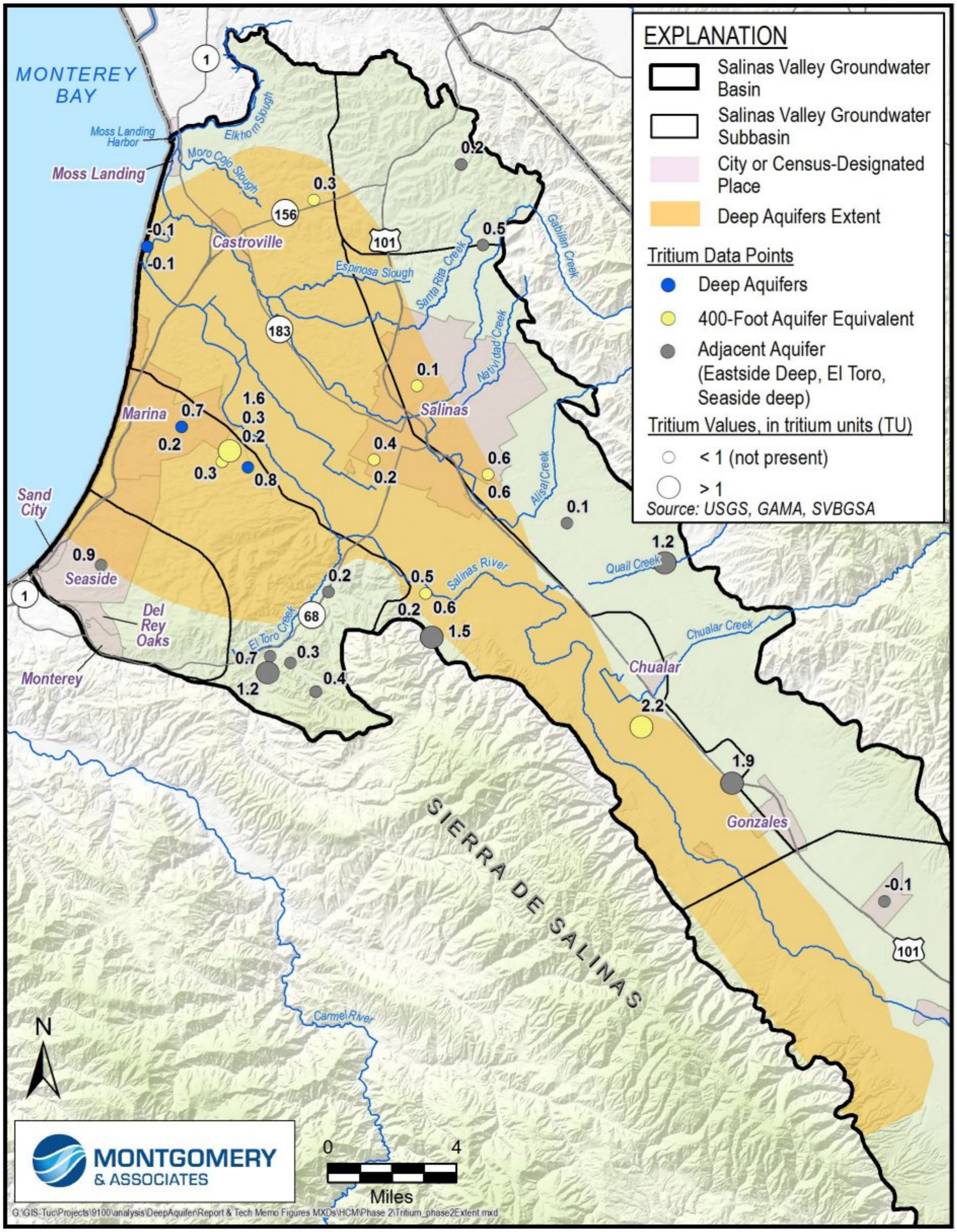


Figure 3-24. Tritium Values at Deep Aquifers, 400-Foot Aquifer Wells, and Adjacent Aquifers

3.5 Potential Natural Recharge and Discharge Pathways

This Study identifies areas of hydraulic connectivity that could be potential pathways for recharge, discharge, or subsurface inflows and outflows. Previous hypotheses about locations of recharge or discharge remain, with some slight refinement. For the purpose of this Study, natural recharge and discharge refer to water entering and exiting the Deep Aquifers through any surficial outcrops. Rainfall percolation and stream leakage that infiltrate directly into the Deep Aquifers sediments would be examples of natural recharge. Subsurface flows in and out of the Deep Aquifers are referred to as inflows and outflows.

Surficial Recharge: The Deep Aquifers are confined, and do not directly receive natural, surficial recharge. Adjacent aquifers may receive natural recharge that flows into the Deep Aquifers as subsurface inflow.

The outcrops of Paso Robles Formation in the Corral de Tierra and Toro Park areas are disconnected from the coastal Deep Aquifers via structural deformation in the form of uplift and anticlines; the Monterey Formation has been uplifted near Highway 68 near the Corral de Tierra, which is the relatively impervious bottom of the basin. The crystalline rocks in Toro Park also do not allow for flow from the Paso Robles Formation into this area. The Toro Creek corridor may represent a potential recharge pathway going towards the Salinas River; however, there is shallower pumping within this area that likely intercepts any recharge to the deeper sediments. Furthermore, there are no data to establish any recharge relationship between the Paso Robles outcrops in the Corral de Tierra and the Deep Aquifers in the main basin.

Any subsurface inflow of natural recharge from adjacent aquifers has long residence time, as supported by the limited isotope data. No surficial recharge of modern water to the Deep Aquifers is observed in the data, indicating no post-1953 surface water entering the aquifer. Outcrops of the Paso Robles Formation primarily occur south of San Ardo, and it would likely take recharge more than a century to reach the extent of the Deep Aquifers.

Subsurface Inflow and Outflow from Adjacent Aquifers: The formations that define the Deep Aquifers extend beyond the limits of the 400/Deep Aquitard, and the Deep Aquifers are likely in hydraulic communication with these adjacent areas. The formations may be a conduit for inflows or outflows. In areas where there is intermingling with alluvial fans, intermixed clays may prevent or slow down the flow of this water. The southern coastal region of the Deep Aquifers is an area that may have the highest potential for subsurface flow within the management timeframe. The aquitard clays are closer to the surface and are truncated by the structural deformations of the area, which allows for fractures and potentially more open pathways in the subsurface. The combination of the edge of the aquitard clays at shallower depths with structural influences may allow for subsurface inflow into the Deep Aquifers near the axis of the Laguna Seca Anticline. However, since data do not show younger water in the Deep Aquifers in this region, this location of inflow is still unsupported.

Vertical Inflow and Outflow Across the 400/Deep Aquitard: The 400/Deep Aquitard is an area of greater clay prevalence that acts as an effective aquitard above the water-bearing strata of the Deep Aquifers. However, there may be gaps that allow for hydraulic connection with the overlying aquifer, such as has been identified through the drilling of an oil well near Somavia Road (Thorup, 1976). Furthermore, the clays may allow for slow diffusion of water between the Deep Aquifers and overlying aquifer, as other investigators have hypothesized (MCWD GSA and SVBGSA, 2022). Slow diffusion could be significant if it occurs over a large area, and it likely would be variable at different locations across the Deep Aquifers extent.

3.6 Limitations in Data and Data Gaps

This Study includes analyses of existing well data along with new AEM, water chemistry, isotopic, and aquifer properties data to understand the Deep Aquifers. Many of the analyses in this Study identified data concurrence and overlap to provide the best interpretations. Even with an abundance of new and multi-faceted data, data gaps and uncertainty remain, as described below.

Well Data: Many data come from deeper production wells that are often screened across the 400/Deep Aquitard and into both the 400-Foot Aquifer and the Deep Aquifers. Furthermore, many of the sediments logged in well completion reports include notable amounts of clay, making it difficult to conclusively identify and locate the 400/Deep Aquitard. As such, the data from these wells come with nuances and complexities that make analyses and syntheses for an isolated aquifer or aquitard more challenging.

AEM Data: AEM data collected in the southernmost areas of investigation have significant gaps as a result of vineyards and other infrastructure that interferes with the signal. Fewer AEM surveys have been collected north of Salinas, or near Prunedale, also as a result of infrastructure. Seawater intrusion also severely impacts resistivity signals, and as a result AEM data throughout the area of seawater intrusion is limited to shallow depths of investigation. These areas still represent gaps in detailed views into the subsurface, particularly at depth.

Water Chemistry and Isotopic Data: Water samples collected by MCWRA and M&A staff focused on the preliminary extent and were used for the water chemistry and isotope analyses. There are very limited data from the inland and Southern portions of the Deep Aquifers as there are no known samples of water chemistry or isotopes in wells screened solely in the Deep Aquifers.

Tritium and carbon-14 data for the Deep Aquifers are currently limited. No data are available from areas at the northeastern margins of the Deep Aquifers extent. Data in this area could be useful for identifying any potential subsurface inflow pathways from the Gabilan Bajada. Additional tritium data from areas near Gonzales might also provide insight on possible subsurface inflow pathways coming from the upgradient portions of the Deep Aquifers.

Aquifer Properties Data: The aquifer tests conducted in the inland areas were based on well selections within the preliminary Deep Aquifers extent. The wells selected for testing are at similar depths as the Deep Aquifers, but are situated within the adjacent Eastside aquifer system based on final extent analyses. As such, the inland portions of the Deep Aquifers still do not have verified aquifer properties like the coastal portions.

As a result of the limitations of the data discussed above, the extents of the Deep Aquifers are restricted only to places with data to verify the presence of the 400/Deep Aquitard. Outside of these verified data points, the Deep Aquifers presence is defined as uncertain, shown on Figure 3-21.

These listed data limitations and data gaps are identified to summarize where there is greater or lesser uncertainty. Most available data are concentrated in areas with more deep wells and greater production, even though the Deep Aquifers extend farther. Subsequently, these data gaps represent opportunities for further investigation and refinement into the management horizon.

4 WATER BUDGET

The Deep Aquifers water budget helps understand changes in groundwater storage, which are a function of groundwater inflows to and outflows from the Deep Aquifers. The water budget adds context to these flows rather than simply estimate the total volume of water present in the Deep Aquifers. Not all groundwater is readily available for pumping, and negative impacts are related to groundwater elevation decline, not total volume of stored water. No previous studies have developed a groundwater budget for the Deep Aquifers.

4.1 Overview and Approach

Groundwater models are the best available tools for developing water budgets. This Study uses 2 groundwater models to develop a historical and recent water budget for the Deep Aquifers. The resulting water budgets estimate the annual volumetric flow rates of groundwater entering and leaving the delineated extent of the Deep Aquifers, encompassing both historical (2004-2017) and recent (2018-2020) conditions, as well as an estimate of annual change in groundwater storage volume over time.

4.1.1 Groundwater Models Selected for Water Budget Development

Since only a few water budget components can be directly measured, most water budget components are estimated by a groundwater flow model. While there is inherent uncertainty associated with estimating flows using groundwater models, they most often provide the best available tools for developing water budgets. Groundwater models are generally developed and calibrated based on an understanding of the hydrostratigraphy of the aquifer system and observed data, such as groundwater elevations, groundwater extraction, aquifer properties, streamflows, and, in the case of certain models, chemical solute concentrations such as chloride. Groundwater models estimate groundwater flow rates based on the data available during model development and can be updated as additional data are collected. All groundwater flow models available for this analysis were constructed prior to the additional data collected as part of this Study; however, when compared to the HCM developed in this Study, they provide reasonable estimates of inflows and outflows.

The construction and calibration of 3 available groundwater models that overlap the Deep Aquifers in Salinas Valley were evaluated to identify the most suitable model(s) to use for the water budget analysis. No single model was appropriate for the development of the water budget across the full lateral extent of the Deep Aquifers. This Study used the Salinas Valley SWI Model for the Deep Aquifers water budget for most of the Deep Aquifers extent, and used the provisional SVIHM[1,2] for the Southeastern Region of the Deep Aquifers, which is outside the SWI Model area. While the Monterey Basin Groundwater Flow Model (MBGWFM) had better calibration within the Monterey Subbasin, it was limited in extent and did not cover the Seaside portion of the Deep Aquifers. The SWI Model was selected because it provides continuous model coverage from the northern coast through the Seaside portion of the Deep Aquifers, and the estimated flows and change in storage are similar to the MBGWFM. The North Marina Groundwater Model and the Seaside Basin Model were also initially considered; however, they only cover small portions of the Deep Aquifers lateral extent. Therefore, the SWI Model and SVIHM were used for this water budget analysis. While combining results from multiple models is not ideal, the SWI Model and the SVIHM are the best available tools to calculate the Deep Aquifers water budget.

Figure 4-1 shows the model extents and how they relate to the lateral extent of the Deep Aquifers. Appendix F provides additional details on the comparison between groundwater models and rationale for selecting the 2 models.

[1] These data (model and/or model results) are preliminary or provisional and are subject to revision. This model and model results are being provided to meet the need for timely best science. The model has not received final approval by the U.S. Geological Survey (USGS). No warranty, expressed or implied, is made by the USGS or the U.S. Government as to the functionality of the model and related material nor shall the fact of release constitute any such warranty. The model is provided on the condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the model.

[2] The provisional SVIHM used by M&A for this analysis is version 7.1, provided on July 24, 2023.

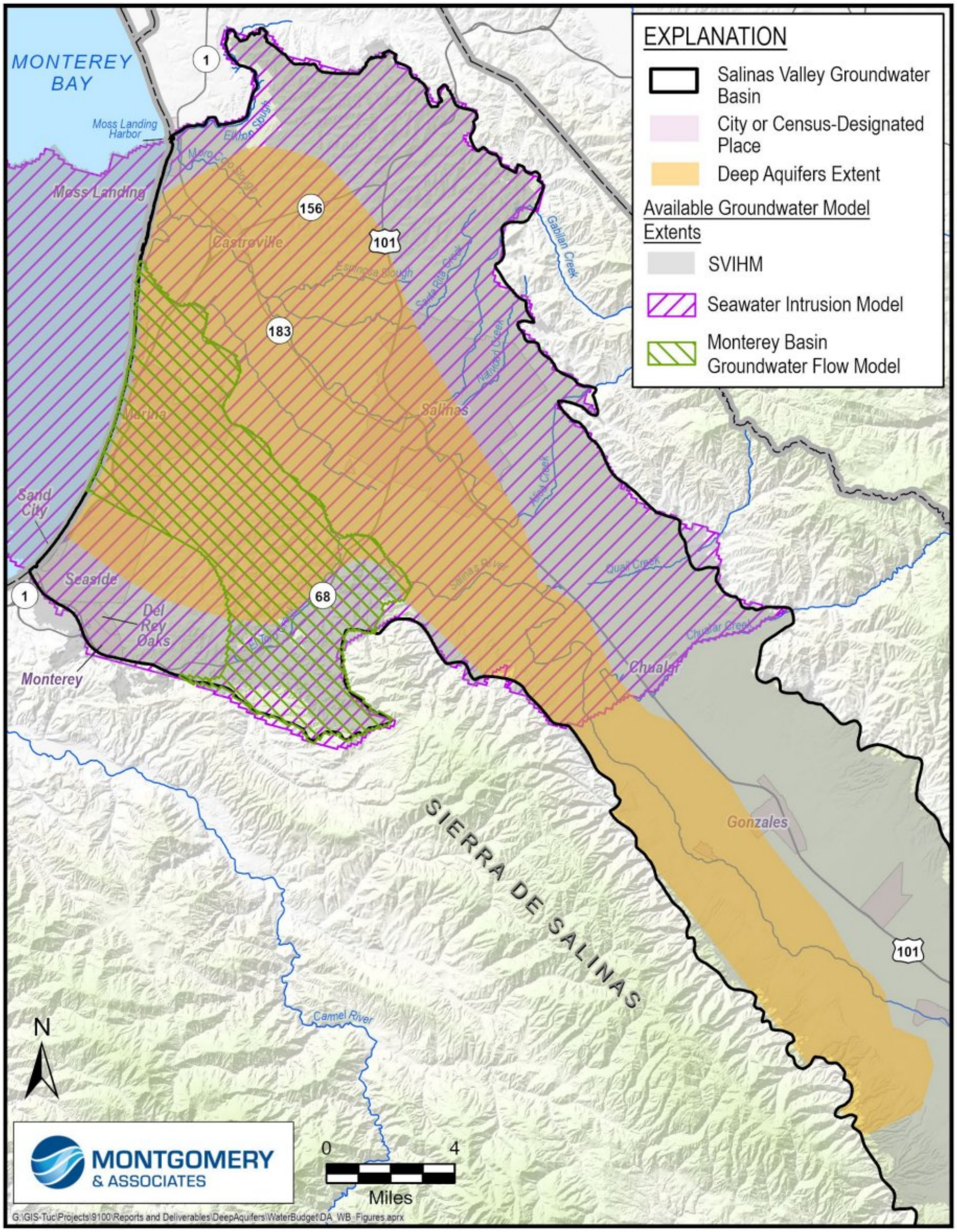


Figure 4-1. Deep Aquifers Extent and Available Groundwater Model Extents

4.1.2 Water Budget Components

The water budget is an inventory of the Deep Aquifers groundwater inflows and outflows. Pumping and injection are the only components of the water budget that can be directly measured, and measured values are used in the development and calibration of the groundwater models. Other components are not easily measured, and therefore are estimated using groundwater models.

The water budget for the Deep Aquifers is calculated within the following boundaries:

- Lateral boundaries: The lateral extent of the Deep Aquifers are described in detail in Section 3.2.1. Areas of uncertainty outside of the extent are not included, such as the offshore portion of the aquifers.
- Bottom: Primarily the top of the Monterey Formation, a shallow marine deposited shale or mudstone (Harding ESE, 2001; Greene, 1977). Where the Monterey Formation is not present in the subsurface, granitic and metamorphic rocks constitute the Basin bottom.
- Top: The 400/Deep Aquitard between the 400-Foot Aquifer and Deep Aquifers.

Figure 4-2 presents a general schematic diagram of the coastal Salinas Valley hydrogeologic conceptual model. The water budget components of the Deep Aquifers include all the inflows, outflows, and change in groundwater storage, as shown on Figure 4-3. Inflows to the Deep Aquifers include injection of surface or recycled water, subsurface inflows from the underlying Monterey Formation (from below), subsurface inflows from the overlying aquitard (from above), and subsurface inflows from adjacent aquifers including aquifers located offshore. This water budget uses the term “recharge” to represent water that directly infiltrates into an aquifers from the ground surface. Water that flows from adjacent aquifers, such as the Gabilan Range Bajada, is considered subsurface inflow for this water budget analysis. Outflows from the Deep Aquifers include groundwater extraction and subsurface outflows to overlying and adjacent aquifers. The hydrologic connection between the 400-Foot Aquifer and Deep Aquifers across the 400/Deep Aquitard likely varies across the Deep Aquifers extent. Insufficient data exists to verify the variation and magnitude of the potential connection between these aquifers.

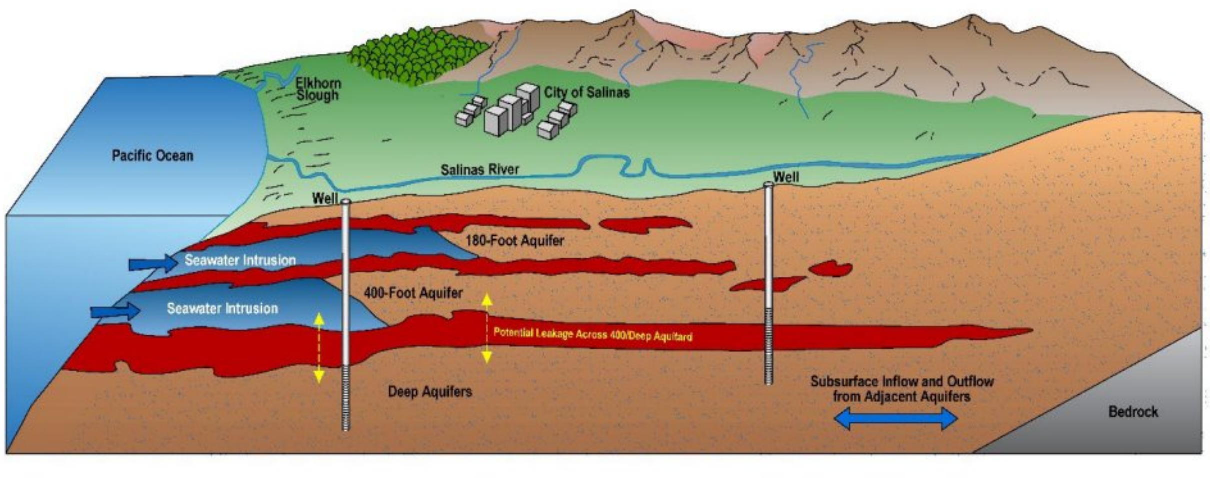


Figure 4-2. Schematic Diagram of the Deep Aquifers Hydrogeologic Conceptual Model

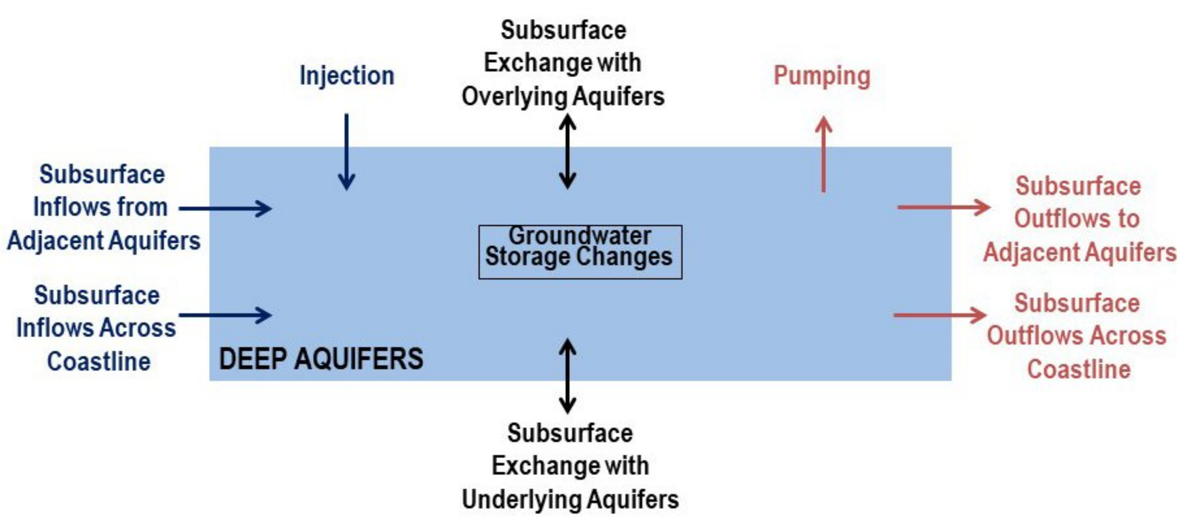


Figure 4-3. Generalized Schematic Diagram of the Deep Aquifers Water Budget

Within the water budgets, subsurface inflows from and outflows to adjacent aquifers are refined by boundary segments to better understand the local interactions with those aquifers. The difference between groundwater inflows and outflows is equal to the change of groundwater in storage.

4.1.3 Water Budget Time Frames

Groundwater extraction from the Deep Aquifers has increased since the 1990s. Water budgets for both historical conditions and more recent conditions are presented here. Each water budget period contains years with varying degrees of precipitation but does not explicitly represent average hydrologic conditions.

- **2004 – 2017 Historical Period:** The historical water budget evaluates how past land use and water supply availability has affected aquifer conditions. Historical water budgets help develop an understanding of how historical hydrology, water demand, and surface water supply availability or reliability have impacted groundwater conditions and change in groundwater in storage. Accordingly, historical conditions should include the most reliable historical data that are available for water budget calculations. 2004 was selected as the start year of the historical period because it was after the CSIP program was implemented. After CSIP came online and delivered an alternative water source for irrigation in the seawater-intruded area, many Deep Aquifers wells stopped pumping and groundwater levels rebounded and stabilized. 2017 was selected as the end of the historical period because it represents the last reliable water year that the SVIHM provides reasonable estimates of water budget components. While pumping occurred in the Deep Aquifers prior to 2004, the water budgets were not extended prior to that date due to limited historical data available for model calibration.

- **2018 – 2020 Recent Period:** The recent water budget is intended to provide insight on the existing supply, demand, and change in storage under the most recent population, land use, and hydrologic conditions. These can be thought of as the best approximation of recent conditions and include the last year of the SWI Model. Current conditions with observed groundwater elevations are included in Chapter 5.

The Deep Aquifers are not as directly affected by interannual climatic variation as the shallower aquifers in the Salinas Valley because the Deep Aquifers do not receive direct precipitation or surficial recharge. However, the Deep Aquifers are confined and groundwater elevations respond to variations in pumping. Figure 4-4 shows historical annual rainfall at the Salinas Airport gage. This figure shows that the periods selected for the historical and recent periods, outlined with blue and grey-dashed boxes, include a mix of wet and dry years. The water year type included as the background is established by MCWRA and consistent with other SVBGSA water budgets. It is a designation based on streamflow in Arroyo Seco. This dataset is used to determine water year type since the Arroyo Seco is an unmanaged surface water body with reliable gage data. Thus, it is not a direct reflection of the precipitation overlying coastal area where most of the Deep Aquifers' pumping occurs. All water budgets are developed for complete water years, although there is a significant variation in pumping between the wet and dry seasons within a given water year.

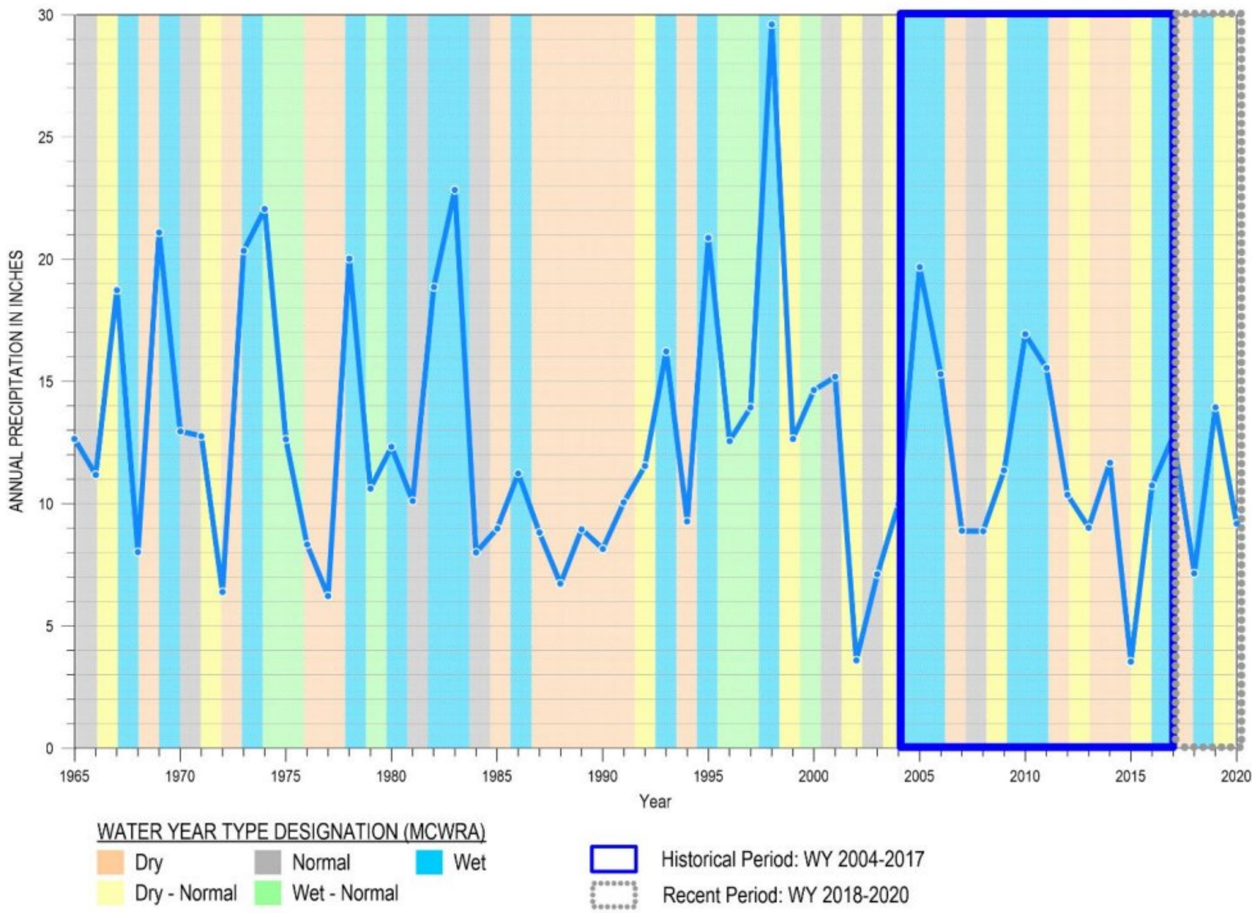


Figure 4-4. Precipitation and Water Year Type for Historical and Recent Water Budget Time Periods

4.1.4 Regions of the Deep Aquifers

The Deep Aquifers is divided into the Seaside Region, Northern Region, and Southeastern Region based on differing geology, water chemistry, groundwater elevation trends, and aquifer use. These 3 budget regions are shown on Figure 4-5. The Seaside Region includes the portion of the Deep Aquifers within the Seaside Subbasin, as well as the adjacent southern portion of the Monterey Subbasin. The boundary between the Seaside Region and Northern Region bisects the Monterey Subbasin. This boundary is based on a mapped groundwater divide, and groundwater chemistry data that show a distinct difference between this region and the other regions. Furthermore, the Santa Margarita Sandstone is present in Seaside Region wells but not Northern Region wells. While the boundary does not coincide with subbasin boundaries, all extraction and injection in the Seaside Region is within the Seaside Subbasin.

The Northern Region represents the coastal and northern portion of the Deep Aquifers, including the area near CSIP, northern Monterey Subbasin, area west of the City of Salinas, and ending just south of Salinas.

The Southeastern Region is the inland or up-valley portion of the Deep Aquifers. This Region was delineated as south of the City of Salinas based on the lack of true Deep Aquifers groundwater elevations and groundwater chemistry data. The lack of data limits the understanding of Deep Aquifers conditions and ability to validate the flows or calibration of the groundwater models. There is also limited pumping within the Southeastern Area, and most pumping is from wells screened across both the 400-Foot and Deep Aquifers.

4.2 Historical and Recent Water Budgets

Historical and recent water budgets are presented for the entire extent of the Deep Aquifers as well as the 3 regions of the Deep Aquifers. Water budgets are provided for the Deep Aquifers extent delineated in this Study, as described in the HCM. The geologic units that constitute the Deep Aquifers extend beyond the 400/Deep Aquitard into areas referred to herein as adjacent aquifers. Any surficial recharge that occurs in the adjacent aquifers could flow into the delineated extent of the Deep Aquifers as groundwater underflow.

4.2.1 Water Budget for Entire Deep Aquifers Extent

The Deep Aquifers water budget is made up of the flows entering and exiting the Deep Aquifers within the combined Northern, Seaside, and Southeastern Regions. Figure 4-5 shows the water budget zones and general net groundwater flow directions. The flow direction arrows indicate areas of net inflows and net outflows as calculated by the groundwater models. Each arrow's direction (inflow or outflow) was determined by the average flow direction for the entire water budget period across the boundary.

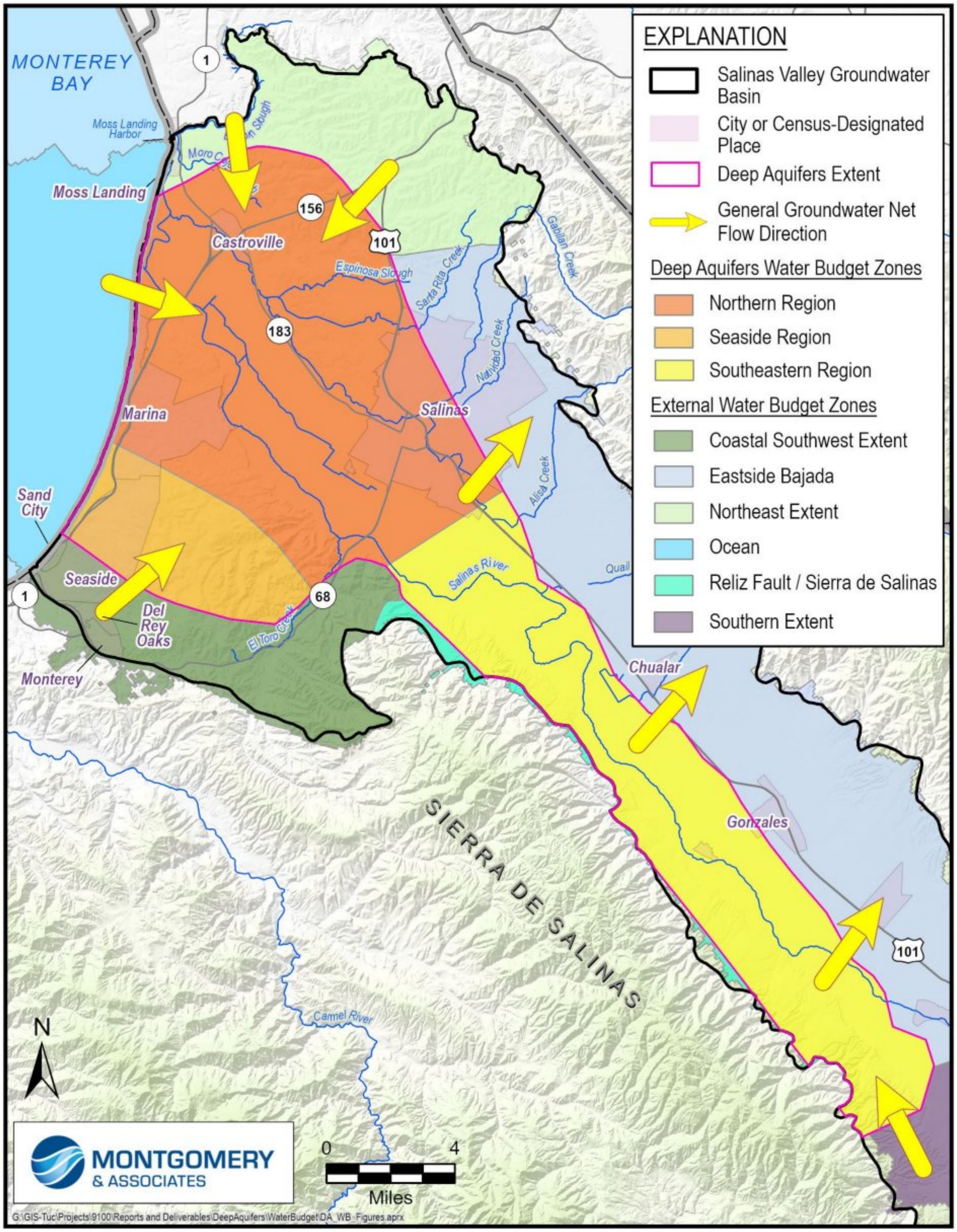


Figure 4-5. Water Budget Zones and General Net Groundwater Flow Directions

Pumping and injection rates are specified in the SWI Model based on measured or reported data; all other components are estimated by the models. Groundwater pumping rates reported to MCWRA through the Groundwater Extraction Management System (GEMS) and to the Seaside Watermaster were used as an input to the SWI Model. The water budgets are developed with models developed prior to the analysis within the Deep Aquifers Study, and therefore the aquifer designations for wells in the models were determined prior to the Study. The SVIHM simulates specified pumping for urban pumping, but does not use specified pumping for agricultural pumping. Agricultural pumping in the SVIHM is dynamically calculated within the model based on specified information for soils, land use, and water supply, and then calibrated to approximately match reported pumping.

The water budgets for the historical and recent periods for the entire extent of the Deep Aquifers are summarized in Table 4-1 and Table 4-2. Flows between Deep Aquifers regions are not included in the full extent water budget; however, they are listed at the bottom of the summary tables to show net groundwater flows between the 3 water budget regions. In each of the water budget summary tables, negative values for Net Change in Storage correspond to a decline in groundwater elevation over the water budget periods. To balance the water budgets presented in these water budget summary tables, the sign on Net Change in Storage needs to be reversed; this is an artifact of the nomenclature used by groundwater flow models. All water budget results are rounded to the nearest hundred acre-foot.

Table 4-1. Historical Simulated Water Budget for Full Deep Aquifers Extent

Water Budget Component (2004-2017 in AF/yr)	Northern Region	Seaside Region	Southeastern Region[2]	Full Deep Aquifers Extent
Pumping[1]	-5,500	-1,800	-2,300	-9,600
Net Change in Storage	-5,700	-400	-3,200	-9,300
Net Leakage from Above	-6,900	-1,000	1,900	-6,000
Net Leakage from Below*	1,300	200	700	2,200
Coastal Southwest Extent	600	1,800	300	2,700
Net flow from Reliz Fault/ Sierra de Salinas	-	-	500	500
Net flow from Northeast Extent	2,200	-	-	2,200
Net flow from Gabilan Range Bajada	-900	-	-4,700	-5,600
Subsurface Inflow Across Coastline*	2,700	700	-	3,400
Net flow from Southern Extent	-	-	500	500
Injection Wells	-	500	-	500
Surficial Recharge/Stream Leakage	-	-	0	0
Well Bore Flow Between Aquifer Layers*	-	-	700	700
Error	-200	0	-600	-800
Internal Net flow from Seaside Deep Aquifers Region	800	-	-	-
Internal Net flow from Southeastern Deep Aquifers Region	200	-	-	-
Internal Net flow from Northern Deep Aquifers Region	-	-800	-200	-

[1] Pumping is estimated by the model and includes wells screened fully and partially in the Deep Aquifers.
[2] Results for Southeastern Region have higher uncertainty due to lack of data. In the Southeastern Region, "Well Bore Flow Between Aquifer Layers" is subtracted from pumping, as presented in Table 4-5 and described in Appendix F.
* Indicates that simulated flow is not consistent with the HCM.
"-" Indicates flow is not relevant for that region.
Values are rounded to the nearest hundred. Values of zero listed are between -50 and 50 AF/yr.

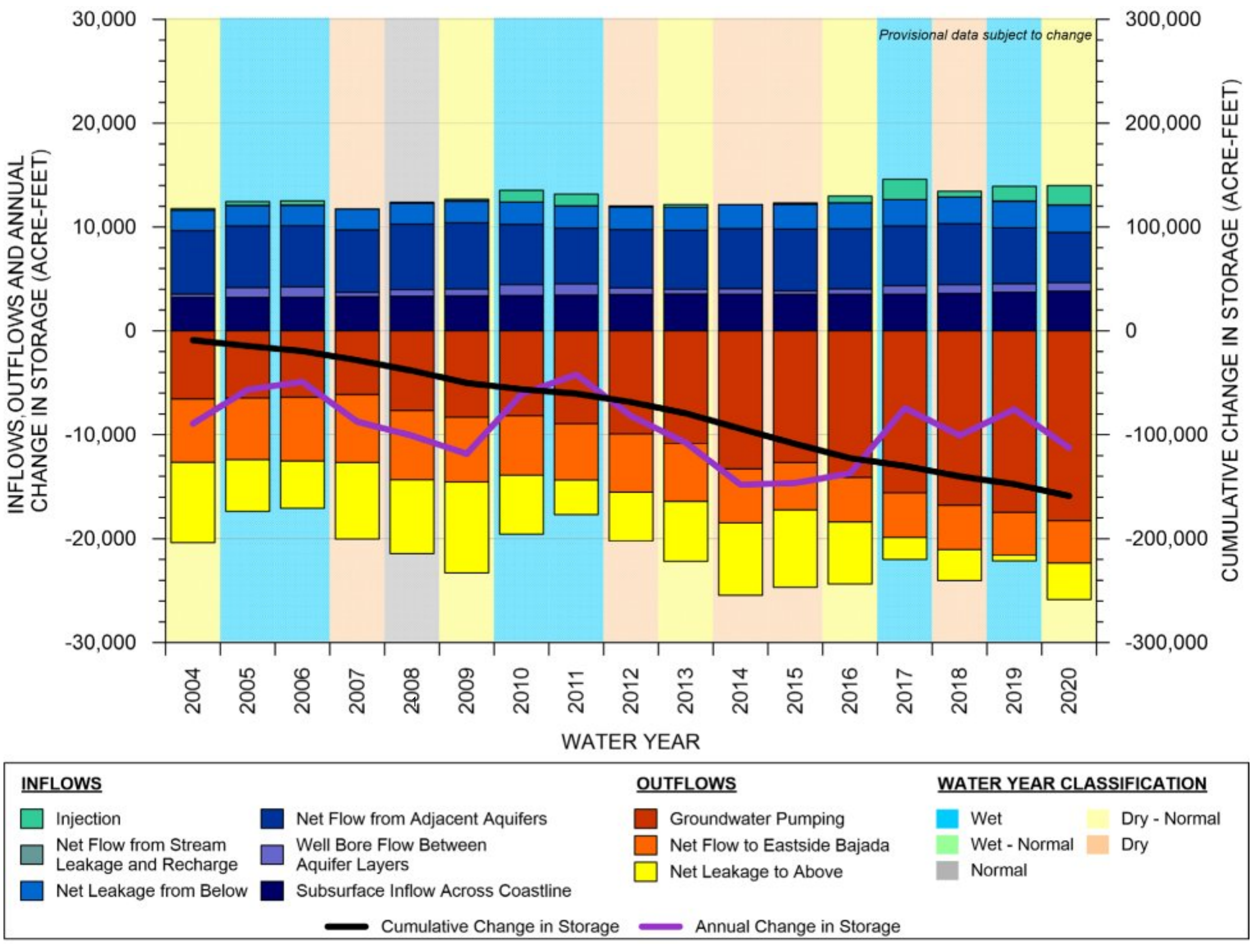
Table 4-2. Recent Simulated Water Budget for Deep Aquifers Regions

Water Budget Component (2018-2020 in AF/yr)	Northern Region	Seaside Region	Southeastern Region[2]	Full Deep Aquifers Extent
Pumping[1]	-13,100	-2,000	-2,500	-17,600
Net Change in Storage	-8,400	0	-1,200	-9,600
Net Leakage from Above	-4,000	-900	2,500	-2,400
Net Leakage from Below*	1,600	200	800	2,600
Coastal Southwest Extent	500	1,700	200	2,400
Net flow from Reliz Fault/ Sierra de Salinas	-	-	500	500
Net flow from Northeast Extent	2,000	-	-	2,000
Net flow from Gabilan Range Bajada	-	-	-4,100	-4,100
Subsurface Inflow Across Coastline*	3,000	700	-	3,700
Net flow from Southern Extent	-	-	400	400
Injection Wells	-	1,300	-	1,300
Surficial Recharge/Stream Leakage	-	-	0	0
Well Bore Flow Between Aquifer Layers*	-	-	800	800
Error	-100	0	900	800
Internal Net flow from Seaside Deep Aquifers Region	1,000	-	-	1,000
Internal Net flow from Southeastern Deep Aquifers Region	700	-	-	700
Internal Net flow from Northern Deep Aquifers Region	-	-1,000	-700	-1,700

[1] Pumping is estimated by the model and includes wells screened fully and partially in the Deep Aquifers.
[2] Results for Southeastern Region have higher uncertainty due to lack of data. In the Southeastern Region, "Well Bore Flow Between Aquifer Layers" is subtracted from pumping, as presented in Table 4-5 and described in Appendix F.
* Indicates that simulated flow is not consistent with the HCM.
"-" Indicates flow is not relevant for that region.
Values are rounded to the nearest hundred. Values of zero listed are between -50 and 50 AF/yr.

Subsurface inflows across the coastline refer to flow from the offshore coastal aquifer system into the Deep Aquifers at the coastline. While seawater intrusion has not been observed in wells within the Deep Aquifers, it is possible that some fresh or saline water is moving across the coastline within the coastal aquifer into the Deep Aquifers.

The annual water budget for the Deep Aquifers is shown on Figure 4-6. On this figure, as well as Figure 4-7, Figure 4-8, and Figure 4-9, inflows, outflows, and annual change in storage are plotted against the left axis. Cumulative change in storage is plotted against the right axis with an order of magnitude different scale. According to this figure, no years indicate a positive annual change in storage. Minor annual variations occur in some components, such as injection, net leakage to hydrogeologic units above, and flow out to the Gabilan Bajada. The largest interannual variation in the Deep Aquifers water budget is the consistently increasing rates of groundwater pumping from the Deep Aquifers. This increase in pumping drives a consistent annual loss in storage, as seen in the cumulative loss in storage series.



1 "Well Bore Flow Between Aquifer Layers" is described in Appendix F.

Figure 4-6. Inflows, Outflows, and Change in Storage for the Full Deep Aquifers

4.2.2 Water Budget for Northern Region

The average annual water budgets for the Northern Region (Figure 4-5) for the historical and recent period are summarized in Table 4-3. The model estimates significant upward gradients in this Region, resulting in flow up from model layers representing the Deep Aquifers into overlying model layers representing the 400-Foot Aquifer. Groundwater flows into this Region of the Deep Aquifers from all directions except in the southeast and east where groundwater flows outward from the Deep Aquifers to the Gabilan Range Bajada. Significant groundwater inflow comes from the portion of the aquifer underlying the ocean. At present, no seawater intrusion has been observed at Deep Aquifers wells within this area. The model suggests that groundwater is flowing into the Northern Region across the coastal boundary, but the extent and salinity of this flow is unknown. The Northern Region has experienced a significant loss in storage.

Table 4-3 Average Annual Simulated Water Budgets for the Northern Region

Water Budget Component	2004-2017 (AF/yr)	2018-2020 (AF/yr)
Pumping[1]	-5,500	-13,100
Net Change in Storage	-5,700	-8,400
Net Leakage from Above	-6,900	-4,000
Net Leakage from Below*	1,300	1,600
Net flow from Coastal Southwest	600	500
Net flow from Seaside Deep Aquifers Region	800	1,000
Net flow from Northeast Extent	2,200	2,000
Net flow from Gabilan Range Bajada	-900	0
Net flow from Southeastern Deep Aquifers Region	200	700
Subsurface Inflow Across Coastline	2,700	3,000
Error	-200	-100

1. Pumping is estimated by the model and includes wells screened fully and partially in the Deep Aquifers.
* Indicates that simulated flow is not consistent with the HCM.
Values of zero listed are between -50 and 50 AF/yr.

The annual water budget for the Northern Region is shown on Figure 4-7. The dark orange bars show that pumping has increased dramatically in recent years within this Region. This increase in pumping is likely driving the increasing rate of loss of groundwater storage in the recent period. The Net Change in Storage value in Table 4-3 represents the entire Northern Region; however, not all areas within the Northern Region are experiencing a loss of storage. Subsurface outflows such as flow out the top of the Deep Aquifers and flow to the Gabilan Range Bajada decrease between the historical and recent period.

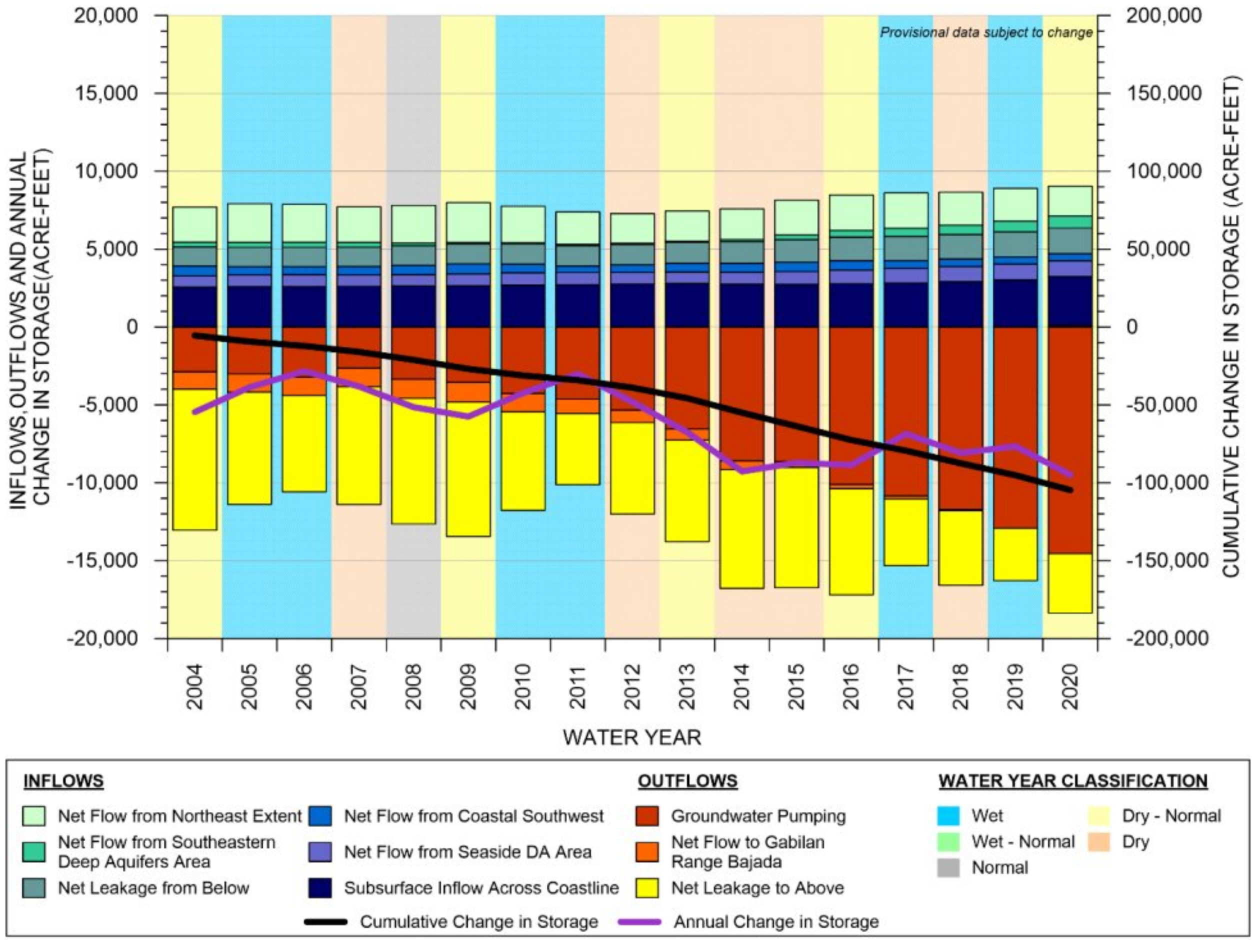


Figure 4-7. Annual Water Budget and Change in Storage for Northern Region

4.2.3 Water Budget for Seaside Region

The average annual water budgets for the Seaside Region (Figure 4-5) for the historical and recent period are summarized in Table 4-4. In general, this Region has upward vertical groundwater gradients, resulting in groundwater moving from the Monterey Formation, through the layers representing the Deep Aquifers, and into the overlying layer. Groundwater generally flows in from the west and south, and out to the east to the adjacent portion of the Deep Aquifers. The model estimates that groundwater is flowing in from the coastal portion of the aquifer at a rate of approximately 700 AF/yr. No seawater intrusion has been observed to date in the Deep Aquifers in this Region. The Seaside Region is the only region of the Deep Aquifers where groundwater injection occurs and is the only region within the Deep Aquifers without a significant loss in storage over the historical and recent periods.

Increases in injection between the historical and recent water budget periods offsets the minor increase in pumping.

Table 4-4. Average Annual Simulated Water Budgets for the Seaside Region

Water Budget Component	2004-2017 (AF/yr)	2018-2020 (AF/yr)
Pumping[1]	-1,800	-2,000
Net Change in Storage	-400	0
Net Leakage to Above	-1,000	-900
Net Leakage from Below*	200	200
Net Flow from Coastal Southwest	1,800	1,700
Net flow from Northern Deep Aquifers Region	-800	-1,000
Subsurface Inflow Across Coastline	700	700
Injection Wells	500	1,300
Error	0	0

1. Pumping is estimated by the model and includes wells screened fully and partially in the Deep Aquifers.
* Indicates that simulated flow is not consistent with the HCM.
Values of zero listed are between -50 and 50 AF/yr.

The largest change between the historical and recent periods is the increase in injection. The remaining water budget components are relatively similar between the historical and recent period. The annual water budget for the Seaside Region is shown on Figure 4-8.

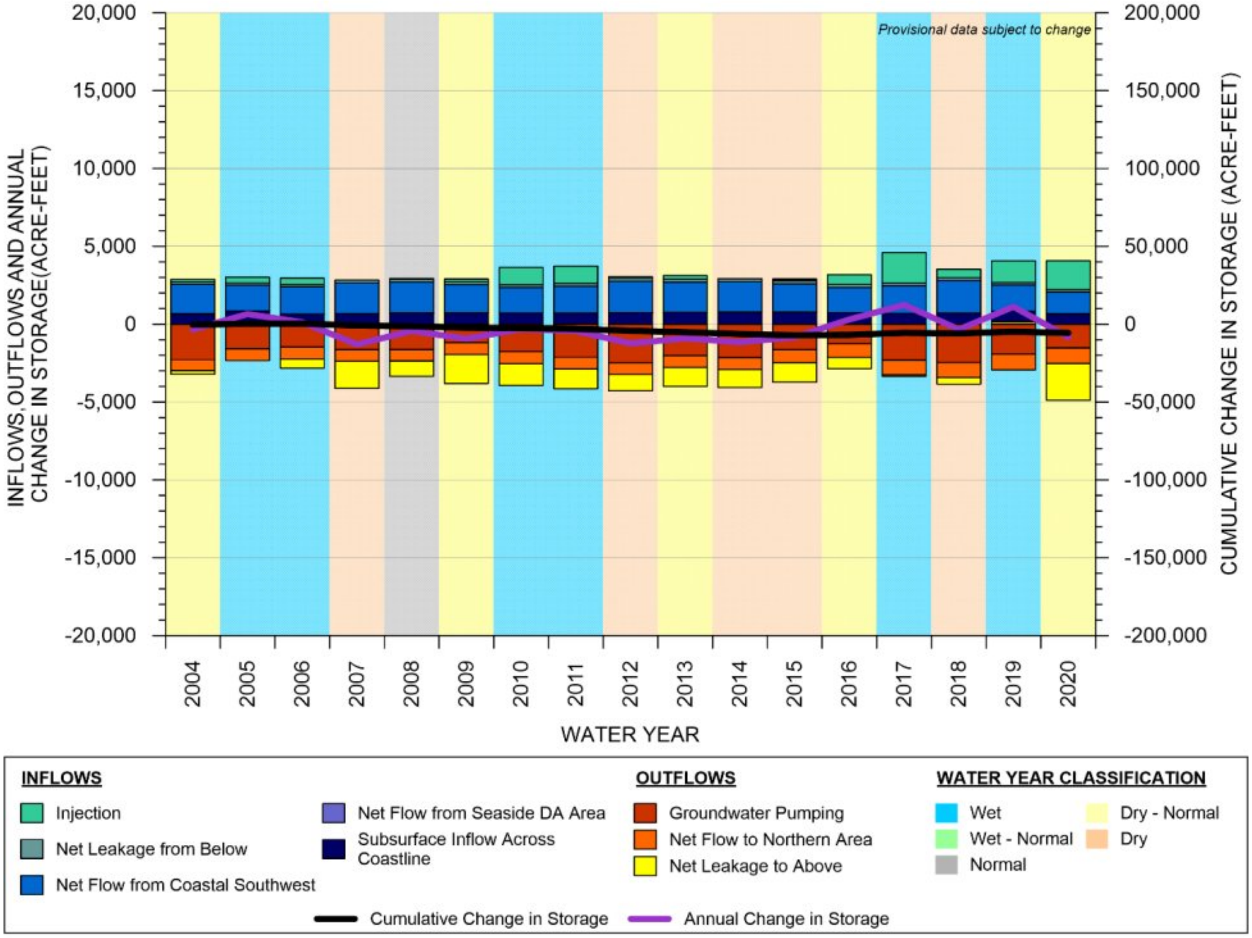


Figure 4-8. Annual Water Budget and Cumulative Change in Storage for the Seaside Region

4.2.4 Water Budget for Southeastern Region

The water budget for the Southeastern Region was developed through pairing together the SWI Model results where available and SVIHM results for the remaining area. Since the SVIHM does not run through 2020, water year 2017 flows are repeated for water years 2018-2020 for the portion of the water budget calculated using the SVIHM. The water budget results reported for this region are considered highly uncertain due to the lack of data in this portion of the Deep Aquifers. The water budget will be improved as data gaps are filled and groundwater models updated accordingly.

The average annual water budgets for the Southern Region (Figure 4-5) are summarized in Table 4-5. The Net Flow from Up Valley term is different between the SVIHM and SWI Models. The discrepancy between these 2 flows is incorporated as part of the error term in Table 4-5. Further details for the Southeastern Region water budget are available in Appendix F.

Table 4-5. Average Annual Simulated Water Budgets for the Southeastern Region

Water Budget Component	2004-2017 (AF/yr)	2018-2020 (AF/yr)
Pumping[1]	-2,300	-2,500
Net Change in Storage	-3,200	-1,200
Net Leakage from Above	1,900	2,500
Net Leakage from Below	700	800
Net flow from Coastal Southwest	300	200
Net flow from Sierra de Salinas	500	500
Net flow from Northern Deep Aquifers Region	-200	-700
Net flow from Gabilan Range Bajada	-4,700	-4,100
Net flow from Up Valley	500	400
Recharge and Stream Leakage	0	0
Well Bore Flow Between Aquifer Layers*[2]	700	800
Error	-600	900

[1] Pumping is estimated by the model and includes wells screened fully and partially in the Deep Aquifers.
[2] In the Southeastern Region, "Well Bore Flow Between Aquifer Layers" is subtracted from pumping, as presented in Table 4-5 and described in Appendix F.
* Indicates that simulated flow is not consistent with the HCM.
Values are rounded to the nearest hundred. Values of zero listed are between -50 and 50 AF/yr.

The annual water budget for the Southeastern Region is shown on Figure 4-9. Overall, most components have minimal year to year variation. The water budget components with largest variation between the historical and recent period are an increase in inflows from overlying aquifers (leakage from above) and a reduction in outflow to the Gabilan Range Bajada. In the Southeastern Region, the model shows water entering from above, while water exits the Deep Aquifers in the more coastal regions. However, there are no observed water levels in the Deep Aquifers to validate this flow.

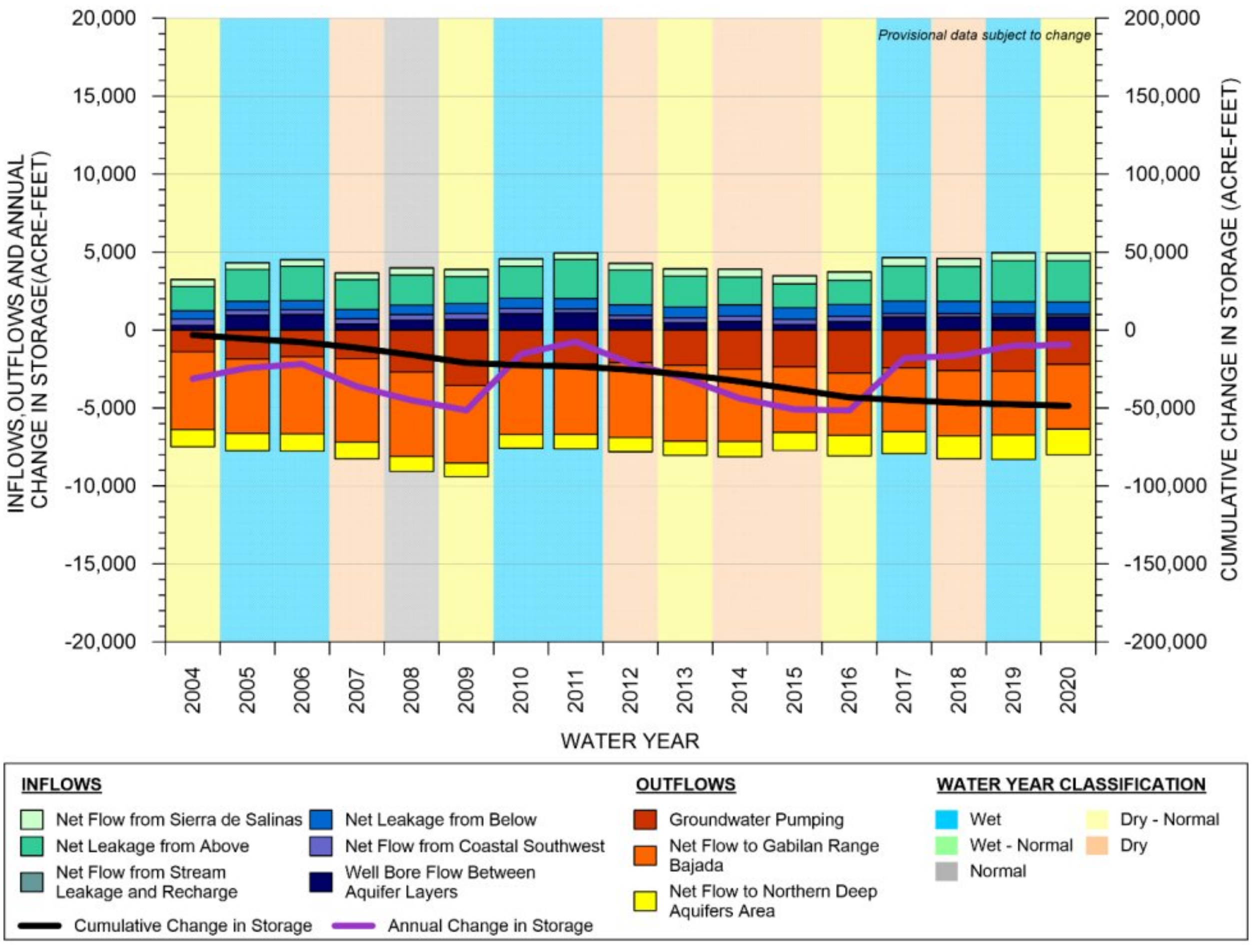


Figure 4-9. Annual Water Budget and Change in Storage for the Southeastern Region

4.3 Uncertainty

The groundwater flows produced by the models used for this water budget analysis reflect the current conceptual understanding of the Deep Aquifers, based on currently available data and models. However, there is uncertainty in many of the groundwater flow estimates.

The models used for this analysis likely overpredict the amount of groundwater flow from underlying aquifer units; reducing this inflow may have slight effects on other inflows and outflows. These will be investigated in future model updates. The HCM suggests that movement of groundwater in the Monterey Formation, which primarily underlies the Deep Aquifers, is limited, and probably only occurs in isolated fractures.

While the models are reasonably well calibrated, simulated vertical gradients across the 400/Deep Aquitard do not always match estimated gradients based on observed water level data, and the SWI Model is potentially overpredicting the amount of groundwater flow exiting the

Deep Aquifers into the overlying layers. When additional monitoring data become available, the simulated distribution and magnitude of exchange between the Deep Aquifer and the 400-Foot or overlying aquifer should be validated.

There is inherent uncertainty associated with all groundwater modeling due to the need for assumptions and generalizations. Furthermore, the calibration of the available models focused on shallower aquifer units with better data availability, such as the 180-Foot and 400-Foot Aquifers. The Deep Aquifers have the least data and therefore the highest uncertainty.

Regardless of the uncertainty, it is clear that groundwater outflows are greater than groundwater inflows in the Deep Aquifers, and the Deep Aquifers are experiencing a loss of groundwater storage. The rate of this storage loss has increased in the recent period as groundwater pumping has increased.

5 HISTORICAL AND RECENT CONDITIONS

Historical and recent groundwater conditions provide further bases for understanding the impact of groundwater extraction and injection on the Deep Aquifers. The recent conditions provide the basis for management guidance. While no seawater intrusion or subsidence have been observed, the current conditions in the Deep Aquifers suggest that the Deep Aquifers are at risk for seawater intrusion and subsidence in the future.

5.1 Extraction and Injection

Because the Deep Aquifers are a confined aquifer system, groundwater extraction and injection drive groundwater elevation changes. Water pumped out of or injected into the aquifers lowers or raises the groundwater elevations respectively, which alters the hydraulic gradients between the Deep Aquifers and the overlying and adjacent aquifers. Steeper hydraulic gradients induce groundwater flow where there is a pathway. Furthermore, the lowering of groundwater elevations is an indication of depressurization of the confined aquifer system, which drives the potential for seawater intrusion and land subsidence.

The locations of current extraction from wells installed in the Deep Aquifers are shown spatially on Figure 5-1, and the progression of extraction and injection over time are shown on Figure 5-2 and Figure 5-3. Figure 5-1 shows the 3 regions of the Deep Aquifers described in Section 4.1.4 to show how conditions vary between different areas of the Deep Aquifers. As shown on Figure 5-1, the Seaside Region and Northern Region represent the 2 main pumping centers in the Deep Aquifers. There is limited Deep Aquifers pumping within the Southeastern Area, and most of this pumping is from wells screened across both the 400-Foot and Deep Aquifers.

On Figure 5-1, circle symbol size correlates with the relative quantity of 2022 Deep Aquifers extraction. Wells completed in both the 400-Foot and Deep Aquifers are designated with a star, indicating that the pumping draws from both aquifers. For wells screened in both the 400-Foot and Deep Aquifers, presumably only a portion of the pumping reported for the well is being extracted from the Deep Aquifers; however, the portion coming from each aquifer is not known. While some of the larger extractors are urban users, the density of agricultural pumping is relatively high west of the City of Salinas and northeast of the City of Marina; this coincides with the areas that are seawater-intruded in the overlying aquifer, as further discussed in Section 5.4.

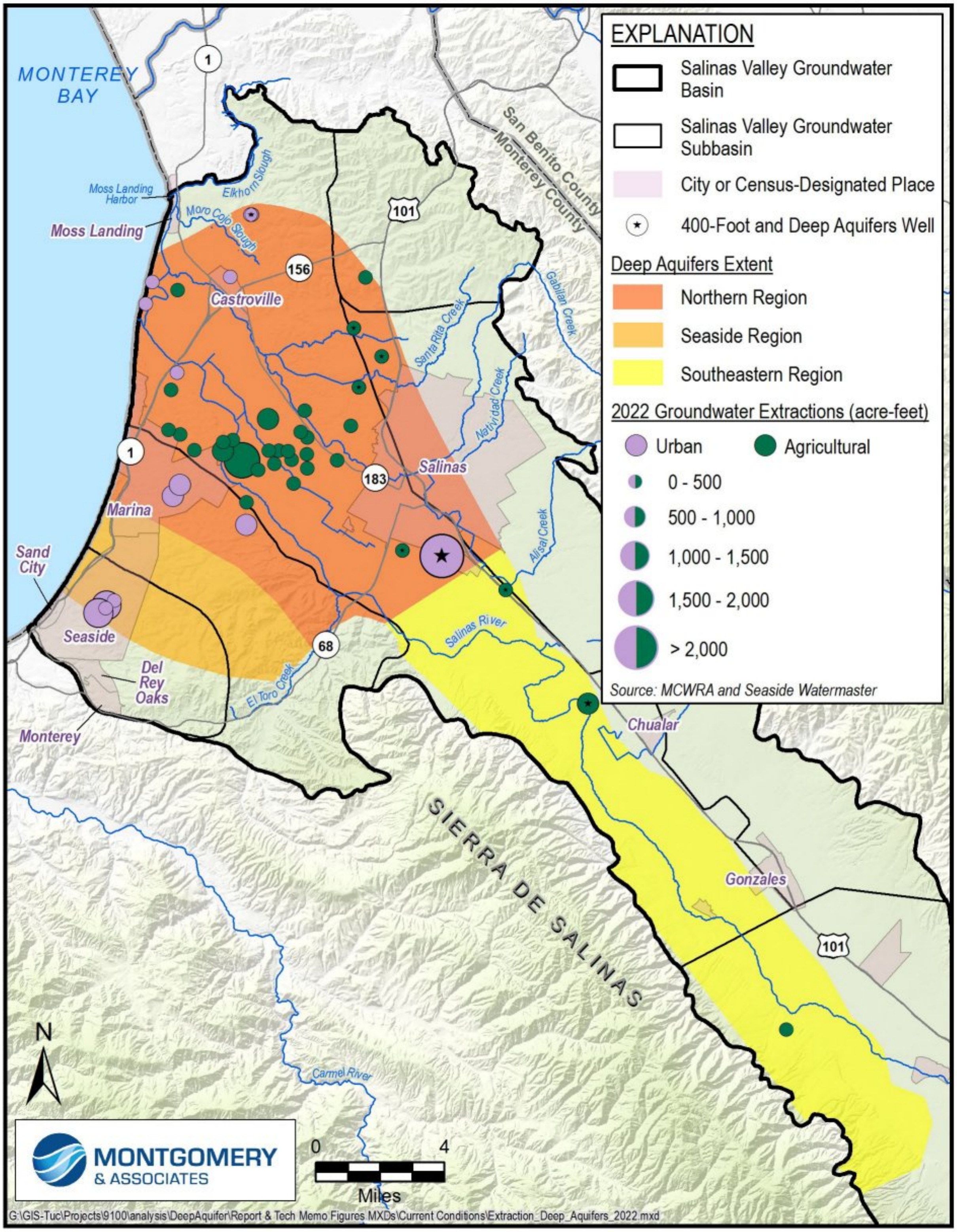


Figure 5-1. 2022 Extraction in the Deep Aquifers

Overall, groundwater extraction from the Deep Aquifers has increased over the past decade, partly in response to seawater intrusion in the overlying aquifers and prolonged drought. Extraction in the Seaside Region has remained relatively steady during this period, largely due to the Seaside Subbasin successfully conforming to terms of the Seaside Basin Adjudication. Extraction, however, has sharply increased over the past decade in the Northern Region — from wells screened in the Deep Aquifers and from wells with screen intervals spanning the 400-Foot and Deep Aquifers. As shown on Figure 5-2, the total extraction from the Deep Aquifers includes the pumping from wells screened only in the Deep Aquifers (blue and green) and wells screened in both the 400-Foot and Deep Aquifers (black). The Seaside Region of the Deep Aquifers has no pumping wells with screen intervals above the 400/Deep Aquitard.

Figure 5-2 shows annual Deep Aquifers extraction from 1995 to 2022, collected by MCWRA's GEMS and the Seaside Groundwater Basin Watermaster. This figure shows pumping data for the current 43 true Deep Aquifers wells and 9 wells completed in both the 400-Foot and Deep Aquifers. In addition, it includes pumping from 2 wells MCWRA has since destroyed: 1 screened in both the 400-Foot and Deep Aquifers and another screened solely in the Deep Aquifers. Of the true Deep Aquifers wells, 37 were previously designated as Deep Aquifers wells by MCWRA, 1 Deep Aquifers well was not previously designated as such by MCWRA, and 5 are in the Seaside Subbasin.

In 1998, MPWMD began to pilot an aquifer storage and recovery (ASR) project in Seaside Region Deep Aquifers. By 2008, this ASR project transitioned from a feasibility study to a permanent project that now consists of a treatment facility and 4 ASR wells. Initially, a pilot well was installed into the Paso Robles Formation for feasibility testing purposes, and subsequently the permanent project wells were installed into the Santa Margarita Sandstone, which has more favorable hydraulic characteristics for injection. All wells were screened below the 400/Deep Aquitard in the Deep Aquifers. In 2020, the Pure Water Monterey (PWM) project began to inject water into the Santa Margarita Sandstone using 4 injection wells. Figure 5-3 shows the annual injection that has occurred in the Seaside Region. As depicted in this figure, injection prior to 2021 (first full year of PWM operation) has been variable and was highly dependent on wetter climate conditions like those experienced in 2017.

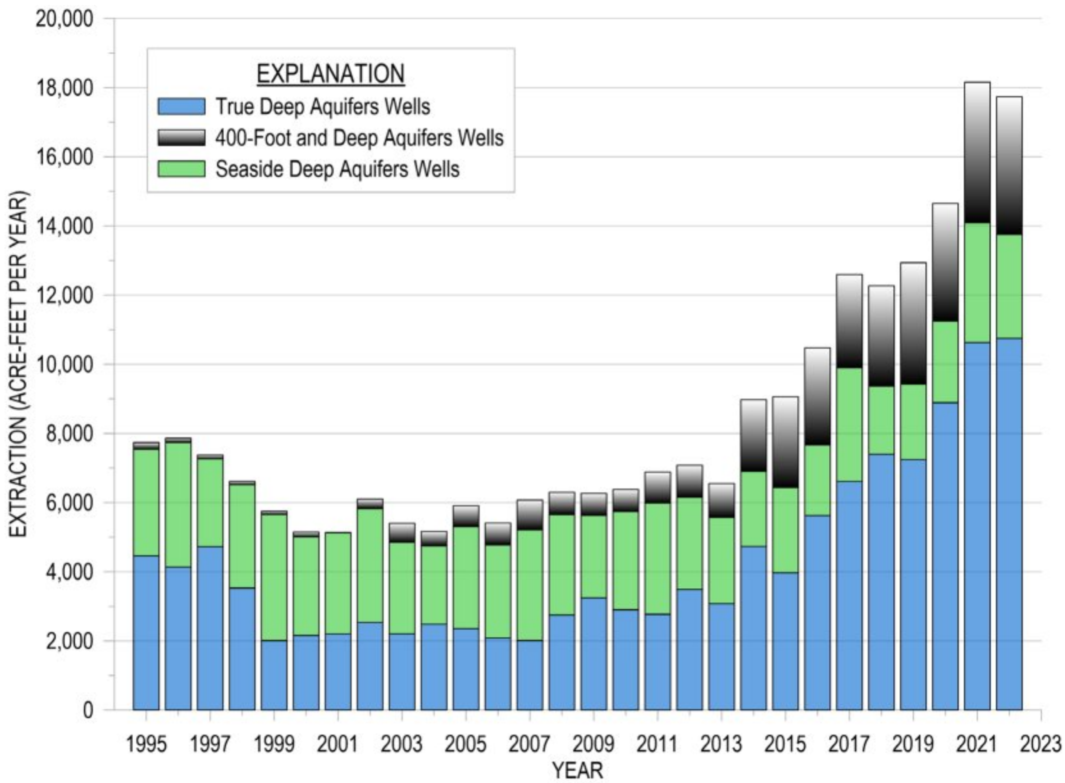


Figure 5-2. Annual Deep Aquifers Extraction from 1995 to 2022

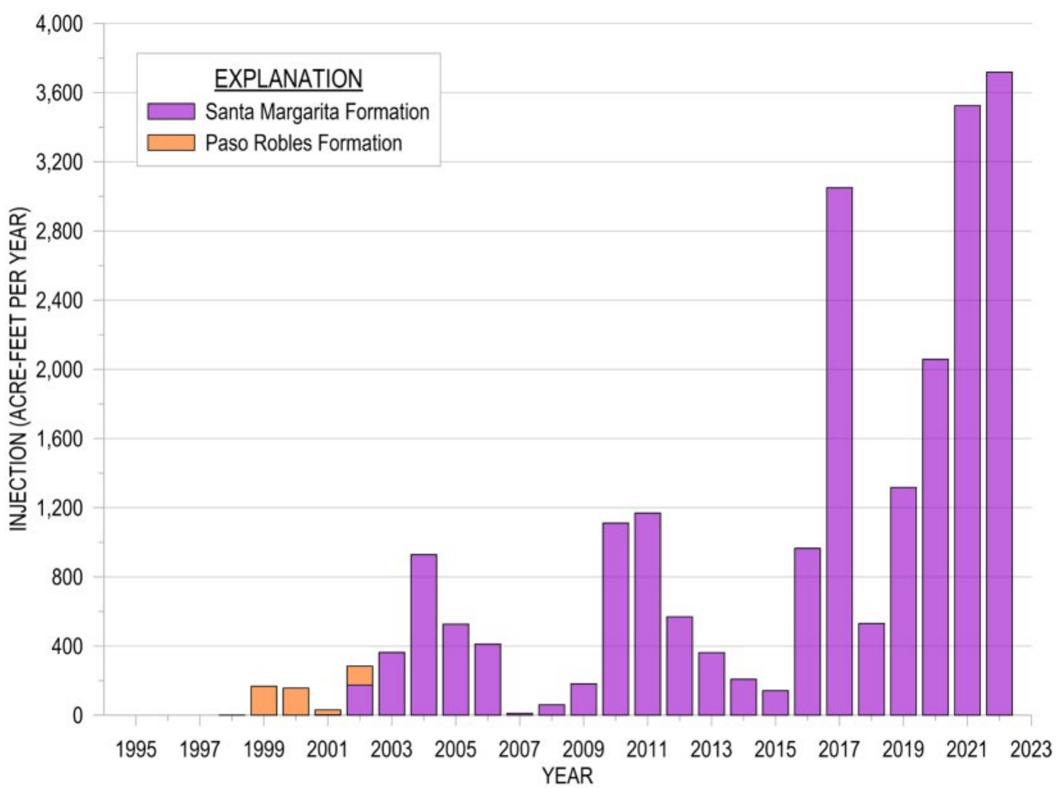


Figure 5-3. Annual Injection in the Seaside Region

Figure 5-4 shows historical groundwater pumping grouped into the 3 regions and separated by water use type. Groundwater extracted from the Deep Aquifers is used mainly for agriculture, but urban users also pump from the Deep Aquifers in the Northern and Seaside Regions.

Most pumping occurs in the Northern Region. Early extraction in the Northern Region occurred from MCWD wells, along the coast from wells screened solely in the Deep Aquifers, and from more inland wells screened across both the 400-Foot Aquifer and Deep Aquifers. After CSIP came online in 1998, Deep Aquifers extraction along the coast decreased for a few years; however, since 2014 both agricultural and urban pumping in the Deep Aquifers have continued to increase.

Although substantially less groundwater extraction occurs in the Southeastern Region in comparison to the other regions, its pumping has also increased, particularly in 2021 and 2022. All pumping in the Southeastern Region is for agricultural purposes, and 2 of the 3 pumping wells are screened across the 400-Foot and Deep Aquifers.

Pumping in the Seaside Region has remained relatively constant since the mid-1990s, fluctuating slightly year to year. Pumping in the Seaside Region of the Deep Aquifers is used for urban purposes; any landscape irrigation that occurs is included as urban use.

Table 5-1 summarizes 2021 and 2022 pumping by region, water use type, and aquifer designation. Pumping in the Northern Region makes up approximately 76% and 78% in 2021 and 2022, respectively. Extraction from wells screened in both the 400-Foot and Deep Aquifers only partially comes from the Deep Aquifers and cannot be separately quantified; this implies that 2022 extraction from the Deep Aquifers is between 13,800 AF/yr and some volume less than 17,700 AF/yr.

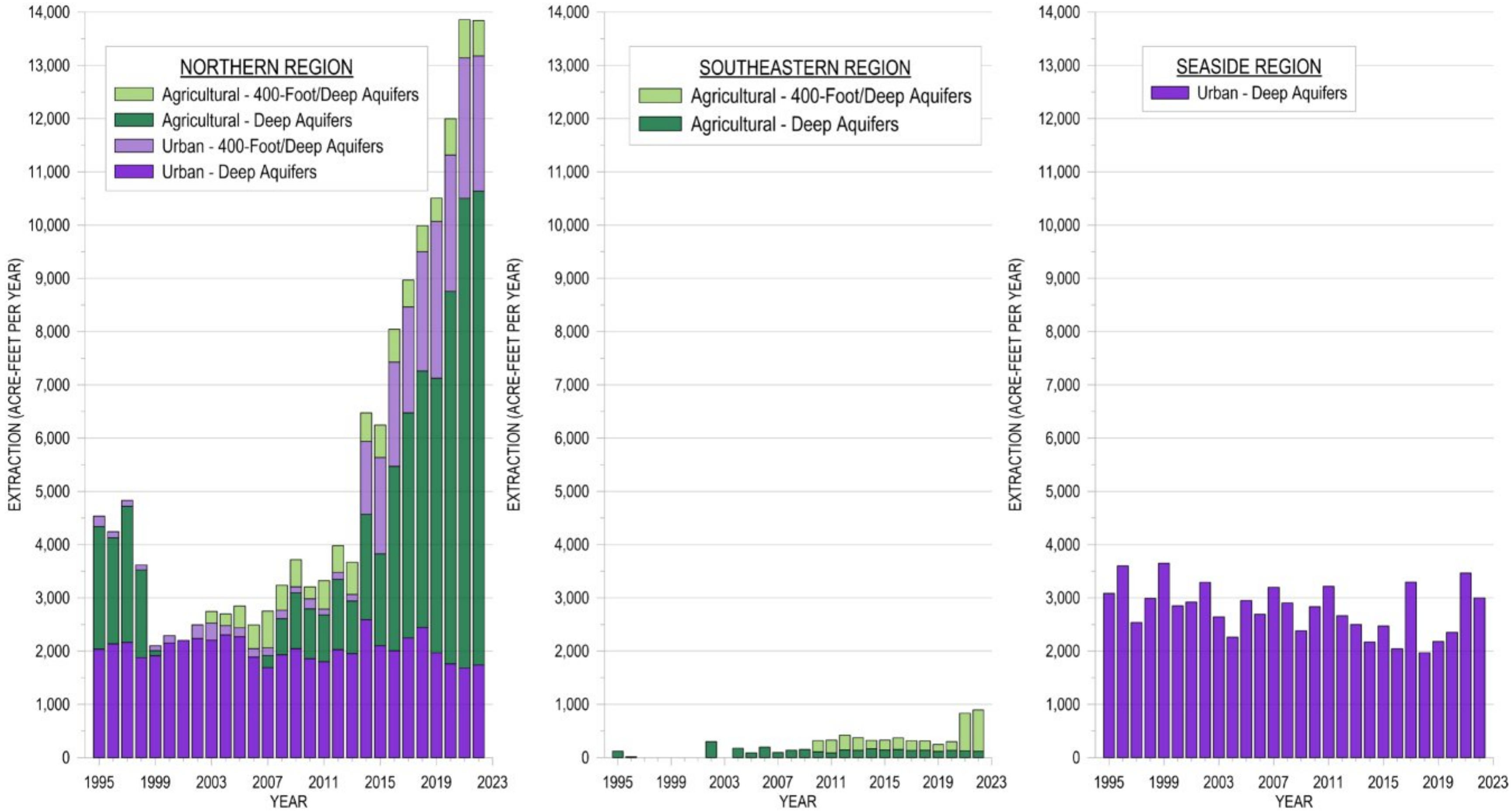


Figure 5-4. Deep Aquifers Extraction by Region and Water Use Type from 1995 to 2022

Table 5-1. Summary of 2021 and 2022 Extraction from the Deep Aquifers

Region	Water Use	Aquifer	2021 Extraction (AF/yr)	2022 Extraction (AF/yr)
Northern	Agricultural	400-Foot and Deep Aquifers	700	700
		Deep Aquifers	8,800	8,900
	Urban	400-Foot and Deep Aquifers	2,600	2,500
		Deep Aquifers	1,700	1,700
		SUBTOTAL	**13,800**	**13,800**
Southeastern	Agricultural	400-Foot and Deep Aquifers	700	800
		Deep Aquifers	100	100
		SUBTOTAL	**800**	**900**
Seaside	Urban	Deep Aquifers	3,500	3,000
		SUBTOTAL	**3,500**	**3,000**
TOTAL (Wells Screened Only in the Deep Aquifers)			**14,100**	**13,800**
TOTAL (Deep Aquifers Wells and Deep Aquifers Wells also Screened in the 400-Foot Aquifer)			**18,100**	**17,700**

[1] Subtotal reflects rounding of unrounded values for each row.

5.2 Groundwater Elevations

Groundwater levels in the Deep Aquifers have fluctuated intermittently but have been on a general downward trend over the last 2 decades. Figure 5-5 shows the cumulative change in groundwater levels since 1983 and 1988 for the Northern and Seaside Regions, respectively. Cumulative groundwater level change is calculated by averaging annual change in fall water level for all groundwater elevation monitoring wells. This figure is based on the data available, therefore, the wells are not uniformly distributed across the extent of the Deep Aquifers. Furthermore, not all wells are monitored every year, so this figure does not fully capture variations in average groundwater level change across each Region. Several years saw a large increase in the number of wells monitored for groundwater elevations; these years are marked with a dashed line on Figure 5-5. Cumulative change in groundwater levels prior to 1995 and 2003 in the Seaside and Northern Regions, respectively, is based on a few wells and represented by light blue lines. Wells used in the development of this figure are listed in Appendix G.

In the Northern Region, decreasing groundwater elevations generally correlate with an increase in annual pumping. In some recent years, there has been an observed increase in fall groundwater elevation measurements in multiple wells, despite a total increase in annual pumping. Analysis of monthly pumping data suggests this is due to variations in pumping at nearby extraction wells in the months immediately preceding the fall water elevation measurements. Additional details on the sensitivity of groundwater elevation to monthly pumping are provided in Appendix G. Despite some interannual fluctuations, and recent increases, groundwater elevations are generally declining across the Northern Region in the Deep Aquifers.

Groundwater elevations are also decreasing in the Seaside Region, despite pumping remaining relatively stable since 1995. In 1995, pumping in the Seaside Region more than doubled, which coincided with the start of heavy pumping of the Paralta well. In 2017, pumping in the Seaside Region increased by approximately 1,300 acre-feet and decreased by approximately the same amount the subsequent year. This change in pumping is reflected in the cumulative change in groundwater elevations in this Region.

Because there are no true Deep Aquifers groundwater elevation monitoring wells in the Southeastern Region, the cumulative change in groundwater elevations was not calculated.

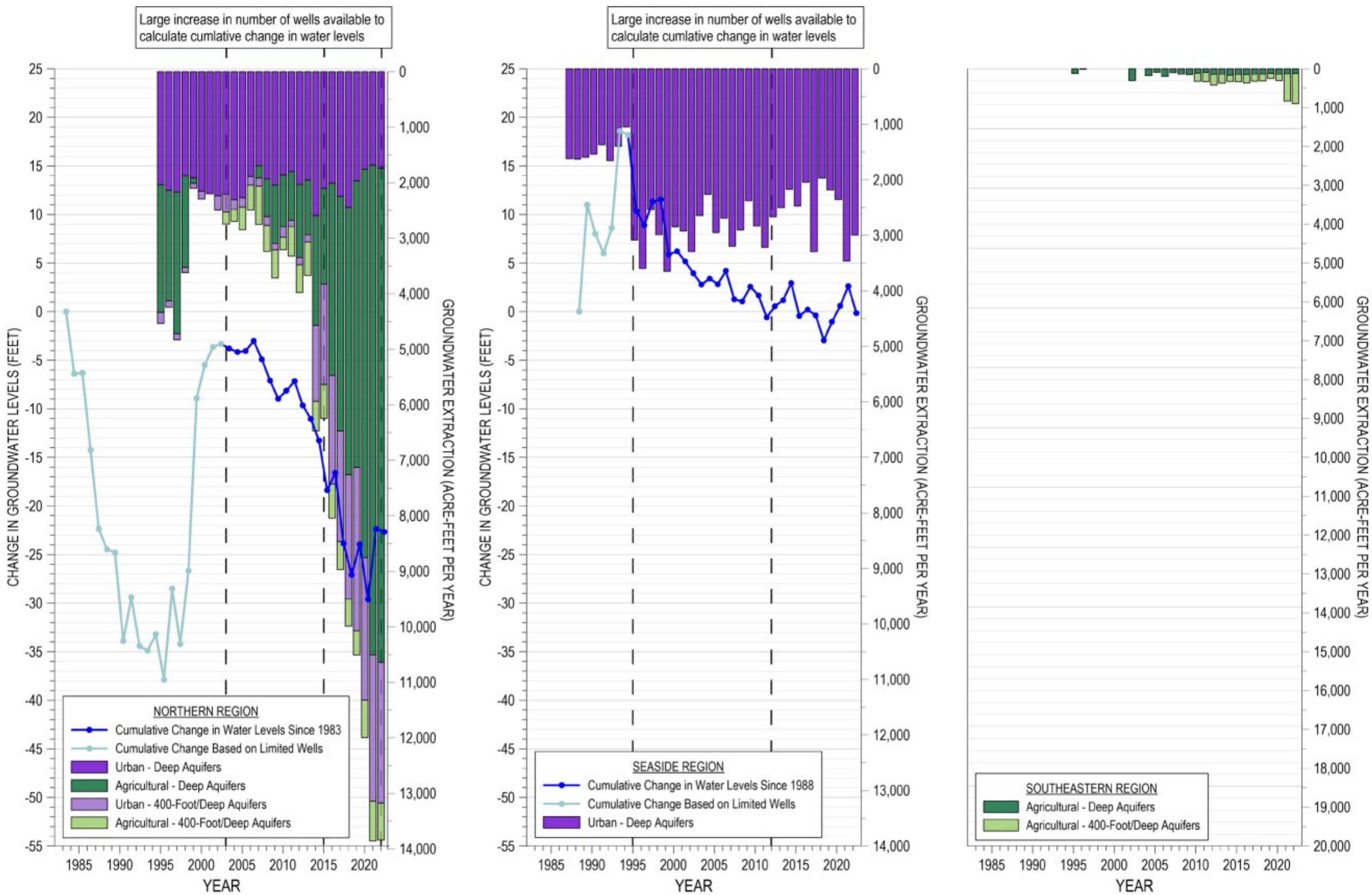


Figure 5-5. Cumulative Change in Groundwater Elevations in the Deep Aquifers per Region

5.2.1 Groundwater Elevation Hydrographs

Example hydrographs for the Northern, Seaside, and Southeastern Regions of the Deep Aquifers area shown on Figure 5-6, Figure 5-7, and Figure 5-8, respectively. Groundwater elevations in most wells in the Northern and Seaside Regions are declining. In these regions, groundwater elevations for all wells are currently below sea level. Groundwater elevations in some older wells along the coast in both these regions were previously above sea level but groundwater elevation records in most newer wells begin below sea level. In the Southeastern Region, a well completed in both the 400-Foot and Deep Aquifers and another in the Deep Zone of the Eastside Aquifer are used as proxies for Deep Aquifers groundwater elevations due to the current lack of available groundwater elevation measurements in true Deep Aquifers wells in this Region. These figures are based on fall groundwater elevation measurements; however, as Appendix G discusses, fall measurements may be influenced by pumping variations in the months preceding measurement.

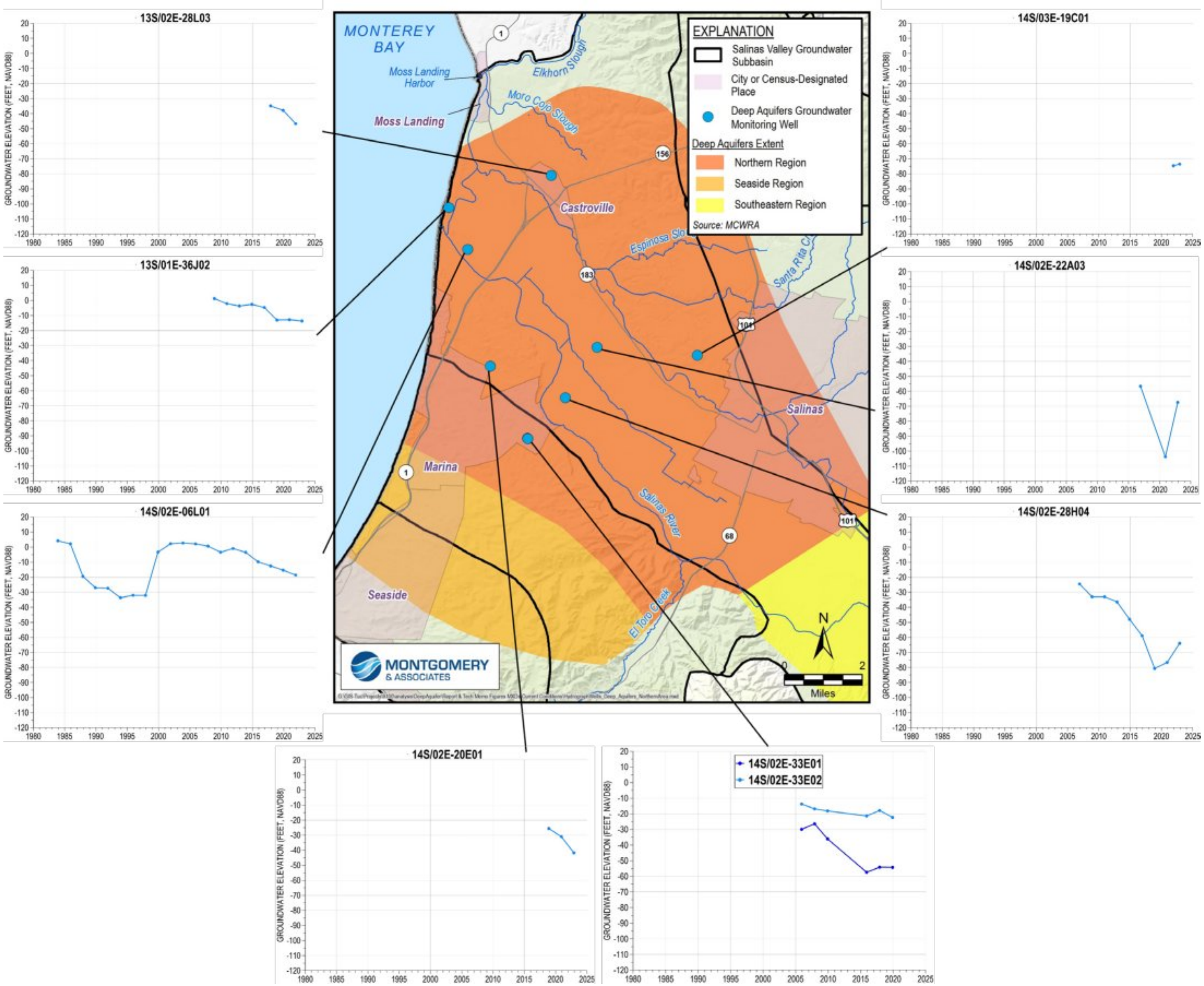


Figure 5-6. Example Hydrographs for the Northern Region

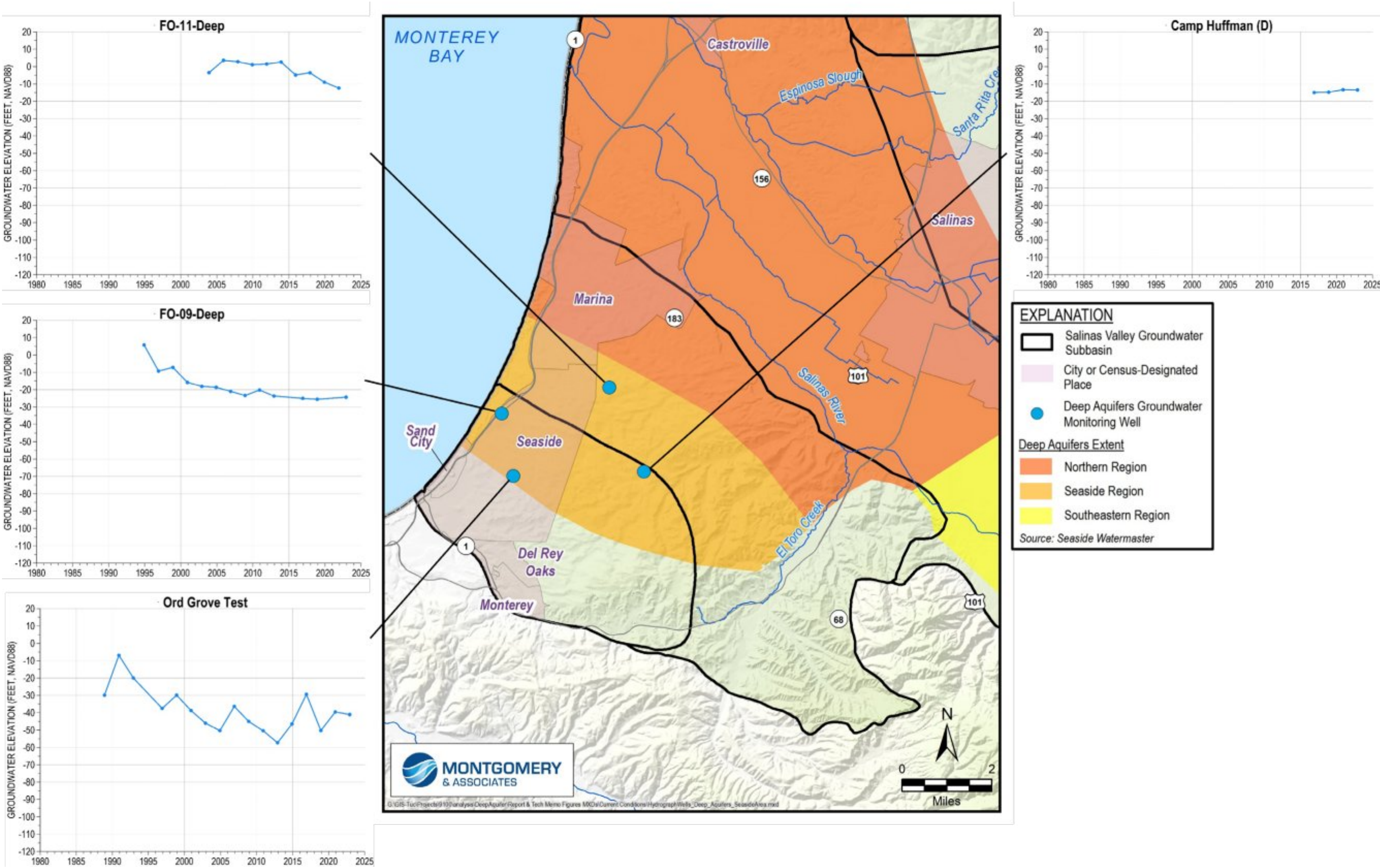


Figure 5-7. Example Hydrographs for the Seaside Region

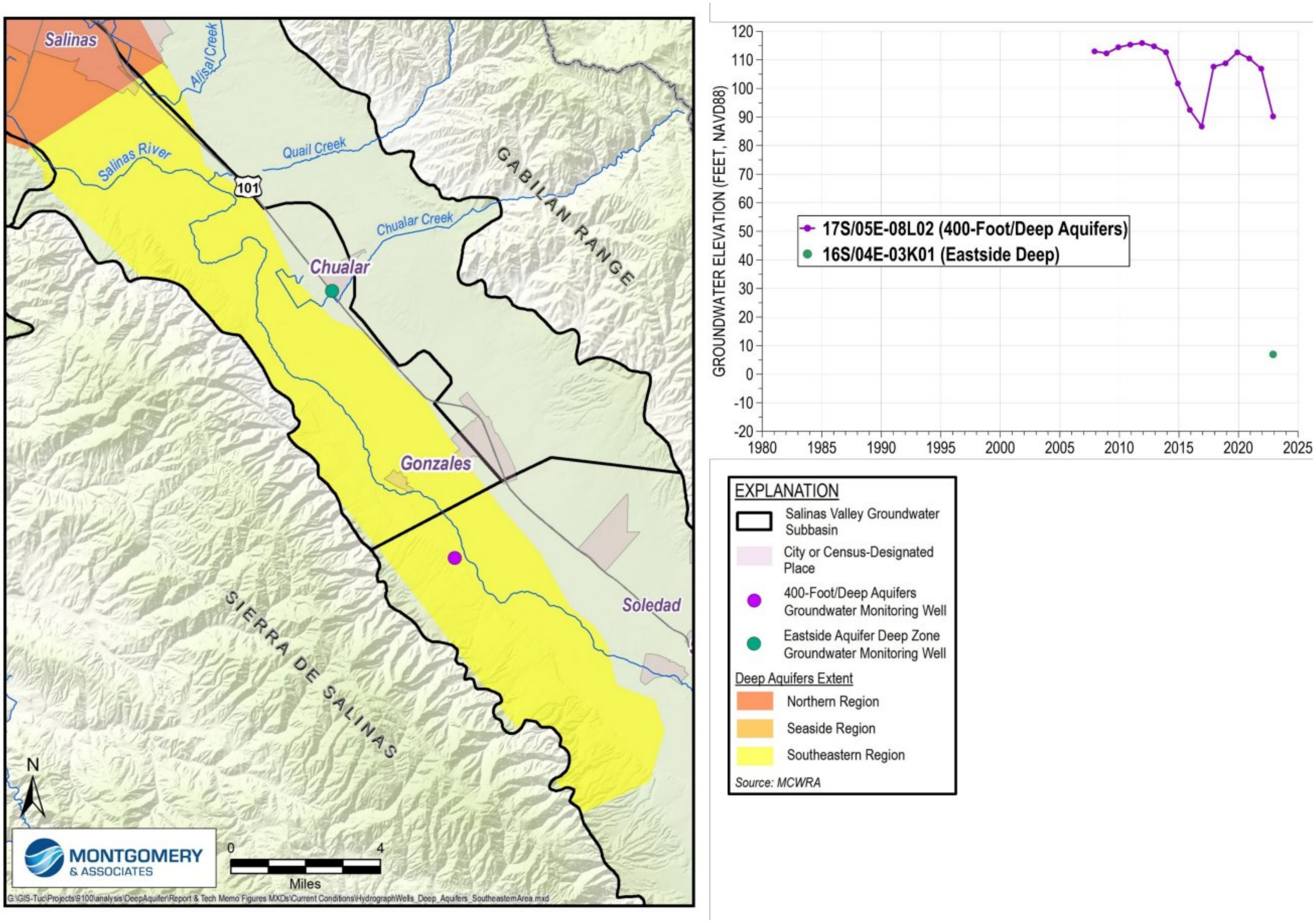


Figure 5-8. Example Hydrographs for the Southeastern Region

Previous reports have documented that groundwater elevations in the Deep Aquifers may differ by geologic formation, with higher groundwater elevations typically occurring in the Purisima Formation and Santa Margarita Sandstone that underlie the Paso Robles Formation. Additionally, these studies indicate groundwater elevations in the Lower Purisima Formation are higher than groundwater elevation in the Upper Purisima Formation in some coastal wells (Feeney, 2023; MacTec, 2005; Hanson, 2002).

Differentiating groundwater elevations between the various formations comprising the Deep Aquifers is challenging because many Deep Aquifers wells are screened across multiple water-bearing zones regardless of geologic formation. Furthermore, the well completion reports for many Deep Aquifers wells do not identify the geologic formations on the lithologic logs. Given that individual formations cannot be definitively assigned to most Deep Aquifers wells, the wells were divided into zones based on their screen depth to approximate the differences between formations, allowing for an analysis of groundwater trends based on depth. The designated upper zone of the Deep Aquifers consists of wells that are mostly screened above 1,000 feet; accordingly, wells in the designated lower zone are those mainly screened below 1,000 feet. Several wells are in both the upper and lower zones of the Deep Aquifers; generally, these wells have very long screens—up to 900 feet long.

Figure 5-9 includes example fall hydrographs for wells completed in the Deep Aquifers and a map with the locations of the wells. This figure shows that groundwater elevations in the lower zone of the Deep Aquifers (represented by the green-colored markers) are higher than the groundwater elevations of the upper zone (represented by the blue-colored markers). This trend is consistent with data for the small subset of wells constructed in a single formation that show that groundwater elevations in the Lower Purisima Formation and Santa Margarita Sandstone are higher than those in the Upper Purisima and lower Paso Robles Formations (Hanson, 2002; Feeney and Rosenberg, 2003).

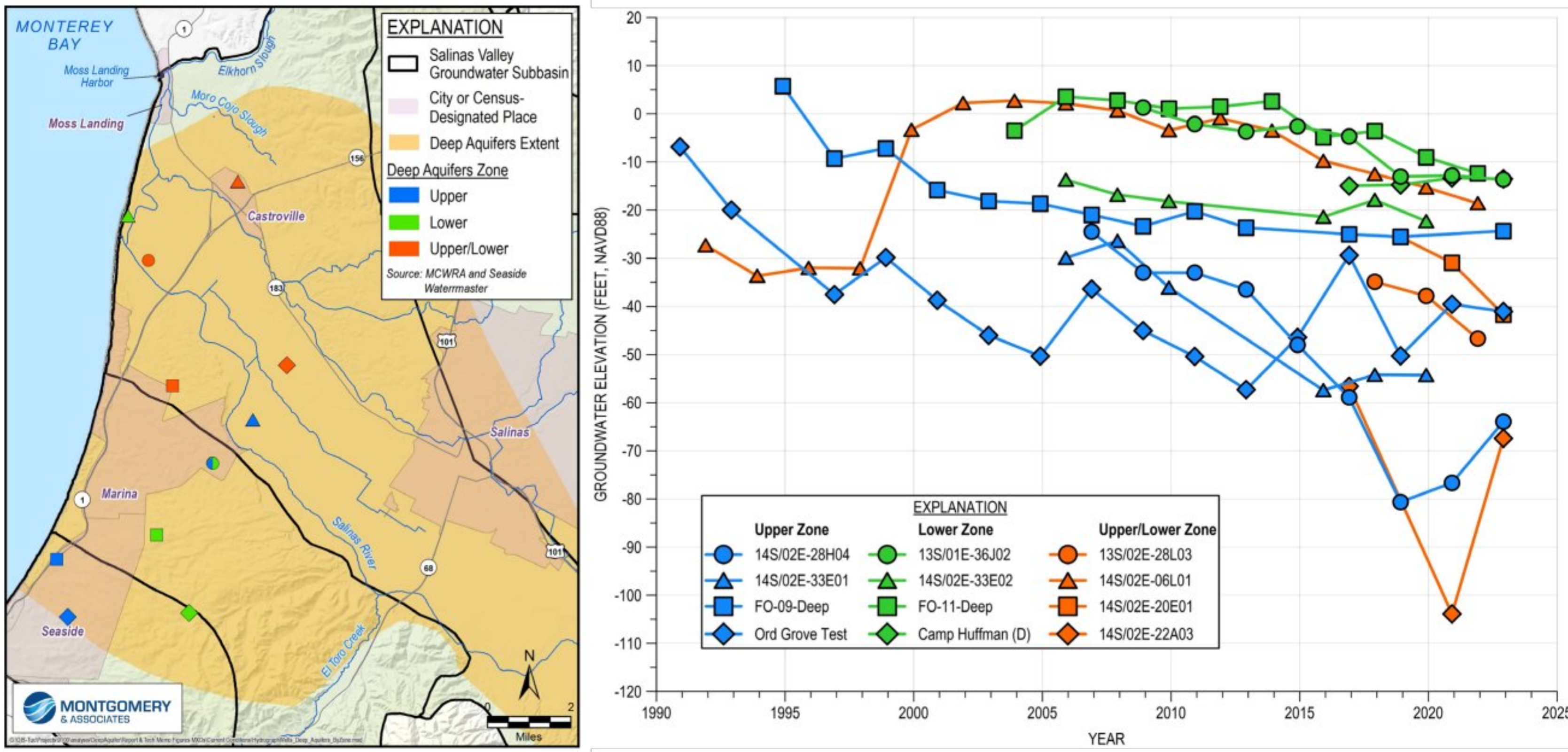


Figure 5-9. Example Hydrographs of Fall Groundwater Elevation Measurements by Deep Aquifers Zone

5.2.2 Groundwater Elevation Contours

Groundwater elevation contours show the direction of groundwater flow and regional groundwater depressions. Figure 5-10 shows the fall 2022 groundwater level contours for the Deep Aquifers and the locations of the wells used to develop the contours. Black dots on this figure are wells that are completed in both the 400-Foot and Deep Aquifers; these wells were not directly used to create the contours but did inform contours in areas where true Deep Aquifers wells are lacking.

The contours show 3 groundwater depressions:

1. Along the coast in the Seaside area
2. West of the City of Salinas
3. Near Castroville

Groundwater flows toward these depressions which generally coincide with the areas where large amounts of pumping are occurring in the Deep Aquifers (Figure 5-1). The contours also show that there is a groundwater divide between the cities of Seaside and Marina where groundwater flows toward the coastal Seaside depression on 1 side and toward the western Salinas depression on the other. Within the City of Marina, a steep hydraulic gradient between 2 nearby wells on either side of the Reliz/Rinconada Fault suggests that the fault zone could be acting as a barrier to flow at this location. The direction of groundwater flow from the northeastern part of the Deep Aquifers toward the 2 northern groundwater depressions is uncertain because there are no groundwater elevation measurements from true Deep Aquifers wells in that area.

The contours are an estimation of groundwater elevations in the Deep Aquifers and will be refined as more data become available, especially in the Southeastern Region of the Deep Aquifers where no groundwater elevation data exist from true Deep Aquifers wells. It should be noted that although groundwater elevations differ in the upper and lower zones of the Deep Aquifers, as described in the previous section, inadequate data are currently available to develop separate groundwater elevation contours for these zones, or for each of the geologic formations comprising the Deep Aquifers.

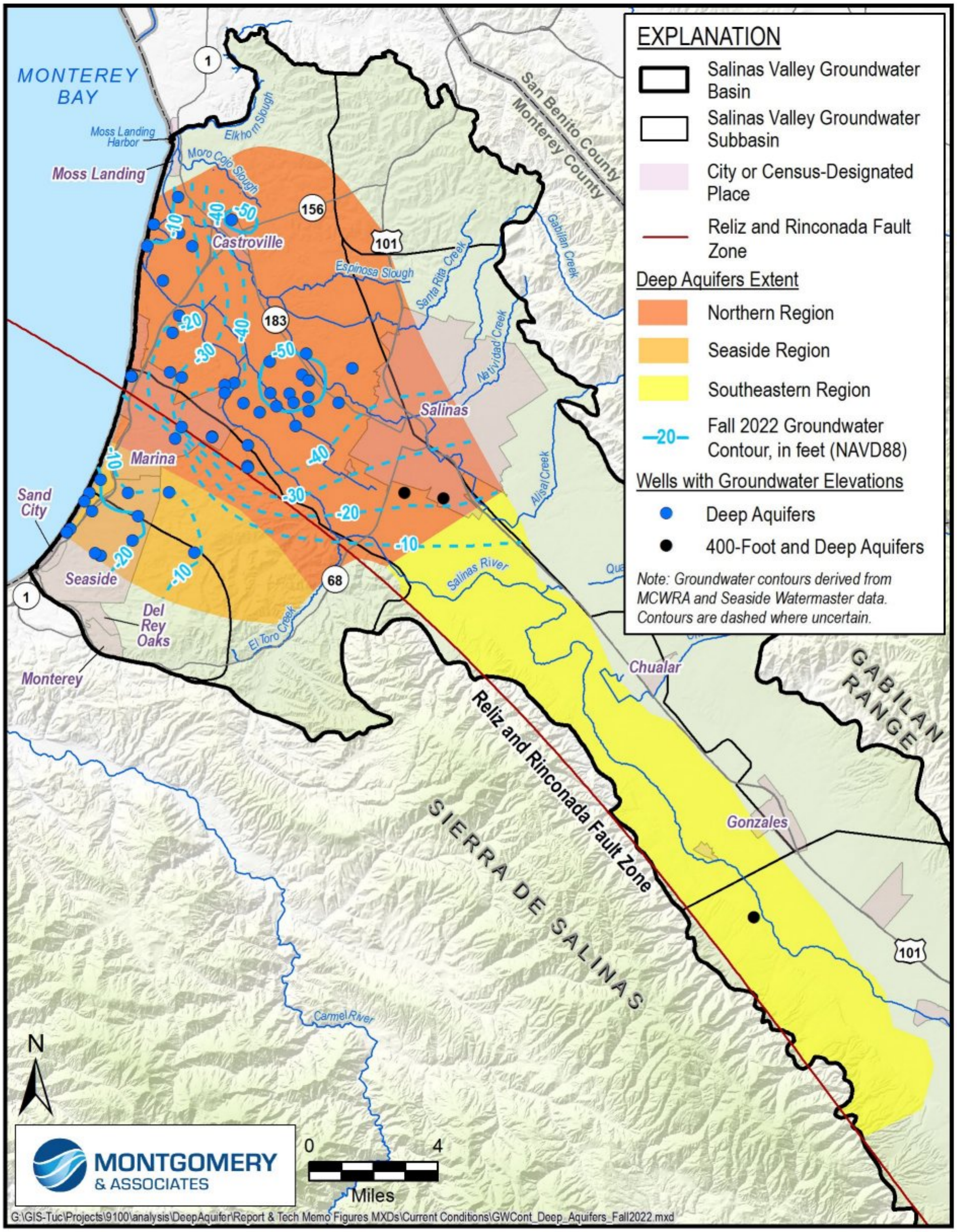


Figure 5-10. Fall 2022 Groundwater Elevation Contours

5.2.3 Vertical Groundwater Gradients

Vertical gradients between the Deep Aquifers and the overlying aquifer vary spatially and temporally. Figure 5-11 depicts the difference in fall 2022 groundwater elevations between the Deep Aquifers and the 400-Foot or equivalent aquifer. The data shown in the Northern Region on Figure 5-11 were not determined using well pairs screened in different aquifers, but rather are groundwater elevations in Deep Aquifers wells compared to the MCWRA fall 2022 contour map of groundwater elevations in the 400-Foot Aquifer. The data shown on Figure 5-11 in the Seaside Region are from paired wells where the upper screen interval was identified above the 400/Deep Aquitard. Wells completed in both the 400-Foot and Deep Aquifers are not shown on Figure 5-11 since their groundwater elevations are influenced by both aquifers.

Figure 5-11 demonstrates a downward gradient from the 400-Foot or equivalent overlying aquifer to the Deep Aquifers in most areas where groundwater monitoring occurs. There are only 2 wells that have an upward gradient from the Deep Aquifers to the overlying aquifer—one within the City of Marina and another slightly outside the boundary between the Cities of Marina and Seaside. The well within the City of Marina is located near the Reliz/Rinconada Fault. Nearby, across the fault, there is a well that has a steep downward gradient from the 400-Foot Aquifer to the Deep Aquifers. This further corroborates that the fault may be acting as a barrier to flow in this area as mentioned in Section 5.2.2. The downward vertical gradient is greatest in the area where most of the Deep Aquifers pumping occurs (Figure 5-1).

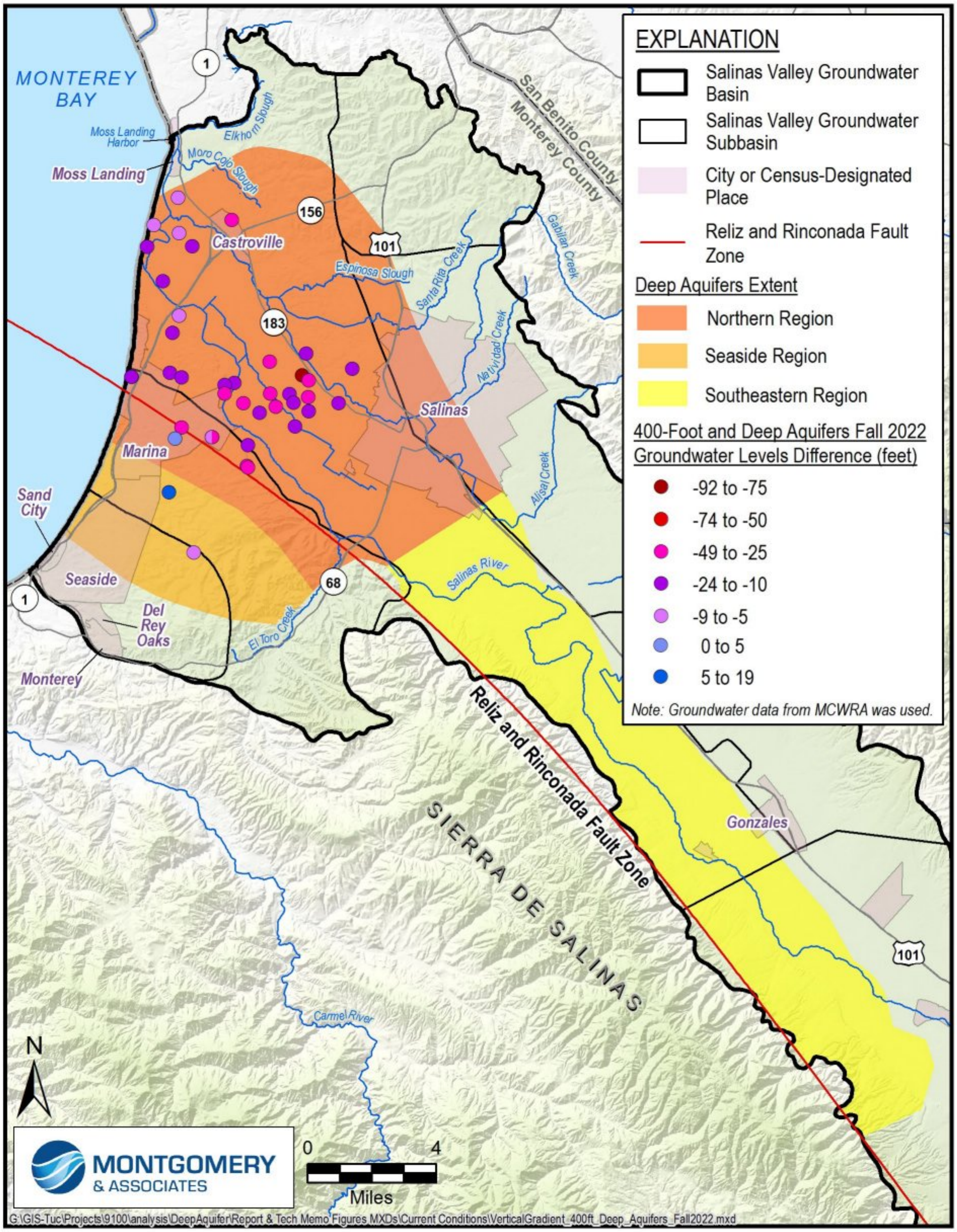


Figure 5-11. Fall 2022 Groundwater Elevations Difference between the Deep Aquifers and Overlying Aquifer

Vertical groundwater gradients in each respective region have changed over time based on the pumping in both the 400-Foot and Deep Aquifers. Figure 5-12 and Figure 5-13 include example hydrographs for a Deep Aquifers well and a well above the 400/Deep Aquitard in different areas of the Deep Aquifers for the Northern and Seaside Regions, respectively. The historical vertical gradients in each region include the following:

Northern Region – Coastal: Groundwater elevations in the Deep Aquifers were historically higher than groundwater elevations in the overlying 400-Foot Aquifer. As pumping in the Deep Aquifers increased, groundwater elevations rapidly declined and fell below those in the 400-Foot Aquifer after the mid-1980s. When CSIP came online in 1998, Deep Aquifers groundwater levels rebounded to above those of the 400-Foot Aquifer again. However, after 2010, groundwater levels in the Deep Aquifers began to decline again and have continued to decline below those in the 400-Foot Aquifer.

Northern Region – Northern Monterey Subbasin: Groundwater elevations in the Deep Aquifers have been lower than those of the overlying 400-Foot Aquifer since at least 2005. However, a previous Deep Aquifers investigation (Feeney and Rosenberg, 2003) indicated that groundwater elevations in the Deep Aquifers were originally near sea level at the time of well completion in 4 production wells in this Region. Deep Aquifers groundwater elevations began to decline soon after groundwater production in these wells began in the mid-1980s. This could be indicative of a reversal in gradient that was not captured in the available records from the dedicated monitoring wells currently in the area, assuming groundwater elevations in the 400-Foot Aquifer were as constant as they are now.

Northern Region – Inland West of Salinas: Available Deep Aquifers groundwater elevation data in this part of the Northern Region dates back to the late 2000s, when Deep Aquifers groundwater elevations were already lower than the overlying 400-Foot Aquifer. There was little Deep Aquifers pumping in this area prior to 2008. Since then, groundwater elevations in the Deep Aquifers have declined at a faster rate than those in the overlying 400-Foot Aquifer, indicative of the significant increase in Deep Aquifers pumping. This Region has experienced the largest decline in groundwater elevations in the Deep Aquifers.

Seaside Region – Monterey Subbasin: Much of the sediments above the 400/Deep Aquitard in this Region—including the Dune Sands, Aromas Sands and upper Paso Robles Formation—are not fully saturated or confined; for this reason, there are very few wells installed in these sediments. The only well pairs in this Region are away from the pumping center. They show Deep Aquifers groundwater elevations higher than those in the overlying aquifer. Groundwater elevations in both the Deep Aquifers and overlying aquifer began to decline around 2013. There are no available groundwater elevation monitoring data above the 400/Deep Aquitard near areas of extraction in this Region.

Seaside Region – Seaside Subbasin: Similar to areas in the Northern Region of the Deep Aquifers, in this area groundwater elevations in the Deep Aquifers have historically been lower than those in the aquifer overlying the aquitard. Groundwater elevations in both the overlying aquifer and Deep Aquifers are decreasing. In recent years groundwater elevations in the overlying aquifer have decreased at a faster rate than the Deep Aquifers in the 2 wells that have groundwater elevation measurements above and below the aquitard. However, well FO-11 has an upward vertical gradient and the Camp Huffman well has a downward gradient.

Southeastern Region: No data from wells screened only in the Deep Aquifers are currently available and vertical gradients within this region are currently a data gap.

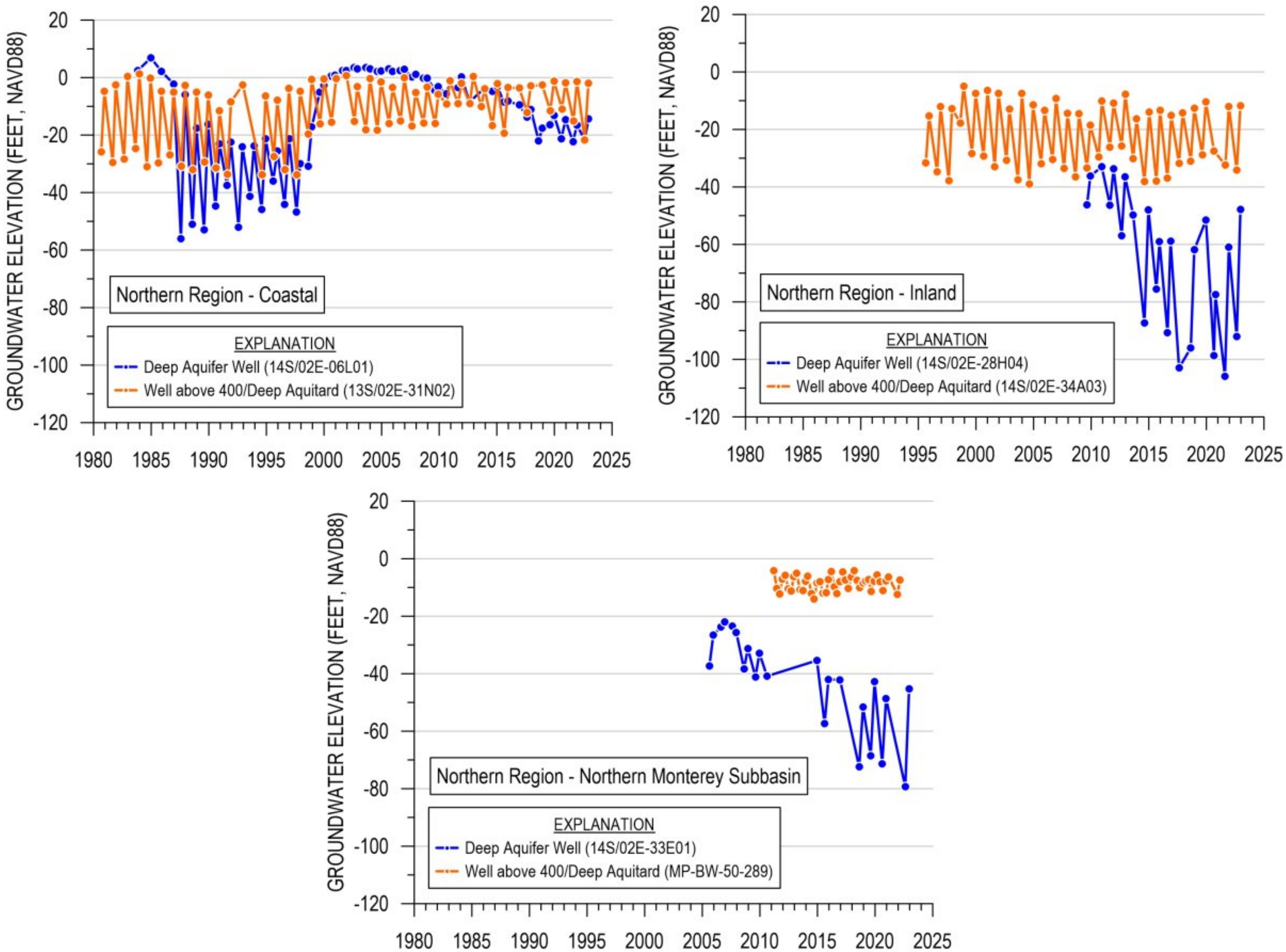


Figure 5-12. Northern Region Example Hydrographs Comparing Groundwater Elevations in the Deep Aquifers and Overlying Aquifer

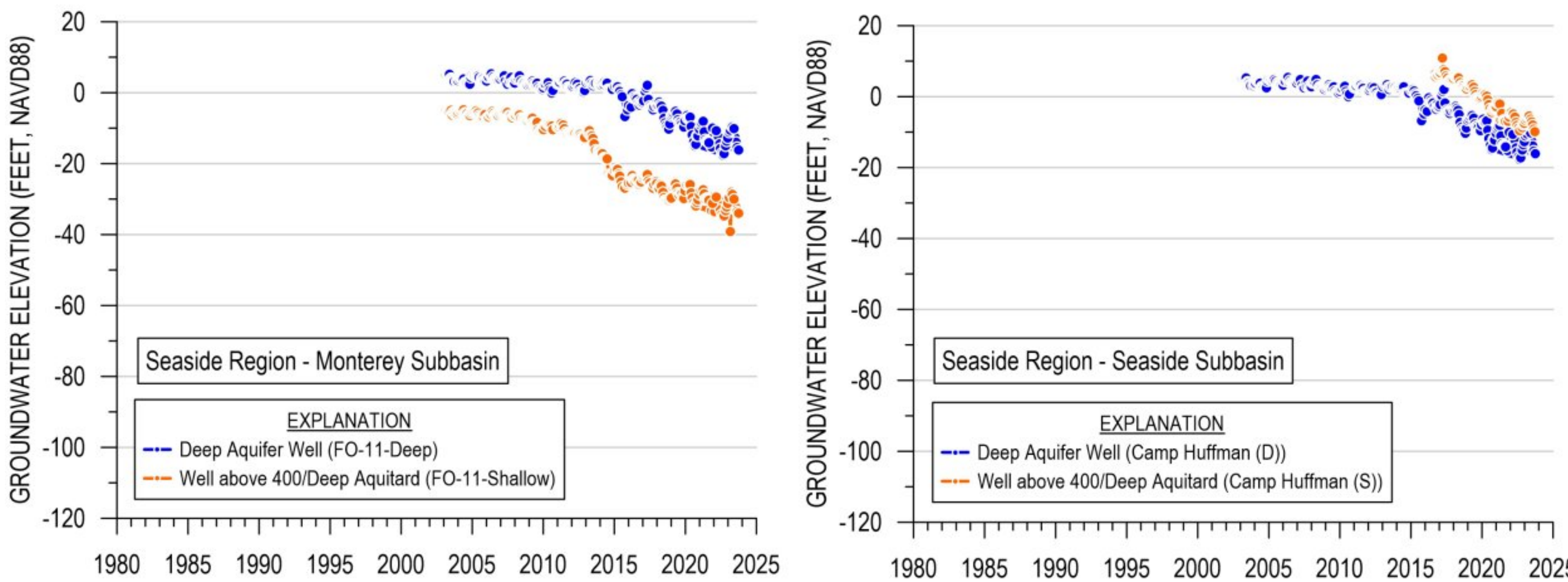


Figure 5-13. Seaside Region Example Hydrographs Comparing Groundwater Elevations in the Deep Aquifers and Overlying Aquifer

5.3 Groundwater Quality

Table 5-2 lists the Deep Aquifers groundwater quality constituents that have exceeded regulatory limits in the past, based on data collected by the SWRCB's Division of Drinking Water (DDW) in the GAMA groundwater information system. Constituents that exceeded the regulatory standards within the past 5 years are highlighted in blue in the table; however, only arsenic exceeds the regulatory limit in the most recent sample.

Deep Aquifers groundwater exceeds Title 22 regulatory limits for arsenic in 1 well, shown in Table 5-2 (SWRCB, 2023). This Castroville well (GAMA well 2710005-009) had an average arsenic concentration of 21 ug/L at the wellhead during testing in 2014 (BESST, Inc., 2014). In August 2023, the measured arsenic concentration in this well was 16.2 µg/L, which is higher than the 10 µg/L regulatory limit. Arsenic is naturally occurring in groundwater in this area.

Figure 5-13 shows that the most recent groundwater samples for all other Deep Aquifers wells do not exceed arsenic Title 22 regulatory limits. Factors that contribute to elevated concentrations of arsenic in aquifers can include long groundwater residence times, rock type, and high pH (USGS, 2019). While there are no other deep wells with elevated arsenic, arsenic is a constituent of concern for shallower wells closer to the Gabilan Range (SVBGSA, 2022).

Table 5-2. Historical Exceedances of the Water Quality Regulatory Limits in Deep Aquifers Wells

Constituent	Number of Exceedances	Exceedance Years
Radium-226 + Radium-228	1	2002
1,1,2,2 Tetrachloroethane (PCA)	1	1988
1,2 Dibromoethane (EDB)	1	2002
1,2,3-Trichloropropane (1,2,3 TCP)	9	1992, 2001-2003, 2007, 2008, 2010, 2011, and 2013
1,2-Dibromo-3-chloropropane (DBCP)	1	2008
2,4-Dichlorophenoxyacetic acid (2,4 D)	1	1984
Arsenic*	14	1998, 1990, 1991, 1993, 2007, 2015-2023
Beryllium	1	1991
Cadmium	1	1988
Di(2-ethylhexyl)phthalate (DEHP)	1	1990
Foaming Agents (MBAS)	1	1993
Gross Alpha radioactivity	6	2006, 2013-2017
Iron*	9	1990, 1993, 1998, 2001, 2010, 2011, 2018, 2022, and 2023
Lindane (Gamma-BHC)	2	1984 and 1990
Manganese*	4	1994, 2011, 2022, and 2023
Mercury	2	1985 and 1988
Methoxychlor	1	1984
Nitrate as N	1	1989
Perchlorate	1	2008
Selenium	1	2016
Specific Conductivity	3	2004, 2008, and 2011
Thallium	1	1991
Total Dissolved Solids	1	2004
Toxaphene	1	1984
Vinyl Chloride	1	1986

** Indicates samples above the regulatory standard were within the past 5 years.*

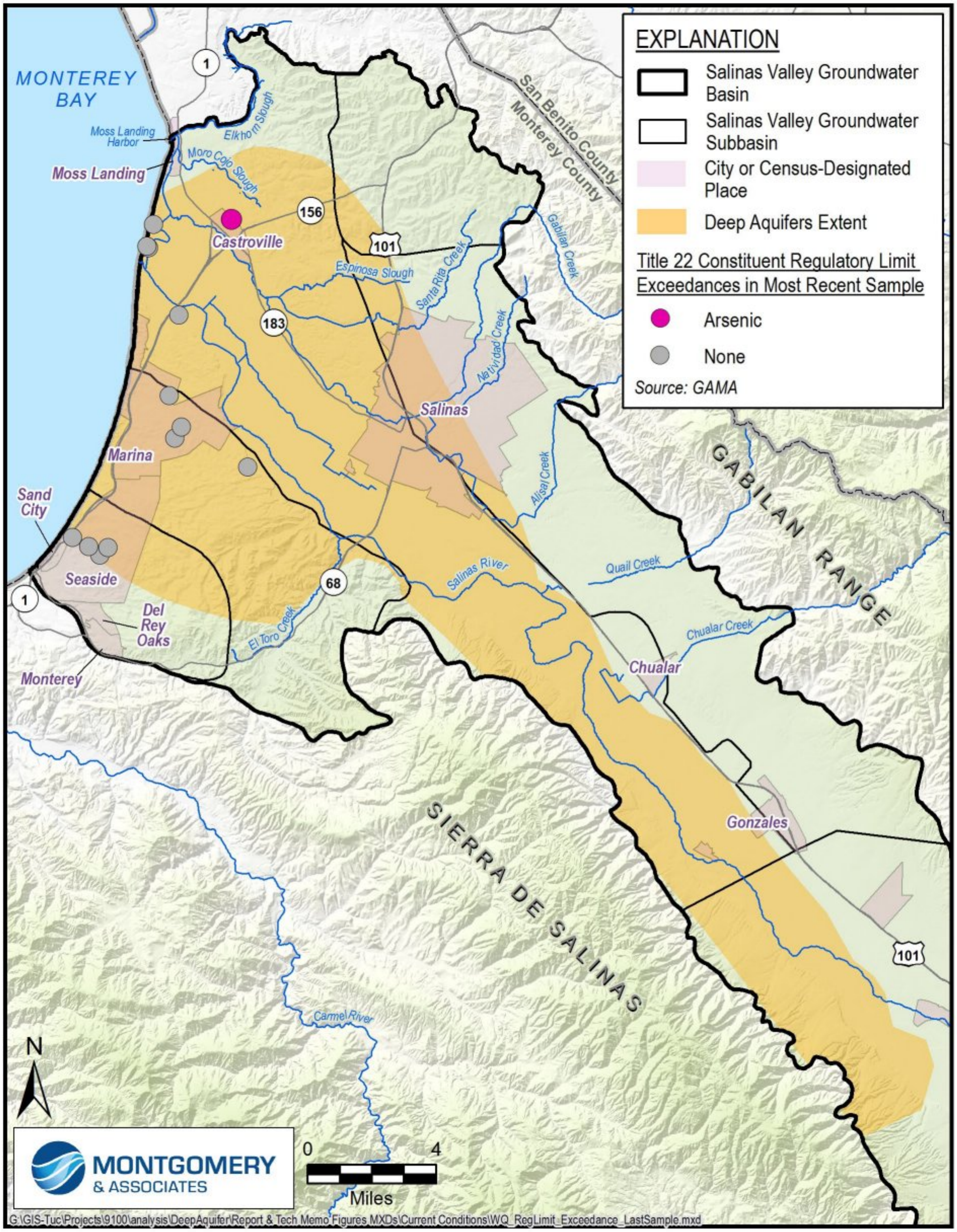


Figure 5-14. Locations of Most Recent Exceedances of Water Quality Regulatory Limits in Deep Aquifer Wells

5.4 Risk of Seawater Intrusion

Although there is no recorded seawater intrusion in the Deep Aquifers to date, there are 3 potential pathways from which seawater intrusion could enter: vertical leakage from the intruded areas of the 400-Foot Aquifer through the 400/Deep Aquitard, vertical migration from poorly constructed wells, or lateral intrusion from the geologic formations underlying the ocean. The first 2 are the most immediate threats, but lateral intrusion through the offshore sediments could slowly be occurring while undetected.

Downward vertical migration of seawater intrusion has a strong possibility of occurrence based on the vertical gradients between the Deep Aquifers and the 400-Foot or equivalent aquifer. The reversal in vertical gradients from an upward to a downward gradient with pumping in the Deep Aquifers has increased the risk of seawater intrusion via this pathway. Vertical gradients are currently downward from the 400-Foot Aquifer to the Deep Aquifers in several areas, as described earlier in this report. This downward gradient can drive downward migration of saline water across the aquitard, which is known to contain intermittent zones of higher permeability silts and sands that have variable thicknesses across the extent of the Deep Aquifers. Figure 5-14 shows the areas with groundwater quality exceeding the MCWRA-mapped 250 milligrams per liter (mg/L) chloride isocontour in the 400-Foot Aquifer. The risk of downward migration of seawater intrusion through poorly constructed wells in those areas also increases with development of a downward vertical gradient.

Similarly, the low groundwater elevations in the Deep Aquifers create an inland hydraulic gradient that increases the risk of seawater intruding laterally from the ocean. At least 1 formation that constitutes the Deep Aquifers, the Purisima Formation, outcrops in the Monterey Bay Canyon and is therefore in direct contact with seawater. Other formations may be near the interface between the mapped seafloor sediments and the ocean, as well as in contact with the Purisima Formation, and subsequently may have potential hydraulic connection through these intermediary/direct contact sediments. Given the uncertainties associated with this complex interplay of hydrogeologic conditions, it is difficult to accurately predict the timing that seawater intrusion could advance inland from offshore sediments.

The Deep Aquifers system consists of multiple geologic formations and aquifers that have been developed by long-screened production wells that mix groundwater from various zones. Any 1 of these productive zones may represent a preferential pathway for seawater intrusion from the ocean. The shallowest zone of Deep Aquifers, historically named the 800-Foot and 900-Foot Aquifers, were developed first and as a consequence have had a longer period of depressurization, and subsequently a potentially higher risk for ocean-derived seawater intrusion. Even if seawater intrusion were to first occur only in the shallower portion of the Deep Aquifers, the numerous wells with long screen intervals act to connect the shallower and deeper zones of the Deep Aquifers, putting the deeper portion of the Deep Aquifers at risk of seawater intrusion, thereby rendering the whole Deep Aquifer system at increased risk.

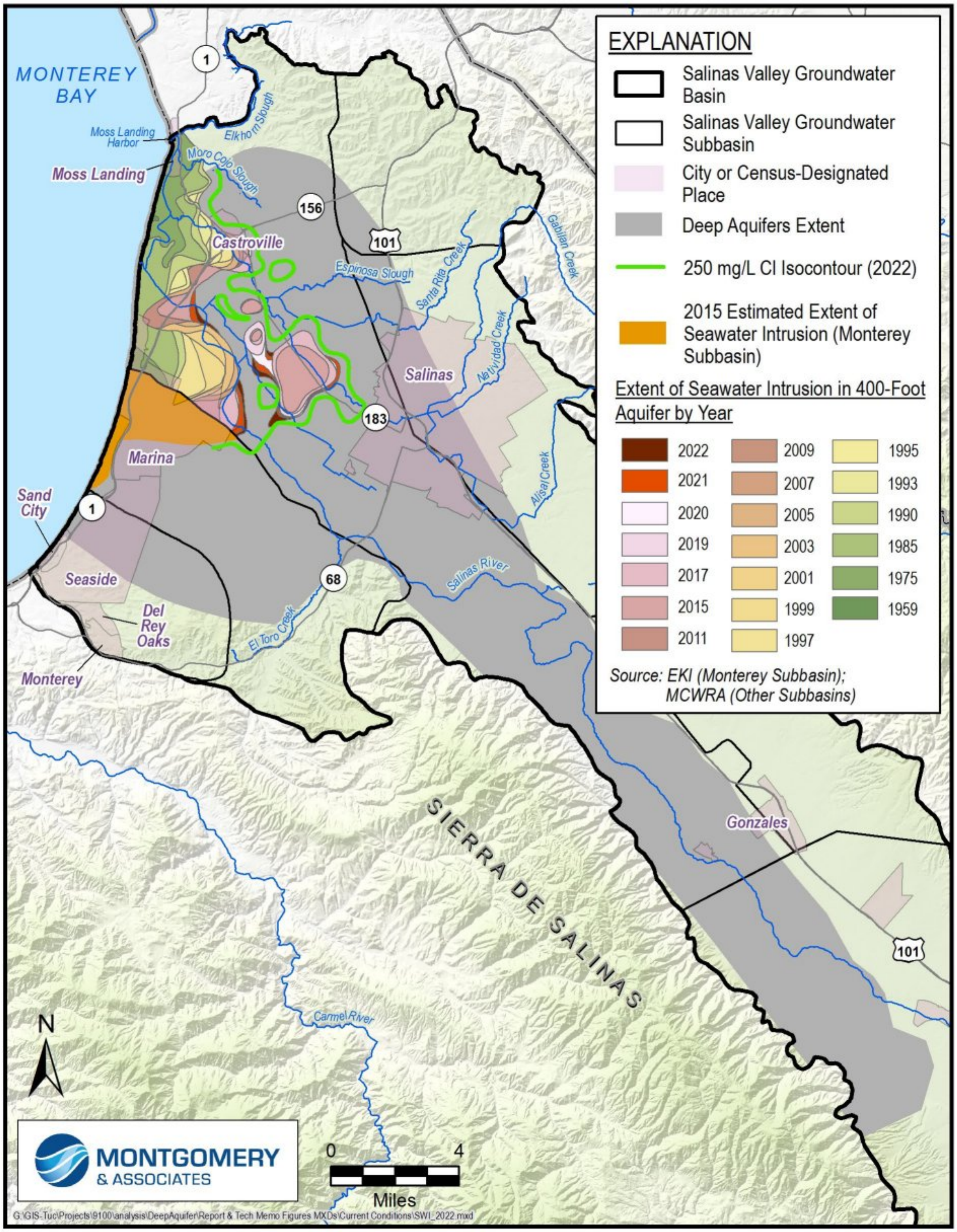


Figure 5-15. Extent of Seawater Intrusion in 2022 in the 400-Foot Aquifer

5.5 Risk of Land Subsidence

Although no historical subsidence has been documented in the area overlying the extent of the Deep Aquifers to date, falling groundwater elevations in the Deep Aquifers pose a risk of land subsidence. Currently, land subsidence can be measured using Interferometric Synthetic-Aperture Radar (InSAR) data. DWR provides these data for the Salinas Valley Groundwater Basin within the estimated error of measurement of +/- 0.1 foot (DWR, 2023). Figure 5-15 shows the annual subsidence was negligible from October 2022 to October 2023 within the extent of the Deep Aquifers. InSAR data detects change at the land surface and cannot delineate in which aquifer subsidence occurs. In the coastal area, seawater intrusion has largely eliminated the risk of subsidence in aquifers overlying the Deep Aquifers, as seawater has filled in the pore spaces and prevented extreme dewatering. Unless seawater intrusion occurs in the Deep Aquifers, declining groundwater elevations indicate there is risk of subsidence.

Land subsidence due to groundwater withdrawals results from imbalanced pressures between the aquifers and aquitards in confined aquifer systems like the Deep Aquifers. Depressurizing, or dewatering, can shift the balance of pressures between the sediments and collapse the pore spaces in aquitards that were previously fully saturated (pressurized). This collapse results in land subsidence (Figure 5-16).

Without a significant amount of testing and modeling, it is impossible to know in advance at what groundwater elevations subsidence will occur; however, the Deep Aquifers conditions indicate strong risk of subsidence unless seawater intrusion were to fill in the pore spaces and prevent dewatering. Subsidence has not occurred at historical groundwater elevations; however, because of associated time delays, it could still be triggered by current groundwater elevations. Dewatering of clays occurs very slowly given the low hydraulic conductivity of clays. Because clay dewatering is slow, subsidence may occur gradually and may not be detected for over a year. The potential for subsidence applies internally to the Deep Aquifers as much as it does to the overlying 400/Deep Aquitard.

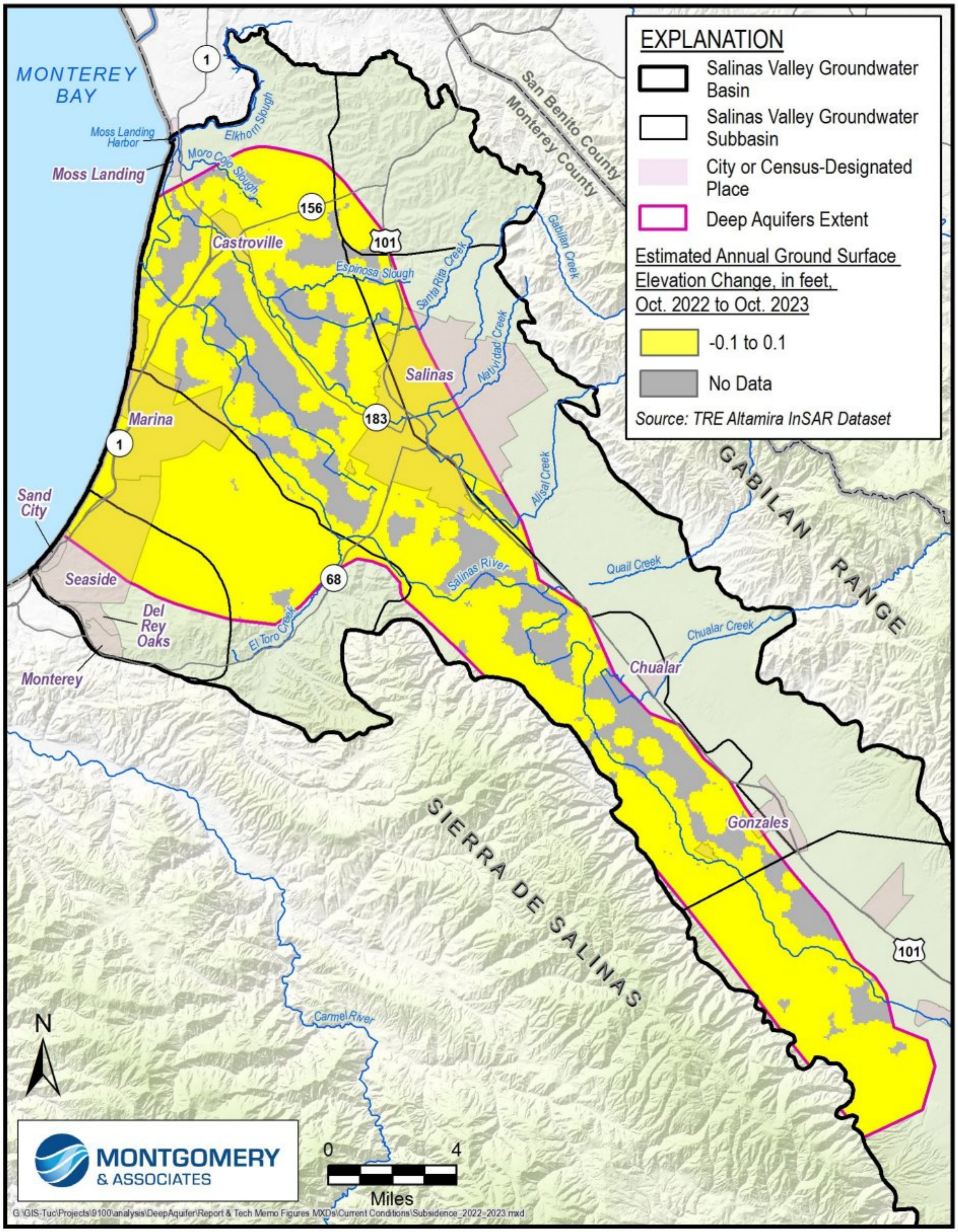


Figure 5-16. Land Subsidence Estimate in the Lower Salinas Valley from October 2022 to October 2023

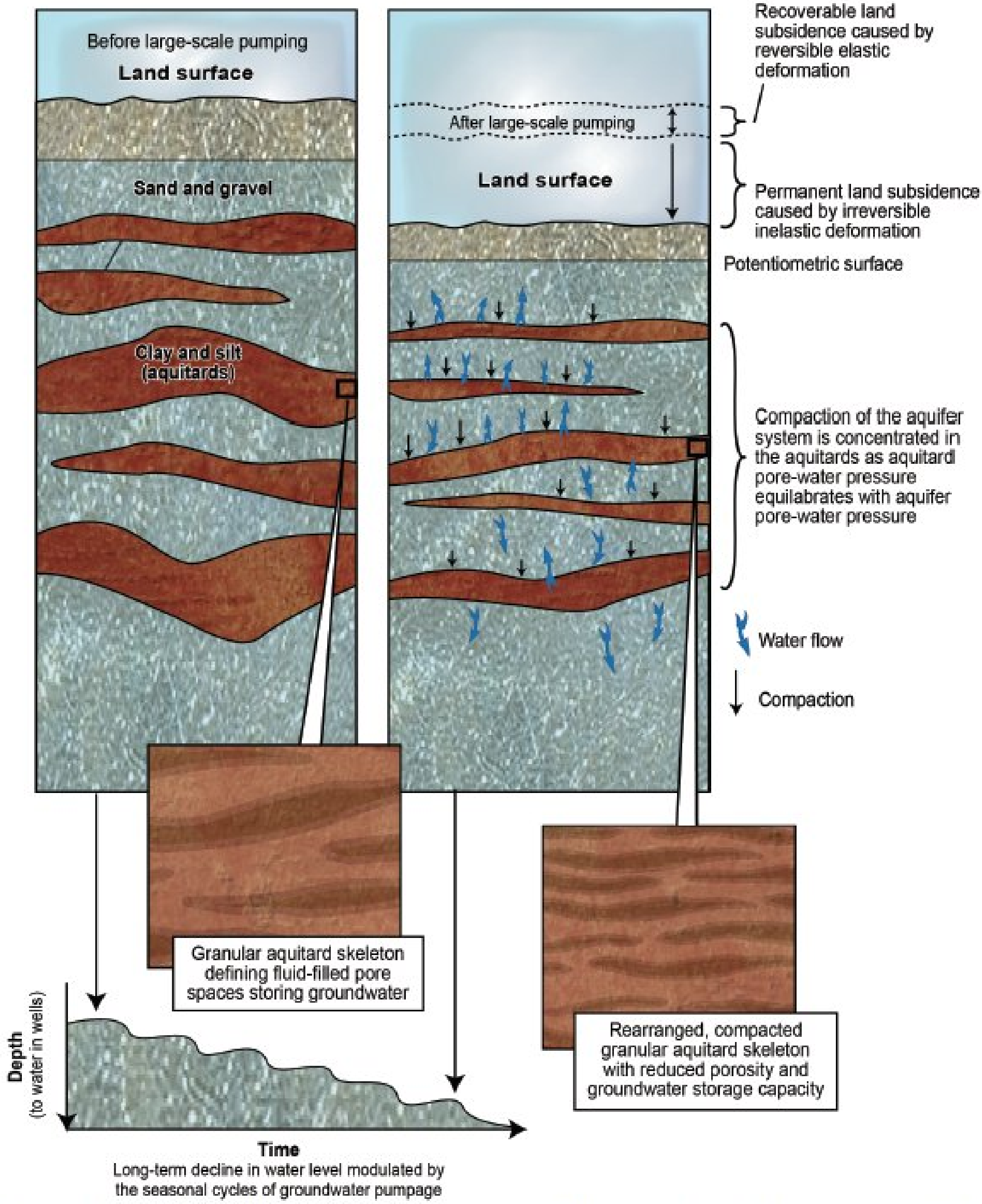


Figure 1. Schematic diagram of land subsidence due to groundwater withdrawal (modified from Galloway and others, 1999).

Figure 5-17. Illustration of Groundwater Depletion Driven Land-Subsidence Mechanism (Lowe, 2012)

5.6 Summary of Recent Conditions and Risk

Increased pumping has caused groundwater elevations in the Deep Aquifers to rapidly decline in recent years, particularly in the Northern Region. Pumping in the Seaside Region has remained relatively stable in recent years; however, even with injection occurring, groundwater elevations continue to decline in some locations. In the Southeastern Region, pumping is much lower than the other regions and there are no groundwater elevation measurements of wells solely screened in the Deep Aquifers. Pumping in the adjacent Eastside alluvial fans could be driving losses in groundwater storage in the Southeastern Region.

If not managed carefully, pumping large amounts of water increases the risk of seawater intrusion or subsidence. While it is not possible to know how much pumping will result in seawater intrusion or subsidence, or how severe the impacts will be, pumping has driven downward vertical gradients in several areas of the Deep Aquifers extent. These low groundwater elevations may contribute to seawater moving towards the low groundwater elevations or may depressurize the clays that could cause subsidence. In addition, the declining groundwater elevations change the direction of groundwater flow, which has the potential of mobilizing constituents of concern that would deteriorate groundwater quality.

6 MANAGEMENT GUIDANCE

Groundwater management must occur within existing regulatory frameworks and address the risks associated with further groundwater elevation declines. Lack of management of the Deep Aquifers could have severe economic implications due to seawater intrusion, subsidence, and lack of regulatory compliance. Local control may also be compromised without adhering to the Seaside adjudication or SGMA.

In the Salinas Valley, local agencies exist that have the jurisdictional and legal authority to require groundwater monitoring, regulate extraction, approve or deny new well installations, and undertake projects to provide in lieu supplies to lessen the burden of extraction controls. Agencies can and should work together to determine who should manage the Deep Aquifers, since individual agencies may have legal and/or financial constraints. A legal review should be undertaken to confirm agency authorities and interpretation of prior agreements. In addition, while authority exists to regulate extraction, the legal review should examine how extraction can be regulated within existing water rights.

This scientific guidance for management is based on the findings provided in this Study. As management must fit within the existing adjudication and regulatory framework, those are first summarized; however, the focus here is on the scientific implications for management. It does not extend to policy decisions regarding distribution of effort, the type of management actions or projects, or how the guidance should be implemented, as those are beyond the current Study scope and should be done together with local agencies that manage groundwater and key stakeholders.

6.1 Regulatory Context for Groundwater Management

The administrative and regulatory context provides both background information that is relevant for managing extractions and constraints on management actions.

6.1.1 Seaside Adjudication

In 2007, the Seaside Subbasin was adjudicated by the Superior Court of the State of California in and for the County of Monterey (California American Water v. City of Seaside, Monterey County Superior Court, Case Number M66343). While termed Seaside Basin within the adjudication, it is referred to as the Seaside Subbasin within this report because it is a subbasin of the Salinas Valley Groundwater Basin, as defined by DWR for the purposes of SGMA, and acknowledges the hydraulically connection with other subbasins. With an amendment to the adjudication, the Court approved the Basin Monitoring and Management Plan (MMP). Groundwater elevations, quality, and extractions are reported to the Seaside Watermaster, who reports conditions to the Court overseeing the adjudication. The Seaside Watermaster also coordinates between the MPWMD and the entities that extract groundwater within the Seaside Subbasin.

As part of the adjudication, the Court mandated an Operating Safe Yield and phased pumping reductions to reach the Natural Safe Yield. The Operating Safe Yield is the maximum annual amount of groundwater resulting from natural replenishment that, based upon historical usage, the adjudication allows to be produced. Of the 5,180 AF/yr initial Operating Safe Yield for the whole subbasin, 4,611 AF/yr was for the Coastal Subarea. Over time the subbasin's Operating Safe Yield was to be reduced to the Natural Safe Yield of 3,000 AF/yr. Most of the Deep Aquifers that fall within the Seaside Subbasin are within the northern part of the Coastal Subarea, where most extraction is concentrated. Within these amounts, the Court divided the Operating Yield among the extracting entities within each subarea.

In addition to their respective portion of the native yield, extractors are allowed to recover non-native water they inject, such as occurs for Pure Water Monterey and Aquifer Storage and Recovery. In WY 2022, extraction of native groundwater was within the Natural Safe Yield. The adjudication does not relate management to groundwater elevations; however, it does specify actions to take if seawater is detected within the Subbasin.

6.1.2 Sustainable Groundwater Management Act

In 2014, California passed SGMA, which requires groundwater basins or subbasins that are designated as medium or high priority to be managed sustainably according to 6 sustainability indicators.

In 2017, local GSA-eligible entities jointly developed the SVBGSA to wholly, or in coordination with other Groundwater Sustainability Agencies (GSAs), develop GSPs and manage groundwater in the 6 non-adjudicated subbasins in the Monterey County portion of the Salinas Valley. In addition, MCWD established itself as a GSA for managing the Marina/Ord Area of the Monterey Subbasin, and the City of Greenfield formed the Arroyo Seco GSA to manage groundwater around Greenfield in the Arroyo Seco Cone Management Area of the Forebay Subbasin. In 2019, the County of Monterey established itself as the GSA for a small portion of land near the coast in the 180/400-Foot Aquifer Subbasin. The Seaside Subbasin is adjudicated and not subject to most SGMA requirements.

The GSAs developed GSPs for each of the 6 Salinas Valley subbasins. The 180/400-Foot Aquifer Subbasin GSP was submitted to DWR in 2020 and approved by DWR in 2021. The other 5 GSPs were submitted in 2022 and approved by DWR in April 2023. The 180/400-Foot Aquifer and Monterey Subbasin GSPs identified the Deep Aquifers as a principal aquifer. The GSPs contain measurable, quantifiable objectives for each of the 6 SGMA sustainability indicators: chronic lowering of groundwater elevations, reduction in groundwater storage, seawater intrusion, land subsidence, water quality, and depletion of interconnected surface water due to pumping. Basins must be managed to reach those measurable objectives by 2040 for the 180/400-Foot Aquifer Subbasin or 2042 for the other subbasins and show progress leading up to those dates. Furthermore, they must avoid undesirable results, which are a combination of quantitative minimum thresholds for each indicator. Subbasins must show that they are making progress and are on track to reach sustainability. If sustainability is not reached or progress is not made within a subbasin, DWR can refer the subbasin to the State Water Resources Control Board (SWRCB) and if it decides to do so, the SWRCB can step in to manage the subbasin.

6.1.3 Agreements on Water Supplies for Former Fort Ord

Fort Ord, which closed in 1994, was a federal military base located in the Seaside and Monterey Subbasins. When active, it had federal water rights and used groundwater for its operations. As part of its closure, the U.S. Army transferred ownership of the base's water system to Marina Coast Water District (MCWD) and the Fort Ord area was annexed into Monterey County Zones of Benefit 2 and 2A (replaced by Zone 2C established for the Salinas Valley Water Project in 2003).

These agreements do not specify how much groundwater extraction may come from the Deep Aquifers, and they do not confirm whether they codify water rights or whether the agreements constitute an understanding between agencies. Legal analysis of these agreements should be included in a broader legal review that evaluates treatment of groundwater rights in the context of potential actions to manage groundwater extraction from the Deep Aquifers.

6.1.4 Local Agency Authority to Regulate Groundwater Extraction and Wells

Local agencies have sufficient authority to regulate wells and groundwater extraction in the Salinas Valley.

- **Well Permitting Authority -** The Monterey County Health Department, Environmental Health Bureau is the primary well permitting agency for the County. MCWRA completes a technical review of proposed well constructions for the Environmental Health Bureau, and the Environmental Health Bureau determines what, if any, level of CEQA review is necessary and issues the well permits. Some cities within the Salinas Valley also retain well permitting authority. In addition, State of California Executive Order N-3-23, which updated and replaced Executive Order N-7-22, created a role for GSAs by specifying that a well permitting agency shall not approve well permits in basins subject to SGMA without GSA verification that groundwater extraction by the proposed well would not be inconsistent with any sustainable groundwater management program established in any applicable GSP, nor would it decrease the likelihood of achieving a sustainability goal for the basin.

- **MCWRA Agency Act –** Section 22 of the MCWRA Agency Act explicitly provides MCWRA with the ability to prohibit groundwater extraction when appropriate studies determine a portion of the groundwater basin to be threatened by loss of usable supply as a result of seawater intrusion. The Act specifies that MCWRA can only enact these prohibitions if a substitute surface water supply adequate to replace water previously pumped from that area and depth is made available to the lands served from that well. More legal analysis is necessary to determine if and to what extent this prevents MCWRA from prohibiting extraction in areas or at depths not threatened by loss of usable supply due to seawater intrusion or where no substitute surface water supply is provided. The Agency Act was enacted prior to the development of SGMA, which requires groundwater sustainability to be achieved according to 6 sustainability criteria.
- **GSAs –** California Water Code §10726.4 (a) (2) provides GSAs the authority to control groundwater extractions by regulating, limiting, or suspending extractions from individual groundwater wells or extractions from groundwater wells in the aggregate. GSAs do not have land use authority; however, the County of Monterey and cities have land use authority. No local agencies have the authority to change water rights. As such, an analysis of applicable water rights should be undertaken prior to enacting any extraction regulations.
- **Monterey County –** All counties in California, including Monterey County, have police powers that allow groundwater regulation. SGMA legislation specifically states that it is the intent of the legislature "to recognize and preserve the authority of cities and counties to manage groundwater pursuant to their police powers."

6.2 Economic Implications of Lack of Management

Economic implications of lack of management of the Deep Aquifers stem from 3 main risks: seawater intrusion, subsidence, and lack of sustainable management.

Seawater intrusion into the Deep Aquifers could render the aquifer unusable where intruded. This could occur from seawater intrusion from the ocean, slow leakage from the intruded overlying aquifer, or through leaky wells. Some groundwater elevations in Deep Aquifers wells are at new lows, and there is now a downward vertical hydraulic gradient in parts of the Deep Aquifers. These conditions put the Deep Aquifers at greater risk of seawater intrusion than they were historically. The economic implication of losing this supply could be high if there is not an overlying aquifer that can provide water sustainably and if the area cannot receive water from an alternative source, such as the Salinas River or the CSIP.

Lack of management puts the area of the Deep Aquifers at risk of subsidence. Low groundwater elevations could slowly dewater the aquitard above the Deep Aquifers and clays within the Deep Aquifers, causing compaction. Subsidence can impact transportation infrastructure (roads, bridges, railways, airports), water infrastructure (supplies, sewers, and treatment), electrical grids and telecommunication infrastructure, and buildings, including hospitals and schools. Subsidence can additionally increase flood risk in low-lying areas.

Finally, lack of sustainable management according to SGMA could trigger the state intervention process, which authorizes the SWRCB to step in to help manage the basin and impose extraction fees. Lack of management could also potentially drive groundwater users to extract more water from the Deep Aquifers if pumping from the overlying aquifers is limited. This additional pumping would likely exacerbate declining Deep Aquifers groundwater conditions.

The Deep Aquifers Study includes guidance for management based on the Study's analysis. It does not fully analyze alternative management options, such as providing water supplies to be used in lieu of groundwater extraction. Furthermore, the Study focuses on the Deep Aquifers, not the overlying aquifers. Results from analyzing existing data as part of the preliminary investigation indicate that the Deep Aquifers are likely hydraulically connected to the overlying 400-Foot Aquifer and surrounding aquifers. There may be additional costs associated with sustainably managing the overlying and surrounding aquifers.

6.3 Guidance for Management

Existing monitoring shows that current groundwater elevation declines are unsustainable. The guidance provided here explains what the previous sections of the report imply for management principles. It recommends management regions, principles to guide management, and parameters to guide management; however, management can be operationalized in a variety of manners in terms of the types of management actions and projects, and specific locations and amounts for injection or demand management. These add to existing regulatory requirements.

Types of Management Actions and Projects

1. **Manage the Deep Aquifers through a combination of 3 general types of management actions and projects: demand management, provision of alternative water supply, and injection.**

This Study has shown that current extraction of the Deep Aquifers is not sustainable, and will lead to undesirable results such as declining groundwater elevations, land subsidence, and seawater intrusion. Groundwater management should meet the management principles described below, but could occur through different types or combinations of management actions and projects. The main options include (1) demand management that plans, controls, and/or reduces the amount of groundwater extracted from the Deep Aquifers; (2) provision of alternative water supplies that meet water needs and enable reduction of extraction; and (3) injection into the Deep Aquifers to increase inflows and groundwater elevations. This Study and the management guidance herein do not differentiate between these options, as they all contribute to changing the balance between inflows and outflows from the Deep Aquifers and would help improve groundwater elevations. All management actions and projects need to be evaluated with regards to their impact on groundwater conditions spatially, in terms of depth, in relation to overlying and adjacent aquifers, and with regard to feasibility.

Location of Management

2. **Differentiate groundwater management by the 3 Regions within the extent of the Deep Aquifers: Northern Region, Seaside Region, and Southeastern Region.**

The Study delineated the extent of the Deep Aquifers; however, management does not need to be uniform throughout this extent. Management should be differentiated by the 3 regions defined in this Study: Northern, Seaside, and Southeastern Regions. These regions have been defined given the differing groundwater chemistry, rates of groundwater elevation decline, amounts of pumping, and availability of data on the conditions of the Deep Aquifers.

The Study recommends separating management between the Seaside Region and Northern Region based on distinct water chemistry, as well as the differences in geologic formations, a groundwater elevation divide, and distance between pumping in each respective region. These are not defined along the jurisdictional boundaries that form the distinction between the adjudicated Seaside Subbasin and the subbasins regulated by SGMA; however, all pumping in the Seaside Region defined here is within the Seaside Subbasin and the wells within the southern Monterey Subbasin are all monitoring wells.

Southeast of the City of Salinas there is a lack of groundwater elevation data and groundwater chemistry data that is from true Deep Aquifers wells, which inhibits the ability to understand the condition of the Deep Aquifers in that region. Monitoring from true Deep Aquifers wells need to confirm the conditions in the Deep Aquifers. This Study recommends tracking the Southeastern Region separately unless and until data shows a specific type of management is necessary.

Recommended Principles to Guide Management

3. **To prevent seawater intrusion from downward migration through the 400/Deep Aquitard or wells, maintain protective groundwater elevations higher than the overlying 400-Foot or equivalent aquifer where intrusion is present.**

There are 3 potential pathways that seawater intrusion could enter the Deep Aquifers: vertical migration from poorly constructed wells, vertical leakage from the intruded areas of the 400-Foot

Aquifer through the 400/Deep Aquitard, or lateral intrusion from the geologic formations underlying the ocean. The first 2 are the most immediate threats. The historical upward vertical gradient between the Deep Aquifers and the 400-Foot or overlying aquifer has reversed to a downward gradient in areas of pumping. While the flow downward through the 400/Deep Aquitard is difficult to verify, since the clay-rich aquitard contains interlayered occurrences of higher permeability silts and sands, the downward gradient itself poses a risk of seawater-intruded waters migrating into the Deep Aquifers from the overlying aquifer. In the areas beneath where the 250 mg/L chloride or its total dissolved solids (TDS) equivalent is mapped in the overlying aquifer, maintain groundwater elevations above the overlying 400-Foot Aquifer groundwater elevations so there is an upward gradient. This upward hydraulic gradient will prevent any downward flow of seawater from the 400-Foot or overlying aquifer through either improperly sealed wells or holes in the aquitard. Management will need to balance multiple goals, such as water supply goals; however, this principle should be taken into consideration.

4. **Assess the preferred option for controlling lateral seawater intrusion.**

Lateral intrusion of seawater from the ocean has not been observed in the Deep Aquifers based on the available data, but is a concern given the low groundwater elevations and inability to detect intrusion in offshore sediments. Lateral seawater intrusion into the Deep Aquifers may be able to be addressed by (1) raising groundwater elevations to protective elevations either through reducing extraction or injecting water to raise groundwater elevations, or (2) including the Deep Aquifers in any future extraction barrier plans. This Study recommends that the relevant management agencies evaluate the options, weigh the benefits and costs of the 2 options for preventing lateral seawater intrusion, and identify a preferred option. Assessing the preferred option may include an analysis using the Salinas Valley SWI Model to test the sensitivity of hydraulic parameters, subsurface inflow, boundary conditions, and the initial conditions of the model to the lateral and vertical migration of seawater. These components of the model all have a large degree of inherent uncertainty. This sensitivity analysis could potentially demonstrate the range of effects each option has for controlling seawater intrusion within the Deep Aquifers.

If the preferred option is not already implemented, if seawater intruding laterally from the ocean is detected, immediately stop extraction in the vicinity of the intrusion while the preferred option is implemented.

5. **To prevent subsidence, keep Deep Aquifers groundwater elevations above historical lows at a minimum.**

As described in earlier sections in the report, the Deep Aquifers is a confined aquifer system, and groundwater elevation declines represent a decrease in pressure. Where low groundwater elevations do not cause seawater intrusion, depressurization can cause aquitards and other clay layers to collapse, resulting in land subsidence. This type of inelastic land subsidence is irreversible and can cause severe damage to infrastructure and property at the land surface.

It is impossible to know if and when subsidence will occur; however, it has not occurred in the Salinas Valley Groundwater Basin to date. Since subsidence has not been detected at historical groundwater elevations, to avoid activating any new subsidence in the future, groundwater elevations should be kept above historical lows. This assumes the 400-Foot Aquifer or its equivalent will also not dip below its historical lows in order to keep the historical saturated pressure relationships the same, or similar. In addition, there is risk of depressurization of the clay layers within the Deep Aquifers.

6. **In the Northern and Seaside Regions, use sustainable/safe yield by region based on the best available tools to guide initial groundwater management, and adjust management over time according to changes in observed groundwater elevations.**

The Northern and Seaside Regions have declining groundwater elevations that indicate current extraction is not sustainable. Whether through injection, demand management, and/or demand reduction where an alternative source of water is supplied, groundwater management needs to change the balance between inflows and outflows to bring groundwater elevations up. Since groundwater models provide the best available tools to develop sustainable/safe yields that account for the complexity of inflows and outflows, they should be used to develop initial injection or pumping reduction quantities. Groundwater model(s) used should be adjusted according to the findings of this Study to improve the groundwater calibration of the Deep Aquifers across their extent.

Initial modeled values for management should be adjusted over time based on how groundwater elevations respond and compare to the levels that meet the regulatory requirements and other recommended management principles identified in this Study. Initial modeled values are insufficient for long-term management, in part because inflows and outflows change as injection and pumping change groundwater elevations. Further, groundwater models may not be able to fully capture complexities associated with varying screen intervals and depths of pumping, particularly given the interspersed layers of clay that exist within the Deep Aquifers. Monitoring observed groundwater elevations will provide the best indication of whether groundwater management has met the principles or to better assess the extent of further management needed.

7. **In the Southeastern Region, manage groundwater if/when declining groundwater elevations in true Deep Aquifers wells indicate a state of chronic overdraft.**

There is currently not sufficient data to determine if groundwater elevations are declining in the Southeastern Region of the Deep Aquifers. Most wells are screened in both the 400-Foot and Deep Aquifers, indicating they draw from both aquifers and any groundwater elevation measurements are influenced by both aquifers. The Study suggests basing groundwater management in this area on groundwater elevations such that specific types of management would be triggered if/when declining groundwater elevations indicate the Deep Aquifers are in chronic overdraft in this Region. No available records contain historical groundwater elevations in this area; however, declining groundwater elevations that do not rebound or stabilize after wet periods or periods of reduced extraction indicate chronic overdraft. Management should also consider the extent to which declines are attributable to Deep Aquifers extraction in this area rather than due to extraction in adjacent or overlying aquifers.

8. **Manage the Deep Aquifers together with overlying and adjacent aquifers.**

The HCM identified potential pathways for subsurface inflow and outflow between the Deep Aquifers and adjacent and overlying aquifers. Groundwater elevations in the Deep Aquifers likely affect and are affected by pumping and groundwater elevations in adjacent and overlying aquifers, and therefore they should be managed together.

Lack of Deep Aquifers wells with long historical records of groundwater elevations inhibits a strong understanding of the historical relationship between the Deep Aquifers and the adjacent aquifers. However, AEM and lithology data suggest that some of the adjacent aquifers may be in hydraulic connection with the Deep Aquifers and may provide subsurface inflow and outflow pathways. Therefore, declining groundwater elevations in the Deep Aquifers increase the horizontal hydraulic gradient flowing into the Deep Aquifers and may facilitate more lateral subsurface flow into the Deep Aquifers. In other areas, pumping may intercept surficial recharge before it has the ability to reach the Deep Aquifers, such as in the Corral de Tierra. Adjacent aquifers may not need to be managed to the same standards as the Deep Aquifers; however, management should be coordinated with Deep Aquifers management as groundwater elevations in adjacent aquifers likely affect subsurface inflows and outflows, and groundwater elevations in the nearby part of the Deep Aquifers.

Regulation of Wells

9. **Ensure any new wells installed in the Deep Aquifers within the Northern and Seaside Regions do not increase net extraction since existing extraction, or existing extraction and injection in the case of Seaside, is still resulting in groundwater elevation declines. New wells in the Southeastern Region should not cause increased net extraction if Deep Aquifers groundwater elevations are found to be declining.**

As the current conditions show, current net extraction is not sustainable in the Northern and Seaside Regions, with net extraction meaning injection and extraction combined. If new production wells are installed into the Deep Aquifers, they should not increase net extraction. If new extraction occurs, it should be balanced by reductions in groundwater pumping in nearby wells or increased injection nearby until groundwater elevations are stabilized and at groundwater elevations that meet regulatory, seawater intrusion, and subsidence goals. This should not increase pumping in shallower aquifers if shallower aquifers have declining groundwater elevations, are not meeting their regulatory goals, or are located nearby seawater intruded areas.

10. In the Areas of Uncertainty outside the delineated extent, take a precautionary approach to new wells by preventing increases in net extraction unless it is determined the Deep Aquifers do not extend into them.

This Study identified Areas of Uncertainty outside of the delineated extent where the Deep Aquifers may extend, but where existing data is inconclusive to confirm the presence of the Deep Aquifers. A preventative management approach should be taken in these areas until additional data can determine whether or not the Deep Aquifers extend into them. For example, any new wells at the depths of the Deep Aquifers in these areas should not increase net extraction from the Deep Aquifers. Even if these areas are later determined to not have the 400/Deep Aquitard present, wells at depth would still be part of an adjacent aquifer to the Deep Aquifers that may affect Deep Aquifers conditions.

11. Destroy wells that may facilitate seawater intrusion leakage into the Deep Aquifers if evidence of leakage is detected and the leakage was caused by the well**.**

As discussed above, the most immediate threat of seawater intrusion is likely through wells with poorly built or degrading well seals. Wells drilled into the Deep Aquifers should be destroyed if monitoring shows elevated chloride levels in the Deep Aquifers and an assessment determines it is likely due to downward vertical migration through a well. Well destruction such as this has been conducted in recent years by MCWRA and should be continued across the entire coastal area of the Deep Aquifers where seawater intrusion has been documented in shallower aquifers.

Process to Manage

12. Adaptively manage Deep Aquifers such that quantity of extraction and injection is reviewed and revised periodically based on groundwater elevations.

Groundwater management should set forth best estimates for how injection and extraction of certain quantities will affect groundwater conditions. Estimates should be refined as tools improve and monitoring shows the impact management has on groundwater elevations. Numerous factors influence groundwater elevations' response to injection and extraction, such as variation in hydraulic conductivities within zones in the Deep Aquifers, presence of clay layers, and spatial density of injection or extraction wells. If groundwater elevation goals are surpassed, it may show that the Deep Aquifers can support a larger volume of extraction; however, if goals are not met, extraction may need to be reduced further or injection increased. Adaptive management is a structured, science-based approach often adopted to manage natural resources in the face of uncertainty (Holling, 1978; Walters, 1986). An adaptive management approach should guide Deep Aquifers management as a "learning by doing" approach where management is adjusted based on the results of monitoring the effect of a management action.

6.4 Conclusion

Groundwater conditions of the Deep Aquifers continue to degrade as extraction and outflows exceed subsurface inflows into the aquifer system. Declining groundwater elevations across much of the extent put the Deep Aquifers at risk of seawater intrusion, subsidence, or both. In addition to regulatory requirements, seawater intrusion and subsidence pose severe economic risk if declining groundwater elevation trends are not reversed. Agencies should work together to develop projects or management actions that meet the recommendations described herein. Bringing groundwater elevations above historical lows and above the 400-Foot or equivalent overlying aquifer will help prevent seawater intrusion and subsidence in the Northern and Seaside Regions. If groundwater elevation declines are observed in the Southeastern Region, it should likewise be actively managed. Finally, this report urges caution with respect to the Areas of Uncertainty outside of the Deep Aquifers extent, where there is insufficient data to establish that the Deep Aquifers do not exist. Groundwater modeling is the best available tool for developing initial sustainable/safe yields on which to base groundwater management; however, after groundwater conditions begin to respond, management should be adjusted according to observed groundwater elevations. This will help agencies adapt to and manage for the uncertain response of groundwater elevations and the impact of external factors.

7 MONITORING RECOMMENDATIONS

Regular monitoring of groundwater conditions is necessary to track trends, identify changes, and serve as a basis for management adjustments. The monitoring recommendations herein build upon the existing monitoring network and are intended to further refine and enhance the tracking and understanding of groundwater conditions in the Deep Aquifers. The recommendations provided below are science-based and are intended to support management objectives including those required by SGMA and the Seaside Basin Watermaster. Groundwater management agencies must determine the economic feasibility of expanding monitoring networks and monitoring frequency.

7.1 Purpose of Monitoring and Assessment

The primary data needed for monitoring Deep Aquifers conditions are groundwater extraction and injection, groundwater elevations, and groundwater chemistry and quality. Each monitoring type provides important information to understand and manage the aquifer system and comply with regulatory requirements:

- **Groundwater extraction and injection data** provide critical information for groundwater management and interpretation of groundwater elevation and quality changes.

- **Groundwater elevation measurements** allow for comparison of current levels to historical levels and indicate the cause of rapid change. Measurements also provide indicators of potential risk of seawater intrusion and subsidence. Sufficient groundwater elevation data enables the development of groundwater elevation contours, which can help assess horizontal and vertical gradients within or across aquifers, better understand where regional declines or more localized cones of depression are occurring, and assess risk to other wells if seawater leaks through a well.

- **Groundwater chemistry and quality sampling data** are used to detect changes in the water type, changes in the concentration or movement of constituents of concern, and detection of seawater intrusion. Changes in groundwater chemistry may also indicate if the water is mixing with overlying and adjacent aquifers. Additionally, periodic sampling of groundwater isotopes can add insight on the depositional environment of groundwater, relationship between groundwater in differing locations, and age of groundwater.

Regular analysis of these data should provide assessment of relationships between extraction, groundwater elevations, and quality. Understanding these relationships is critical for effective groundwater management.

7.2 Groundwater Extraction and Injection Monitoring Recommendations

Groundwater extraction drives most of the changes in groundwater conditions in the Deep Aquifers. Currently, MCWRA collects and reports extraction data annually from wells with a 3-inch or greater discharge pipe within Zone 2, 2A and 2B, which overlap with most of the Deep Aquifers extent. In the Seaside Subbasin, MPWMD collects pumping and injection data, and reports these data monthly and annually. Currently, 45 wells that are screened only in the Deep Aquifers report groundwater extraction. Of the wells that are screened in both the 400-Foot and Deep Aquifers, 8 report extraction and 1 does not.

- Groundwater Extraction Monitoring Recommendation: have all wells partially or fully screened in the Deep Aquifers report extraction, regardless of discharge pipe size.

The 1 domestic well that does not currently report extraction should be added to the GEMS program, in addition to any new wells installed in the Deep Aquifers.

7.3 Groundwater Elevation Monitoring Recommendations

Because elevation can indicate rapid change in groundwater conditions, monitoring groundwater elevations is essential. An adequate monitoring network should help assess changes in groundwater elevations, groundwater flow, and relationships to overlying and adjacent aquifers.

MCWRA, MPWMD, and MCWD monitor and collect groundwater elevations in the Deep Aquifers at varying frequencies. Current groundwater elevation monitoring includes 71 wells across the entire extent of the Deep Aquifers. MCWRA collects groundwater elevation measurements for 37 true Deep Aquifers wells, according to the definition and extent set forth in this Study. This includes 7 wells that are monitored by MCWD. MCWRA also monitors groundwater elevations in 3 wells completed in both the 400-Foot and Deep Aquifers. MPWMD collects groundwater elevation data for 31 wells within the Deep Aquifers for the Seaside Watermaster, including groundwater elevations reported by California American Water.

Data from existing monitoring wells were reviewed to make recommendations on monitoring network refinements. Groundwater elevation monitoring aims to obtain representative conditions of the Deep Aquifers and does not need to include all wells screened in the Deep Aquifers.

- Groundwater Elevation Monitoring Recommendation: refine monitoring network, fill data gaps, and collect data from all Deep Aquifers monitoring wells at least quarterly.

This Study recommends 82 wells for the groundwater elevation monitoring network. The network consists of 75 existing wells inclusive of 4 newly installed monitoring wells plus 5 wells that are not currently monitored for groundwater elevations. There are 7 data gaps in the existing monitoring well network; therefore, to fill these data gaps at least 7 new monitoring wells are recommended as additions to the monitoring network. Wells outside the spatial extent of the Deep Aquifers and wells completed above the top of the 400/Deep Aquitard are not considered representative of the Deep Aquifers, since they are influenced by groundwater in the overlying and adjacent aquifers. However, in some instances, wells screened outside the Deep Aquifers are recommended to provide supplementary information due to the lack of available true Deep Aquifers wells in a particular area.

The recommended groundwater elevation monitoring network is separated into 3 categories:

- **Representative Monitoring Sites (RMS)** are intended to represent Deep Aquifers conditions. For the subbasins subject to SGMA, these wells should be included in the SGMA monitoring networks as RMS wells. All completed wells in the Deep Aquifers that are under the jurisdiction of the Seaside Groundwater Basin Watermaster are considered RMS except the Paralta well, which is likely influenced by nearby aquifer storage and recovery operations. For this reason, the ASR and deep injection wells in the Seaside Region are excluded from the monitoring network.

- **Alternative Monitoring Sites** are true Deep Aquifers wells that supplement RMS for the development of groundwater elevation contours.

- **Ancillary Monitoring Sites** are not true Deep Aquifers wells either because they have a screen interval that extends above the top of the 400/Deep Aquitard, or they are located in adjacent aquifers outside of the Deep Aquifers extent like those in the Gabilan Bajada. Ancillary monitoring sites supplement RMS wells where there are no Deep Aquifers monitoring wells, e.g., where only wells that are dually-completed in the 400-Foot and Deep Aquifers exist. Ancillary monitoring sites may, over time, be replaced by true Deep Aquifers wells.

Monitoring frequency currently varies between daily, monthly, quarterly, biannually, and annually. This Study recommends groundwater elevation monitoring be conducted at least quarterly in all monitoring wells to capture the seasonal high, seasonal low, and a fall groundwater elevation that is typical after the end of the irrigation season when groundwater elevations rebound but before winter rains occur. Wells already monitored quarterly or more frequently should continue on their existing schedule.

Figure 7-1 shows the existing wells recommended for groundwater elevation monitoring, along with data gap areas where new monitoring wells could be useful. As previously mentioned, 5 wells that are not currently monitored for groundwater elevations are being recommended as additions to the Deep Aquifers monitoring network. Adding these wells to the network requires permission from the well owner and site visits to confirm the wells' adequacy. Replacements for

FO-09-Shallow in the Seaside Subbasin and 3 Deep Aquifers monitoring wells in the 180/400-Foot Subbasin were recently installed. These newly drilled wells are shown on Figure 7-1. In the Southeastern Region, if there is additional pumping or if true Deep Aquifers groundwater elevation monitoring shows declines away from pumping, more monitoring wells should be considered. Table 7-1 summarizes the number of recommended monitoring wells that are existing in each area, and Appendix H lists which wells are being recommended as an RMS, ancillary, or alternative monitoring well.

If new production wells are installed, they should be evaluated to determine if they would be useful for addition to the groundwater elevation monitoring network. MCWRA reviews new well construction designs to ensure the well is screened solely in the Deep Aquifers to meet Monterey County Code 15.08. MCWRA staff also makes a recommendation to the Monterey County Health Department upon review of the site-specific geologic and geophysical data and suggest modifications to the final well construction design if needed.

There are not enough existing monitoring wells to develop detailed groundwater elevation contours throughout the entire extent of the Deep Aquifers except for in the Seaside and Monterey Subbasins. Contours can be developed from this network, but many new wells would need to be added to create contours with greater certainty. Existing groundwater elevation monitoring, with the recommended improvements to the network, are sufficient for current groundwater management.

In addition to many wells installed in the Deep Aquifers also being screened in the 400-Foot Aquifer, most Deep Aquifers wells are screened across multiple formations within the Deep Aquifers, including the lower Paso Robles Formation, the Purisima Formation, and Santa Margarita Sandstone. These formations can have different groundwater elevations, which can make contouring difficult. While contours of each formation would be helpful for understanding the differences between formations, many additional monitoring wells would be required with discrete screens in each of the formations. These data are not needed for effective management because most production wells are screened across multiple formations.

Table 7-1. Recommended Groundwater Elevation Monitoring Network Summary

Region	Monitoring Network	Total Recommended Wells	Wells not Currently Monitored[1]
Northern	RMS	25	3
	Alternative	15	0
	Ancillary	3	2
Seaside	RMS	25	1
	Ancillary	1	0
Southeastern	RMS	2	2
	Ancillary	2	1
Adjacent Aquifers (Eastside Deep Zone)	Ancillary	2	0
TOTAL (Existing Wells Only)		75	9
TOTAL (Existing Wells Plus Wells Needed to Fill Data Gaps)		82	16

[1]Wells not currently monitored are included in the total recommended wells.

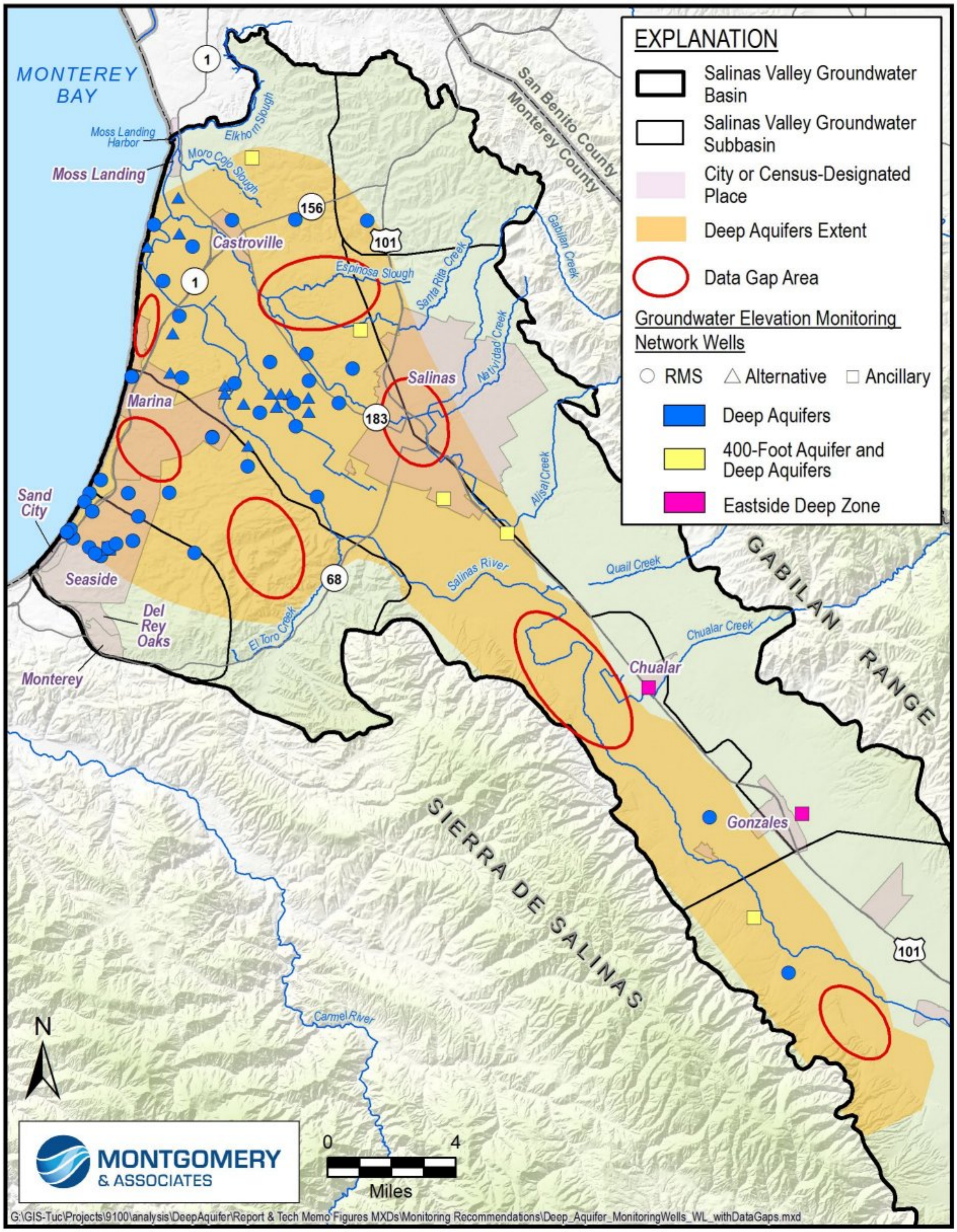


Figure 7-1. Recommended Groundwater Level Monitoring Network

7.4 Groundwater Quality Monitoring Recommendations

Monitoring groundwater quality involves tracking 3 related components: changes in water chemistry, concentration and transport of contaminants of concern, and indications of seawater intrusion. The groundwater quality monitoring network for the Deep Aquifers should adequately assess these 3 components. In addition, induction logging can help detect changes in salinity, and periodic sampling of isotopes can add insight on the depositional environment of groundwater, relationship between groundwater in differing locations, and age of groundwater.

7.4.1 Groundwater Quality Monitoring

Across the extent of the Deep Aquifers, 47 true Deep Aquifers wells–all in the Seaside and Northern Areas–are currently sampled for water quality at various frequencies. No wells are currently sampled for groundwater quality in the Deep Aquifers within the Southeastern Area. Groundwater quality is monitored by or reported to several agencies within the extent of the Deep Aquifers: MCWRA, MPWMD, the Seaside Groundwater Basin Watermaster, SWRCB DDW, and the Irrigated Lands Regulatory Program (ILRP). These agencies monitor different constituents and at different frequencies, as listed in Table 7-2. MCWRA primarily monitors Deep Aquifers wells for the purpose of seawater intrusion monitoring; therefore, the wells are mainly located northwest of the City of Salinas. All wells that supply drinking water systems with more than 15+ connections report water quality data to DDW. These data include water system information and at times contain screen interval information that enable identification of Deep Aquifers wells. Water quality for many agricultural wells throughout the Salinas Valley is reported through the ILRP. However, ILRP data are not currently distinguishable by aquifer; well construction information or an aquifer designation is needed to determine whether the wells are completed in the Deep Aquifers. Wells monitored and reported to the Seaside Watermaster are sampled by MPWMD, Cal-Am, and the City of Seaside.

Table 7-2. Groundwater Quality Monitoring Frequency and Constituents

	MCWRA	SWRCB DDW	Seaside Watermaster	ILRP
Purpose	Monitor seawater intrusion	Drinking water quality	Monitor seawater intrusion	Monitor discharge of wastes from commercial irrigated lands
Primary Constituents	General minerals (major cations/anions), total alkalinity, chloride, nitrate, conductivity, and pH	Title 22 constituents	General minerals (major cations/anions)	Nitrate, pesticides, nitrate as nitrogen or nitrate + nitrite as nitrogen, 1,2,3-trichloropropane, pH, specific conductance, temperature, total dissolved solids, and general minerals
Frequency	At least annually	At least quarterly	Biannually	Irregular
Geographic Area	Primarily northwest of Salinas	All drinking water systems of 15+ connections	Seaside Subbasin and Monterey Subbasin	Agricultural lands

- Groundwater Quality Monitoring Recommendation: refine monitoring network, fill data gaps, and adjust monitoring frequency based on risk of seawater intrusion and constituents of concern previously found.

This Study recommends 66 wells for inclusion in the water quality monitoring network. The network comprises 59 existing wells and at least 7 new wells to fill the data gaps in the monitoring network. Wells not fully screened in the Deep Aquifers defined in this Study should not be included in the representative Deep Aquifer water quality monitoring network. One well (16S/04E-03K01) in the Eastside Aquifer Deep Zone is recommended as an ancillary monitoring well, due to lack of true Deep Aquifers wells in the area. The 4 recently installed groundwater elevation monitoring wells should be included in the groundwater quality monitoring network. The Paralta well in the Seaside Subbasin is also being recommended as an ancillary monitoring well. As previously explained, this well is near aquifer storage and recovery operations, which likely affects its water quality. The ASR and deep injection wells in the Seaside Region are excluded from the network.

This Study recommends the wells in the current water quality network continue to be monitored for their respective constituents for each monitoring program. In addition, wells added to the groundwater elevation monitoring network should be sampled once at a minimum for major cations and anions and arsenic, nitrate, iron, and manganese to aid in better understanding the connectivity and baseline conditions of the Deep Aquifers, if possible. If no exceedances of Title 22 standards for drinking water wells or ILRP standards for agricultural production wells are found, or if the well is a dedicated groundwater elevation monitoring well that is not pumped regularly, the wells should be sampled again every 5 years. If notable changes are detected in a sample of a production well, then sampling should be increased to at least annually to better evaluate the cause of water quality changes.

Figure 7-2 shows the recommended water quality monitoring wells that are existing along with data gap areas that indicate locations where new monitoring wells would be useful. This figure includes the 2 new monitoring wells in the Northern Area, 1 new monitoring well in the Southeastern Area, the replacement well for FO-09-Shallow in the Seaside Area, and the 3 existing wells that are not currently being monitored for water quality. To add existing production wells to the monitoring network, private well owners will need to report quality or be contacted to secure permission to monitor the well for water quality and the monitoring agency will need to perform a site visit to ensure the well can be used for monitoring.

Taking groundwater quality samples from deep monitoring wells can be difficult given the equipment and techniques needed to collect. If new production wells are installed, they should be evaluated with respect to the water quality monitoring network to determine if they should be added. Table 7-3 summarizes the number of recommended monitoring wells that are existing in each area and Appendix H lists the monitoring wells, their current monitoring frequency, and whether they are being recommended as an RMS or ancillary monitoring well.

Table 7-3. Recommended Groundwater Quality Monitoring Network Summary

Region	Monitoring Network	Total Recommended Wells	Groundwater Elevation Monitoring Wells not Currently Monitored[1]	Production Wells not Currently Monitored[1]
Northern	RMS	41	6	1
Seaside	RMS	14	1	0
	Ancillary	1	0	0
Southeastern	RMS	2	1	1
Adjacent Aquifers (Eastside Deep Zone)	Ancillary	1	0	0
TOTAL (Existing Wells Only)		59	8	2
TOTAL (Existing Wells Plus Wells Needed to Fill Data Gaps)		66	15	2

[1]Wells not currently monitored are included in the total recommended wells.

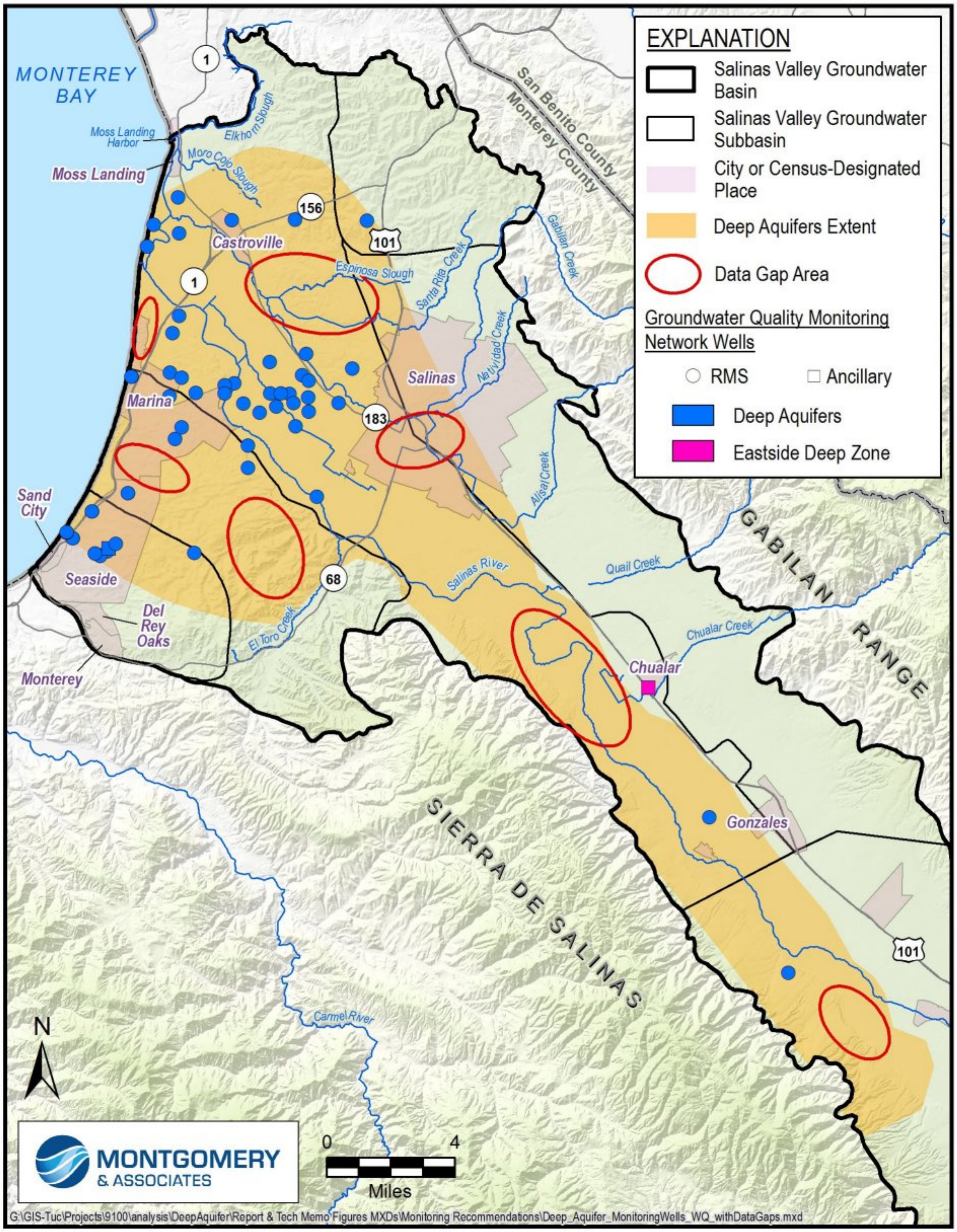


Figure 7-2. Groundwater Quality Monitoring Wells

7.4.2 Induction Logging

Induction logging may be used in addition to groundwater quality monitoring to assess the potential risk of migration of seawater downward from the seawater-intruded portions of the 400-Foot Aquifer or laterally from the ocean. By measuring the electromagnetic field along a borehole, induction logging can detect changes in electrical conductivity (salinity) of the aquifer material surrounding an open borehole or non-metallic well casing for its entire depth. Particularly while there is a downward gradient from the overlying aquifer to the Deep Aquifers in areas of seawater intrusion, induction logging may be used for early detection on downward migration of chloride. Induction logging of Deep Aquifers wells located within the seawater-intruded area should be tested regularly to detect differences in chloride. However, if any increases in salinity are observed in the Deep Aquifers via induction logging, sampling at that well or a nearby well must occur to determine the chloride concentration at that location.

7.4.3 Periodic Isotope Sampling

Isotope data can provide insight on residence time and inflow to the Deep Aquifers. Isotope sampling has not been part of an ongoing monitoring effort. The isotope sampling conducted as part of this Study provides a baseline for further isotope analysis. Data indicate that Deep Aquifers groundwater is isotopically lighter than groundwater in overlying aquifers. Changes from the Deep Aquifers' baseline isotopic signature to isotopically heavier water would provide insight on possible surficial recharge mechanisms at various locations. Isotopic baseline sampling is also recommended for the 3 new monitoring wells installed in the 180/400-Aquifer Subbasin, and any other new well added to the water quality monitoring network. Stable isotope data from adjacent aquifers could help provide insight on relationships with the Deep Aquifers, particularly if expanded to include more wells from the Eastside alluvial fans, El Toro Primary Aquifer System in the Corral de Tierra Management Area, and areas of the Seaside Subbasin that are outside of the Deep Aquifers extent. Stable isotope data should be collected every 3 to 5 years (consistent with assessment of water elevations, quality, and extraction, as described below) from monitoring wells within and outside the Deep Aquifers extent and compared to previously collected isotope data.

7.5 Periodic Assessment

Periodic assessment of long-term trends and relationships is necessary to identify changes in groundwater conditions, aquifer relationships, and impacts from pumping.

- <u>Periodic Assessment Recommendation</u>: conduct an initial assessment of groundwater condition trends and relationships after 3 years of post-Study data collection, then extending to 5-years thereafter, as data trends become more defined.

Assessment of the relationship between extraction, groundwater elevations, and quality has not been done on a consistent basis but will become more important as the Deep Aquifers are managed more comprehensively. Spatial and temporal changes may be incremental and difficult to detect with individual groundwater elevation, water chemistry, and extraction measurements. Therefore, trends in Deep Aquifers groundwater elevations, as well as relationships with overlying and adjacent aquifers, should be assessed on a 3-to-5-year basis in relation to water quality and, especially, extraction.

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