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TECHNICAL MEMORANDUM

DATE: March 20, 2025 **PROJECT #:** 9100.68

TO: Salinas Valley Basin Groundwater Sustainability Agency (SVBGSA)

FROM: Victoria Hermosilla, P.G., Tiffani Cáñez, Staffan Schorr, Derrik Williams, P.G., C.Hg.

REVIEWED BY: Abby Ostovar, Ph.D.

PROJECT: Salinas Valley Hydrogeological Conceptual Model (HCM) Updates

SUBJECT: Langley Subbasin HCM Update: Data, Methods, and Findings

INTRODUCTION

Since submittal of the Langley Aquifer Subbasin (Langley Subbasin or Subbasin) Groundwater Sustainability Plan (GSP) in 2022, SVBGSA and partner agencies have analyzed new information and filled data gaps identified in the GSP. With this information, Montgomery & Associates (M&A) updated the Hydrogeologic Conceptual Model (HCM) for the Subbasin to better inform management decisions and prepare for the upcoming 5-Year Periodic Evaluation. M&A worked with key partners to acquire data and review analyses, including Monterey County Water Resources Agency (MCWRA). The updated HCM strengthens the historical understanding of the Subbasin presented in the GSP to guide SGMA implementation with greater accuracy. Concurrently, the updated HCM refines the geologic model that forms the basis for the groundwater flow modeling.

The HCM update focused on key areas where new data indicated a need for an updated understanding. The primary updates to the HCM included:

- Revising the bedrock surface that delineates the bottom of the groundwater basin and refining the weathered bedrock surface that contributes to small domestic wells
- Incorporating the observed hard pan intervals into the Aromas Sands Aquifer understanding, and relating these hard pan intervals to the known water quality challenges in the Subbasin
- Incorporating the results of the *Deep Aquifers Study* (Study) (Montgomery & Associates, 2024) that defined the 400/Deep Aquitard that separates the 400-Foot Aquifer from the Deep Aquifers where it is present in the Subbasin

This memo summarizes the data used, the analyses and methods employed, and the findings for the updated Langley Subbasin HCM.

DATA

The data used to update the HCM are detailed in the following subsections.

Published Cross Sections and Reports

The 2022 Langley Subbasin GSP summarized published cross sections and reports. For this HCM update, the following reports and cross sections were reviewed again, compared with new data and information, and incorporated into the revised HCM.

- *North County Hydrogeologic Study* (Fugro West, 1995)
- *Final Report, Hydrostratigraphic Analysis of the Northern Salinas Valley* (Kennedy/Jenks, 2004)
- *Hydrogeologic Report on the Deep Aquifer, Salinas Valley, Monterey County, California* (Thorup, 1976; Thorup, 1983)
- *Integrated Plan to Address Drinking Water and Wastewater Needs of Disadvantaged Communities in the Salinas Valley and Greater Monterey County IRWM Region* (Greater Monterey County Integrated Regional Water Management Program, 2017)
- *Addressing Nitrate in California's Drinking Water* (Harter, T. *et al*, 2012)
- *Deep Aquifers Study* (M&A, 2024)

Well Completion Reports (WCRs)

Well Completion Reports (WCRs) helped refine geologic interpretations and included important information such as driller-observed lithology, screen intervals, and date of well installation. Some WCRs were more detailed than others with more frequent lithologic descriptions, electric logs (e-logs), and other construction or water level details.

M&A obtained WCRs through the California Department of Water Resources (DWR) Online System for Well Completion Reports (OSWCR) database, the County of Monterey Health Department, Monterey County Water Resources Agency, other collaborating partner agencies, and private entities. In particular, MCWRA provided hundreds of well completion reports that were mostly supplementary to other geophysical data, but in some regions they were the only data available.

Numerical Groundwater Flow Model Layers

Previous and current groundwater flow models reflect various conceptual understandings of the Subbasin. Models reviewed for the HCM update included:

- The provisional Salinas Valley Integrated Hydrologic Model (SVIHM). The Salinas Valley Geologic Framework (Sweetkind, 2023) defines the spatial extent, depth, and distribution of geologic material textures for the provisional SVIHM. This geologic dataset was developed by the U.S. Geological Survey (USGS) to cover the entire Salinas Valley and includes a geological framework with key documentation.
- The Salinas Valley Seawater Intrusion Model (SWI Model) (M&A, in production). This model was developed by M&A for SVBGSA and County of Monterey, and covers the coastal area of the Salinas Valley north of Chualar.

These models were primarily used to compare and refine the depths and thicknesses of the hydrostratigraphic layers for the Salinas Valley Groundwater Basin HCM update.

Geophysical Data

The primary types of geophysical data used in this HCM update include the following:

- Airborne Electromagnetic (AEM) resistivity data. These data were collected by the California Department of water resources (DWR), and SVBGSA between 2020 and 2023. These data provide a broad coverage of general lithologic trends.
- Borehole resistivity data. These geophysical data are collected in boreholes prior to well installation, and provided detailed interpretation of localized lithology.

Both of these types are electrical resistivity data, which are collected by sending electrical pulses into the subsurface and receiving signals back.

AEM Data

AEM surveys measure both the solid and liquid resistivity of materials in the subsurface over large areas. Lower resistivity materials include clays, silts, and groundwater with high total dissolved solids (TDS) concentrations. Higher resistivity materials include sands and gravels, some types of bedrock, and groundwater with lower TDS concentrations. AEM data are useful for filling gaps between known data points such as wells. This effort focused on reviewing and analyzing the lower resistivities at various target depths where aquitards or clay intervals are expected.

Two sets of AEM surveys were used to fill data gaps, confirm other data, and refine the delineations of primary aquifers and aquitards. These data came from the following surveys:

- DWR Survey Area 8, 2022 (DWR, 2022)
- Deep Aquifers Survey, 2023 (M&A, 2024)

E-logs/Borehole Geophysical Logs

Borehole geophysical logs measure the resistivity of materials in the subsurface adjacent to a borehole. Like AEM data, borehole geophysics can help qualitatively differentiate between clays, silts, sands and gravels, high TDS water, and low TDS water. Borehole geophysics data show much more detail than AEM data, but only reflect conditions immediately adjacent to a borehole. Several borehole geophysical logs used were sourced from other studies or included with WCRs.

Geologic Maps

Geologic maps provide a visual representation of the rocks, formations, and structures encountered at land surface. The 2 primary maps used for this HCM update were the Wagner *et al.*, 2002 surface geology map and the Digital Geologic Map of Monterey County, California, 1934-2001 (Rosenberg, 2001). These geologic maps supplemented other data during the HCM update by verifying surface expressions of the various lithologic units.

Empirical Observation

On April 10, 2024, M&A staff accompanied Langley Subbasin Committee member Doug Kasunich on a field trip to observe local geologic and hydrogeologic features in the Subbasin that have an impact on groundwater. He drove the team from the Prune Tree shopping center at the intersection of Highway 101 and Vierra Canyon Road, to the Queen of Heaven Cemetery, and then up Pesante Canyon Road. Mr. Kasunich has many years of experience drilling and servicing wells in the area, and subsequently spoke at length about the local subsurface conditions encountered in this Subbasin.

An overarching theme of the field trip was pointing out examples of the prevalence and irregularity of the consolidated areas within the Aromas Sands, as well as their observable impacts on groundwater flow. Discussion and stops also included locations of clays in canyon bottoms, as well as areas of known nitrate and arsenic impacts to drinking water. Many of the field trip stops corresponded with outcrops of Aromas Sands hard pan and former drill locations that Mr. Kasunich had experience with. Additional details and photos of this field trip are in Appendix 1 of this memo. These observations provided critical insight into the character of the subsurface in the Subbasin.

METHODS

Geologic modeling and visualization software was used to update the Subbasin hydrostratigraphy through the following steps, starting with the data with the most confidence:

1. Integrating and reviewing the data using Leapfrog Geo software
2. Prioritizing data based on reliability and availability
3. Selecting the best data to define the new hydrostratigraphic layers
4. Interpolating the data to create new hydrostratigraphic layers within Leapfrog Geo software

Geologic Modeling Software

Developed by Seequent, Leapfrog Geo software was the primary 3D modeling and visualization software used to relate and analyze the different types of data described above. All data were imported into the software, methodically reviewed, and compared to each other.

Data Prioritization

Various data have differing levels of confidence. The list below demonstrates the general hierarchy of confidence in the various data types used in this analysis:

1. Geologic Maps
2. Empirical Observations
3. Published Cross Sections and Reports
4. Borehole Logs (Well Completion Reports and e-logs)
5. AEM data
6. Groundwater Flow Models

Concurrently using multiple data sources can improve confidence in geologic interpretations. For example, confidence in AEM data can be significantly improved when it is combined and coordinated with geologic maps or borehole logs.

Data are not uniformly distributed throughout the Subbasin. Wells and associated WCRs are more concentrated in areas with more infrastructure, whereas AEM flightlines generally cover areas with less or no infrastructure. Therefore, hydrogeologic interpretations are more strongly influenced by the availability of data in different areas.

Hydrogeologic interpretations initially focused on areas with a higher density of multiple data types to cross validate data. Developing confidence in any data type allowed analyses using those data to expand horizontally and vertically and revise the HCM as needed.

The decision-making procedures for updating the HCM generally used the following guidelines. These guidelines do not represent a decision-making hierarchy, rather they are a group of guidelines that interact in various ways based on circumstances in each particular area.

- Newer geologic maps were prioritized over older geologic maps.
- Newer published cross sections were prioritized over older published cross sections, unless there was higher confidence in older cross sections based on the author and how the sections correlated with other data.
- Geologic maps provided anchor locations for the geologic surface contacts, including bedrock outcrops, where available.
- Empirical observations provided refined details, insights, and contextualized the geologic formations within the hydrostratigraphic framework.
- The hydrostratigraphy was refined by jointly using AEM data, WCRs, and published cross sections in places where the various data types overlapped. This strengthened confidence in AEM data interpretation.
- Where AEM data and cross sections did not align, well logs used to develop the cross section were reviewed and used in conjunction with the AEM data.
- AEM data were the primary data source for hydrostratigraphic interpretation in areas with limited borehole data.
- E-logs and published cross sections were used where AEM data were not available, and correlated with the nearest AEM data.
- WCRs were used as verification and interpolation points for key priority areas.
- Areas with no other nearby data relied on the SVIHM geologic model or SWI Model layers to interpolate the hydrostratigraphic layers.

Figure 1 shows a prime example of an analysis that encompasses many types of data and shows how they are correlated to provide a more cohesive understanding of the hydrostratigraphy of the Salinas Valley Groundwater Basin (Basin). The cross section on Figure 1 was exported from the Leapfrog geologic model and spans the 180/400-Foot Aquifer Subbasin, the Monterey Subbasin, and the Seaside Subbasin. Hydrostratigraphy in the north (left on Figure 1) is based on well completion reports with finer sediments highlighted in blue. Hydrostratigraphy in the center of Figure 1 is based on AEM data, with finer sediments highlighted in blue. A previously published map of the Monterey Formation (HydroMetrics, 2009) provided structural data in the south, as well as locations of surface outcrops of Monterey Formation highlighted with yellow disks. Published cross sections, e-logs, and surface geology maps are not shown on the figure; however, in this location they were also reviewed for confirmation of other data. Through careful analysis and integration of all data types, a new bedrock surface was developed, shown in pink mesh and green contour lines on Figure 1. This figure best illustrates the data synthesis methodology applied to each subbasin in the Salinas Valley Basin, and should be viewed as a conceptual depiction of the types of data and decision processes used to update the Langley Subbasin HCM.

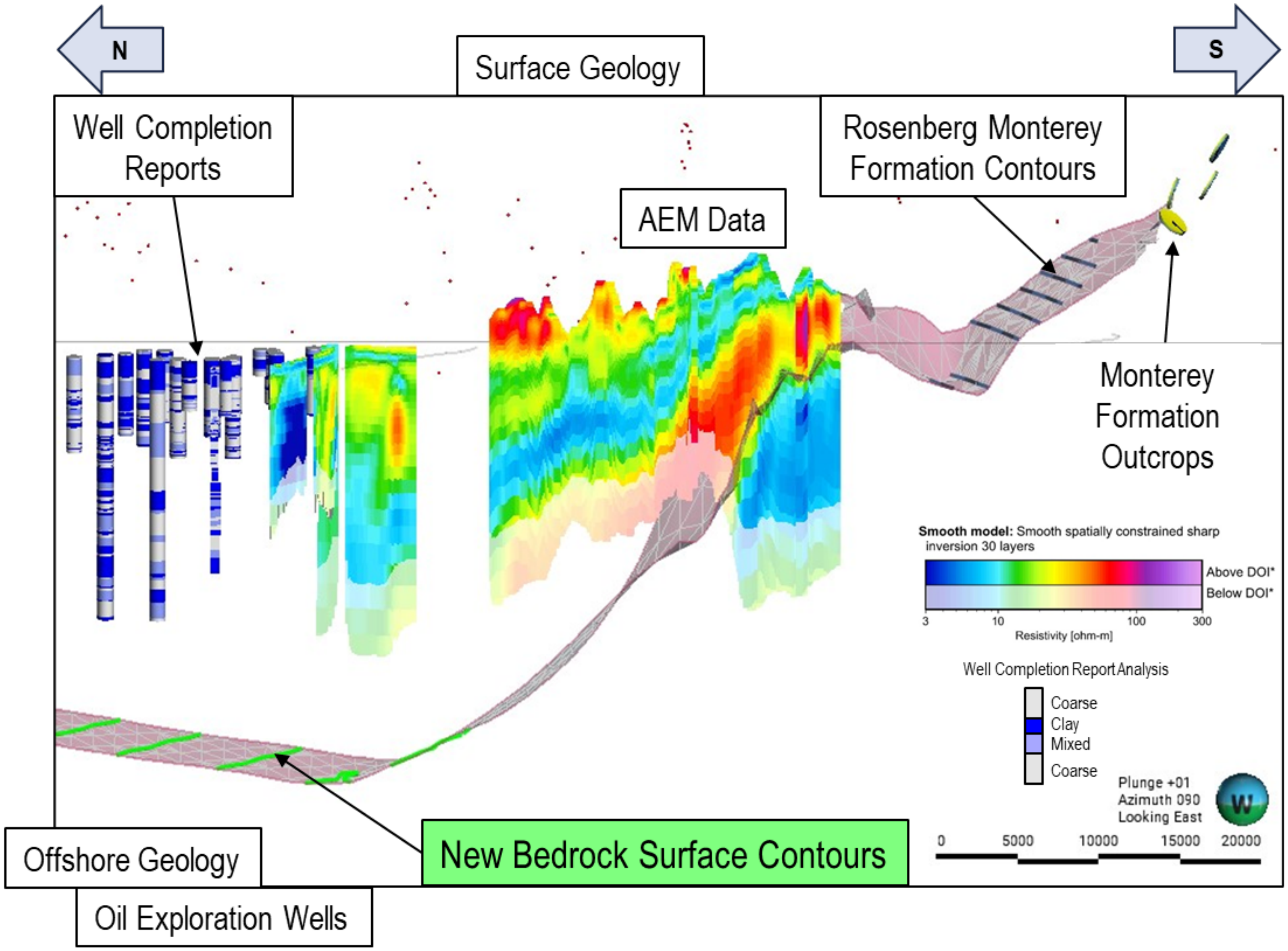

Figure 1. Example of Different Types of Data Juxtaposted in Leapfrog Geo Software to Delineate Updated Bedrock Surface; Consistent with Figure 2

Across the Subbasin, hydrostratigraphic decision-making was prioritized from deepest layers to shallowest layers. The bedrock surface was the first priority and was modified using AEM data and WCRs where available. After revising the bedrock surface, the HCM was revised by incorporating hard pan areas noted in WCRs to identify locations and if there were regional trends. Analyzing the hard pan areas included a closer look at the nitrate issues reported in the Subbasin to determine if hard pan in the subsurface contributed to the concentration of water quality issues. Following that, the location and depth of the aquitard between the 400-Foot Aquifer and Deep Aquifers (400/Deep Aquitard) was revised based on the Deep Aquifers Study (M&A, 2024).

RESULTS/FINDINGS

Results of the 3 primary HCM updates listed in the introduction are detailed below.

Bedrock Surface

Principal Data Used: AEM data, WCRs, SVIHM layer elevations, surface geology maps

Understanding the depth and geometry of the bedrock helps determine the available aquifer space for groundwater storage in the Langley Subbasin. Equally as important is understanding the depth, geometry, and thickness of a weathered bedrock interval, which is partly used as an aquifer for small domestic wells in this Subbasin. Historically, the competent bedrock surface and the weathered bedrock surface have been difficult to map and model. The best conceptualization previously was in the Fugro West (1995) cross section D-D'.

There are fewer AEM data in the Langley Subbasin than in other parts of the Salinas Valley Basin due to more prevalent and dispersed infrastructure that interfere with the instrumentation. The available AEM data are located in transects that are closer to the Gabilan Range. The AEM data in these few transects show a higher resistivity material much shallower in the subsurface than the layer that represents the bedrock in the SVIHM, which is based in part on the Durbin *et al.*, (1978) bedrock surface.

WCRs played a key role in determining the weathered and competent bedrock surface. The lithology descriptions that may denote bedrock include: decomposed granite (DG), rock, large granite cobbles, and granite. Drilling operations are commonly stopped when bedrock is encountered in the Salinas Valley, and therefore, lithologic log intervals with bedrock notation are frequently thin and at the bottom of the boreholes.

For this analysis, WCRs for about 475 wells were analyzed, and about 40 of those WCR lithology logs identified bedrock. Lithologic descriptions in the logs were variable and sometimes confusing. For example, some logs described thick intervals of "granite" overlying thick intervals of decomposed granite or fractured granite, with more "granite" below. For this study, the lowest interval of "granite" was assumed to be actual bedrock, overlain by fractured or decomposed granite. The thickness of the decomposed granite is variable across the Subbasin. The updated bedrock surface is conceptualized as dipping downward more gradually from the surficial contacts at the Gabilan Range, before diving more steeply down toward the axis of the Basin, as shown on Figure 2.

Figure 2 illustrates the updated depth and geometry of the bedrock surface in the Langley Subbasin. However, there may be exceptions within the Subbasin that do not conform to the general bedrock depth and geometry. This Subbasin will require continued data collection and conceptualization refinement for a better understanding of groundwater conditions for informing management decisions.

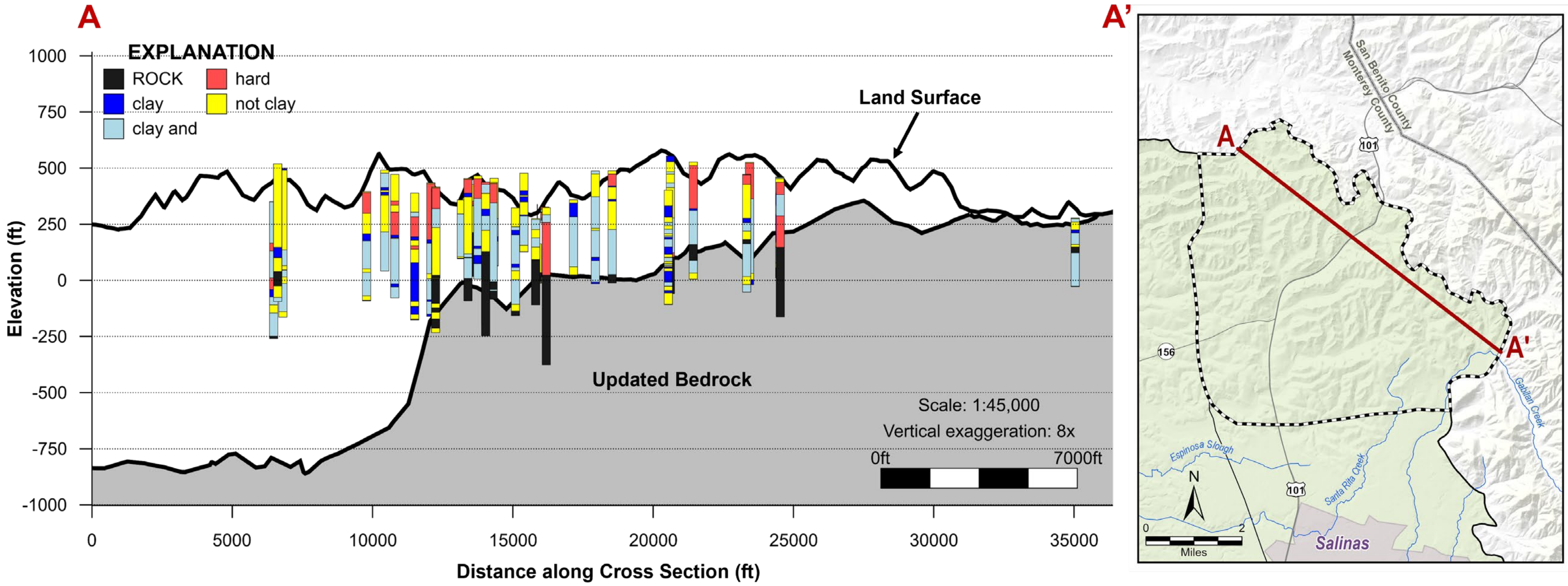

Figure 2. Updated Conceptual Understanding of Bedrock Surface and Key Data Used

Aromas Sands Hard Pan

Principal Data Used: Empirical Observation, WCRs

The Aromas Sands is the primary component of the Langley Subbasin Aquifer, and has been noted in the GSP as a complex aggregation of materials deposited in varied, localized environments, which makes it difficult to correlate significant stratigraphies over distance (Fugro West, Inc., 1995). While many geologic formations in the Salinas Valley Basin are varied, localized environments resulting in a complex aggregation of materials, the expression of these localized environments in the Langley Subbasin and their subsequent impact on groundwater conditions is not fully understood.

The updated conceptualization of the Aromas Sands within the Langley Subbasin builds on this previously published understanding with field observations. On April 10, 2024, two M&A team members toured the southern portion of the Langley Subbasin with committee member Kasunich to view exposed outcrops of the Aromas Sands. He pointed out the locations of hard pan, or greater consolidation within the formation, and highlighted surface expressions of lateral groundwater flow, which followed these localized areas of consolidation within the formation. Figure 3 includes 2 photos from this field trip to illustrate this hard pan.

Mr. Kasunich also brought knowledge of wells he had previously drilled or serviced in particular locations, and could readily speak of the wild variance in water levels in wells drilled within close proximity within the Aromas Sands. For example, a well drilled at a higher elevation could encounter water within 100-200 feet below land surface, and a nearby well drilled at the bottom of a canyon wouldn't encounter water until 500-600 feet below land surface.

Building on these observations, M&A staff again reviewed the WCRs to try to identify hard pan or consolidation in drill logs, and attempted to build out correlated relationships. However, as past investigators have noted, correlating these kinds of relationships across distances within this area is very difficult to do. Furthermore, even if there were discernable relationships that could be found, the Langley Subbasin topography is characterized by its canyons that cut into the Aromas Sands. Water levels in one area could have poor correlation to water levels in another area by virtue of surface erosion. This is illustrated well on Figure 4-1 of the GSP. The prevalence of driller-noted hard pan was notable in the second review of the WCRs. Although previously published reports describing the Aromas Sands have noted variable hard pan occurrences within the unit, the second WCR review unveiled many more of these intervals than expected. This suggests that the Aromas Sands Unit is more complex than previously conceptualized, and the localized consolidation may have a larger impact on groundwater than previously understood.

Figure 3. Photos from April 10, 2024, Showing Localized Consolidation/Hard Pan Areas within the Aromas Sands in the Langley Subbasin

Water Quality Relationships

The Langley Subbasin has a high domestic well density and a higher prevalence of small water system wells because it has been developed primarily as a rural residential area. Both domestic and small system wells tend to be shallower because well owners have neither the resources nor needs for deeper wells. As noted above, wells are also completed at shallower depths in this Subbasin when drilling activities encounter perched water at shallower depths due to the localized consolidation (hard pan) throughout the Aromas Sands. Also installed at shallow depths, albeit shallower than water production wells, are septic systems. The Langley Subbasin has a relatively high number of septic systems, both because there is no regional sewer service in the rural areas, and high densities of domestic wells are often accompanied by high densities of septic systems.

The nexus of the small wells and septic systems relationship in the Langley Subbasin is the hard pan: the hard pan within the Aromas Sands creates conditions for perched water where small wells may draw from, but also where septic system outflows may occur. As Mr. Kasunich mentioned in the field trip, many instances of perched water within the Subbasin may be encountered at very shallow depths (i.e., 7 feet), which is a similar depth of septic leach field installation depths (i.e., 10 feet). The second review of the WCRs showed that the hard pan is far more prevalent within the Aromas Sands than previously understood, which increases the prevalence of the small well-septic system nexus within the Subbasin, and subsequently the potential for direct impact on water quality.

Nitrate contamination has been reported in small and local water systems in this Subbasin, with septic tanks being identified as the source of this nitrate contamination (Harter *et al.*, 2012). Figure 4 includes both domestic well density and nitrate contaminant level data to demonstrate the relationship between domestic wells and areas of nitrate contamination. DWR's OSWCR database was used to show the domestic well density per square mile section. The nitrate contamination data are from the Aquifer Risk Map updated annually by the State Water Resources Control Board's Safe and Affordable Funding for Equity and Resilience (SAFER) Program. SAFER's Aquifer Risk Map was created to identify areas where domestic wells and state small water systems (5-14 service connections) may be using groundwater that does not meet the primary drinking water standards. The Aquifer Risk Map is produced by summarizing water quality data for each square mile section if available, and state small water systems are then assigned a potential risk status based on the section where they are located. The Maximum Contaminant Level (MCL) for nitrate (as N) is 10 milligrams per liter as defined in Title 22 of the California Code of Regulations. The risk status is evaluated based on whether the 20-year average or highest recent sample is above the nitrate MCL. The detailed methodology used to develop this map can be found at https://www.waterboards.ca.gov/water_issues/programs/gama/docs/armmethods24.pdf. Figure 4 highlights that the increased risk for higher nitrate concentrations in groundwater generally occurs in areas with a higher density of domestic wells.

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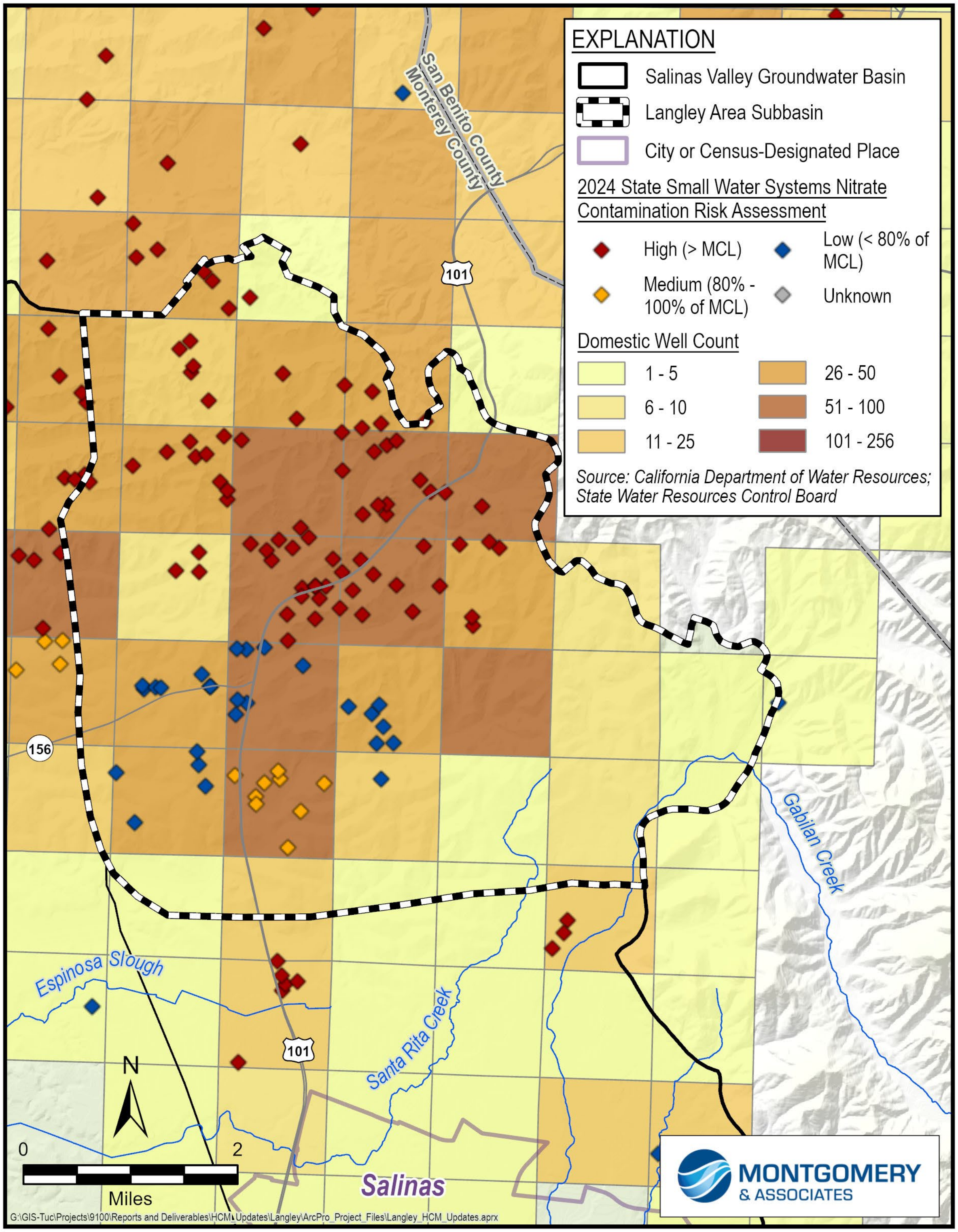


Figure 4. Comparison of Domestic Well Density and Nitrate Contamination in Small Water Systems within the Langley Subbasin

400/Deep Aquitard and Deep Aquifers' Extent

Principal Data Used: Previously published studies, WCRs

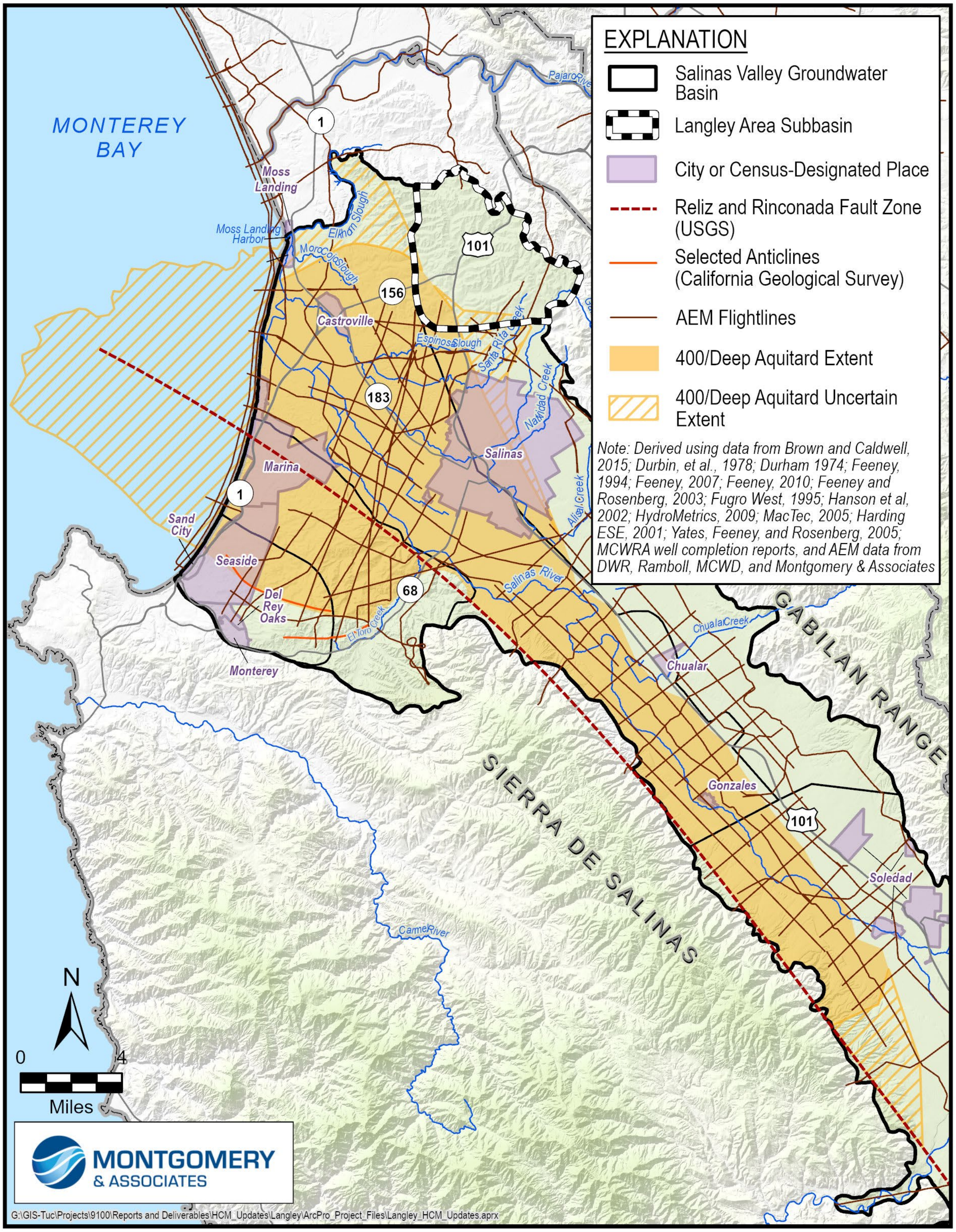
The Deep Aquifers' extent was revised by incorporating results and data from the *Deep Aquifers Study* (Study) (M&A, 2024). Attachment A to the Study details the data, methods, and extent findings, which are summarized here.

No cohesive description of the Deep Aquifers' depth and extent existed prior to the Study. The previous understanding of the Deep Aquifers focused on the coastal areas of the 180/400-Foot Aquifer and Monterey Subbasins, where the majority of the deep wells were installed. The *Deep Aquifer Investigation - Hydrogeologic Data Inventory, Review, Interpretation and Implications* (Feeney and Rosenberg, 2003) detailed the geology that constitutes the Deep Aquifers and summarized the known Deep Aquifers wells' screened intervals, extraction, and locations.

The *Hydrogeologic Report on the Deep Aquifer, Salinas Valley, Monterey County, California* (Thorup, 1976) defined the Deep Aquifers as the entirety of the Paso Robles Formation within the Salinas Valley Basin and developed recharge and storage estimates assuming the whole formation was the Deep Aquifers. Other subsequent studies and analyses generally defined the Deep Aquifers based on the presence of the overlying 400-Foot Aquifer or MCWRA-designated Deep Aquifers wells, but notably there was no defined extent.

The updated understanding of the Deep Aquifers presented in the Study focused on the presence of the 400/Deep Aquitard to delineate the Deep Aquifers from the shallower principal aquifers. Accordingly, the Deep Aquifers incorporate all the productive zones below the 400/Deep Aquitard, including the previously named 800-Foot, 900-Foot, 1,100-Foot, and 1,500-Foot Aquifers; and comprise portions of the Paso Robles Formation and Purisima Formation. Insufficient data exist to subdivide the Deep Aquifers into component horizons.

The Study delineated the lateral extent of the Deep Aquifers throughout the majority of the 180/400-Foot Aquifer Subbasin and into adjacent subbasins. The extent of the Deep Aquifers in the Langley Subbasin is shown on Figure 5, which is consistent with the extent defined in the Deep Aquifers Study. This figure includes areas marked as the uncertain extent, but current data are not sufficient to conclusively determine if Deep Aquifers are present. Three key types of data anchored the Deep Aquifers in the Langley Subbasin: a WCR for a deep well with demonstrated 400/Deep Aquitard presence in the lithology descriptions, the R. Thorup 1976 map of the Paso Robles Formation in the subsurface, and a small sliver of AEM transect where the 400/Deep Aquitard can be identified in the resistivity data.



(M&A, 2024)

Figure 5. Deep Aquifers' Previous and Updated Extents, as Determined by the Deep Aquifers Study

CONCLUSIONS

The Langley Subbasin HCM presented in the GSP was developed using the best available data and information available at the time. This HCM update uses the best available data and information procured since GSP development and provides clear refinements for the Subbasin overall.

The following are principal updates to the Langley Subbasin HCM:

- The competent bedrock surface that delineates the bottom of the groundwater basin, and the weathered bedrock surface that contributes to small domestic wells were both refined using additional WCRs and AEM data where applicable. The competent bedrock surface was found to be shallower near the Gabilan Range, and the weathered bedrock surface has variable thickness across the Subbasin based on WCRs.
- Incorporating the abundance of observed hard pan intervals into the Aromas Sands Aquifer understanding, and relating these hard pan intervals to both the small wells and known septic-derived nitrate contamination in the Subbasin. The hard pan intervals were found to be more abundant than previously understood, which likely plays a large role in the incongruous groundwater elevations as well as the high nitrate concentrations in shallow pockets of groundwater.
- Incorporating the 400/Deep Aquitard that separates the 400-Foot Aquifer from the Deep Aquifers where it is present in the Subbasin based on a key WCR, a previously published report, and AEM data in the southwestern corner of the Subbasin.

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