Deep Aquifers Addendum to the Salinas Valley Water Conditions
First Quarter of Water Year 2020-2021

1. Background of the Deep Aquifers

The Deep Aquifers are formational aquifers, consisting of several aquifer units within the Paso Robles Formation, Purisima Formation, and Santa Margarita Sandstone. A lot about the Deep Aquifers is still unknown, including the extent of these formations that are productive water-bearing unit in the Salinas Valley, the hydrogeologic properties of the aquifer units, what separates each aquifer unit from each other, and what separates the Deep Aquifers from the overlying 400-Ft Aquifer.

The Paso Robles Formation (Paso Robles) is a Pliocene- Pleistocene unit that consists of lenticular beds of sands, gravel, silts and clays. Potential depositional environments of these layers includes alluvial fan or braided stream[1], by the ancient Salinas River[2], and alluvial fan, lake and floodplain deposits[3]. The Paso Robles outcrops in 37,500 acres of Monterey County, including the El Toro area and west side of the Salinas Valley[4]. The Paso Robles is also exposed at the land surface in San Luis Obispo County. The lower portions of the 400-Ft Aquifer and upper portions of the Deep Aquifers are in the Paso Robles formation. The degree of hydrologic separation between these is unknown.

The Purisima Formation (Purisima) is a Pleistocene aged, shallow marine unit composed of clays and shale[1], siltstone, sandstone, and conglomerates[5]. Micro-fossils from Purisima core samples indicate a marine shelf environment around 0-150 feet below sea level[6]. In geologic logs, a shift to more clays, particularly blue clays, and shales seen are a good indicator of this shift to a marine deposited environment. The Purisima outcrops on the southwest side of the Monterey submarine canyon, as well as on land in Santa Cruz County[4]. The Purisima is not exposed on land in Monterey County.

The Santa Margarita Sandstone (Santa Margarita) is a late Miocene deposited, shallow marine friable arkosic sandstone unit[5]. Some studies describe this as a transgressive sandstone unit[4]. The Santa Margarita can be seen below the Purisima, or below the Paso Robles where the Purisima is absent.

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[1] Harding ESE. 2001. *Final Report Hydrogeologic Investigation of the Salinas Valley Basin in the Vicinity of Fort Ord and Marina Salinas Valley, California.*
[2] Thorup, Richard R. 1976. *Report on Castroville Irrigation Project Deep Test Hole and Freshwater Bearing Strata Below the Pressure 400-Foot Aquifer, Salinas Valley, CA.*
[3] Greene, H.G. 1970. *Geology of Southern Monterey Bay and its Relationship to the Ground Water Basin and Sea Water Intrusion.* U.S. Geological Survey, 50 p.
[4] Feeney, M.B., and L.I. Rosenberg. 2003. *Technical Memorandum- Deep Aquifer Investigation- Hydrogeologic Data Inventory, Review, Interpretation and Implications.* 40 p.
[5] Greene, H.G. 1977. *Geology of Southern Monterey Bay Region.* U.S. Geological Survey, 347 p.
[6] Hanson, R.T., Rhett R. Everett, Mark W. Newhouse, Steven M. Crawford, M. Isabel Pimentel, and Gregory Smith. 2002. *Geohydrology of a Deep-Aquifer System Monitoring Well Site at Marina, Monterey County, California.* U.S. Geological Survey, 289 p.

Purpose of this Addendum

The Salinas Valley Water Conditions Report (Quarterly Conditions Report), produced every quarter of the water year, provides a brief overview and discussion of water conditions including precipitation, reservoir storage and groundwater level trends. More than 100 wells are measured each month to monitor seasonal groundwater level fluctuations in the Salinas Valley. A subset of wells is used to generate average groundwater levels for each aquifer or subarea. Currently, the Quarterly Conditions Report does not include the Deep Aquifers. This addendum will show Staff's analysis of current Deep Aquifers conditions and trends and will be updated every quarter. This information is being presented while Staff continues to analyze which data will be used to represent groundwater level trends in the Deep Aquifers for the Quarterly Conditions Report.

2. Groundwater Levels

Staff collects groundwater levels from thirty-two Deep Aquifers wells on a monthly basis. In addition, seven Deep Aquifers monitoring wells have pressure transducers which collect hourly groundwater level data. Three groups of Deep Aquifers wells are discussed below; wells in the Deep Aquifers in the Paso Robles Formation, wells in the Deep Aquifers in the Purisima Formation, and a Deep Aquifers set using both the Paso Robles and Purisima wells.

Paso Robles Groundwater Levels

Eight wells have been identified to represent the Deep Aquifers in the Paso Robles Formation (Table 1). The screened formation of each well was identified in previous reports or was made by Staff based on interpretation of geologic logs and geophysical logs if available. The depths of these wells range from 840 feet below ground surface (ft-bgs) ft-bgs to 1605 ft-bgs, with screened intervals ranging from 600 ft-bgs to 1600 ft-bgs. These wells were selected because there is a long period of consecutive monthly groundwater level measurements to use for this analysis. Wells with a shorter, but still consistent, period of record were included if the location helped expand spatial coverage of Paso Robles wells (Figure 1).

Table 1. Paso Robles Deep Aquifer Wells

State Well ID	Facility Code	Year Drilled	GSE (ft-msl)	Depth (ft-bgs)	Screened Interval (ft-bgs)	Screened Formation	Monthly Groundwater Level Period of Record [4]
13S/02E-19Q03	75	1980	13	1562	1280-1550	Paso Robles [1]	October 1983- Current
13S/02E-31A02	1153	1985	11	1600	850-1600	Paso Robles [1]	October 1986- Current
13S/02E-32E05	10164	1984	8	1605	775-1585	Paso Robles [1]	June 1986- Current
14S/01E-24L05	22277	2000	67	970	930-950	Paso Robles [2]	November 2002- Current
14S/02E-06L01	1672	1976	13	1560	880-1540	Paso Robles [1]	October 1988- Current
14S/02E-33E01	26313	2005	140	1095	1045-1095	Paso Robles [3]	June 2018- Current
14S/02E-28H04	22929	2006	26	1180	940-1160	Paso Robles [3]	July 2018- Current
15S/03E-05R52	22905	2006	52	840	600-820	Paso Robles [3]	April 2016- Current

1. Feeney and Rosenberg, 2003; 2. Hanson et. al, 2002; 3. Based on interpretation of geologic log; 4. Period of record where relatively consistent monthly measurements were collected

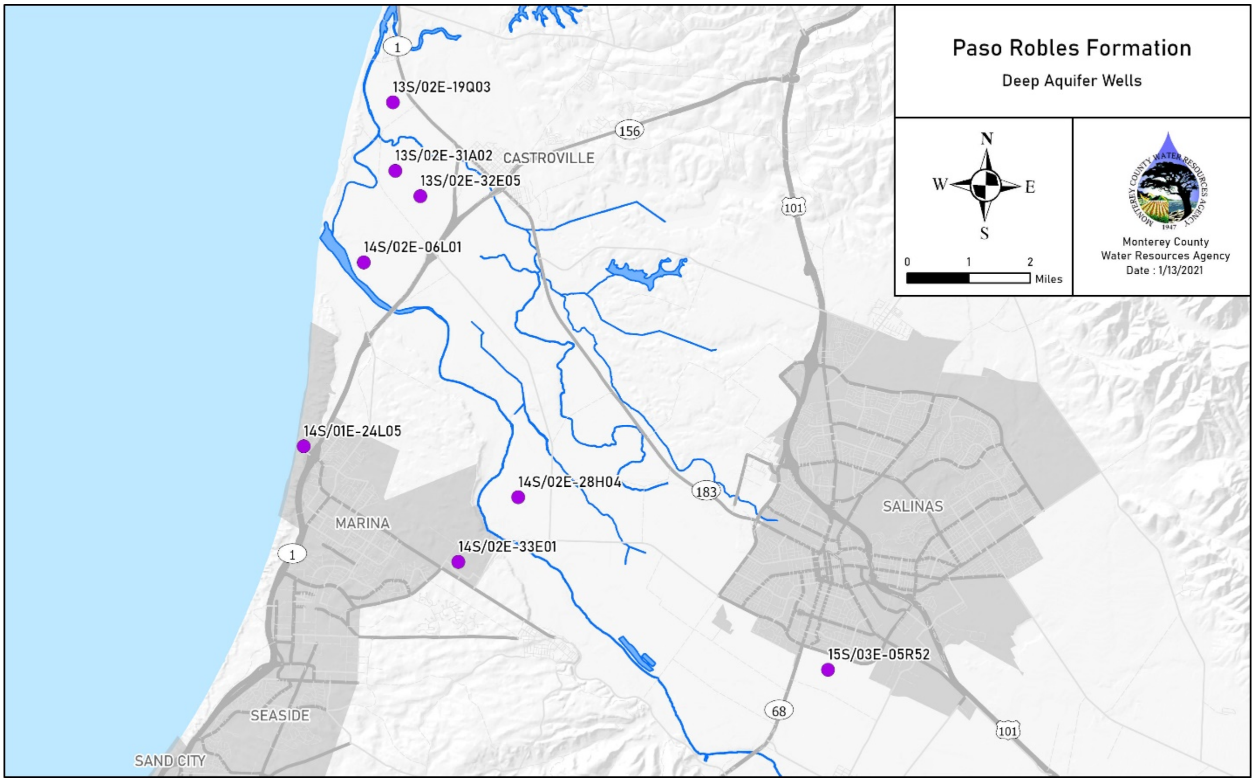

Figure 1. Deep Aquifer wells in the Paso Robles Formation used for groundwater level hydrographs, labeled by State Well ID

Individual hydrographs for the selected Paso Robles wells can be seen in Figure 2. Groundwater elevations are all below sea level. The variability in groundwater levels varies spatially. Wells in the northern coastal region (e.g., 19Q03, 31A02, 06L01, 32E05) have higher groundwater levels on average and see less seasonal variability. This is in an area where less pumping is occurring from the Deep Aquifers, likely resulting in less seasonal drawdown of groundwater levels here.

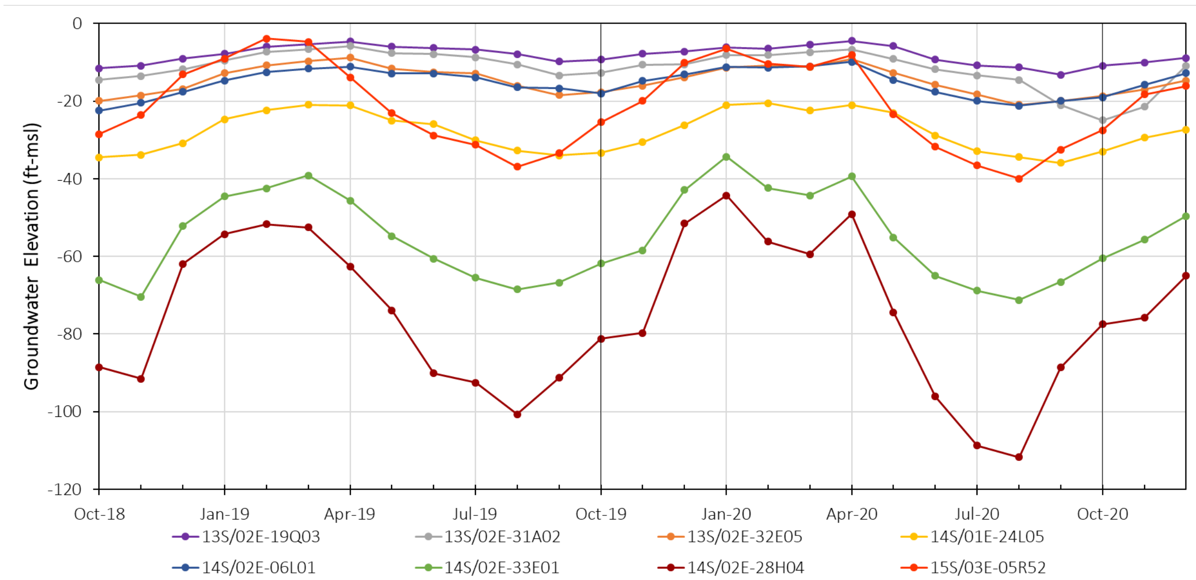

Figure 2. Individual hydrographs for selected wells, WY 2019 to First Quarter WY 2021

Lower groundwater elevations and a larger seasonal drawdown is seen in Deep Aquifer wells further inland. These wells are closer to areas where more Deep Aquifer extractions are occurring. Groundwater extraction data for the 2020 reporting year is currently being collected. A more in-depth analysis of the effect of groundwater extractions on Deep Aquifer groundwater levels will be included in a future version of this addendum. A noticeable trough in groundwater levels is seen in several wells in February and March 2020. Potential causes of this will be analyzed and included in later versions as well.

In the Quarterly Conditions report, groundwater elevations from a representative set of wells in each aquifer or subarea are averaged together to compare water levels across water years (WY). Average groundwater elevations of the eight Deep Aquifers wells in the Paso Robles formation can be seen in Figure 3 for the last water year, WY 2020 (pink), and the current water year, WY 2021 (blue). Average elevations by the end of the first quarter of WY 2021 were twenty-six feet below sea level. WY 2021 started with groundwater elevations lower than those at the start of WY 2020, and by the end of the quarter were four feet lower than elevations last December. Since not all the wells used in this average have groundwater levels from 2018 or earlier, a dry year and 30-year average line were not included.

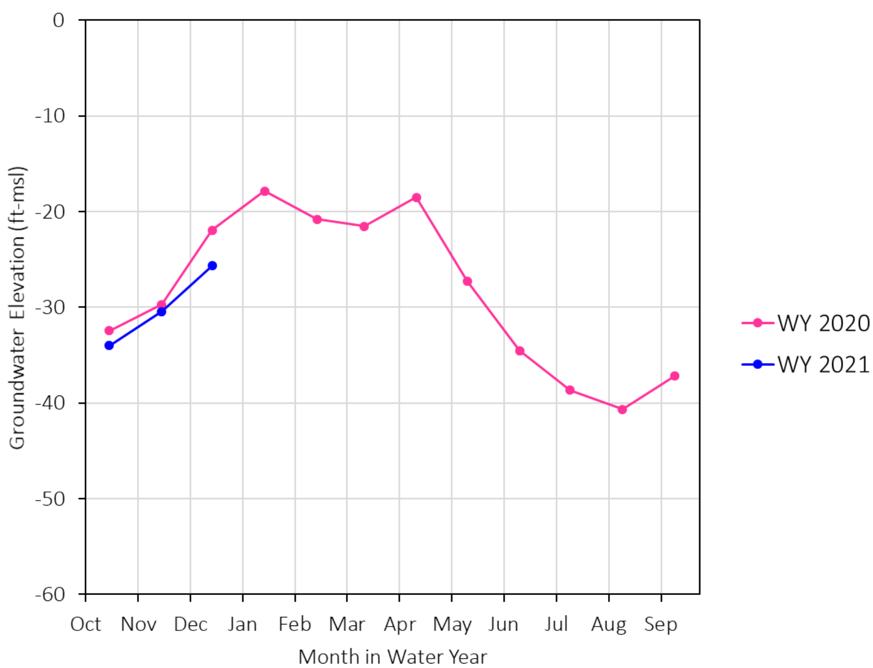

Figure 3. Average hydrographs for Paso Robles Deep Aquifer Wells (n=8)

Purisima Groundwater Levels

Four wells have been identified to represent the Deep Aquifers in the Purisima Formation (Table 2). The screened formation of each well was identified in previous reports or was made by Staff based on interpretation of geologic logs and geophysical logs, if available. The depths of these wells range from 1080 ft-bgs to 1880 ft-bgs, with screened intervals ranging from 1040 ft-bgs to 1860 ft-bgs. These wells were selected because there is a long period of consecutive monthly groundwater level measurements to use for this analysis, and because these wells appear to be screened exclusively in the Purisima formation. Wells with a shorter, but still consistent, period of record were included if the well's location helped expand spatial coverage of Purisima wells (Figure 4).

Table 2. Purisima Deep Aquifers Wells

State Well ID	Facility Code	Year Drilled	GSE (ft-msl)	Depth (ft-bgs)	Screened Interval (ft-bgs)	Screened Formation	Monthly Groundwater Level Period of Record [3]
14S/01E-24L02	22274	2000	67	1880	1820-1860	Purisima[1]	November 2002- Current
14S/01E-24L03	22275	2000	67	1430	1410-1430	Purisima[1]	November 2002- Current
14S/01E-24L04	22276	2000	67	1080	1040-1060	Purisima[1]	November 2002- Current
14S/02E-33E02	26314	2005	140	1760	1680-1760	Purisima[2]	June 2018- Current

1. Hanson et al., 2002; 2. Based on interpretation of geologic logs; 3. Period of record where relatively consistent monthly measurements were collected

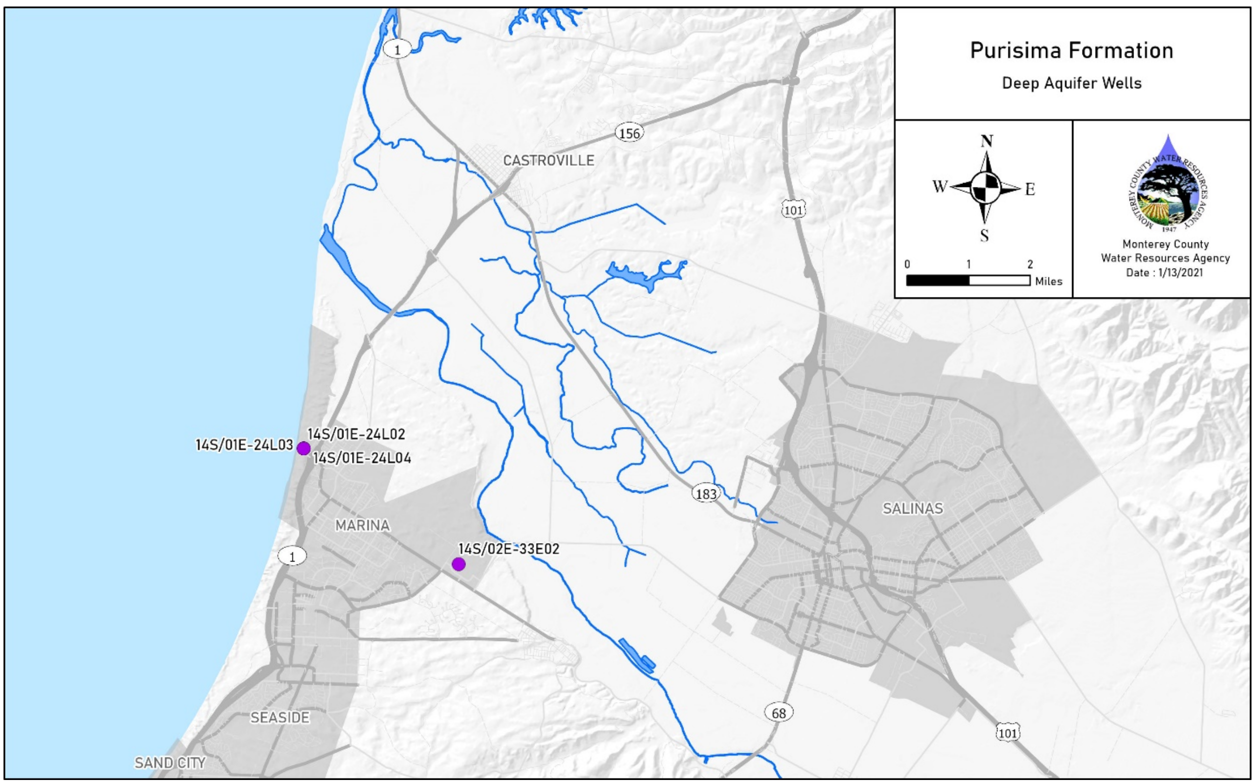

Figure 4. Deep Aquifer wells in the Purisima Formation used for groundwater level hydrographs, labeled by State Well ID

Individual hydrographs for the selected Purisima wells can be seen in Figure 5. Similar to the Paso Robles, groundwater elevations in the Purisima are all below sea level. The trough seen in Paso Robles groundwater levels in February and March 2020 can also be seen in Purisima groundwater levels, though not as pronounced. Potential causes of this will be analyzed and included in later versions of this addendum.

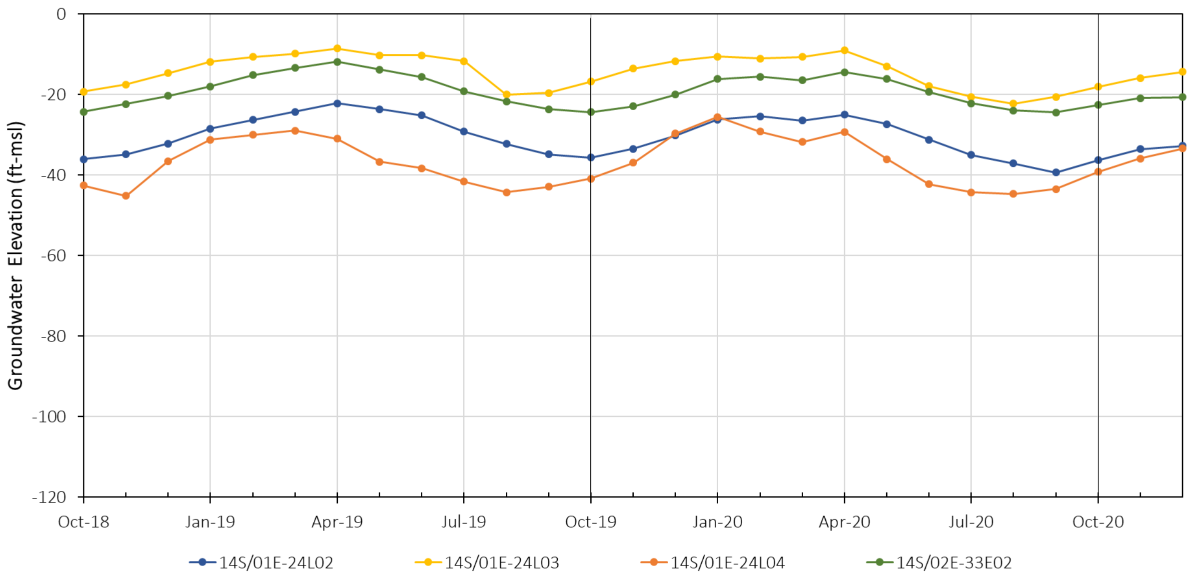

Figure 5. Individual hydrographs for selected wells, WY 2019 to First Quarter WY 2021

Average groundwater elevations of the four Deep Aquifers wells in the Purisima formation can be seen in Figure 6 for WY 2020 and WY 2021. Average elevations by the end of the first quarter of WY 2021 were twenty-five feet below sea level, barely above the average elevations in the Paso Robles. Groundwater elevations in WY 2021 started out similar to those at the beginning of WY 2020, but fell two feet lower by the end of the quarter. Since not all the wells used in this average have groundwater levels from WY 2015 or earlier, a Dry year and 30-year average line was not included.

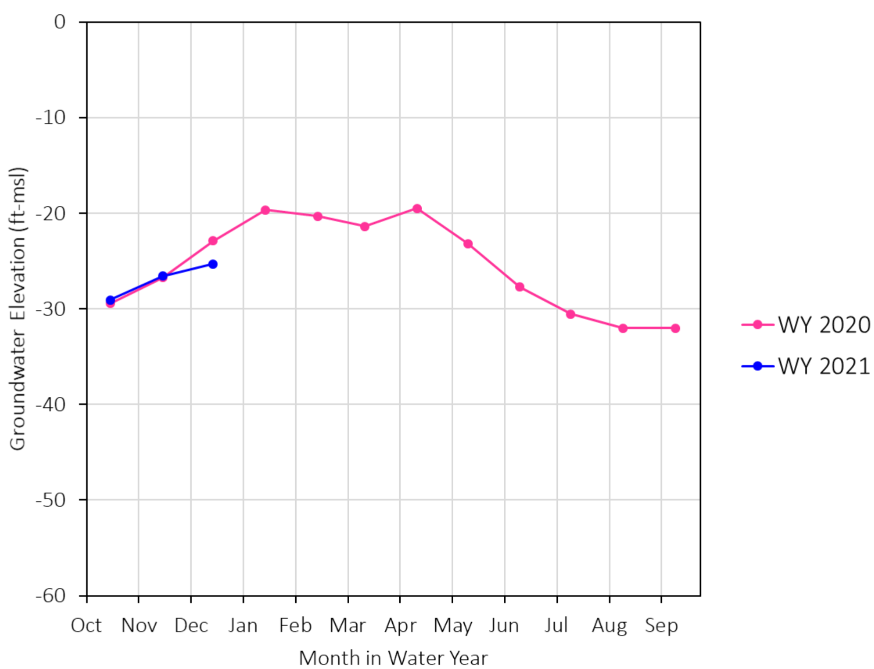

Figure 6. Average hydrographs for Purisima Deep Aquifer Wells (n=4)

Paso Robles and Purisima Combined

One option for the Quarterly Conditions Report is averaging the Paso Robles and Purisima screened wells mentioned above together for a single set of Deep Aquifers hydrographs, instead of two. This approach would make adding new wells to this set easier, since most of the recently constructed Deep Aquifers wells are screened in both the Paso Robles and Purisima formations. However, it would move away from comparing groundwater levels in the Paso Robles versus Purisima formation in the Quarterly Conditions Report.

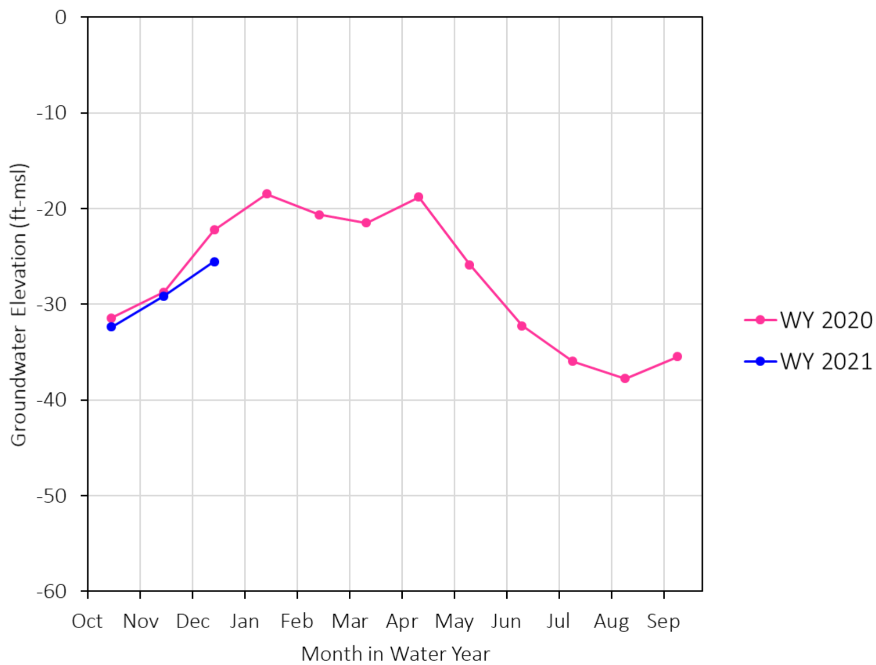

Figure 7. Average hydrographs for Deep Aquifer Wells, Paso Robles and Purisima combined (n=12)

Figure 7 shows the groundwater level hydrographs for WY 2020 and WY 2021 if the Paso Robles and Purisima wells were averaged together. The hydrographs show similar trends as the Paso Robles and Purisima set hydrographs. Average elevations by the end of the first quarter of WY 2021 were twenty-six feet below sea level. WY 2021 started with lower groundwater elevations than those at the start of WY 2020, and by the end of the quarter remained two feet lower than last December.

3. Vertical Hydraulic Gradients

Vertical hydraulic, or pressure, gradients can be calculated by finding the difference in groundwater elevations between two aquifers. The direction of the vertical hydraulic gradient determines the potential direction of flow between two aquifers, so long as pathways exist for water to move. Table 3 shows the average groundwater elevations from the end of the quarter, December 2020, in the Deep Aquifers and the overlying aquifers.

Table 3. Average Groundwater Elevations (ft-msl) December 2020				
180-Ft Aquifer[1]	400-Ft Aquifer[1]	Paso Robles Deep Aquifer Wells	Purisima Deep Aquifer Wells	Combined Paso Robles and Purisima Deep Aquifer Wells
7’	0’	-26’	-25’	-26’

1. Salinas Valley Water Conditions for the First Quarter of Water Year 2020-2021

In December 2020, groundwater elevations in the 180-Ft aquifer were seven feet higher than groundwater elevations in the 400- Ft aquifer, and the vertical hydraulic gradient between the two was -7 ft (400-Ft Aquifer elevation minus 180-Ft Aquifer elevation). A negative vertical gradient value represents downward flow, while a positive vertical gradient represents upward flow. The negative gradient in this case means water has the potential to move from the 180-Ft aquifer downward into the 400-Ft Aquifer. As discussed in the 2017 Recommendations Report[7], a combination of the downward gradient, geology, regional seawater intrusion in the overlying 180-Ft aquifer, groundwater pumping and well construction/conditions allowed for inter-aquifer seawater intrusion between the 180 and 400-Ft Aquifers.

Looking at the groundwater elevations between the 400-Ft Aquifer and the combined Deep Aquifer wells, the vertical hydraulic gradient is -26 ft (Combined Deep Aquifer wells elevation minus 400-Ft Aquifer elevation). Again, the negative vertical gradient means there is a mechanism in place for 400-Ft aquifer water to move downward into the Deep Aquifers. Unlike the overlying aquifers, we don’t have enough information about potential pathways that exist for water to move between the Deep Aquifers and the overlying 400-Ft Aquifer.

This way of looking at vertical gradients between aquifers relies on a single average groundwater elevation to represent the entire aquifer. However, the difference in vertical gradients also varies spatially. Figure 8 shows the spatial differences in groundwater elevations between the 400-Ft Aquifer and Deep Aquifers in August 2020. This map was generated by taking the difference between the 400-Ft /East Side Deep Aquifer August 2020 contours and the groundwater elevation at each Deep Aquifer well sampled that month. A raster surface was then interpolated from those points. Red colors represent areas with negative vertical gradients, meaning vertical flow would be downward from the overlying 400-Ft Aquifer into the Deep Aquifers. Blue colors would represent areas with positive vertical gradients where vertical flow would be upward from the Deep Aquifers into the 400-Ft Aquifer. In August 2020, groundwater elevations in the Deep Aquifers were entirely below elevations in the 400-Ft Aquifer. Differences between the two aquifers were smallest near the coast, the smallest difference being -2.7 feet, but ranged upward of -72.4 feet difference further inland. A similar map will be generated for December 2020 and included in a future version of this addendum once contour lines from the Annual 2020 sampling event are finalized. Further discussion on the historical trends and changes in vertical gradients will also be included.

[7] Monterey County Water Resources Agency. 2017. *Recommendations to Address the Expansion of Seawater Intrusion in the Salinas Valley Groundwater Basin.* https://www.co.monterey.ca.us/home/showdocument?id=57396

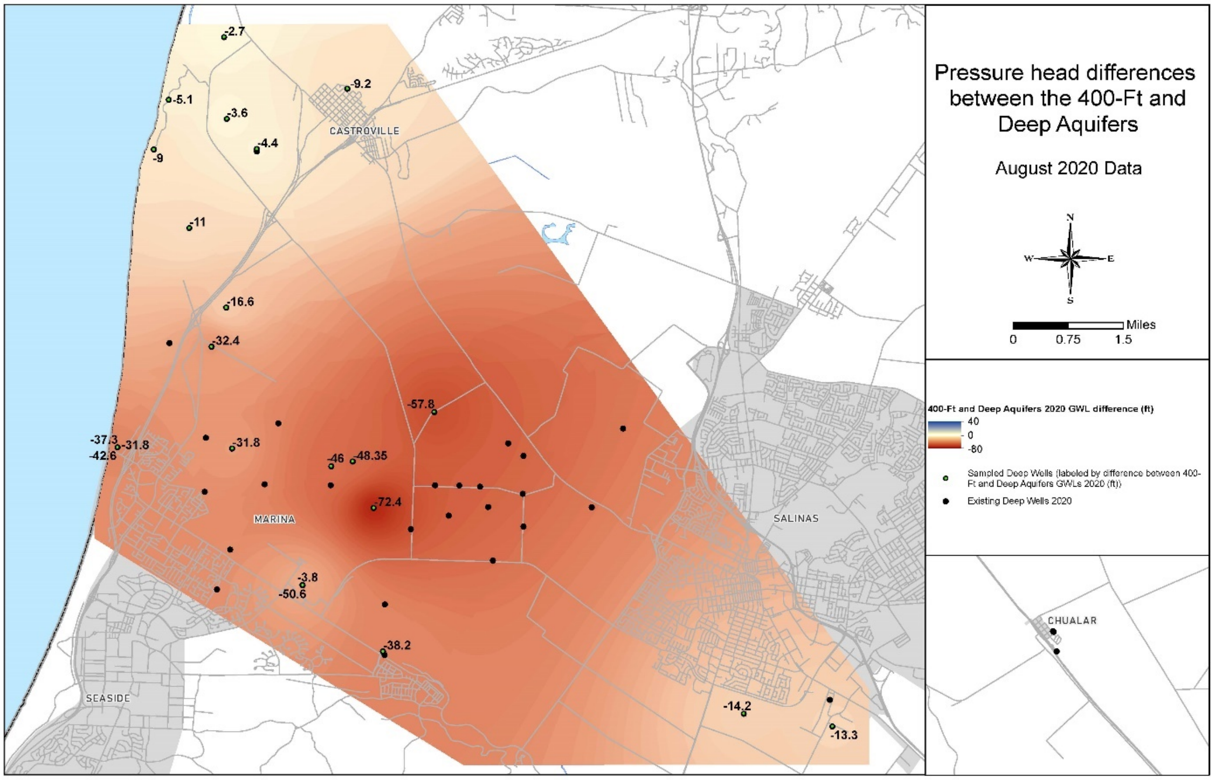

Figure 8. Vertical Hydraulic (or Pressure) head differences between the 400-Ft and Deep Aquifers, August 2020