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TECHNICAL MEMORANDUM

To: Ron Duncan

From: Sean Culkin, Cameron Tana

Date: August 17 2016

Subject: Santa Cruz Mid-County Basin Groundwater Model Boundaries Update

1. INTRODUCTION

In November 2015, HydroMetrics Water Resources Inc. (HydroMetrics WRI) prepared the *Soquel-Aptos Groundwater Flow Model: Subsurface Construction (Task 3)* technical memorandum (HydroMetrics WRI, 2015). This memorandum documented the development of the conceptual model, the hydrostratigraphy, and the subsurface boundary conditions for the groundwater flow model portion of the forthcoming groundwater-surface water model in what is now called the Santa Cruz Mid-County Basin (Mid-County Basin or the basin).

This document is an addendum to that memorandum. This document summarizes recent updates and changes to the model boundary conditions. The groundwater component of the model continues to use the U.S. Geological Survey's (USGS) MODFLOW software for groundwater modeling. The previous *Soquel-Aptos Groundwater Flow Model: Subsurface Construction (Task 3)* outlined the planned boundary conditions during model construction but did not correspond to any model simulations; all initial runs of the groundwater model to date have incorporated the changes to the boundary conditions outlined in this document.

In general, model boundaries have been selected to follow existing watershed boundaries or other hydraulic boundaries within the model domain. Large portions of the northern, western, and eastern edges of the model are still assigned no-flow boundary conditions. The changes summarized in this document apply to the general head and time-variant specified head boundaries within the model. These updates are being applied to initial calibration runs of the model and are still subject to change pending future findings. A summary of the boundary condition types and extents is shown in Figure 1. Initial groundwater model simulations have shown that applying these new boundary conditions contributes to overall reasonable groundwater flow directions though the model domain.

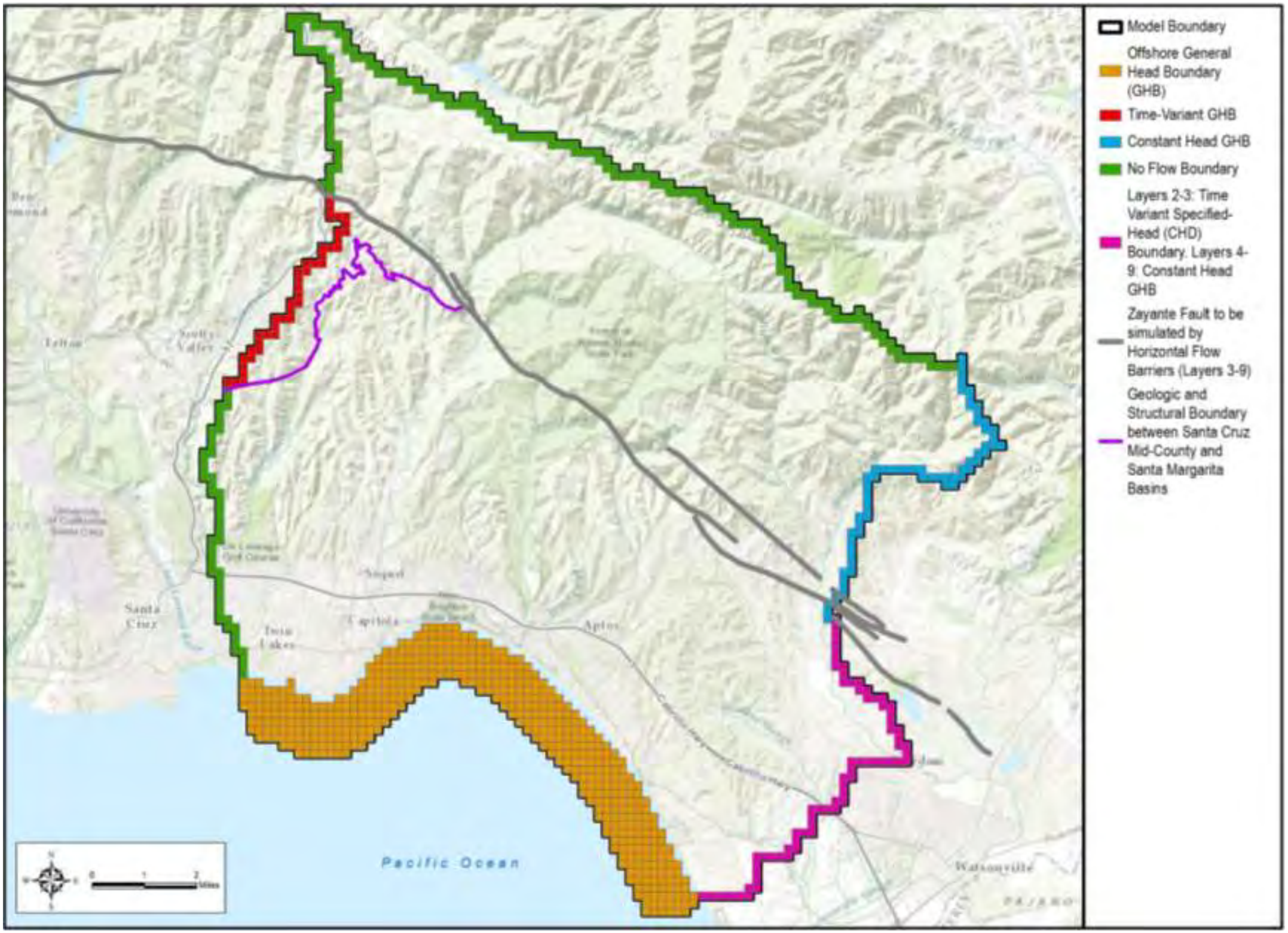

Figure 1: Summary of Boundary Conditions

2. MODIFICATIONS TO THE OFFSHORE SEAFLOOR BOUNDARY

The general head boundary cells representing the areas where the Aromas and Purisima formations outcrop on the sea floor are shown as the band of offshore orange cells in Figure 1. This boundary is simulated with the MODFLOW general head boundary (GHB) package. As the domain of the model extends approximately one mile offshore, specific hydrostratigraphic units are simulated to outcrop along the seafloor within the model domain, including the Aromas, Purisima DEF/F, Purisima D, Purisima BC, and Purisima A units. The Tu and Purisima AA units do not outcrop on the seafloor within the model domain, but may do so west of the model boundary. The general head boundaries representing outcropping units will have conductances representing conductivity of hydrostratigraphic units and thickness of sea floor layer. General head boundaries are also applied along the edge of model in offshore layers below the outcropping layer to represent a connection to where the lower layer outcrops outside of the model grid. These general head boundaries will have conductances representing conductivity of unit and distance to outcrop from the edge of the model.

The offshore boundary in the final version of the model is expected to have fixed heads in these GHB cells of 0 feet above mean sea level (MSL). This will be appropriate when using the seawater interface package (SWI2). The SWI2 package uses input values of seawater density at these boundary cells to calculate an equivalent freshwater head in areas identified as on the seawater side of the seawater-freshwater interface.

The SWI2 package may not be ready to be used with GSFLOW prior to initial calibration, and therefore HydroMetrics WRI modified the boundary heads for initial simulations performed prior to the addition of the SWI2 package. For these simulations, equivalent freshwater heads must be calculated manually. Various relatively straightforward conversions exist in literature for modifying seawater boundaries in groundwater models for both confined (as in the Purisima) and unconfined (as in the Aromas) aquifers (e.g., Lu et. al, 2015). The sensitivity of overall model results to freshwater equivalent head corrections is expected to be low, but will be evaluated as part of the initial groundwater model calibration process.

3. MODIFICATIONS TO THE SHARED MID-COUNTY AND SANTA MARGARITA BASIN BOUNDARY

Groundwater modeling studies of the Santa Margarita Basin and Scotts Valley area have demonstrated that groundwater west of a structural divide in the granitic basement of the basin is directed roughly westward, away from the Mid-County Basin. This structural divide generally parallels the shared boundary between the Santa Cruz Mid-County

Basin and the adjacent Santa Margarita Basin, which is shown on Figure 1. These findings were incorporated into a basin boundary modification request (HydroMetrics WRI, 2016a) which successfully proposed boundaries for the Mid-County Basin to the California Department Water Resources and a concurrent request (HydroMetrics WRI, 2016b) that defined the area around Scotts Valley to the west of the Mid-County Basin as the Santa Margarita Basin. Figure 2 shows a geologic map of this boundary area, including interpolated granite elevation contours demonstrating the westward slope of the geologic structures, the Mid-County and Santa Margarita basin boundaries, and the watershed boundary (blue line), which corresponds closely to the Mid-County Basin model boundary (also shown).

Assigning a no flow boundary at the model boundary west of this structural divide will likely result in unreasonable groundwater mounding and flow directions in the thick portion of the simulated Tu unit west of the divide. It is also problematic to inactivate model cells west of the structural divide because this area is within the Mid County Basin's surface watershed, and contains steams that necessarily contribute flow into the basin.

HydroMetrics WRI modified the western model boundary to accommodate likely groundwater flow across this boundary. A GHB boundary condition was applied to the western boundary of the model between the intersection of the granitic structural divide with the western model boundary and the Zayante Fault, which is also the northern boundary of the Santa Margarita Basin; these are the cells shown in red on Figure 1. Detail of the Mid-County and Santa Margarita Basin boundary area is also shown in Figure 2.

A single conductance value will be applied to this GHB that will be varied as part of the calibration process. In order to assign time-variant head values to this boundary, a review of available groundwater elevation data was conducted in the adjoining region of the Santa Margarita Basin. Three groundwater monitoring locations operated by Scotts Valley Water District (SVWD) were identified in this area as having groundwater elevation data from the Lompico and Butano Formations, which are relatively deep aquifer units overlaying the granitic basement west of the structural divide, which probably corresponds most closely with the undifferentiated Tu groundwater model layer where it encroaches into the Santa Margarita Basin. The Tu layer of the model is a relatively undifferentiated layer comprising materials between the base of the Purisima formation and the granitic basement.

The three monitoring locations, SVWD #11A/B, SVWD #3B, and SVWD #7A, are shown in Figure 3. Historical groundwater elevation data for these wells are shown in Figure 4 and Figure 5. Both of these plots show a trend of declining groundwater elevations through the 1980s and 1990s, probably in response to increased pumping in Scotts Valley. Groundwater elevations begin to level off over approximately the past 15 years. Figure 6 shows a recent conceptualization of groundwater elevations within Scotts Valley. Depressed groundwater levels toward the center of the valley indicate a potential for groundwater flow laterally from the sides of the valley, including from the area east of the basin boundary (dashed black line) which corresponds with the western boundary of the Mid-County Basin model.

As the calibrated groundwater model covers the period of data shown in Figure 4 and Figure 5, these long-term trends are incorporated into the groundwater model by interpolating the data from these wells to the GHBs on the western model boundary where that boundary adjoins the Santa Margarita Basin. Figure 7 summarizes how trends from these monitoring wells were assigned to this boundary condition. For reference, Figure 7 also shows the extent of the Tu model layer (orange cells), Mid-County basin boundary (black line) and Zayante Fault (red line) in this area. Long-term trends from SVWD #3B and #7A were assigned to the GHB head values along the northern part of the model boundary (purple shaded area), and the head values for the southern portion of this boundary (blue shaded area) are interpolated between trends at SVWD #3B/7A and SVWD 11A/B. The southern terminus of this boundary area reflects the SVWD #11A/B trend, as this well is towards the southern part of Scotts Valley.

SVWD well data were not available in 1984 and 2015. For these years, trends from the closest available data were extended to complete the time series applied to the boundary condition.

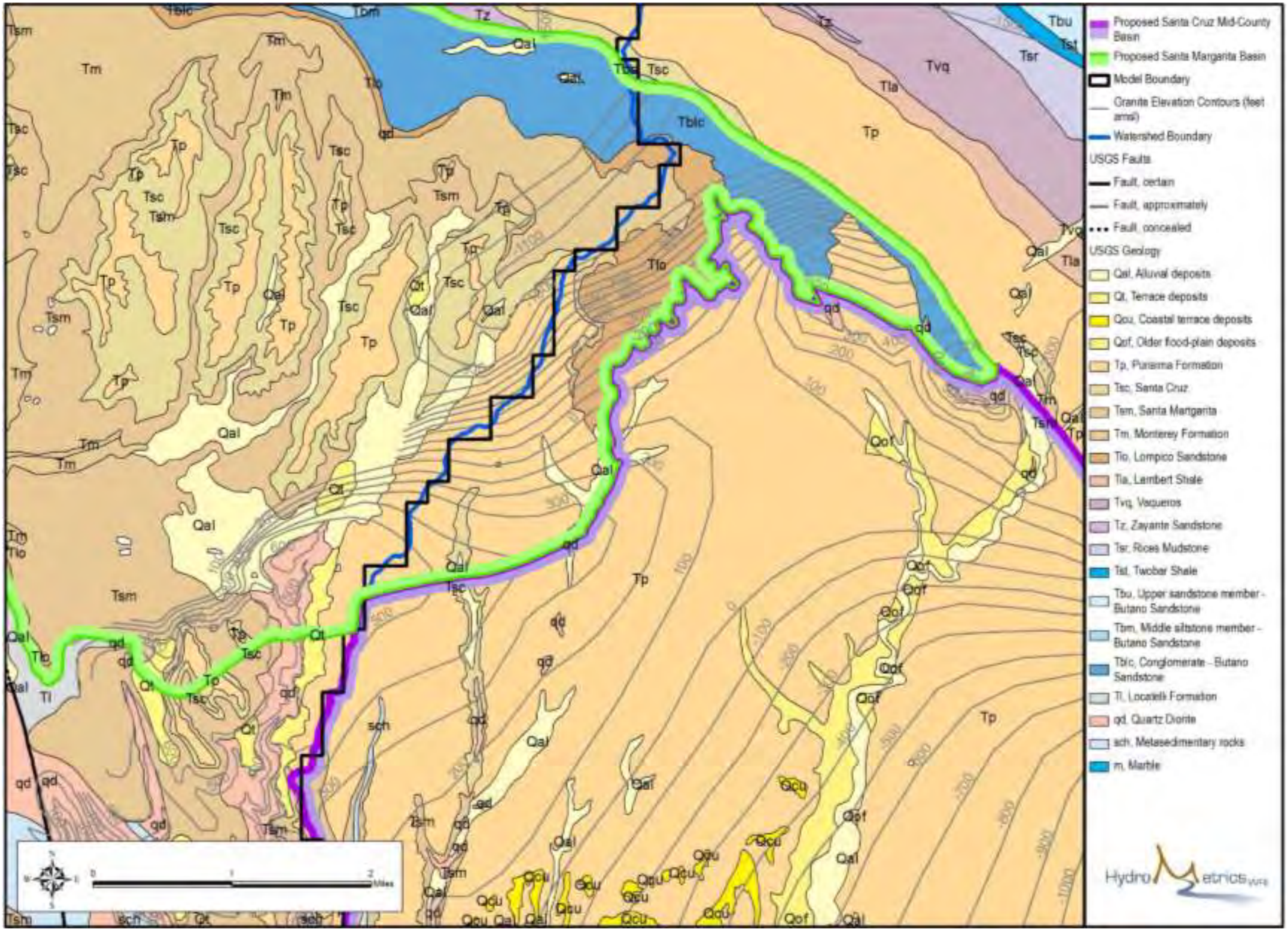

Figure 2: Detail of Shared Mid-County and Santa Margarita Boundary Area

Figure 3: SVWD Monitoring Locations (source: Kennedy/Jenks Consultants)

Figure 4: SVWD #11A/B Historical Groundwater Elevation Data (source: Kennedy/Jenks Consultants)

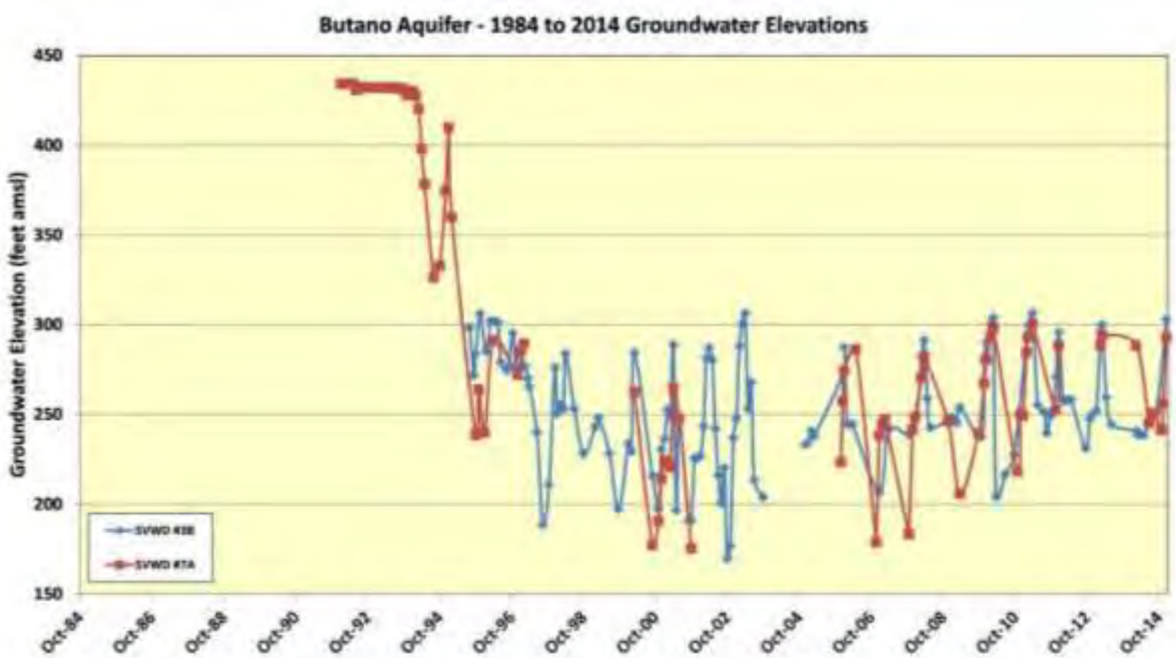

Figure 5: SVWD #3B and #7A Historical Groundwater Elevation Data (source: Kennedy/Jenks Consultants)

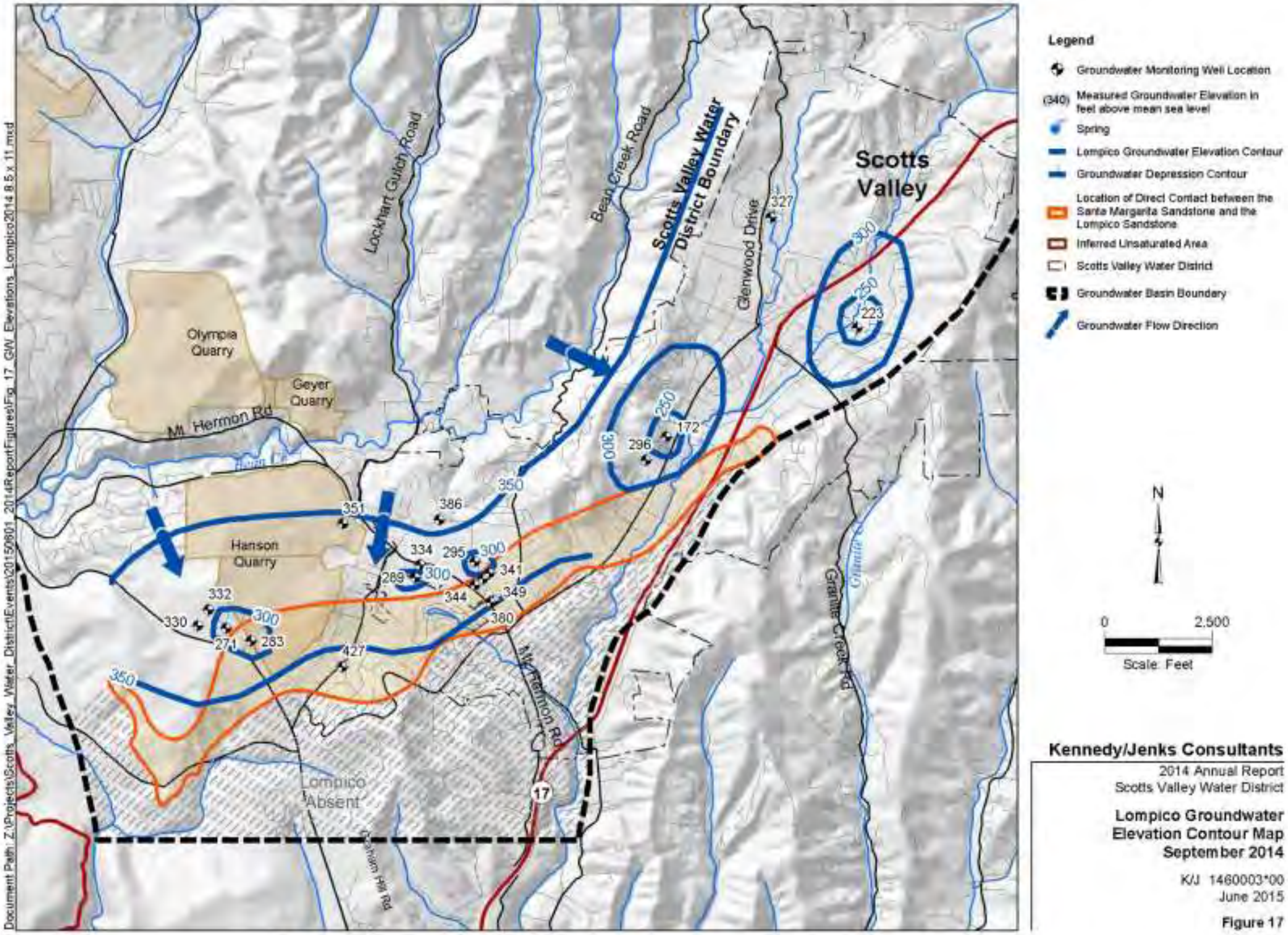

Figure 6: Scotts Valley Area Groundwater Elevation Contours (source: Kennedy/Jenks Consultants)

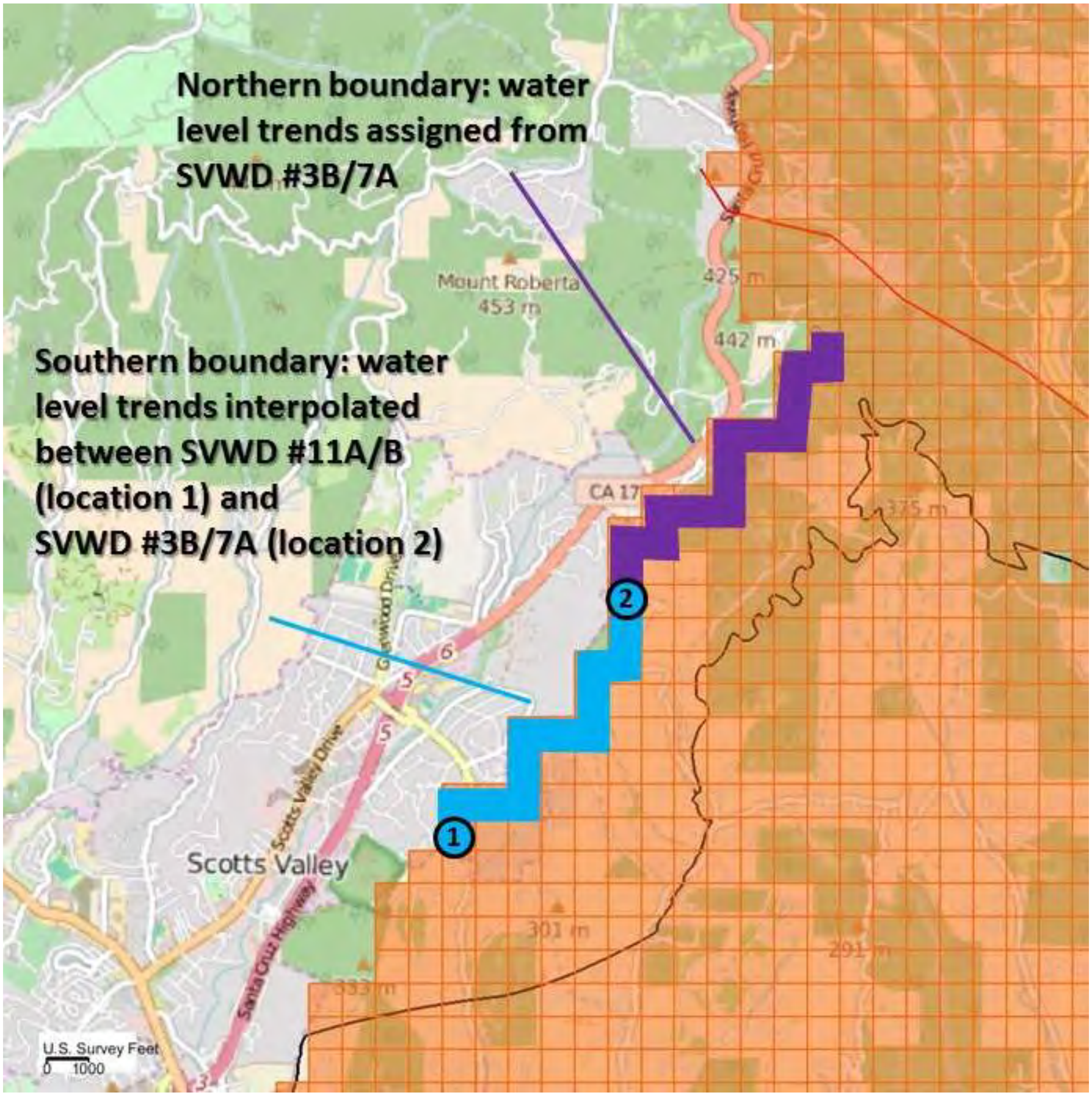

Figure 7: Time-Variant General Head in Shared Mid-County and Santa Margarita Boundary Area

4. Modifications to the Eastern Model Boundary North of the Zayante Fault

The Zayante Fault will be represented by the horizontal flow barrier (HFB) package. This fault offsets two distinct blocks of the Purisima formation, and has been identified as a barrier to flow and basin boundary by several previous studies (Johnson et. al., 2004). The

HFB will be applied to layers 3-9, as layers 1 and 2 are representative of the overlaying Aromas formation and surficial alluvium which are not part of the Purisima units separated by the fault. The location of this fault in the model domain is shown in Figure 1. Implementing these flow barriers between cells north and south of the fault will provide resistance to flow between the well-defined Purisima unit layers south of the fault and the undefined Purisima Formation north of the fault. HFB conductance will be estimated during model calibration.

Low HFB conductance values may present a significant barrier to groundwater flow between units on the north and south sides of the fault. Since the undifferentiated Purisima north of the fault will receive recharge from precipitation and streamflow, groundwater in the model has the potential to mound north of the Zayante Fault. Our modification is that an additional GHB has been applied to the eastern boundary of the model north of the Zayante Fault to avoid mounding and unreasonably high groundwater levels in this area. Figure 1 shows this GHB area of blue cells north of the fault on the eastern boundary of the model. The head and conductance along this boundary will be varied as model work progresses to maintain reasonable groundwater head elevations north of the Zayante Fault.

Few groundwater monitoring locations or estimates of groundwater elevation north of the Zayante Fault are available. Pajaro Valley Water Management Agency (PVWMA) produces groundwater contours as part of their basin management. Figure 8 shows representative groundwater contours in the vicinity of the Mid-County Basin's eastern boundary, indicating a roughly west-to-east groundwater flow direction out of the Mid-County basin and into the Pajaro Basin. Available PVWMA groundwater contour information only extends along part of the eastern GHB of the model north of the Zayante Fault. However, we can assume from this figure that groundwater elevations are above sea level and the Pajaro Valley likely receives groundwater flow from the Mid-County basin model area north of the fault. Based on these limited data, a constant reference head value between 0 and 35 feet MSL will be applied to the GHBs for the initial groundwater simulation and calibration models to enforce flow out of the model area north of the fault. This boundary condition will apply to the Purisima DEF/F, the shallowest outcropping unit in this area, and all deeper hydrostratigraphic units. This value may be updated as calibration proceeds; however, it is unlikely that model calibration will be sensitive to this boundary condition because the majority of pumping wells and groundwater calibration targets will be south of the fault.

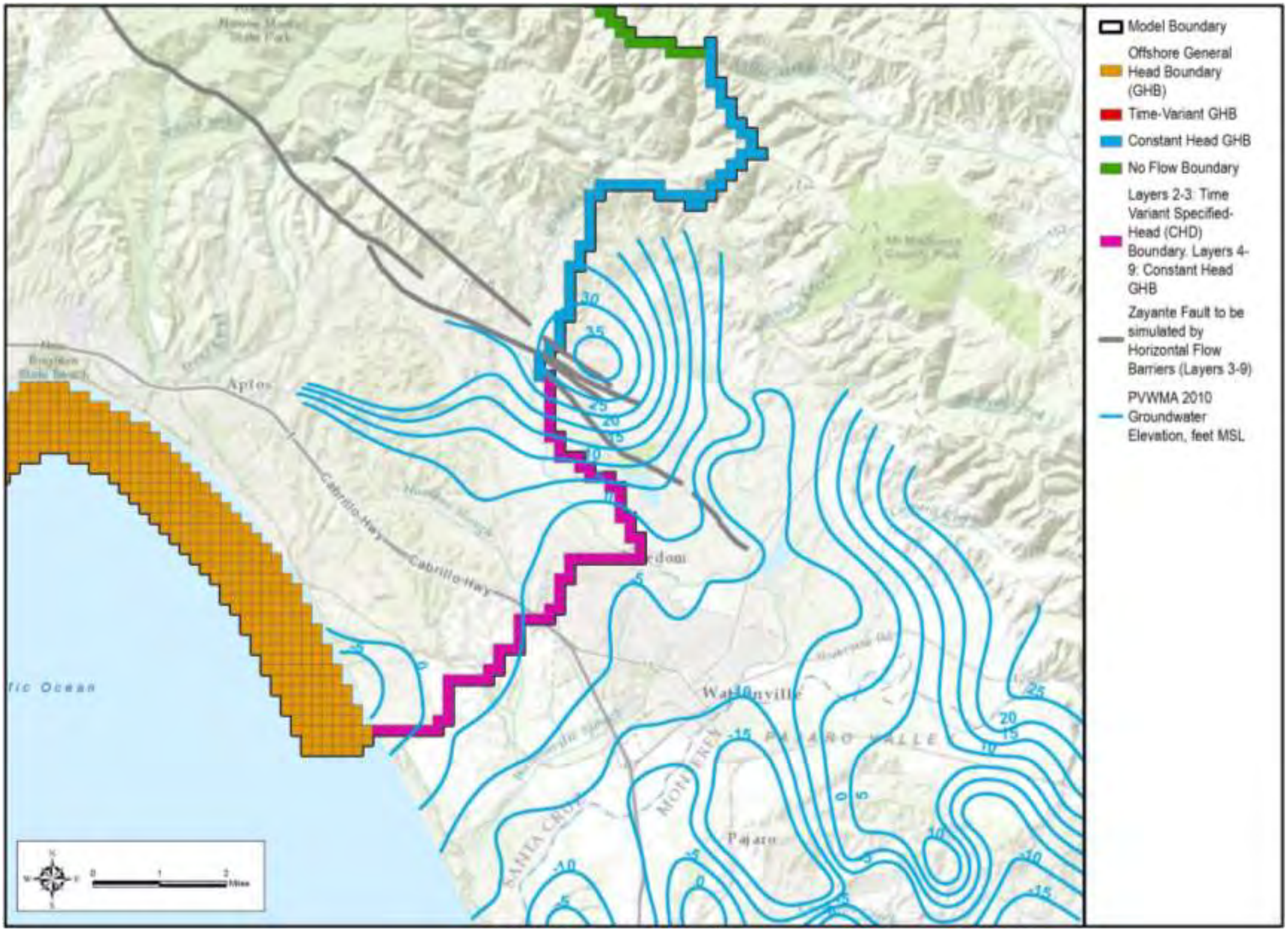

Figure 8: Pajaro Basin Groundwater Elevation Fall 2012 (source: PVWMA)

5. MODIFICATIONS TO THE SOUTHEASTERN MODEL BOUNDARY

The southeastern boundary is the only boundary that does not intersect a watershed or naturally-occurring hydraulic barrier. This boundary is similar to the southeastern boundary of the Central Water District (CWD) model (HydroMetrics WRI/Kennedy-Jenks, 2015) in the coastal plain area of the City of Watsonville. All model layers intersecting this boundary were initially assigned time-variant heads using the time-variant specified-head (CHD) package based on available PVWMA groundwater elevation data. However, PVWMA wells are screened within the Aromas or shallower undifferentiated units of the Purisima, and therefore do not represent the hydrogeology of the deeper Purisima units. Therefore, the southeastern boundary of the Mid-County Basin model will be a combination of time-variant CHD boundary cells in the shallower Aromas and Purisima DEF/F layers, and constant head GHB boundary cells in the deeper Purisima formation units that intersect this boundary.

In previous modeling done for the CWD (HydroMetrics WRI/Kennedy-Jenks, 2015), historical groundwater elevations through 2015 and lateral groundwater gradients were used to apply a generalized spatial trend to the CHD boundary in this area. For the Mid-County basin groundwater model, data through 2015 were obtained for 7 selected PVWMA wells, including 2 well pairs, at 5 monitoring locations (see Figure 9) near the southeast model boundary, and interpolated time-series water level trends were updated to include the additional data. The interpolated seasonal trends vary around a constant long-term average, and these interpolated values were applied to CHD boundary cells at locations along the southeastern boundary at points corresponding to the relative position of the nearby PVWMA wells. Figure 9 presents an example of how and where time-variant head data area applied to the Aromas and DEF/F layers of the southeastern CHD boundary.

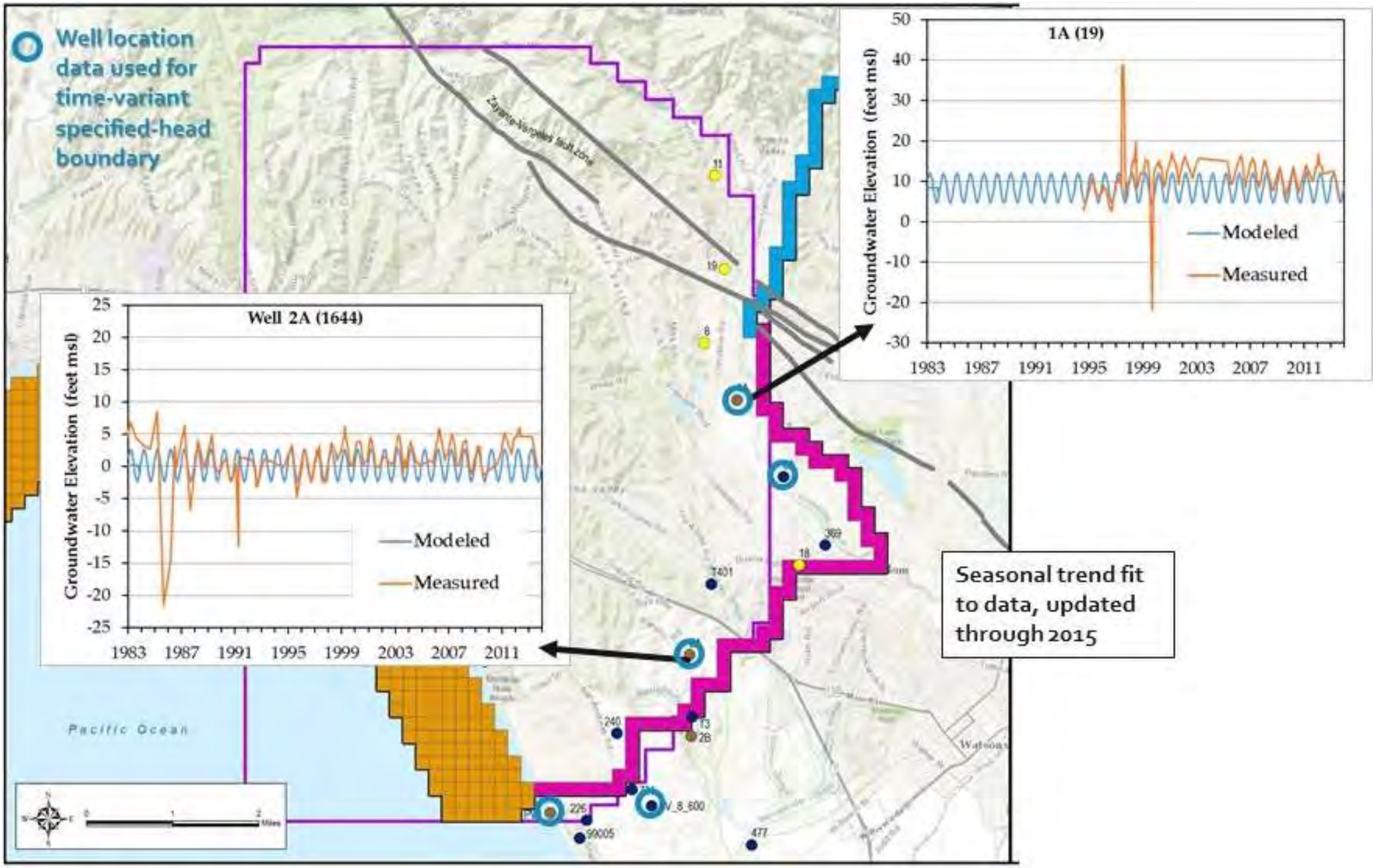

Figure 9: Southeastern Time-Variant Head Model Boundary for Aromas and Purisima DEF/F

For groundwater model layers representing the Purisima Formation deeper than the DEF/F layer that intersect the southeastern boundary of the model, a more straightforward approach to assigning GHB reference heads has been applied. Rather than a time-variant CHD boundary, constant head GHB cells will be set to 0 feet MSL, or the freshwater equivalent conversion consistent with the approach described in the seafloor outcrop boundary section. This approach is applied to the Purisima D, BC, B, A, and AA model layers that intersect this boundary. It is likely that the ocean ultimately constitutes a head boundary for the deeper layers of the Purisima in this area, since they outcrop to the sea floor. However, the outcropping areas for these layers are far beyond the domain of the groundwater model, and so cannot be explicitly simulated.

GHB conductance along the entire southeastern boundary will be adjusted by layer as part of the calibration process. For the Purisima layers beneath the DEF/F layer, conductance is expected to be low compared to the conductance of the seafloor boundaries as described above, due to the large linear distance between where these units intersect the southeastern boundary and their eventual outcrop area.

6. References

HydroMetrics WRI, 2015. *Soquel-Aptos Groundwater Flow Model: Subsurface Model Construction (Task 3)*. November.

HydroMetrics WRI, 2016. *Santa Cruz Mid-County Groundwater Basin Boundary Modification, Prepared for Soquel-Aptos Groundwater Management Committee.* March.

Johnson, N.M., D. Williams, E.B. Yates, and G.T. Thrupp, 2004, *Technical Memorandum 2: Hydrogeological Conceptual Model*, Prepared for Soquel Creek Water District, September.

Lu, C. A.D. Werner, C.T. Simmons, and J. Luo, 2015. A correction on coastal heads for groundwater flow models. *Groundwater* 53.1: 164-170.