APPENDIX 2-E

SANTA CRUZ MID-COUNTY BASIN CONCEPTUAL MODEL UPDATE MEMORANDUM

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TECHNICAL MEMORANDUM

To: Ron Duncan

From: Sean Culkin, Cameron Tana

Date: March 31, 2017

Subject: Santa Cruz Mid-County Basin Conceptual Model 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 Santa Cruz Mid-County Basin (Mid-County Basin or the basin) groundwater-surface water model (the model). In August 2016, HydroMetrics WRI submitted the *Santa Cruz Mid-County Basin Groundwater Model Boundaries Update* technical memorandum (HydroMetrics WRI, 2016), which is an addendum to the initial conceptual model document. Since August 2016, HydroMetrics WRI has made progress calibrating the surface water and groundwater components of the model, and as developed an integrated groundwater-surface water model using the GSFLOW model code.

This document serves as an addendum to both previous memorandums, and summarizes additional recent changes to the model. Calibration efforts have yielded insights into groundwater elevation distribution and dynamics within the basin that were not satisfactorily represented by the previously-presented conceptual model. Therefore, the changes to the conceptual model documented here have been incorporated into the simulated hydrostratigraphy of the basin to allow for a more comprehensive calibration to basinwide groundwater elevations.

2. Conceptual Model Changes

This section describes two general conceptual model changes applied to the basin and the model.

2.1. Fault Distribution within the Basin

Previous descriptions of the basin include one major fault, the Zayante Fault, which roughly bisects the model domain along a northwest-southeast trending line (Figure 1). This fault divides all layers of the groundwater model, including layers representing the Aromas Formation, Purisima Formation, and the composite hydrostratigraphic unit between the base of the Purisima Formation and the granitic base of the basin (HydroMetrics WRI, 2015). Following basin boundary modification in 2016, the Zayante Fault is also currently the northern boundary of the Santa Cruz Mid-County Basin. North of the Zayante Fault, there are no groundwater elevation observation points that have been added to the model, and the hydrostratigraphy of the area is considered to be "undifferentiated." South of the Zayante Fault, groundwater level observations can be evaluated in each aquifer or aquitard layer, which are each simulated by individual model layers.

Within the basin, relatively high seasonal or annual average groundwater elevations of 100 feet or more above mean sea level (MSL) exist at observation well locations clustered south of the Zayante Fault. Farther south of the fault in coastal areas, average groundwater elevations are closer to MSL, or below MSL in cases where groundwater has been depressed by pumping wells. Additionally, lateral groundwater gradients are relatively flatter in coastal areas than inland areas. This trend results in an area of relatively steep lateral groundwater gradients approximately 1.5 miles south of the Zayante Fault, as shown in groundwater elevation maps produced for the previous Central Water District (CWD) model (Figure 2). This trend is especially prevalent in units of the Purisima Formation (model layers 3 through 7), but general trends of higher-to-lower groundwater elevations from inland to coastal areas is observed throughout the basin.

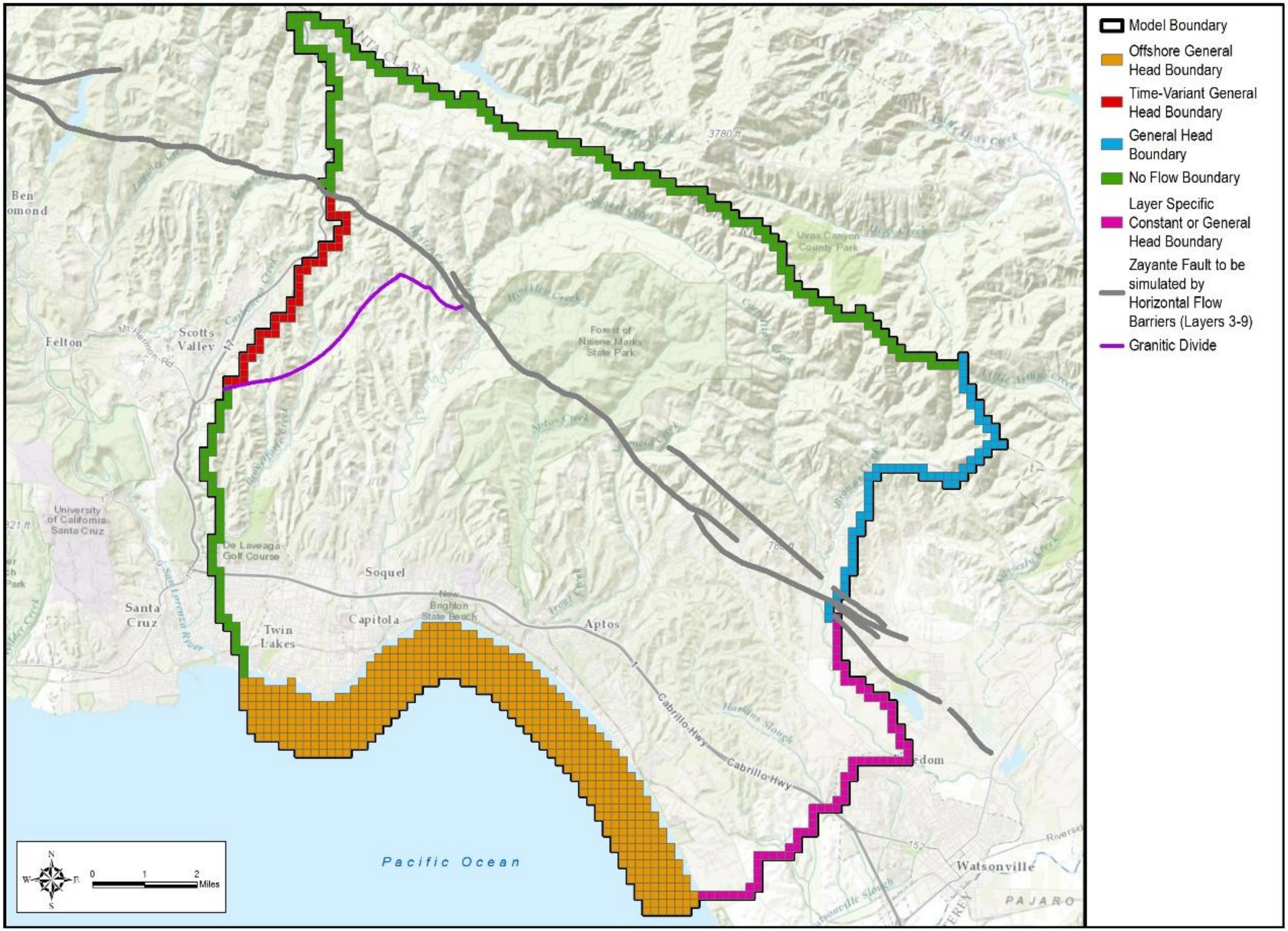

Figure 1: Summary of Model Domain Area and Boundaries (HydroMetrics WRI, 2015)

A similar area of steep lateral gradients was also evident in results from the groundwater model prepared for the CWD, documented in *Aromas and Purisima Basin Management Technical Study, Santa Cruz Integrated Regional Water Management Planning Grant Task 4* (HydroMetrics WRI, 2014). Figure 2 shows an example of simulated groundwater elevation contours in the Purisima formation with an area of steep groundwater gradient in the CWD service area south of the Zayante Fault. One step taken to achieve this simulated gradient in the calibration of the CWD model was to apply a relatively high range of hydraulic conductivity, where low conductivity areas result in steeper gradients by resisting lateral groundwater flow. Figure 3 shows the distribution of hydraulic conductivity values applied to the Purisima Formation in the CWD model, ranging over four to five orders of magnitude.

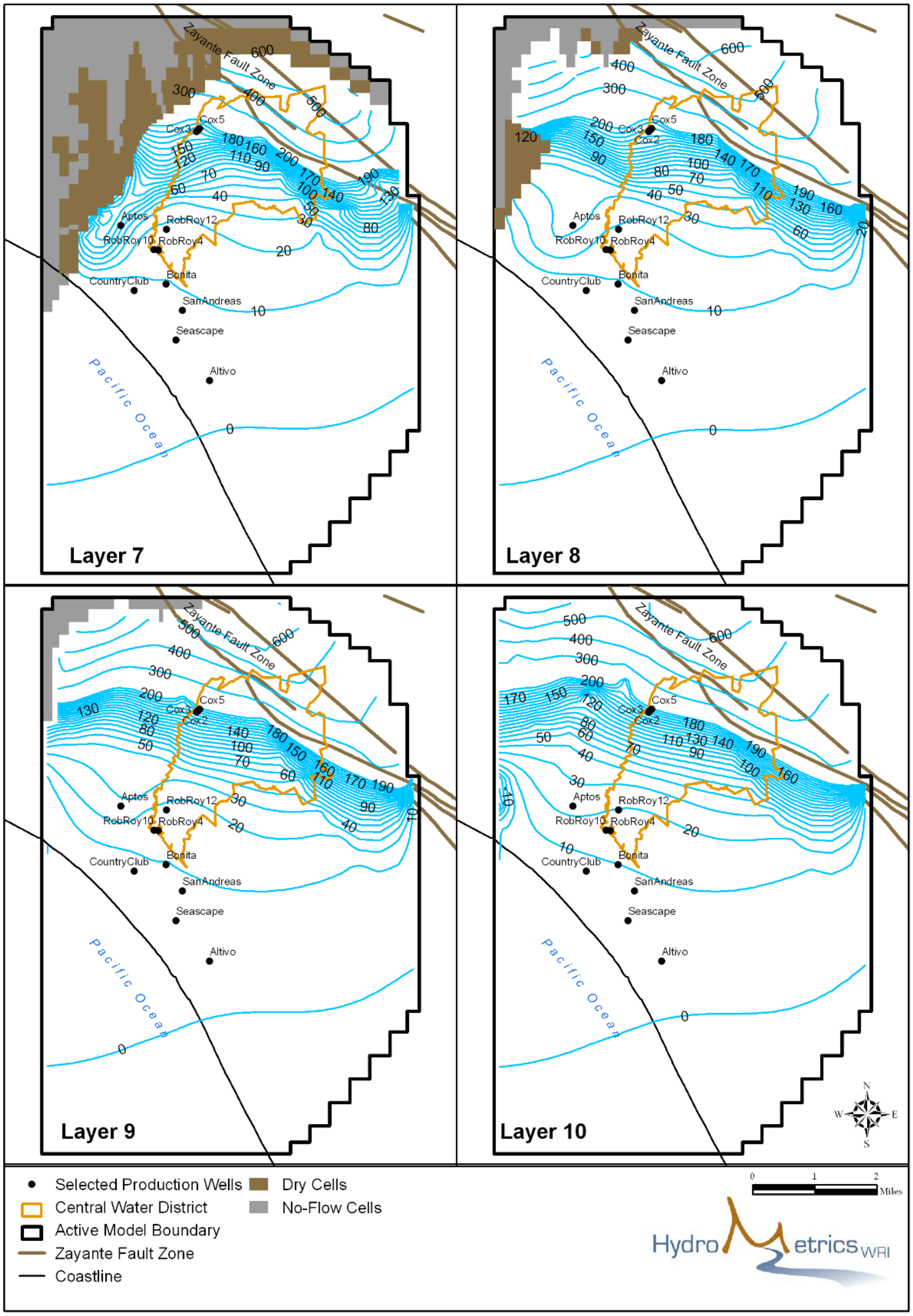

Figure 2: Simulated Groundwater Elevations (feet MSL) in Purisima Formation (HydroMetrics WRI, 2014)

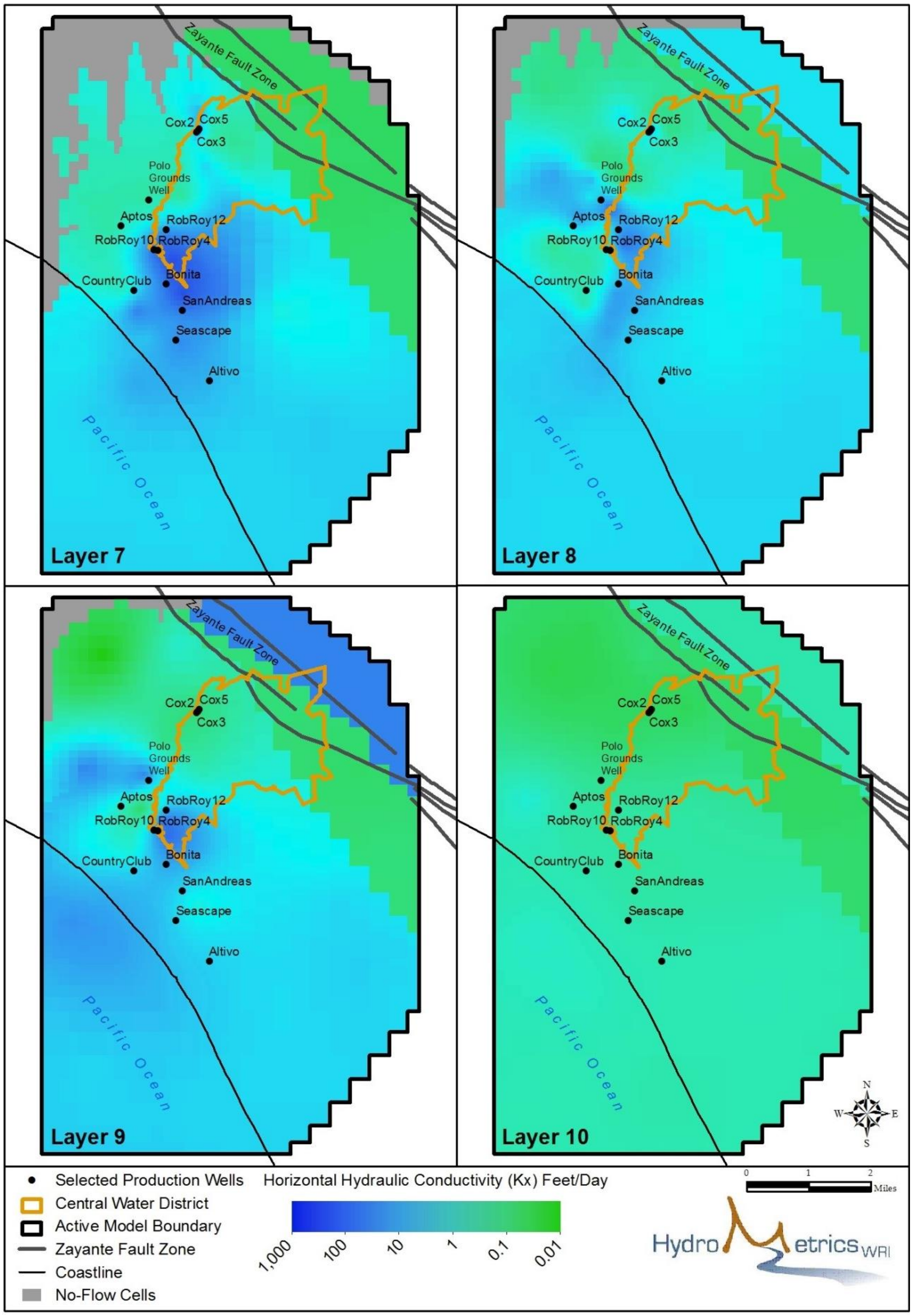

Figure 3: Horizontal Hydraulic Conductivity for Purisima Formation (HydroMetrics WRI, 2014)

To investigate alternatives to applying a large hydraulic conductivity range to simulated Purisima Formation layers within the Mid-County Basin model, HydroMetrics WRI investigated the potential for additional faulting in this area of the basin. Often, faulting can act as a barrier to groundwater flow due to lower conductivity clays within the fault, or by causing an abrupt change in formation conductivity across the fault. This can facilitate large changes in groundwater elevation on either side of the fault. Discussions with former Santa Cruz County geologist Mike Cloud led to our review of a U.S. Geological Survey (USGS) report of earthquakes and faults within the greater San Francisco Bay Area, including Santa Cruz county (USGS, 2004). This investigation indicates that, based on seismic activity in the area, there is evidence of some faulting south of the Zayante Fault within the domain of the Mid-County Model. HydroMetrics WRI has projected the location of the faults mapped by the USGS as shown in Figure 4. Although the mapped extent of this additional faulting is relatively limited in the USGS report, it generally corresponds with the area of steep groundwater gradients observed in the Mid-County Basin.

Academic thesis work performed in the 1950s has also yielded some evidence of additional faulting in this area of the basin. Alexander (1953) observed deformation of the marine terraces near Capitola between Aptos and Rio del Mar. This axis of deformation appears to have an east-west alignment similar to faulting found in the USGS report and inferred from regional groundwater elevation gradients.

Based on these studies and lines of evidence, HydroMetrics WRI added a second fault generally aligned with the data shown in the USGS report. This second fault is tentatively named the Aptos Fault. The simulated Aptos Fault is south of the Zayante Fault, and follows a similar northwest-southeast trend. For modeling purposes, the Aptos Fault extends through all Purisima Formation model layers, and extends from approximately the western outcrop of the Purisima Formation through the USGS-mapped fault zones. The location of the simulated fault in relation to the Zayante and USGS-mapped faults is shown in Figure 4.

Adding the Aptos Fault results in improved model fit to observed groundwater elevations north and south of the fault. HydroMetrics WRI will maintain this hydraulic flow barrier within the model domain through calibration of the model; the final conductance, position, and extent of the simulated fault will be presented in the report of final model calibration. We believe that based on the evidence available, a hydraulic flow barrier is preferable and more consistent with regional geology than assigning other hydraulic parameters such as hydraulic conductivity to achieve model calibration.

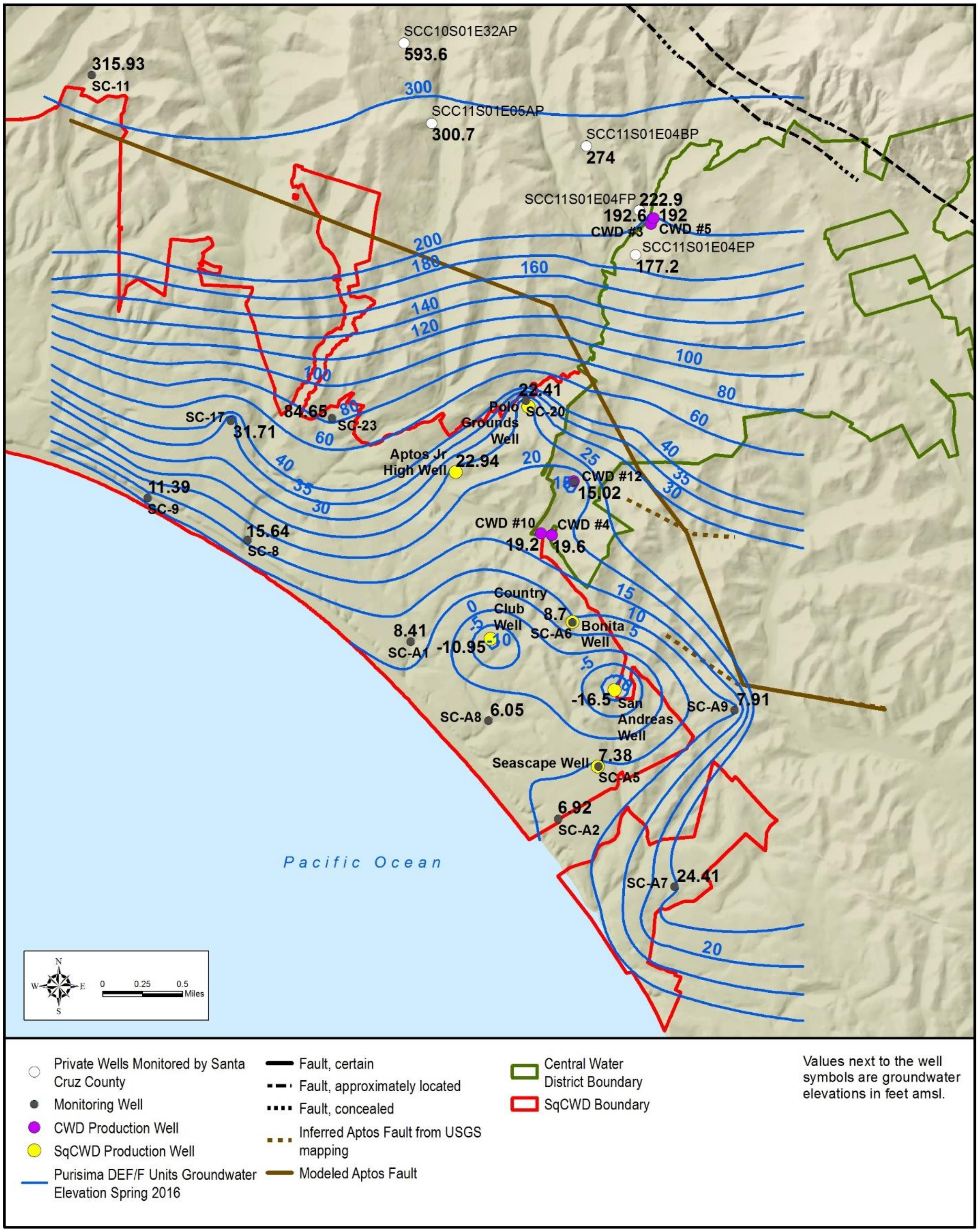

Figure 4: Faulting and Groundwater Elevations in the Aptos Area of the Santa Cruz Mid-County Basin

2.2. Pajaro Area Boundary Condition

The Mid-County Basin model contains a general head boundary (GHB) north of the Zayante Fault along the eastern boundary of the model domain near the service area of Pajaro Valley Water Management Agency (PVWMA; see blue line on Figure 1). This boundary is intended to allow an outlet for groundwater to flow east out of Mid-County Basin into the Pajaro Basin per the conceptual model of the shared boundary area (HydroMetrics WRI, 2015).

Few groundwater monitoring locations or estimates of groundwater elevation north of the Zayante Fault are available. However, through calibration we determined that assigning a relatively low general head value to this GHB boundary as described in the previous memo resulted in simulated heads north of the fault that are too low to maintain the relatively high heads observed south of the Zayante fault in the Purisima Formation. Reviewing the CWD model boundary conditions indicates that constant head conditions were applied to that model north of the Zayante Fault corresponding with Ryder Gulch (Figure 5). The head values applied to this boundary condition in the CWD model are relatively high, and exceed 200 feet MSL, corresponding with the relatively high elevation of discharging streams in this area.

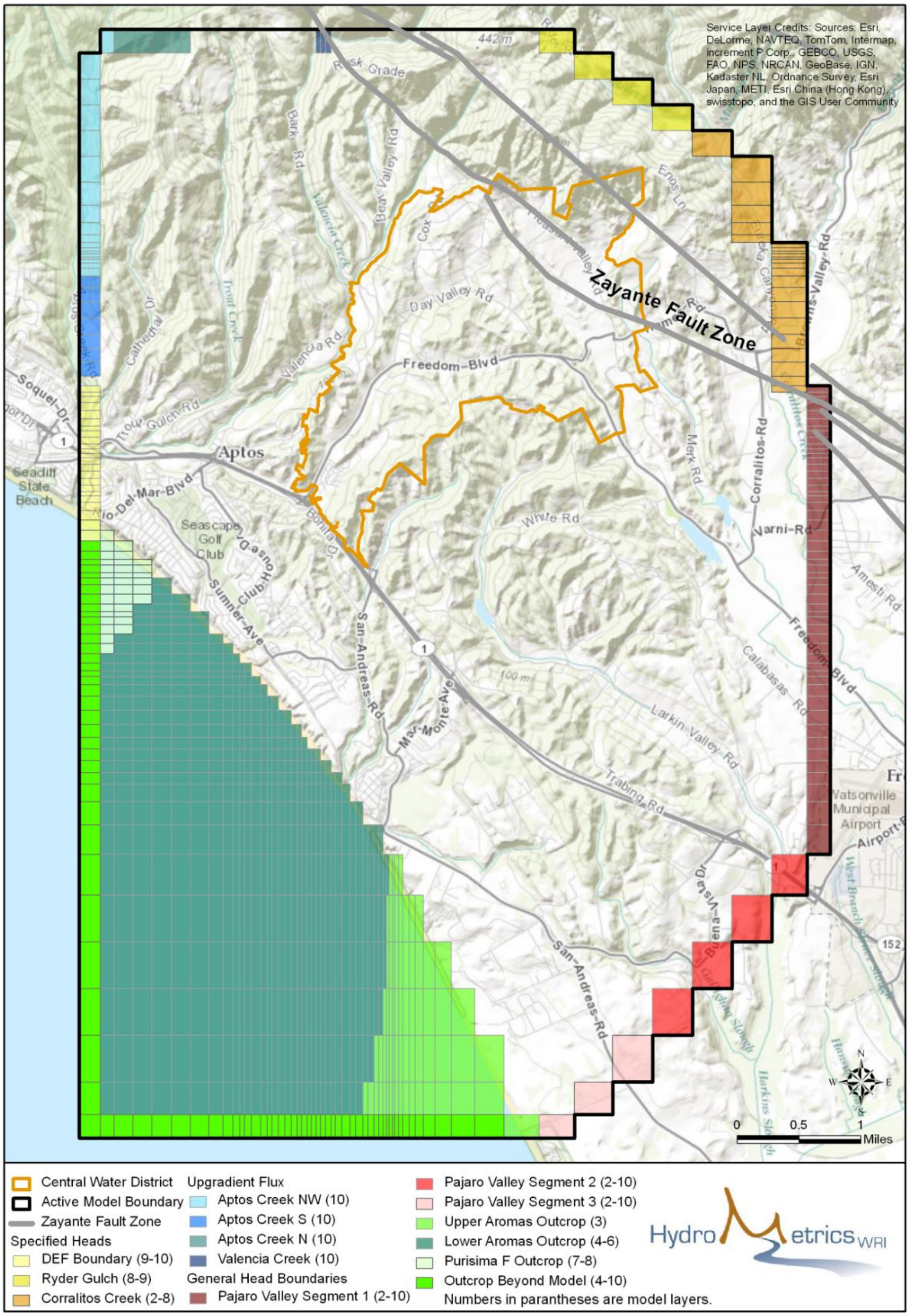

Figure 5: CWD Model Boundary Conditions (HydroMetrics WRI, 2014)

The GHB boundary of the Mid-County model has been updated to reflect higher general heads, consistent with previous modeling efforts. This has resulted in a more reasonable simulated groundwater elevation change across the Zayante Fault and has contributed to more accurately represented groundwater elevations at observation points south of the Zayante Fault. The final configuration of this boundary that results in the best fit to observed data will be presented following final calibration.

3. References

Alexander, C.S., 1953. The marine and stream terraces of the Capitola-Watsonville area. University of California Publications in Geography, v.10, p. 144.

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